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The Journal of the
INSTITUTE OF METALS
and
METALLURGICAL ABSTRACTS

In this issue:

JANUARY 1944

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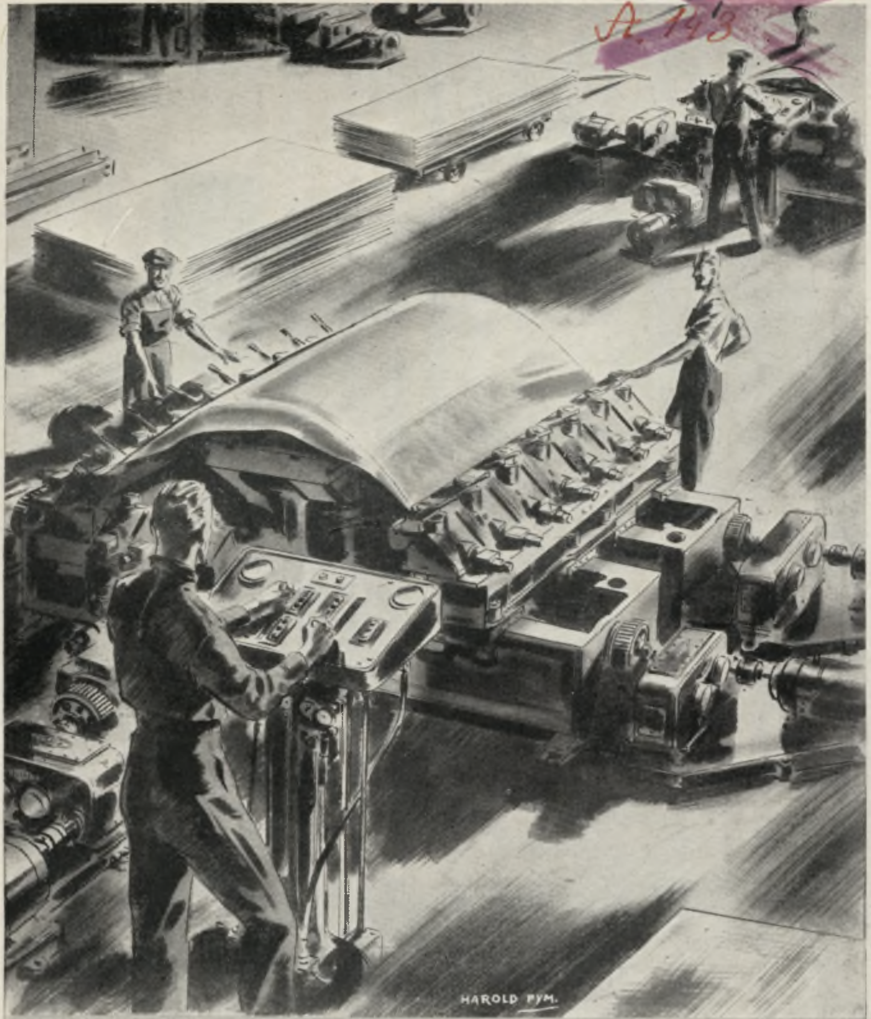
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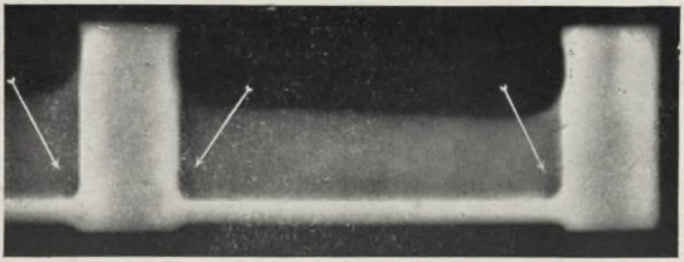

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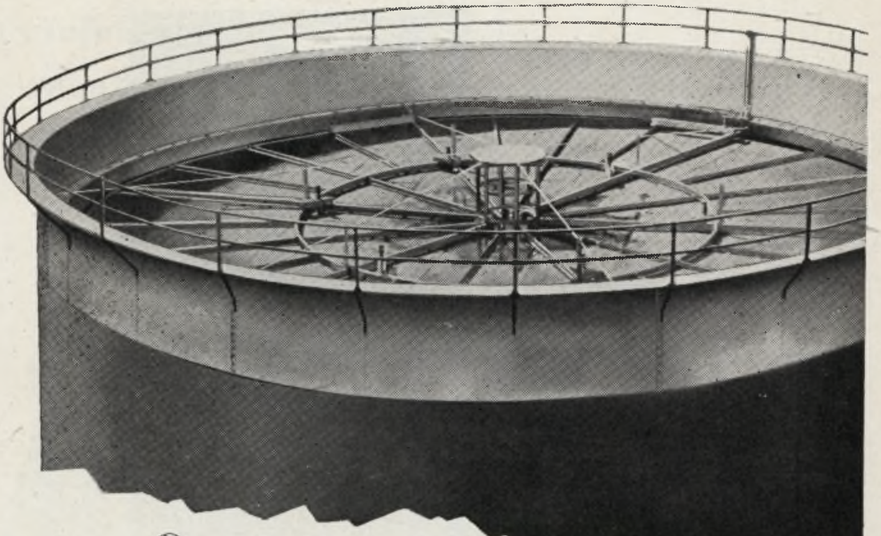


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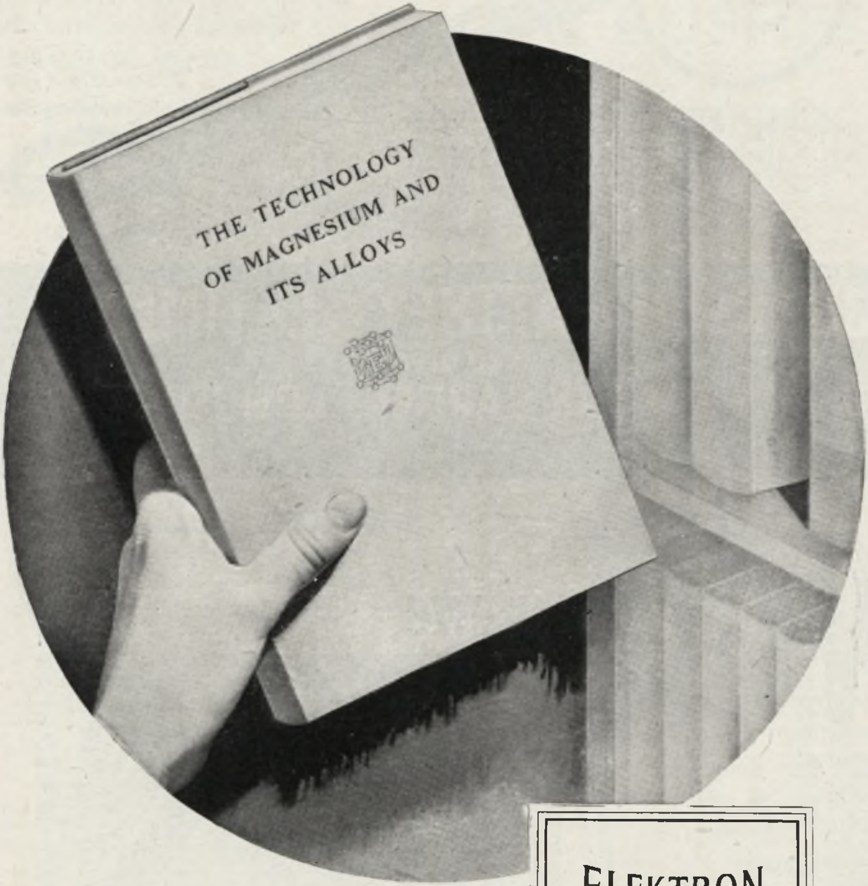
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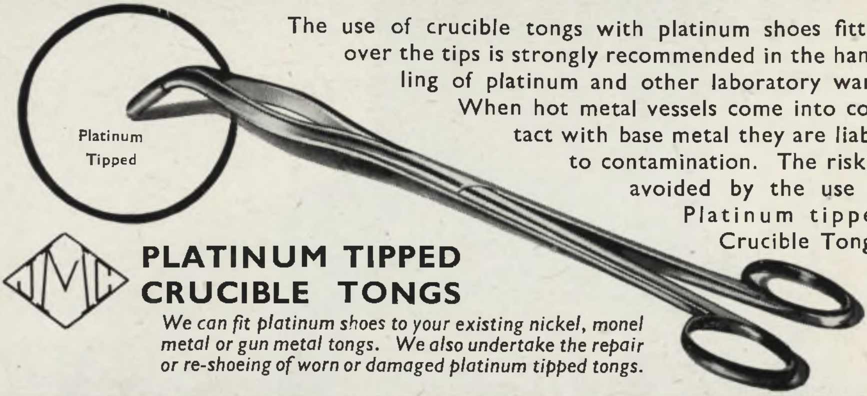
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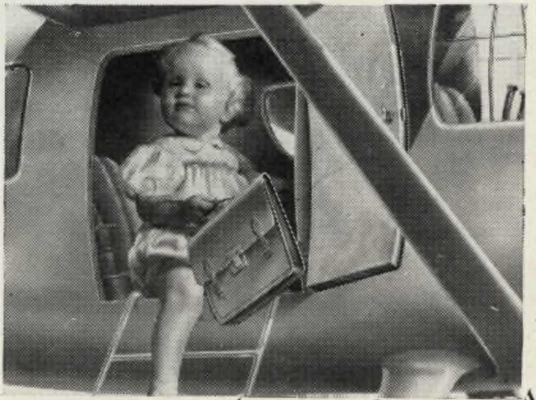

The Journal of the
INSTITUTE OF METALS

JANUARY, 1944

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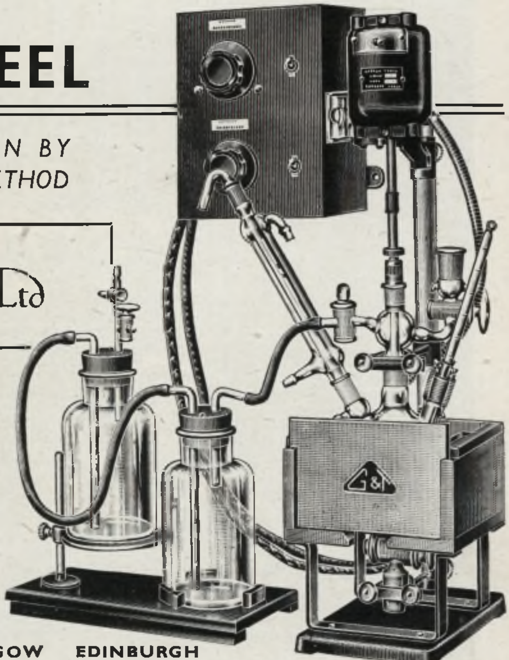

A NEW YEAR MESSAGE
FROM THE PRESIDENT

I HAVE again this year the privilege of addressing a New Year Message to the members of the Institute of Metals, and I do so with particular pleasure because, despite the difficulties inherent under war conditions, the Institute has once again come through a most successful period, and finds itself increasingly well placed to be of service to its members when the transition from war to peace takes place.

In my message last year, I ventured to suggest that before many months had passed we should see " the victorious results of the long period of patient planning and concentrated effort which the United Nations had been devoting to the task of defeating the Axis Powers." Now, at the dawn of a new year, we can, in fact, look back on the year that has just passed and record an almost unbroken series of successes for the Allied arms in every quarter of the globe.

Throughout this heartening time, the non-ferrous metals industry has continued to be of outstanding importance to the country's war effort, and it must surely be an encouragement to those who are engaged in the industry, whatever their position may be, to feel that they have played so vital a part in helping to achieve the victory which will not now be long delayed.

In all this work the Institute of Metals has taken its place, and it is satisfactory to be able to record that not only have there been more than 200 new members elected during the past year, but that the Institute has now the record membership in its history of over 2500. This has been achieved despite the fact that, owing to the circumstances of war, more than 400 members have been either temporarily or permanently lost to the Institute.

The financial position continues to be increasingly satisfactory, and ensures that when peace comes, full advantage can be taken of the changed conditions to render the Institute of even greater service to its members than it has been hitherto.

In this connection, members will be interested to know that the Council have been giving continuous attention to the problems which will face the Institute when hostilities cease, for they are well aware that it must continue to play an increasingly important rôle in the non-ferrous metals world.

With this in mind, they have appointed an " Exploratory Committee " to review the whole of the activities of the Institute, and to consider how best to extend its usefulness to its members and to the metallurgical industry as a whole. A notice in regard to this appears in the present issue of the *Journal*, from which it will be clear that the Council are anxious to avail themselves of the help and ideas of the younger members, whose task it will be in the years to come to carry on the work and traditions of the Institute.

To all the members of the Institute, whether at home or overseas, and especially to those who are temporarily deprived of freedom owing to war conditions, I would like to express my heartfelt good wishes for the New Year, and for the tasks that lie ahead both in war and peace.

J H M Greenly

President.

The Journal of the Institute of Metals

SUBJECT INDEX

VOLS. XXVI-LXIII

In the Press

This volume will be ready early in February and copies may then be obtained on application to the Secretary or through any bookseller. ¶ The index is a complete guide to the Proceedings of the Institute from 1921 to 1938, and to Metallurgical Abstracts from 1921 to 1933. ¶ The companion Name Index volume is already available at the same price.

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THE INSTITUTE OF METALS
4 Grosvenor Gardens, London, S.W.1

January, 1944.

THE INSTITUTE OF METALS

President:
Lieut.-Colonel Sir JOHN GREENLY, K.C.M.G., C.B.E., M.A.

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

Editor of Publications:
Lieut.-Colonel S. C. GUILLAN, T.D.

Administrative and Editorial Offices:
4 GROSVENOR GARDENS, LONDON, S.W.1

Telephone:
SLOANE 6233

Annual General Meeting.

Notice is hereby given that the 36th Annual General Meeting of the Institute of Metals will be held at No. 4 Grosvenor Gardens, London, S.W.1, on Wednesday, the 15th day of March, 1944, at 11 a.m., for the purpose of considering the Report of Council for the year ended December 31, 1943, and the Treasurer's Report and Statement of Accounts to June 30, 1943 (to appear in the February issue of the *Journal*); of electing Officers and Members of Council and Auditors for the year 1944–45; and of transacting the ordinary general business of the Institute required to be dealt with at such meeting.

By Order of the Council,
G. Shaw Scott,
Secretary.

January 1, 1944.

May Lecture, 1944.

Sir Harold Spencer Jones, M.A., D.Sc., F.R.S., the Astronomer Royal, has accepted the Council's invitation to deliver this year's May Lecture. His subject will be "Metals in the Stars." The lecture will be delivered on Wednesday, May 17, in the Hall of the Institution of Mechanical Engineers (by the courtesy of the Council of the Institution).

Honorary Members.

Sir Wm. Lawrence Bragg, O.B.E., M.C., M.A., D.Sc., Ph.D., F.R.S., Cavendish Professor of Experimental Physics, Cambridge, has been elected by the Council as an Honorary Member. He is President of the Institute of Physics and a May Lecturer, having given the 25th annual discourse to the Institute of Metals in 1935 on "Atomic Arrangement in Metals and Alloys." His father, the late Sir William H. Bragg, was also an Honorary Member and May Lecturer.

An Honorary Member has now been appointed by the Council in each of the four principal United Nations:

China: Her Excellency Madame Chiang Kai-Shek.
Great Britain: Sir Lawrence Bragg.
United States of America: Dr. Irving Langmuir.
Union of Soviet Socialist Republics: Professor P. Kapitza.

Other Honorary Members and the countries that they represent are:

France: Professor A. M. Portevin.
Sweden: Professor C. A. F. Benedicks.

Committee on Future Policy.

The Council has appointed a Sub-Committee to examine and report upon the activities of the Institute and the possibility of their expansion so as to give better service to its members and to the metallurgical industry as a whole.

The members of the Sub-Committee will be: Sir John Greenly, Dr. W. T. Griffiths, Sir Ronald Charles, Mr. G. L. Bailey, Mr. W. F. Brazener, Dr. Maurice Cook, Mr. Roosevelt Griffiths, Mr. A. J. Murphy, and Mr. H. S. Tasker.

The Sub-Committee will value constructive suggestions from members, and each one will receive careful and sympathetic consideration. Suggestions should be addressed to the Secretary.

Honorary Council Membership.

By virtue of a reciprocal arrangement between the Councils of the Institute of Metals and the Iron and Steel Institute, the President for the time being of each Institute becomes an Honorary Member of Council of the other Institute.

Subject Index to the Journal Vols. 26–63.

Within the next few weeks, copies will be available of the Subject Index to the *Journal* Volumes 26 to 63, publication of which has been delayed by the war. The index covers the papers published in the *Journal* between 1921 and 1938 and the abstracts between 1921 and 1933. Members who possess the *Journals* for these years, or a substantial part of them, will find that the Index provides a valuable key. Those members and others who placed orders when the publication of the Index was first announced, will receive copies as soon as they come from the press. The price of the volume is 15*s*., post free, and new orders should be sent to the Secretary without delay. The companion Name Index, which appeared early in 1940, is still available, also price 15*s*., post free.

The Nomenclature of Alloys.

The report of the Institute's Committee on the Nomenclature of Alloys, published in 1914 (*Journal*, Vol. **11**, pp. 45–56), recommended that alloys should be denoted by the names of their component metals, placed in the order of increasing numerical importance from the point of view of chemical composition by weight.

In general, the Institute has endeavoured to follow this system in its publications, although familiar terms in universal use in English, such as brass, bronze, nickel silver, have naturally been retained where appropriate. The system recommended in 1914 has not, however, been widely accepted, and the contrary method of placing first the metal present in largest proportion is fairly common in this country and is general in America and other countries. The Council has therefore decided, on the recommendation of its recently constituted Nomenclature Committee, that in future the practice of the Institute's publications shall conform with current usage elsewhere.

The following rule will therefore be adopted forthwith in the *Journal* and other publications of the Institute:

When an alloy is named by stating the chief elements it contains before the word "alloy," the elements will be given in the order:

(1) the element present in largest proportion, followed by

(2) the other elements present. These will be stated in order of descending proportion by weight, except in a very few cases where another order is well established. In such cases the customary order will usually be followed.

It will be observed that the Institute has made this rule for its own guidance, and that the use of established terms and expressions such as brass, bronze, leaded gun-metal, is not in any way affected.

The following examples illustrate the nomenclature to be adopted by the Institute:

96% aluminium, 4% copper—an aluminium–copper alloy.
90% copper, 10% lead—a copper–lead alloy.
94% aluminium, 5% zinc, 1% magnesium—an aluminium–zinc–magnesium alloy.
88% lead, 12% tin—a lead–tin alloy.
94% magnesium, 5% aluminium, 1% zinc—a magnesium–aluminium–zinc alloy.

The new system will be employed in the Institute's publications from the beginning of this year.

Membership Additions.

There were elected on December 16:

As Members.

Arthur, James Thomas, Camborne, Cornwall.
Brown, Hiram, B.S., Niagara Falls, N.Y., U.S.A.
Brunton, Robert Laurence, Hamilton, N.Z.
Clarke, Frederick Cuerel, B.Sc. (Eng.), London.
Davies, John Leslie, Briton Ferry, Glam.
Dorf, John, Edgware, Middlesex.
Green, William Ernest, Wolverhampton.
Gregory, Richard Cecil, London.
Harrison, Eric James, Birmingham.
Hedgecock, Percy David, London.
Hulme, Dennis Scanlan, B.Sc., Grays, Essex.
Lee, Geoffrey Reece Karl, London.
Marshall, John Kerrison, Croydon, Surrey.

MILROY, Alexander, Gideon, Feltham, Middlesex.
MUKERJEE, Sunil Coomar, London.
OXBY, George Alfred, B.Met., Sidcup, Kent.
PRESTON, Kenneth Huson, London.
SAIN-MILETIĆ, Branko, B.Sc., Barnet, Herts.
THOMAS, Joseph Byron, Swansea.
TORRY, Alan, Sheffield.
WATSON, Thomas, Sheffield.

As Student Members.

BOX, Henry Francis, West Wickham, Kent.
BRADSHAW, Anthony Vernon, London.
BRIGG, John, N. Wembley, Middlesex.
BUSBY, Arthur Donald, Birmingham.
COCKBILL, George William, Walsall.
CRUICKSHANK, James Alan Terry, Glenorchy, Tasmania.
DAVIES, Harold James, Swansea.
DAVIES, William Howell, Swansea.
DAVIS, Francis Henry, Barry, Glam.
ELLWOOD, Cecil Reginald, Birmingham.
FLOYD, Ronald William, B.Sc., Birmingham.
FOWLER, Robert Thomas, Bexley Heath, Kent.
GRIFFITHS, Peter Donald, Swansea.
GRGIC, Slavko, Birmingham.
HANCOX, Donald Ernest, Coventry.
HUGHES, Thomas Garfield, B.Sc., Briton Ferry, Glam.
JACKMAN, Hannah Nancy, Berkhamsted, Herts.
JAMES, Kenneth William, Briton Ferry, Glam.
JONES, Howell Henry Montagu, B.Sc., Tech., Briton Ferry, Glam.
LEECH, Edward Arthur, London.
MACFARLANE, Donald Ian, Whyteleafe, Surrey.
OLNEY, Maurice Joseph, Swansea.
PARTRIDGE, John Montague, London.
PERRYMAN, Eric Charles William, N. Farnborough.
POKORNY, Hans Walter, London.
REYNOLDS, Norman Montgomery, Coventry.
ROWLING, Peter James, West Croydon, Surrey.
WARD, Joan Grimshaw, London.
WILLIAMS, Raymond Campbell, London.

As Associate Member.

MARINCAS, John George, Trenton, N.J., U.S.A.

LETTER TO THE EDITOR

Alloy Nomenclature.

SIR,

The question of alloy nomenclature raised by Mr. Freeman Horn appears to us to have a very definite and logical answer. In English usage, the adjective invariably precedes the noun. Thus, one instinctively refers to *grey* cast iron, *stainless* steel, and *corrosion-resisting* nickel alloys.

It follows that whatever may be the practice in other languages, when writing English the name of the alloying element should precede that of the major constituent. It is proper to refer to magnesium-rich alloys of aluminium and magnesium only as aluminium–magnesium alloys, and to term them—as in Fox and Lardner's paper—magnesium–aluminium alloys is undoubtedly incorrect and misleading. A few exceptions—such as in the widespread reference to 80 : 20 *nickel–chromium* alloys—must be permitted as a concession to illogical custom, but these are so few and well established that they are unlikely to give rise to any serious confusion.

It would seem that by adopting a uniform and clearly stated nomenclature in the *Journal* and *Metallurgical Abstracts*, the Publication Committee could give a valuable lead in this matter.

Yours faithfully,
A. R. POWELL.
J. C. CHASTON.

Wembley,
November 30, 1943.

[Mr. Powell and Dr. Chaston support the recommendation of the Institute's first Nomenclature Committee in its report published in 1914. The Council's new decision is set out on the opposite page, and it may perhaps be worth while emphasizing that the new rule applies only when the word " alloy " is present. Our correspondents' contention that the name of the minor constituent should precede that of the major one, is upheld in such terms as " aluminium brass," " phosphor bronze," " beryllium copper," where the word " alloy " is absent.—EDITOR.]

News and Announcements

Conference on X-Ray Analysis.

The Third Conference on "X-Ray Analysis in Industry" has been provisionally arranged to take place in Oxford on March 31 and April 1, under the auspices of the X-Ray Analysis Group of the Institute of Physics. Details will be sent to non-members on application to Dr. H. Lipson, F.Inst.P., Honorary Secretary of the Group, c/o Crystallographic Laboratory, Free School Lane, Cambridge.

PERSONAL NOTES

Lieutenant-General Sir Ronald Charles, the Chief Royal Engineer and Honorary Treasurer of the Institute, has just returned from a short tour in India. During his visit he inspected field units of the Royal Engineers, the three Corps of Sappers and Miners, and other Groups of Indian Engineers.

General Charles is the Colonel of the Bengal Sappers and Miners, at whose headquarters he met two or three retired Viceroy's commissioned officers and sappers who had served with him when he was a regimental officer. He inspected the training battalions and other depôt units on parade, and visited the messes of the officers, British warrant and non-commissioned officers, and of the Viceroy's commissioned officers. He was struck with the military and technical efficiency of all the units whom he visited, as also by the fine spirit which imbued all ranks of the Indian Engineers.

Marriage.

Dr. E. W. Fell, M.Sc., F.R.I.C., to Miss M. F. Taylor, at Friends Meeting House, Malton, on December 7.

Obituary.

Mr. Henry Rogers, M.B.E., an Original Member of the Institute, died on December 8, in his 82nd year.

MEETINGS OF OTHER SOCIETIES

Royal Society of Arts.

Light Alloys in Post-War Britain. By E. C. Goldsworthy. (*February* 2. John Adam St., Adelphi, London, W.C.2, at 1.45 p.m.)

Midland Metallurgical Societies.

The Utilization of Secondary Copper-Base Materials. By H. J. Miller, M.Sc. (*February* 3. James Watt Memorial Institute, Great Charles St., Birmingham, at 6.15 p.m.)

Manchester Metallurgical Society.

Non-Ferrous Metals and Alloys in Enemy Aircraft. By H. Sutton, D.Sc. (*February* 9. Engineers' Club, Albert Square, Manchester, at 6.30 p.m.)

APPOINTMENTS VACANT.

Company established ninety years, handling every grade of non-ferrous scrap, desires competent dealer to re-establish European and Overseas contacts, with particular reference to common and precious residues. Strictly confidential to Box No. 108, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

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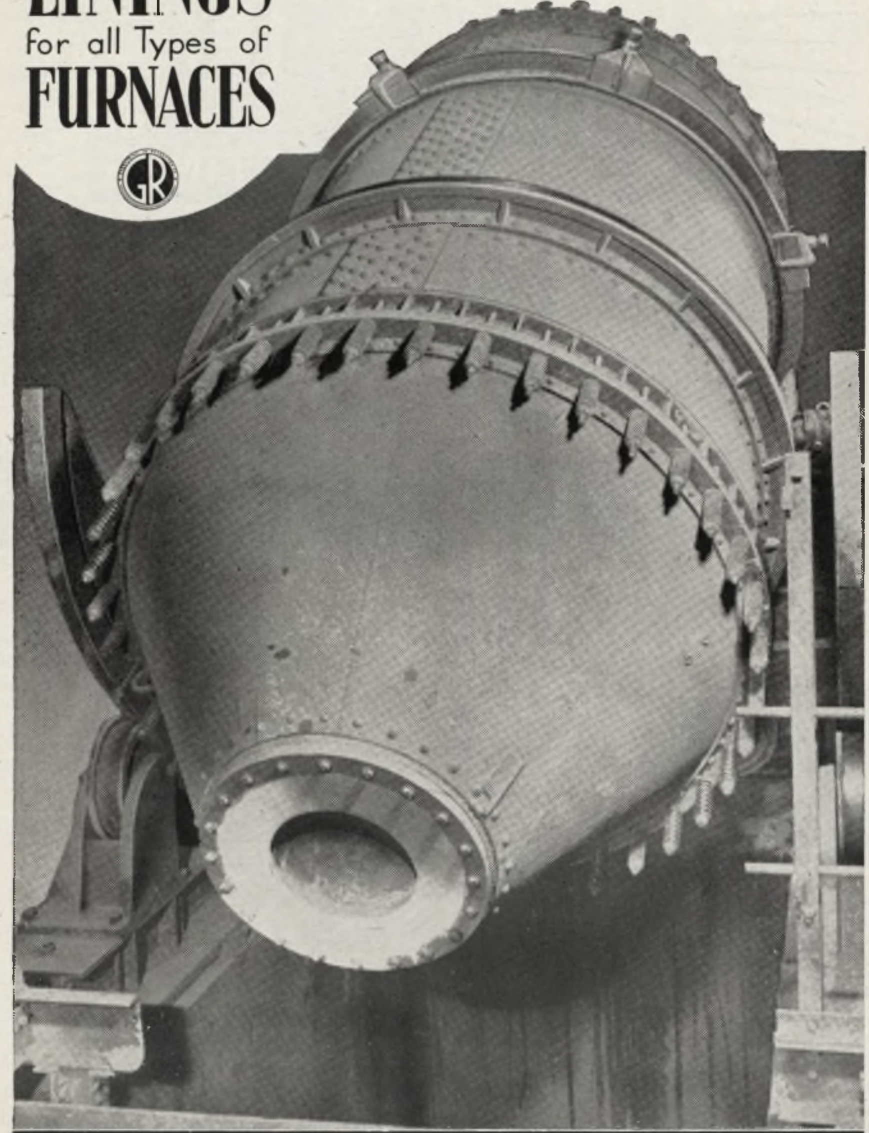
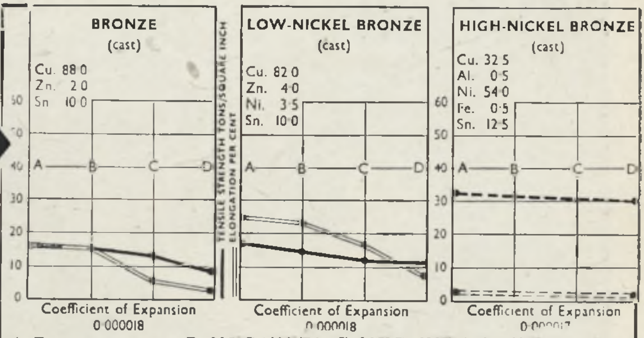
Laboratory assistant required, male or female, to assist in analytical control of metals and ores connected with manufacture of arc-welding electrodes. Education at least to Matriculation standard. Salary £150–300 p.a., according to age and qualifications. Under 20 years of age preferred, but not essential. London area. Employment under Essential Works Order. Box No. 113, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

Required for West London works, metallurgical chemist, preferably with experience in the examination of electrodeposits and also anodic films on light alloys. Send details of experience, salary required, and age to Box No. 114, Institute of Metals, 4 Grosvenor Gardens, London, S.W.1.

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Cu. 88·0
Zn. 2·0
Sn 10·0
LOW-NICKEL BRONZE
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Zn. 4·0
Ni. 3·5
Sn. 10·0
HIGH-NICKEL BRONZE
(cast)
Cu. 32·5
Al. 0·5
Ni. 54·0
Fe. 0·5
Sn. 12·5
TENSILE STRENGTH TONS/SQUARE INCH
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DAMPING CAPACITY AT LOW STRESSES IN LIGHT ALLOYS AND CARBON STEEL, WITH SOME EXAMPLES OF NON-DESTRUCTIVE TESTING.*

By the late Dr.-Ing. LEOPOLD FROMMER,† Member, and A. MURRAY.†

SYNOPSIS.

This work was undertaken to establish: (1) a reliable and accurate method for measuring the damping capacity of materials, particularly metals; (2) the significance of the damping capacity as a physical property of the material in terms of other known characteristics; (3) the influence exerted by structural defects, such as cracks and porosity, upon the measured damping, and thus to afford means for non-destructive testing; and (4) the practicability of employing damping measurements as a means of quality control and inspection of raw material and finished components.

By careful design, and as the result of experiment, it has been found possible to separate excessive external damping losses from the intrinsic damping which it was desired to measure. It has been established that at room temperature the damping capacity of the principal aluminium alloys is of the order of 10^{-5} as expressed by the logarithmic decrement. The measured damping is a constant up to a maximum shear stress of 30 lb./in.^{2}.

The damping of aluminium alloys appears to depend upon the degree of precipitation present, being highest for maximum solid solution and lowest in the annealed state.

The damping is markedly increased by small cracks or such porosity as would not normally occasion the rejection of a cast ingot. In some instances localized defects modify the damping at the various harmonics, so that the position of the defect can be estimated. This latter feature depends upon the experimentally determined fact that the torsional damping does not vary over the available frequency range.

The damping of a 0·6 per cent. carbon steel has been studied up to a maximum stress of 90 lb./in.^{2} and has been found to be $0{\cdot}5 \times 10^{-4}$ for the tempered condition and $0{\cdot}7 \times 10^{-4}$ for the oil-quenched condition, these values being closely reproduced through successive cycles of heat-treatment. Whilst the damping values found by this technique are comparable with those obtained by other workers employing a somewhat similar technique, they are many times smaller than those found at stresses a few times higher by the Föppl–Pertz technique (*J. Iron Steel Inst.*, 1936, **134**, 393).

I.—INTRODUCTION.

Object of Research.

THE aim of this research is the investigation of the usefulness of damping measurements for metallurgical research and non-destructive testing. Ideally, the damping factor measured should give constant or correlatable values over a reasonably wide range of testing con-

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* Manuscript received September 28, 1943.

† Research Laboratories, High Duty Alloys, Ltd.

ditions, enabling reproducible results to be obtained for different specimens of the same material and of identical metallurgical history; the presence of a defect would then be detected by an anomalous value of the damping capacity.

The complexities encountered in measurements of the damping capacity in the range of stresses applied in engineering (*i.e.*, up to the fatigue limit) arise because the damping in this stress range is governed by elastic–plastic relations which must be expected to vary considerably with the prevailing stress and the conditions of testing (*e.g.*, the number of stress cycles performed). This accounts for the sensitive dependence of the damping on the amplitude of the cyclic stress, and suggests that more direct relations might obtain at very low amplitudes, where possibly the damping capacity might tend to assume a constant value which could be described as the " damping capacity at vanishing amplitude." Provided that damping capacity at vanishing amplitude were a constant of the material, it would be a significant quantity for the indication of specific features of the structural condition and internal soundness of the specimen or of its metallurgical and physical history. However, such a quantity may be entirely different in meaning from the damping capacity prevailing in the range of stresses encountered in normal engineering practice. Some investigators refer to the damping capacity at vanishing amplitude as " internal friction " or as " mechanical hysteresis." It was, however, considered advisable to retain the term " damping capacity," or briefly " damping," in view of the experimental phenomenon by which this property is recognized and measured, in preference to other terms which might be understood to imply hypotheses as to the nature of the dissipative forces. It is therefore to be understood that whenever the term " damping capacity " is used, the damping capacity at vanishing amplitude is meant unless expressly stated otherwise.

Definition of Damping Capacity.

Various investigators have defined damping capacity in somewhat different forms which have been reviewed in various publications. Frequently the damping is defined as :

$$e = \frac{\Delta E}{E},$$

where ΔE = energy dissipated per cycle,

and E = max. vibrational energy (*i.e.*, vibrational energy at the beginning of a cycle),

or E = elastic energy stored at maximum stress (*i.e.*, after $\frac{1}{4}$ of a cycle).

However, in a resonant rod the quantity measured is not the vibrational energy but the amplitude of the oscillation, from which the former quantity is then deduced according to general elastic theory. It appears preferable, therefore, to define damping capacity in terms of the observed quantities, viz., amplitudes, and in this work the logarithmic decrement of the decay of the vibration amplitude has been taken as a measure of the damping capacity of the material.

The logarithmic decrement

$$\lambda = \log \frac{A_0}{A_1} = \frac{1}{ft} \log \frac{A_0}{A_n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where A_0 = initial amplitude,
A_1 = amplitude after one complete oscillation,
A_n = amplitude after n complete oscillations,
t = time measured from amplitude A_0 to amplitude A_n,
f = frequency.

In practice it is usual to calculate λ from observations of the time t for the amplitude A_n to fall to a definite fraction of A_0. If this time becomes too short to be measured accurately, λ may be determined from a measurement of the breadth of the resonance curve when the specimen is in forced vibration at the resonance frequency. If the breadth is taken as the frequency difference, Δf, for which half maximum amplitudes are obtained,

$$\lambda = \frac{\pi}{\sqrt{3}} \cdot \frac{\Delta f}{f} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where f is the resonance frequency.

In the present work the decay times have always been sufficiently long for λ to be determined from equation (1).

Some investigators, using the analogy of electrical circuits, have expressed the damping capacity by the quantity Q, which, in the electrical case, represents the "sharpness" of a tuned circuit and equals $\frac{\pi}{\lambda}$. Thus, the quantities used by various investigators as a measure of the damping capacity can all be expressed in terms of λ as:

$$\lambda = \frac{\Delta E}{2E} = \frac{\pi}{Q} = \frac{\pi}{\sqrt{3}} \cdot \frac{\Delta f}{f} = \frac{1}{ft} \log \frac{A_0}{A_n}.$$

Work Done by Previous Investigators.

Various investigators have determined damping capacity at small amplitudes from the resonance curve of forced vibrations or measurements of the logarithmic decrement of free oscillation of systems consisting of, or containing, the specimen under examination.[1–8]

The results of all these investigations, however divergent in detail, concur in indicating that for very low fibre stresses the damping capacity has a definite value which is of a lower order than that found within the range of engineering stresses. Beyond this, the research work published by previous investigators yields little information on the fundamental points which determine whether the " damping capacity at vanishing amplitude " is a well-defined metallurgical property, on the measurement of which new methods of structural research and of non-destructive testing can be based. The damping values reported for the same material by different research workers vary widely, and with regard to some fundamental points the published results appear to be even contradictory. Insufficient metallurgical data are given to enable the causes for these discrepancies to be traced to special features of the particular specimens examined. It seems probable that in much of the previous work the quoted damping values include considerable extraneous losses, as will be made evident by our own data.

In view of this, it was decided to attack the problem from fundamentals, to develop a technique which could be relied upon to yield measurements representative of the internal damping even in specimens of very low damping capacity (where the elimination of the extraneous losses is of greater importance), and then to investigate the characteristic features of the intrinsic damping capacity of metals and alloys. In particular, it was decided to investigate the correlation of the damping capacity with macro- and micro-structure and with soundness of the specimen.

II.—MATERIALS.

After tentative experiments on a variety of specimens of widely varying shape and size, and of different materials, it was decided to use comparatively large specimens (similar to those frequently occurring as raw products), chiefly of light alloys and, to a limited extent, of steel.

The principal disadvantage of using large specimens arises from the increased difficulty of obtaining a uniform and homogeneous metallurgical condition perfectly free from defects. The advantages of using large alloy specimens are :

(*a*) The relative extraneous losses (in proportion to the intrinsic dissipation) diminish with increasing size of the specimen. These losses arise mainly from three sources : (1) air losses (by friction and by acoustic radiation) ; (2) losses by energy transfer to the suspension system ; (3) losses caused by the translation instruments used for excitation and measurement. The relative air losses would naturally decrease with increasing ratio of volume to surface, all other factors remaining equal. The losses due to transfer of energy to the suspension device and the translation losses become increasingly prominent with decreasing bulk.

(*b*) Bulky specimens are less responsive to fortuitous extraneous excitation (such as draught or distant noise), which cannot always be excluded and which, in view of the necessarily sensitive nature of the suspension system, can be troublesome during measurements on small samples.

(*c*) In specimens of considerable length, the fundamental frequencies of longitudinal and torsional vibrations are comparatively low, and a number of overtones are measurable (between 500 and 12,000 cycles/second). This is of particular value in the interpretation of damping in terms of homogeneity.

(*d*) Large specimens can be cut up into smaller parts, thus enabling measurements at the same frequencies to be made on specimens of identical material but of widely different sizes.

(*e*) Such specimens assist in the development of a method which can be applied immediately to the testing of actual production samples.

Light alloys manufactured under the supervision of High Duty Alloys Laboratory were used in this work, since these materials are produced under carefully controlled conditions at all stages during manufacture. Moreover, large numbers of standard production specimens were available which could be returned to production after testing, thus economically widening the scope of the work. The light alloys investigated were, notably :

Hiduminium R.R.56—as extruded and swaged.
Hiduminium R.R.59—as cast and swaged.
Y alloy—as cast and swaged.
Duralumin—as swaged and extruded.

In addition, some work was done on the magnesium alloy

Magnuminium 288.A—as swaged.

Chill-cast ingots of 3–7 in. diameter and 2 ft. length, and cylindrical bars (wrought, forged, swaged, or extruded), 3–5 in. in diameter and 2–8 ft. in length, made of these alloys, were submitted to investigation in the various relevant stages of heat-treatment. Amongst these were specimens which, during production, had been purposely subjected to varied metallurgical treatments.

Investigations were also carried out on mild carbon steel bars of 3 in. diameter and 3 ft. length.

It proved necessary to confine the damping measurement to specimens with smooth surfaces, free from casting or forging skin or scale, preliminary experiments having established the considerable influence of hard crust or scale on the damping value. Therefore, chill-cast, as well as forged or swaged specimens, were usually turned on the lathe, while extruded bars were generally tested without any machining of the cylindrical surfaces.

For the bulk of the work only cylindrical specimens were used, these being more amenable to mathematical treatment. However, some tapered specimens were measured for the purpose of non-destructive testing.

III.—METHOD.

General Conditions.

Existing evidence indicated low intrinsic damping capacities at vanishing amplitudes; this fact governed the selection of the method of measurement. Previous investigators, notably Zener and Förster and Köster, had reported values as low as 10^{-4}, and tentative experiments at High Duty Alloys had confirmed this order of magnitude. Since experimental errors in general increase the damping value measured, it was to be expected that the actual intrinsic damping capacity of some metals might be of a still lower order.

Thus, the elimination of extraneous sources of dissipation was a pre-requisite necessitating a method of supporting the specimen such that the sum total of all frictional and other external losses should be of an order considerably lower than 0·001 per cent. of the elastic vibrational energy of the specimen. Any direct contact between the specimen and other solids which could lead to noticeable transfer of energy had to be avoided; consequently, all methods involving clamping or fastening the specimen to a rigid frame were considered unsuitable. Likewise methods which necessitate the clamping of the specimen to any other solid body taking part in the vibrational movement (as in the case of a resonant pendulum) appeared unsuitable, since the frictional losses in the joint could not be controlled as long as the intrinsic damping capacity of the specimen itself was unknown. The most promising method appeared to be that of the " resonant bar."

Principle of the " Resonant Bar."

This method consists in exciting in a freely suspended bar (" free-free ") a strictly monochromatic oscillation, and determining the damping capacity, either by measuring the rate of decay of free oscillations, or by measuring the shape of the resonance curve of forced oscillations.

It is to be noted that for either method of measurement oscillations of a strictly " monochromatic " character are essential. If the specimen does not vibrate at one frequency only, but at several frequencies (*e.g.*, at a fundamental frequency and overtones), the equations for λ are no longer applicable. The driving force must, therefore, either be strictly monochromatic, or, if it has any overtones of appreciable intensity, these must not be in resonance with any of the natural frequencies of the specimen; otherwise the latter frequencies would be co-excited.

Modes of Vibration.

Freely suspended cylindrical or prismatic bars are capable of free oscillations in three principal modes, viz., transverse (or flexural), longitudinal, and torsional vibrations. In each of these modes, the number of resonance frequencies is infinite. Approximate formulæ for the natural frequencies of homogeneous cylindrical bars (or circular cross-section) are well known.

The transverse frequencies do not form a harmonic series, but occur approximately in the ratios: 3^2, 5^2, 7^2, 9^2, where 3^2 represents the fundamental tone; whereas both longitudinal and torsional frequencies form harmonic series.

In practice, slightly " inharmonic behaviour " of the specimens in longitudinal and torsional vibrations facilitates monochromatic excitation. It would be difficult to provide a periodic exciting force completely free from overtones. These are, however, harmless if they do not coincide with any of the natural frequencies of the specimen; the specimen therefore acts as a " frequency filter."

In preliminary experiments, tentative measurements of the damping capacity were made in all three modes in order to choose the most suitable one for the bulk of the research. In the case of transverse and longitudinal vibrations, these values may differ considerably from the intrinsic damping of the specimen, owing to air losses. They are of use, however, for detecting co-excitation of alien modes of vibration (due to overlapping of resonance ranges); *e.g.*, when exciting torsional vibrations in air, interference may arise from transverse or longitudinal resonance frequencies 20 cycles/second away. All measurements were made in air. These preliminary tests led to the following conclusions:

Transverse Vibrations.

Air losses are considerable, since the flexural movement generates air waves over the whole surface of the specimen. Elimination of air losses by experiments *in vacuo* presents many difficulties with large specimens, and such experiments, though of considerable scientific interest, could contribute little to the development of a method suitable for non-destructive metallurgical testing of large samples.

The suspension losses (*i.e.*, dissipation of energy in the supporting system) are very difficult to control in the case of flexural oscillations. Special care was taken in designing the suspension system to minimize energy dissipation, but serious losses did remain owing to the dilatational component of the vibration.

When working under optimum conditions, the damping values obtained were reproducible within 5 per cent., and were fairly consistent for the same material, from one specimen to another, within the lower ranges of frequency (100–400 cycles/second). In this range faultless specimens of wrought Hiduminium R.R.56 and Duralumin, both dead-soft annealed, gave values of $\lambda = 0{\cdot}3 - 0{\cdot}5 \times 10^{-4}$. For higher frequencies, however, a complicated variation of the damping values with frequency was found, for which no simple interpretation is possible. It may be assumed that this is due largely to the air losses already mentioned, which must be expected to be considerable at mid-range audio frequencies.

Longitudinal Vibration.

In longitudinal oscillations the tendency towards transfer of vibrational energy to the suspension system is naturally less than for transverse oscillations and can be minimized by suitable arrangements. Acoustic radiation is negligible from the sides of the specimens, but persists from the end surfaces owing to the reciprocating movement of the latter (piston effect). Frictional air losses remain. Thus, air losses, while less prominent than in the case of transverse vibrations, are still serious.

Preliminary measurements of the damping capacity gave well-reproducible results. The damping capacity of specimens of various aluminium and magnesium alloys was found to be approximately constant in the higher overtones, while in the lower tones it showed as much as 100 per cent. increase.

Torsional Vibrations.

This mode appeared from the outset to offer fewer experimental difficulties and to be of greater scientific interest and practical importance than the preceding modes, as long as the investigation was limited to specimens of the shape of solids of revolution. The fact that the torsional mode of vibration is the only mode in which only one type of

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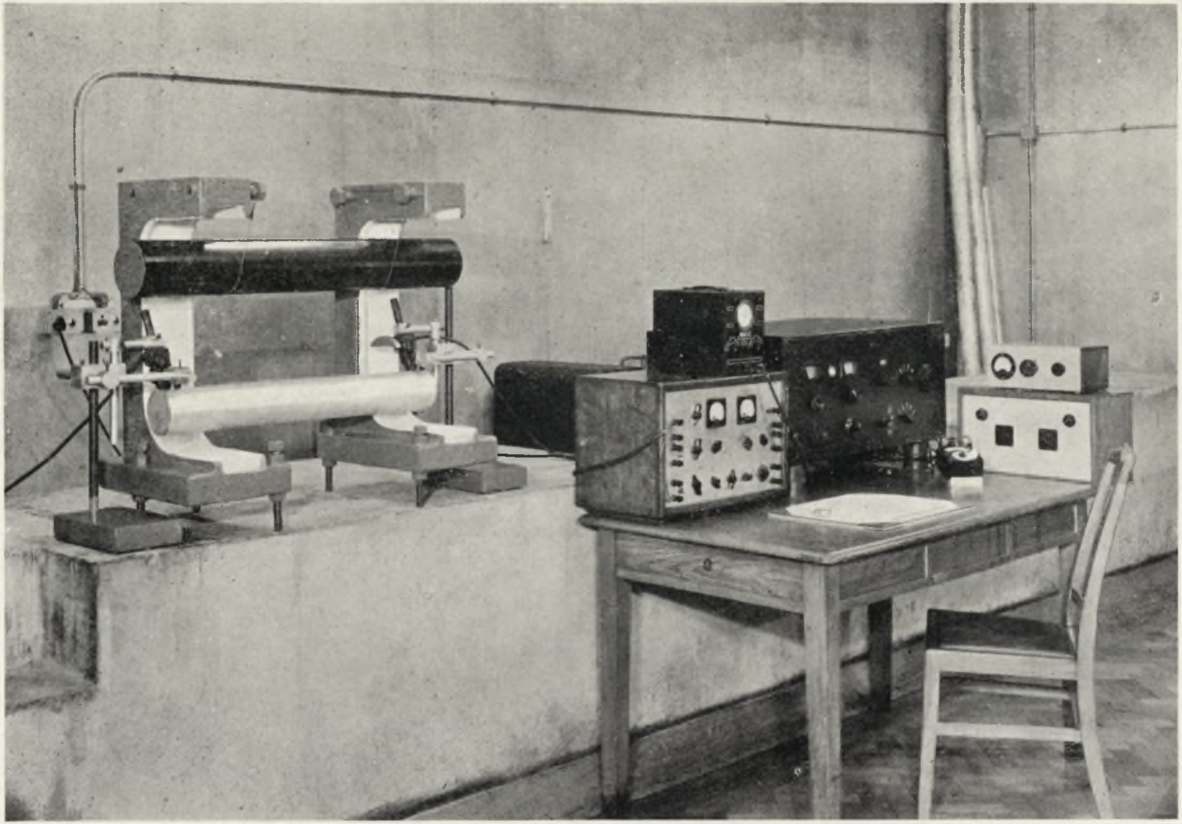


FIG. 17.—General View of the Equipment.

stress, viz., pure shear, occurs, all dilatation effects being absent, is of paramount importance. Results obtained with torsional vibrations should therefore be more easily interpretable.

The prospect of eliminating extraneous losses is much better than in the other modes, since the surfaces of a solid of revolution perform only tangential movements which are not conducive to the production of sound waves. Frictional losses between the air and the surfaces of the specimen, together with a very small amount of acoustic radiation, are the only air losses occurring, and there is every indication that these are small. The special type of suspension system employed reduces suspension losses to a second-order effect.

Consequently, it was decided to concentrate on the investigation of the damping capacity in torsional vibrations, and the present work refers to this mode unless the contrary is expressly stated.

IV.—APPARATUS.

A special form of audio-frequency signal generator is used to excite vibrations in the specimens at the appropriate resonance frequency, by feeding the signal, suitably amplified, to an eddy-current–permanent-magnetic field-exciter device placed close to, but not touching, one end of the specimen bar. The bar, held in a special suspension system, vibrates in the "free-free" state, and the excited vibrations are detected by a device similar to the exciter. The alternating current generated in this detector is amplified and fed to a robust a.c. voltmeter, which gives a reading proportional to the vibration amplitude. The decay of the amplitude after the exciter is cut out is timed by means of a stop-watch. A general view of the apparatus is shown in Fig. 17 (Plate I).

Design Details of Specimen Suspension System.

In developing the specimen suspension two important considerations were borne in mind : (*a*) the transfer of energy may be minimized by connecting the vibrating mass to a much larger rigid mass by means of a weak elastic coupling, and (*b*) since the vibrating system has a preferred direction of vibratory motion, energy losses may be minimized by designing the suspension system (for torsional oscillations only) so as to permit freedom of movement in this direction.

Fig. 1 illustrates one of the two support stands and suspension systems arranged for a typical specimen of 4 in. diameter and 3 ft. length. It will be seen that the specimen F rests in thin wire loops H, which pass round the bottom of the specimen and over the balance beams *E*. The loop, of wire 0·009 in. in diameter or as thin as possible compatible with the load imposed, is made by interlinking small loops formed on each end of the wire. This link and the associated " twists " rest in the groove in the top curved surface of the balance beam, so that the weight of the specimen holds the link against the beam, thus preventing the " twists " from slipping undone.

The apex of the Vee-suspension *D* passes under the balance beam, whilst the loops forming part of the sides of the Vee pass round the inertia bar *C*. This coupling system between the specimen and the inertia bar represents the first barrier to energy loss. This principle is again exemplified by the seven-stranded wire cable *B*, supporting the inertia bar *C*, on the two suspension bolts *A*, which are screwed into the cast stand *G*. Finally, the cast stand *G* is placed upon a massive concrete block (see Fig. 17, Plate I), which serves as a working platform for all the various stands and equipment; it is 25 ft. long, 3 ft. wide, and 5 to 6 ft. deep, projecting 3 ft. above floor level; and it is separated from the foundations of the laboratory building. This latter precaution is taken to isolate the system from vibrations in the building, whilst the link between the concrete block and the cast stands provided by the three bolts in the base of the cast stand is another example of the principle of " weakly coupled " mass systems.

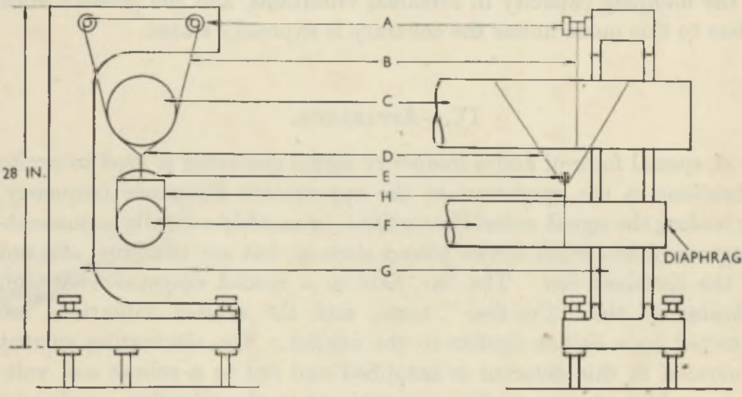


Fig. 1.—Details of Support Stand and Suspension.

The Balance Beams.

Perhaps the most important feature of the suspension system is the balance beam (Fig. 2), which allows the specimen freedom to oscillate through a small angle during torsional vibrations. The balance beam oscillates about the apex of the Vee-suspension as an axis, and where the specimen loop leaves contact with the groove in the balance beam, only the bending elasticity of the steel wire is called into action. The chief source of friction is at the pivot, where the relative movement during vibration is least. Moreover, even at the largest amplitudes employed, the maximum velocity of the specimen loop is only 1·0 mm. per second and the maximum displacement 0·00013 mm. The length of the balance beam is determined by the diameter of the specimen, a 4-in. beam, for example, serving for 3½–4½-in. specimens. The "stabilizing" distance (Fig. 2) is made 1 millimetre, experience showing that a greater distance than this would tend to overstabilize the system and so destroy the rotary freedom of the balance-beam system.

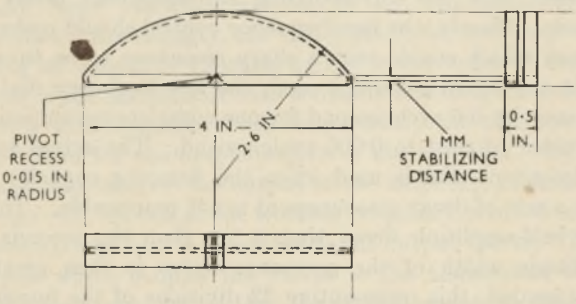


Fig. 2.—Details of Balance Beam. Material: R.R.59 Alloy.

A simple suspension (strictly at the nodes) would have to be moved to the appropriate nodes for each frequency. Not only would this be generally troublesome, but at the fundamental tone such a suspension becomes impracticable. The balance beams make careful positioning of the specimen loops unnecessary and give far more accurate and reproducible measurements. The suspension described has been employed up to the twentieth tone of a specimen without significant error being introduced by not adjusting the suspension to the nodes.

The Electrical Equipment.

The electrical equipment is designed so that vibrations can be excited and detected in specimens of varied dimensions, at any frequency in the range 100–12,000 cycles/second, without actual mechanical contact with the specimen, thus avoiding uncertain and excessive energy losses.

The Audio-Frequency Signal Generator.

The requirements from the audio-frequency signal generator are severe for this class of instrument, and no existing oscillator is entirely satisfactory. The accuracy of frequency calibration need not be better than ± 0·5 per cent., since the equations for the calculation of the logarithmic decrement involve only the first power of the frequency. The signal generator is standardized at one point in terms of a tuning fork, and, because of the known harmonic behaviour of certain of the specimens, many other reference points can be obtained.

A fine adjustment for the frequency is an essential feature necessitated by the sharpness of the resonance curves of the usual specimens. For example, the resonance breadth at half amplitude for a normal decrement of $1{\cdot}0 \times 10^{-5}$ measured at 1000 cycles/second is 0·0055 cycles/second, and the corresponding half-amplitude decay time is 69·3 seconds. Clearly, the fine-frequency control should make changes of frequency which enable such a sharp resonance to be tuned fairly easily. In the signal generator used, the fine-frequency dial changes the frequency by 0·6 cycle/second for one complete revolution and the dial is divided to read to 0·006 cycle/second. The actual reading of the fine-frequency dial is used when the damping capacity value is such that a rate of decay measurement is not practicable. This occurs when the half-amplitude decay time is less than two seconds and the half-amplitude width of the resonance curve is then greater than 0·19 cycle/second, this representing 32 divisions of the fine-frequency dial. For torsional oscillations, measurements of this type do not occur with specimens of steel or aluminium alloys over the frequency range employed in this work. With transverse vibrations, however, such measurements are the rule rather than the exception. With both of the above types of measurement the stability of the frequency affects both the speed and accuracy of measurement.

In decay-time measurements the drift of the frequency should not be so great that the driving frequency passes right through the resonance range of the specimen before a steady amplitude of vibration is established, and it can be shown that the short-time frequency drift of the oscillator should be better than 0·005 cycles/second in one or two minutes.

The signal generator employed is of the "beat" frequency type in which the output of two radio-frequency oscillators is mixed, on the heterodyne principle, so that the difference frequency of the two oscillators is selected and amplified to a level of 1 watt. By this means a range of 60 to 6000 cycles/second is obtained, over which the frequency is smoothly adjustable.

Although the measured frequency stability of the signal generator cannot be the same from day to day owing to power-supply fluctuations, ambient-temperature conditions, and the limiting stability of the components, it has been observed to be uniform in one direction over a period of 8 hrs., during which the drift was approximately 1 cycle/second. Therefore the drift appears to be of the order of 0·002 cycles/second/minute, which can be considered satisfactory.

By means of an electronic frequency doubler, the 6000 cycles/second frequency limit of the signal generator was raised to 12,000 cycles/second.

Power Amplifier.

The signal generator has a nominal power output of 1 watt. This energy was, however, found to be inadequate for exciting sufficiently large vibration amplitudes at frequencies about 3000 cycles/second. Accordingly, the signal generator feeds a power amplifier having an output of 12 watts and of a conventional design. The impedance of the transmitter coils is mainly reactive, the value increasing linearly with frequency, and consequently the coils constitute an unsuitable load for the output valves of the amplifier. By means of condensers connected to the output of the amplifier, in series with the transmitter coil, the coil at the working frequency is tuned so that only the resistive component is presented to the output valves. The output transformer which couples the valves to the transmitter coil is provided with four tappings, so that the resistance can be approximately matched to the valves.

The Electromagnet Exciter and Detector Units.

These are suitable for the longitudinal, torsional, or transverse modes by suitable orientation with regard to the specimen. For the experiments two types have been used, working on the following principles: (*a*) moving-iron principle (as in telephone receivers), and (*b*) induced eddy currents acting upon a stationary field. The moving-iron type of exciter and detector involves fixing a small block of a low hysteretic alloy (Radiometal) on the end faces of the specimen with sealing compound. The most generally satisfactory cement was found to be Cenco-Sealstix, but the moving-iron units were eventually replaced wherever possible by eddy-current units, which require no attachment to the specimen.

By associating a small auxiliary permanent magnet with one of the electromagnet instruments, eddy-current excitation and detection of torsional vibrations is accomplished. The requirement is simply that eddy currents induced in the metal of the specimen by the alternating field of the electromagnet should be acted upon by the flux from the auxiliary permanent magnet at such an angle as will produce a torque on the specimen.

The Detector Amplifier and Output Meter.

The alternating voltage generated in the coils of the receiver is fed into the input transformer of a four-stage amplifier of conventional design, whilst to the output (0·1 watt maximum) of the amplifier an a.c. voltmeter of the copper-oxide-rectifier type is connected for indicating vibration amplitudes.

Two factors are important in the choice of a suitable output meter for this work. The first is that the period of the moving system shall be small compared with the shortest decay time to be measured; in the instrument employed, the time for the pointer to reach one-tenth of the full scale from a maximum reading is less than 0·2 second, which time is small compared with the shortest decay times measured, viz., 3 seconds. The second factor is that the scale shape of the instrument shall be independent of frequency. Variation of scale shape was observed, but as it was a variation of less than 2 per cent. of the half-scale value over the frequency range 250–12,000 cycles/second, it was ignored in computations; no change at all was observed between 1000 and 12,000 cycles/second.

Auxiliary Devices.

Meter-Scale Calibration.

To establish the relation between the input voltage to the amplifier and the deflection of the output meter, a special attenuator unit was designed so that definite ratios of input voltage to the amplifier provided the necessary data of scale shape.

The Cathode-Ray Oscilloscope.

In the general view of the equipment (Fig. 17, Plate I) a cathode-ray oscilloscope will be noted. This instrument is normally connected across the output meter so that it indicates the amplitude of vibration and provides a picture of the wave-form of the vibration. It is also used to verify that the frequency of vibration of the specimen coincides with the drive frequency, since it sometimes happens that a fundamental frequency will excite the second tone in the specimen. Occasionally, on exciting a given tone, a higher overtone is co-excited, which may not disappear during the decay of vibration when the power is cut off, and for the detection of this the oscilloscope is a valuable accessory.

Extraneous Interference and the Problem of Shielding.

Stray or leakage fields at the receiver instrument during decay-time measurements sometimes develop voltages which can cause serious errors in the measurements.

There are two principal sources of interference, the first being the radiations from induction furnaces, welding machines, spectrographic apparatus, &c. This type of interference has been minimized by lining the laboratory with aluminium sheet and laying wire netting under the floor boards and inside the skylights. In addition, radio-frequency filters were fitted to the incoming power lines, so that radiation picked up on these lines would not be re-radiated into the room and into the equipment.

Radiation from the transmitter coil to the receiver coil during excitation cannot affect the damping-capacity measurements, since the power is cut off during the measurement. However, when the specimen is shorter than usual, or where the radiated field is unusually large, this form of direct pick-up by the receiver is troublesome; in cases where this is large compared with the received voltage due to the vibration, tuning is difficult, particularly in the initial stages, as the full amplifier sensitivity cannot be employed.

Apparatus for Measurement of Small Amplitudes.

For the purpose of measuring decay times or of plotting resonance curves, relative values of amplitude as obtained from the meter readings are sufficient, but any statement as regards actual stresses, a knowledge of which is of importance in view of the dependence of damping on the maximum fibre stress, necessitates investigation of absolute values of amplitude.

The use of " vanishing " amplitudes, as in the greater part of the present research, prohibits measurements by direct optical means (*e.g.*, a reading microscope), and the complexity of the magnetic field in the neighbourhood of the receiver renders accurate determination directly from meter readings extremely difficult both theoretically and experimentally. In view of the sharpness of the resonance curves experienced with the specimen, " motional impedance " measurements, as described by Wegel and Walther,[1] are hardly practicable.

The method finally adopted involved calibration of the detector unit for known amplitudes determined by interferometric methods.[9] It is estimated by this means that the maximum fibre stress in the majority of the experiments which were recorded was between 0·5 and 30 lb./in.^{2} for light alloys and between 1·5 and 90 lb./in.^{2} for steels.

V.—MEASUREMENT ON LIGHT ALLOYS.

The specimens are measured not only in the fundamental frequency but also in as many overtones as fall within the frequency range of the signal generator. For specimens of length $2\frac{1}{2}$–$3\frac{1}{2}$ ft., the fundamental frequency is between 1475 and 2060 cycles/second, and consequently 5–8 harmonics are measurable.

Method of Measurement.

The signal generator is adjusted to the calculated resonance frequency of the specimen under investigation, the ultimate fine tuning being effected by observing the response of the bar, as indicated by the detector device. When the maximum amplitude of vibration of the specimen is obtained, the generator power is cut off, and the time interval during which the deflection of the output meter falls from full scale to half scale is noted with a stop-watch. When this first decay time has been measured, the sensitivity of the detector amplifier is increased so as to bring the meter deflection back to full scale, and the period of the decay to half scale is measured again. This procedure is repeated, until the vibration of the bar has decayed to such an extent that the detector signal is insufficient, with the amplifier at maximum sensitivity, to bring the deflection of the meter to full scale. Thus, a series of half-amplitude decay times for diminishing values of the amplitude are obtained, enabling the dependence of the damping on amplitude to be checked for each decay.

The limitations of this method are given by the stop-watch error and the period of the meter, which are estimated to give a combined maximum error in the decay-time measurement of 0·3 second. This can be seen in Table I, which shows the values of the half-amplitude decay times for a bar of usual size having a damping capacity typical of light-alloy specimens.

TABLE I.—*Damping Capacity as a Constant.*

*Hiduminium R.R.*59 *Aluminium Alloy Wrought Bar*, 4 *in. Diameter*, 5 *ft. Long.*

Harmonic Number.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Frequency, cycles/second . . .	1068	2126	3185	4250	5310	6370	7440	8500	9560	10,640
Aver. half-amplitude decay time, seconds	57·3	27·6	19·4	14·5	10·9	9·6	8·2	7·0	6·15	5·2
$\lambda \times 10^4$ . . .	0·113	0·117	0·112	0·112	0·119	0·113	0·115	0·116	0·118	0·124

When, in the higher tones, the half-amplitude decay time becomes too short to be measured with sufficient accuracy, the "double decay time " can be measured instead. By double " decay time " is meant the period during which the amplitude decays to a quarter of its original value.

At amplitudes within the range previously mentioned, the logarithmic decrement for the decay of free vibration was found to be essentially constant throughout the decay, indicating that for a given frequency damping capacity is a constant of the specimen, independent of amplitude. The constancy of the logarithmic decrement means that the time during which the amplitude falls from any given value to any given fraction of that value is constant throughout the whole period of decay; hence the graph of the decay time against the logarithm of the amplitude should be a straight line.

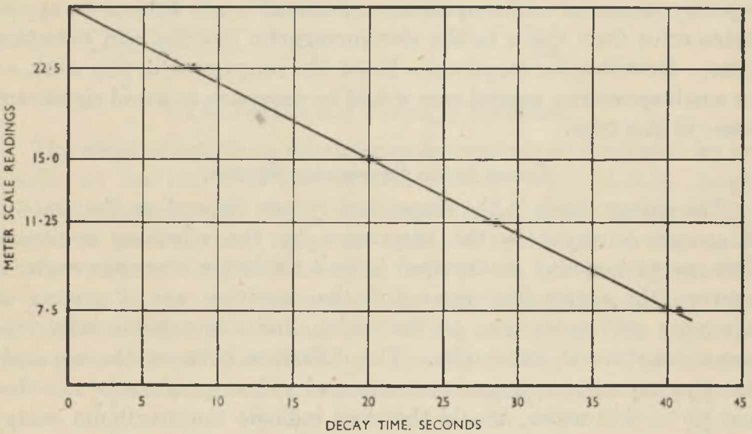


Fig. 3.—Constancy of Logarithmic Decrement.

The results of one typical series of measurements are given in Fig. 3 and relate to an extruded Duralumin bar of 4 in. diameter and 41 in. length, in the fully heat-treated condition (solution treated for 8 hrs. at 495° C., quenched in boiling water, and aged naturally).

The results are typical of a very large number of similar measurements obtained on specimens of various kinds of light alloys in various metallurgical conditions; specimens have been examined over a wide range of frequencies (from about 800 to 12,000 cycles/second) and show complete independence of damping capacity on amplitude within the range considered.

In rare cases it is found that the rate of decay as measured immediately after cutting off the driving energy is greater than the rates of decay at subsequent times, which are all constant within experimental error. However, it can easily be shown that this is not an amplitude effect, since, if the same specimen is now excited to a higher amplitude, the anomaly may still occur immediately after switching off the exciting force; but the previously observed constant rate of decay is again found for all subsequent measurements, including those made when the amplitude has decayed to its former maximum value, where the effect was first observed. It is therefore clear that the anomalous initial rate of decay is not due to a dependence of damping on amplitude, but that it is connected with phenomena resulting from switching off the driving force.

Energy Losses Due to Extraneous Dissipation.

A comprehensive series of experiments has shown that damping capacity measured under optimum conditions is not subject to appreciable error from losses in the electromagnetic erecting and detecting units. However, for frequencies below the range used in this work, or for small specimens, special care would be necessary to avoid significant losses of this type.

Losses in the Suspension System.

The energy losses in the suspension system depend on the amount of energy conveyed to the suspension by the vibrating specimen. This energy loss may be expected to be a minimum when the contacts between the suspending wires and the specimen are at regions of minimum movement, *i.e.*, at the nodes, and a maximum when the suspensions are at anti-nodes. The difference between the apparent damping capacities of a specimen measured with suspensions (*a*) at nodes, and (*b*) at anti-nodes, should therefore indicate the maximum energy dissipation occurring in the suspension system.

The damping capacity of an extruded Duralumin bar of 4 in. diameter and 41 in. length, in the fully heat-treated and aged condition, was measured in the first 6–8 resonance frequencies:

(*a*) with the suspensions $1\frac{1}{2}$ in. apart at the centre of the bar,
(*b*) with the suspensions at the nodes of the second harmoic, and
(*c*) with the suspensions at the extreme nodes of the third harmonic.

The results are plotted graphically in Fig. 4, which shows that when the suspensions are at a favourable position, *i.e.*, at or near the nodes of the harmonic in question, the energy dissipated in the suspensions must be very small indeed, since at the nodes the motion of the bar is negligible. (It should be remembered, however, that these results were obtained using fairly large specimens. With smaller specimens these and other losses may become appreciable.)

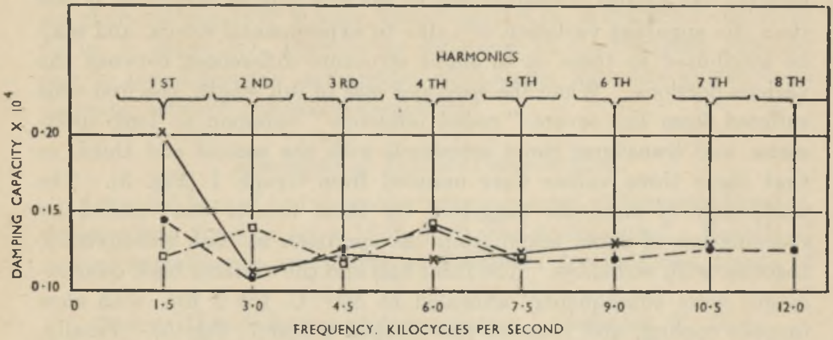


Fig. 4.—Influence of Position of Suspensions.

— - — □ — - — Suspension wires at node of 1st harmonic.
— — — ● — — „ „ „ 2nd „
——— × ——— „ „ „ 3rd „

The Influence of Length of Specimen.

The effect of length on damping measurements is illustrated by the results on an extruded bar of Hiduminium alloy R.R.56, length 275 cm., diameter 12·7 cm. Measurements at all the available harmonics in the frequency range up to 12,000 cycles/second were made on the specimen for the full length, each of the half-lengths obtained by cutting in two, and on each of the quarter-lengths resulting from halving the length at the back end of the extrusion. The results of these measurements are shown graphically in Fig. 5. The distance

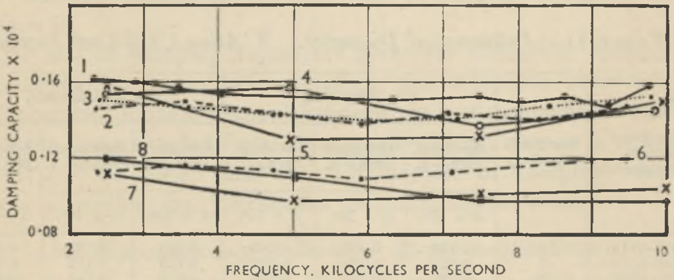


Fig. 5.—Aluminium Alloy Extruded Bar.

Key.

1. Bar when 275 cm. long, as extruded.
2. Front half of bar (133·5 cm.), as extruded.
3. Back half of bar (132 cm.), as extruded.
4. Front section of back half (63 cm.), as extruded.
5. Back section of back half (63·5 cm.), as extruded.
6. Front half after annealing.
7. Back section of back half after annealing.
8. Back section of back half after solution-treatment and ageing.

between the graphs corresponding to the five lengths employed is less than the apparent variation of λ due to experimental errors, and may be attributed to these or to slight structure differences between the various portions. When the specimen was of full length, the first tone suffered from the severe "nodal influence" common to long specimens, and transverse tones interfered with the second and third, so that these three values were omitted from Graph 1 (Fig. 5). The uniformity of structure suggested by these results was verified by examination of slices taken from the specimen at each sub-division, together with end slices. The front half and the extreme back quarter-length were subsequently annealed at 350° C. for 2 hrs. with slow furnace cooling, and retested (see Graphs 6 and 7, Fig. 5). Finally, the extreme back quarter-length was solution-treated and aged in the standard manner, with the resultant damping values shown in Graph 8 (Fig. 5). It can therefore be concluded that for the ratio of length of four to one the measured damping value remains unchanged in any essential degree provided the specimen is longitudinally uniform. It is also seen that the "as-extruded" condition was as metallurgically uniform as the annealed or fully heat-treated condition, although the damping in the extruded state was approximately 30 per cent. higher. This feature of damping capacity, viz., independence of length of specimen, has been consistently confirmed.

The Influence of Diameter and Cross-Section.

Systematic reduction of the diameter of a given specimen may give rise to an increase of the measured damping, caused solely by the greater air friction due to increase in surface area/volume ratio. There is also the probability that no specimen has a uniform structure throughout the cross-section, this being particularly true of cast ingots. When, therefore, the cross-section is inhomogeneous, reduction of the diameter may be expected to modify the measured damping capacity.

TABLE II.—*Influence of Diameter. Y Alloy Chill-Cast Ingots.*

Frequency Range, cycles/second.	Harmonic Number.	4 in. Diameter.			6¼ in. Diameter.		
		Specimen 109A3–4.	Specimen 109A3–6.	Specimen 109A3–7.	Specimen 126A103	Specimen 126A104–1.	Specimen 126A104–5.
		$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.
2070–2115	1	0·132	0·138	0·140	0·130	0·139	0·123
4160–4225	2	0·119	0·125	0·139	0·129	0·132	0·122
6240–6350	3	0·120	0·129	0·144	0·138	0·131	0·123
8320–8450	4	0·126	0·133	0·145	0·143	0·132	0·122

Table II shows the damping values in the first four harmonics of six chill-cast ingots of Y alloy, three ingots 4 in. in diameter and three 6¾ in. in diameter. There is no difference in the damping capacity due to the difference in diameter comparable with the variation in damping between individual specimens.

Specimens of Tubular Cross-Section.

Annealed bars of 4 in. diameter were measured in the usual manner, drilled along the axis by a 1¾-in. drill, and re-measured. Results of typical experiments are shown in Table III for chill-cast ingots of Y alloy. Column 5 shows the damping values immediately before drilling, and it will be noted that after drilling (Column 6) the damping values are noticeably higher. Part of this increase may be attributed to strain hardening and layer stresses induced by the drilling operation, since suitable annealing restores the pre-drilled damping values (Column 7).

TABLE III.—*Influence of Cross-Section. Chill-Cast Y Alloy.*

Frequency, cycles/second.	Harmonic Number.	As 4 in. Diam. Chill-Cast.	As 4 in. Diam. Annealing.	2 Months after Annealing.	Drilled, 1¾ in. Diameter Hole.	Annealed after Drilling.
		$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.
2100	1	0·140	0·139	0·149	0·177	0·153
4200	2	0·137	0·138	0·150	0·167	0·146
6300	3	0·144	0·142	0·158	0·183	0·159
8400	4	0·145	0·153	0·168	0·206	0·177

Two sets of damping values are given for the above specimen in the annealed condition before drilling, the difference between them being that two months elapsed between the measurements. The first test in the " as-annealed " state was made within a day or so of annealing. It can be stated that such an increase in damping over two months is genuine, many examples occurring in this work.

(a) *Reproducibility of Results. Experimental Errors.*

The total error in λ is less than 6 per cent. This accuracy is adequate for our present needs; no significance can at present be attached to differences in λ of 20 per cent. between specimens of similar kind and metallurgical history. The errors of the equipment and technique assume greatest importance when studying structural changes in a given specimen, as for instance during the ageing of an alloy at room temperature. However, in this case, it is usually possible to maintain identical conditions such as suspension arrangement and frequency. Examination of results reveals that the damping values usually increase by about 6–10 per cent. over periods from 2 months to 1 year, and since the technique employed in the later measurements is such as would have afforded a slightly lower damping value (about 2–3 per cent.), in the absence of any genuine change in the intrinsic damping of the material, it may be concluded that the damping is not quite constant over such periods.

(b) *Evidence that Damping Capacity is an Intrinsic Property of Material in a Given State.*

With the knowledge that damping values depend on simple properties of the material and not on experimental conditions, data were collected to determine the relation between these values and features of the structural state. Accordingly large numbers of specimens were secured from standard production sources, and measurements were made on them. They show the degree of uniformity of values obtained for any given alloy; marked departures from average values prompted further investigation which usually enabled the discrepancies to be attributed to anomalies in the structure or treatment of the bar.

Cast Materials.

In Tables IV–VII are shown the damping values obtained for various specimens of chill-cast aluminium alloy. Each specimen was an ingot machined to 4 in. diameter, and the lengths were 25 in. for Hiduminium R.R.59, and 30 in. for Y alloy. Table IV illustrates the magnitude and uniformity of damping values to be expected from groups of 8 ingots cast under standard production conditions. It will be noted that the two groups of R.R.59 alloy differ by 20 per cent., whilst in each group the deviation of individual specimens from the mean of the group is within ± 10 per cent. The difference of 20 per cent. between the two groups may be attributed to the degassers employed; the group having the higher average damping was thought to contain porosity to a small extent. It has since been established that the carbon tetrachloride degasser is more efficient. However, it will be shown later that the damping must be over $0{\cdot}20 \times 10^{-4}$ for shrinkage and porosity to be readily seen with the naked eye on a polished surface and that this damping value of $0{\cdot}20 \times 10^{-4}$ may usually be regarded as indicating satisfactory material for forging, but on the lower limit of acceptance for production purposes.

The Y alloy groups were cast under identical conditions, with the representative mean values in close agreement; damping values of $0{\cdot}130$–$0{\cdot}140 \times 10^{-4}$ were typical. The tests were made before the

Table IV.

Hiduminium R.R.59 Alloy, Chill-Cast.

Composition : 40% scrap, 40% remelt, 20% virgin aluminium.

Degassed with CCl_4. Grain-size 1–3 mm.

Melt No. 8A105.

Ingot No.	1.	2.	3.	4.	5.	6.	7.	8.	Mean.
Average of $\lambda \times 10^4$ in 2nd and 3rd harmonics . . .	0·158	0·154	0·161	0·145	0·153	0·152	0·139	0·150	0·152
Deviation of average $\lambda \times 10^4$ from mean value of melt, per cent. . . .	4·0	1·3	6·0	−4·6	0·7	Nil	−8·5	−1·3	...

Degassed with Hiduflux. Grain-size 2–3 mm.

Melt No. 8A104.

Ingot No.	1.	2.	3.	4.	5.	6.	7.	8.	Mean.
Average of $\lambda \times 10^4$ in 2nd and 3rd harmonics . . .	0·191	0·190	0·180	0·179	0·190	0·178	0·169	0·186	0·183
Deviation of average $\lambda \times 10^4$ from mean value of melt, per cent. . . .	4·4	3·8	1·6	3·8	−2·7	−7·7	1·6	...	...

Hiduminium Y Alloy, Chill-Cast.

Composition : 44% scrap, 18% remelt, 38% virgin aluminium.

Degassed with CCl_4. Grain-size 4–10 mm.

Melt No. 43A133.

Ingot No.	1.	2.	3.	4.	5.	6.	7.	8.	9.	Mean.
Average of $\lambda \times 10^4$ in 2nd and 3rd harmonics . . .	0·138	0·140	0·131	0·125	0·125	0·138	0·133	0·128	0·127	0·132
Deviation of average $\lambda \times 10^4$ from mean value of melt, per cent. . . .	4·5	6·0	−0·8	−5·3	−5·3	4·5	0·8	−3·0	−3·8	...

Degassed with CCl_4. Grain-size 4–10 mm.

Melt No. 43A134.

Ingot No.	1.	2.	3.	4.	5.	6.	7.	Mean.
Average of $\lambda \times 10^4$ in 2nd and 3rd harmonics . . .	0·144	0·141	0·136	0·130	0·143	0·130	0·137	0·137
Deviation of average $\lambda \times 10^4$ from mean value of melt, per cent. . . .	5·1	2·9	−0·7	−4·1	4·4	−5·1	Nil	...

introduction of the eddy-current instruments with which slightly more uniform values between individual specimens and between harmonics of a given specimen might be expected. All these specimens in Table IV were part of a separate study of casting technique and forgeability, and it is of interest to note that 32 forgings were made from each of the four groups. All the R.R.59 forgings were successful, but there were 12½ per cent. rejects with the Y alloy forgings. Since the damping values were such as to rule out the presence of porosity and any marked shrinkage, it seems probable that the rather coarse grain was responsible for these failures.

Tables V, VI, and VII show the constancy of the damping of chill-cast material over periods of months, and also the effect of annealing.

TABLE V.—*Chill-Cast Hiduminium R.R.59 Alloy.*

Tested in the Chill-Cast State 6 Months after Casting.				
Melt No.	Ingot No.	Average $\lambda \times 10^4$ for 2nd and 3rd Harmonics.	Percentage Deviation of λ of Ingot from Mean Value of Melt.	Brinell Hardness Number.
115A13M	1	0·143	−3·4	...
	2	0·141	−4·7	...
	3	0·144	−2·7	84·0
	4	0·149	−0·7	97·4
115A11	1	0·159	7·5	96·6
	2	0·149	0·7	91·0
	Mean	0·147		
Tested in the Chill-Cast State 10 Months after Casting.			Percentage Change of λ during 4 Months.	
115A13M	4	0·159	6·7	
115A11	1	0·158	−0·6	
	2	0·147	−1·3	
	Mean	0·155		
Tested after Annealing.			Percentage Change of λ due to Annealing.	
115A13M	4	0·151	−5·0	67·8
115A11	1	0·144	−8·9	66·3
	2	0·138	−6·0	65·5
	Mean	0·144		

TABLE VI.—*Chill-Cast Y Alloy, Grain-Size* 2 *mm.*

Tested in the Chill-Cast State 5 Months after Casting.					Tested in the Chill-Cast State 10 Months after Casting.			Tested in the Annealed State 10 Months after Casting.	
Melt No.	Ingot No.	Average $\lambda \times 10^4$ of 2nd and 3rd Harmonics.	Percentage Deviation of λ of Ingot from Mean of Melt.	Brinell Hardness Number.	Average $\lambda \times 10^4$ of 2nd and 3rd Harmonics.	Percentage Increase of λ between 1st and 2nd Tests.	Brinell Hardness Number.	Average $\lambda \times 10^4$ of 2nd and 3rd Harmonics.	Percentage Change of λ Due to Annealing.
109A3	1	0·138	5·4	89	0·140	1·5	72·4	0·120	−9·3
	4	0·120	−8·4	107	0·127	5·8	64·2	0·116	−7·9
	6	0·127	−3·1	84·7	0·130	2·4	72·4	0·130	Nil
	7	0·141	7·6	91·7	0·148	5·0	72·8	0·140	−5·0
	8	0·131	Nil	92·3	0·138	5·3	74·4	0·132	−4·3
Mean of melt		0·131	...		0·137	4·0	...	0·129	...

TABLE VII.—*Chill-Cast Y Alloy, Grain-Size* 8–10 *mm.*

Tested in Chill-Cast State 5 Months after Casting.				Tested in the Chill-Cast State 10 Months after Casting.			Tested in the Annealed State 10 Months after Casting.		
Melt No.	Ingot No.	Average λ × 10⁴ of 2nd and 3rd Harmonics.	Percentage Deviation of λ from Mean Value of Melt.	Brinell Hardness Number.	Average λ × 10⁴ of 2nd and 3rd Harmonics.	Percentage Increase of λ between 1st and 2nd Test.	Brinell Hardness Number.	Average λ × 10⁴ of 2nd and 3rd Harmonics.	Percentage Change of λ Due to Annealing.
109A6	1	0·103	−13·5	92·2	0·114	10·7	67·8	0·107	− 6·1
	2	0·113	− 5·0	109	0·127	12·4	63·3	0·110	−13·4
	3	0·127	6·7	...	0·134	5·5	2nd test 19 months after casting.		
	4	0·138	16·0	...	0·142	2·8			
	5	0·133	11·8	...	0·138	3·8			
	6	0·109	− 8·4	105	0·109	Nil	76·3	0·104	− 4·6
	7	0·109	− 8·4	91	0·117	7·3	73·7	0·110	− 8·5
	Mean	0·119	Mean of 1, 2, 6, and 7		0·117	7·6	Mean	0·108	− 7·4

In addition, Tables VI and VII show that the grain-size of the material seems to have little influence on the damping, particularly in view of the results for the Y alloy groups of Table IV. Thus, for a grain-size of 8–10 mm., the damping averages $0{\cdot}120 \times 10^{-4}$; an average grain-size of 2 mm. gives $0{\cdot}135 \times 10^{-4}$, and one of 4–10 mm. gives similar values. Thus, it may be concluded that damping measured within the assumptions of this technique is largely independent of grain-size, although in view of the size of these specimens the grain-size effect quoted is a broad generalization which does not rule out the possibility of smaller specimens of uniform grain-size showing noticeable differences, especially if the range of grain-size employed is extended.

The small change in damping that results from annealing these chill-cast alloys is worthy of note, since the chill-cast condition is equivalent to an extremely efficient quenching, as indicated by the Brinell hardness values. Moreover, the time interval between the casting and the measurement may have afforded a certain degree of natural ageing. Nevertheless, the reduction in damping brought about by annealing is to within 10 per cent. of the value as chill-cast, and despite the possibility of errors in measurement, the genuine changes are surprisingly small, considering the structural difference between the two states.

Swaged and Extruded Materials.

It was thought that mechanically worked material would be more homogeneous than cast alloy and freer from porosity and shrinkage. Measurements on swaged and extruded bars of the principal aluminium alloys similar to those in general use, together with a bar of magnesium alloy (Magnuminium 288), are shown in Tables VIII, IX, and X. In Table VIII are grouped the results for swaged bars from all the light alloys used in this research; all measurements refer to the annealed condition. It will be noted that the R.R.59 bars have a damping of about $0{\cdot}11 \times 10^{-4}$, whereas in the chill-cast state this material rarely affords an average damping lower than $0{\cdot}14 \times 10^{-4}$. It seems possible that this difference is due mainly to the inevitable high degree of microporosity and shrinkage in cast material. The difference here stated is exceptionally large; cases have arisen in which this difference is so small as to be scarcely distinguishable. Moreover, residual defects in swaged material would probably be confined to the axis of the bar and have less influence on the damping than the more dispersed defects occurring in cast material.

Results obtained with annealed R.R.56 swaged and extruded bars (given in Tables VIII and X, respectively) show a divergence of 20 per cent. The measurements upon extruded bars (Table X) reveal an unexpected temporal variation of the damping of annealed material. The damping value alters from $0{\cdot}118 \times 10^{-4}$ after annealing to $0{\cdot}143 \times 10^{-4}$ after a period of six months; re-annealing at any stage restores the original damping value. Inconclusive results had previously indicated this result, but the magnitude of the change in this specimen removed all doubt as to the validity of the change. It is usually assumed that the annealed state is the most stable structural state; here we have seen that fully aged material shows greater stability. It will be observed that the damping values for the swaged R.R.56 bars agree with those for the above extruded specimen before the second anneal. In the case of the swaged material, however, only a few days elapsed between annealing and measurement. The difference in damping immediately after annealing may be due to inefficient annealing of the swaged material despite the Brinell hardness values. The most noticeable features of the results on the swaged and extruded Duralumin bars (Tables VIII and IX) are: (1) the considerable difference between the mean dampings for swaged and extruded materials, and (2) the wide divergence of the values obtained for the extruded material. It may be remarked that the value $0{\cdot}06 \times 10^{-4}$ for extruded Duralumin is the lowest recorded in this work. Nowhere do the results indicate unsound material, and no explanation of the above variation has been discovered. Of the swaged Y alloy specimens little can be said; the values agree fairly well with those for the best cast material.

TABLE VIII.—*Swaged Bars, Machined to 4 in. Diameter, Tested in the Annealed State.*

Material.	Specimen.	Fundamental Frequency, cycles/second.	Average $\lambda \times 10^4$ of 7 Harmonics.	Brinell Hardness Number.
Hiduminium R.R.56	A.15	1200	0·142	48·4
	A.16	1130	0·141	47·2
	A.17	1170	0·144	49·0
Hiduminium R.R.59	B.1	1055	0·109	58·2
	B.2	1105	0·107	56·4
Hiduminium Y Alloy	Y.3	900	0·129	53·3
	Y.4	910	0·120	55·8
Duralumin	D.16	1130	0·119	54·3
	D.17	1005	0·105	55·0
	D.19	880	0·116	55·5
Magnuminium 288	M.1	1650	0·091	69·8

TABLE IX.—4-*in. Diameter Extruded Duralumin Bars.*

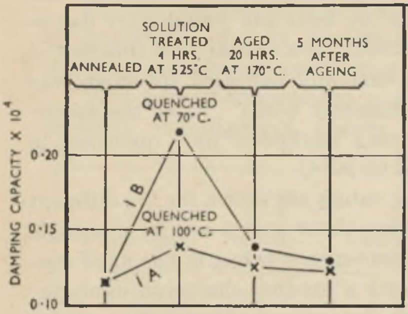
Specimen.	Fundamental Frequency, cycles/second.		Tested in the " As-Extruded " Condition.					Average.	Tested in the Annealed Condition.						Average.
D.101	975	Harmonic No.	1	2	3	4	5		Half length *A*	1	2	3	4	5	
		$\lambda \times 10^4$	...	0·072	0·070	0·065	0·065	0·067		...	0·058	0·059	0·061	...	0·059
		Harmonic No.	6	7	8	9	10		Half length *B*	1	2	3	4	5	
		$\lambda \times 10^4$	0·073	...	0·073	0·074	0·079	0·075		0·069	0·061	0·062	0·065	0·070	0·065
		Harmonic No.	1	2	3	4	5			1	2	3	4	5	
D.102–2	2033	$\lambda \times 10^4$	0·123	0·115	0·120	0·129	...	0·122		0·093	0·089	0·090	0·099	0·100	0·094
D.102	1425	$\lambda \times 10^4$	0·090	0·089	0·094	0·098	...	0·093		...	0·077	...	0·091	0·088	0·085
D.102–4	1925	$\lambda \times 10^4$	0·114	0·118	0·115	...	...	0·116		0·088	0·084	0·088	0·090	0·095	0·089

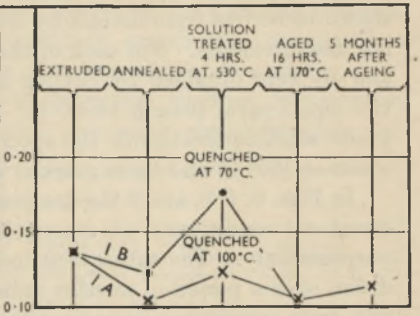
TABLE X.—*Extruded Hiduminium R.R.*56 *Bar R*68*J*96–19 *F*, *Diameter* 5 *in.*, *Length* 51 *in.*

Condition.	Harmonic Numbers.									Average.	Brinell Hardness Number.
	2.	3.	4.	5.	6.	7.	8.	9.	10.		
	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	
Extruded . . .	0·147	0·151	0·145	0·140	0·146	0·143	0·151	0·151	0·155	0·148	66·2
Annealed . . .	0·113	0·117	0·115	0·111	0·114	0·118	0·121	0·124	0·126	0·118	48·3
,, after 3 months .	0·130	0·145	0·127	0·126	0·126	0·124	0·126	...	...	0·129	...
,, after 6 months .	0·142	0·154	0·144	0·142	...	...	...	...	...	0·143	47·1
Re-annealed . . .	0·116	...	0·115	0·115	0·117	0·117	...	...	...	0·116	46·1

The Influence of Heat-Treatment on the Damping Capacity of Aluminium Alloys.

The following experiments were undertaken to investigate the relation between damping capacity and the structural state of the principal aluminium alloys and to determine the structure-sensitivity





Influence of Heat-Treatment.

Fig. 6.—Swaged Hiduminium R.R.59 Alloy.

Fig. 7.—Extruded Hiduminium R.R.56 Alloy.

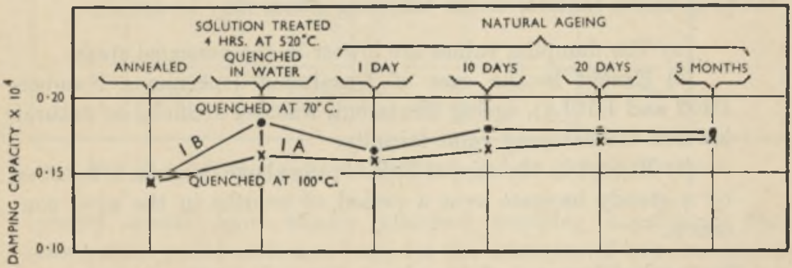


Fig. 8.—Influence of Heat-Treatment. Swaged Hiduminium Y Alloy.

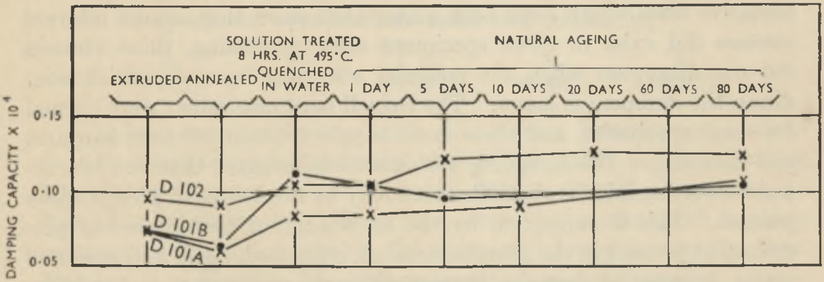


Fig. 9.—Influence of Heat-Treatment. Extruded Hiduminium Du Brand.

D101A quenched in water at 100° C.
D101B „ „ „ 70° C.
D102 „ „ „ 100° C.

of the present technique. Selected specimens of Duralumin, Y alloy, R.R.59, and R.R.56 alloys were subjected to damping measurements in annealed, solution-treated, and aged conditions; the results are shown in Figs. 6, 7, 8, and 9. To ensure the greatest homogeneity, the Y alloy and R.R.59 specimens were swaged under careful supervision; the R.R.56 and Duralumin specimens were extruded bars, shown to be free from defects by fracture tests and preliminary damping measurements. For each of the tests, two similar bars (marked *A* and *B*) were obtained by cutting a carefully annealed specimen into two equal parts (length 18–40 in., diameter 4 in.). After the appropriate solution-treatment, the specimens marked *A* were quenched in water at 100° C. and those marked *B* at 70° C.

In Figs. 6, 7, 8, and 9 the damping values are shown for the different structural conditions; the lines joining these points are for graphical purposes only. The subsequent measurements taken in the aged condition over a period of months indicate a gradual change in damping, and some importance may be attached to the gradients of the lines. The values are the average for those harmonics which were clearly unaffected by experimental conditions such as nodal influence. Of the damping values themselves the following points may be noted :

(*a*) The damping values are lowest in the annealed state.

(*b*) Except in the case of Duralumin (specimens Numbers D102 and D101A), ageing treatment, whether artificial or natural, lowered the damping value initially.

(*c*) Except in the case of R.R.59, the above decrease is followed by a steady increase over a period of months in the aged condition.

The marked increase of damping in the case of the water quench at 70° C. may be due to the creation of internal stresses. However, tentative tests which have been undertaken show that, whilst internal stresses did exist in these specimens after quenching, these stresses did not disappear when the material was fully aged, in which condition the damping is lower. The Brinell hardness values were normal for these specimens, and there is no simple relation between hardness and damping. The foregoing considerations suggest that the characteristic responsible for the differences may be the degree of precipitation present. This is supported by the knowledge of the degrees of precipitation present in the solution-treated, quenched, aged, and annealed states, increase in damping corresponding to an increase in precipitation. It is further suggested that the temperature of quench also controls the degree of precipitation possible, and so provides a higher damping than that for the quench at 100° C.

Finally, the lowering of the damping of the extruded specimens by the annealing treatment may be attributed to the removal of the effects of cold work caused by extrusion.

VI.—The Damping of 0·6 Per Cent. Carbon Steel Bars.

For the purpose of a preliminary survey of the damping of steels, six specimens of 3 in. diameter and 3 ft. length were submitted to damping tests at successive stages of a cycle of heat-treatment.

This survey was carried out to determine whether specimens of identical metallurgical history and possessing metallographic uniformity would have closely matched damping capacities. Such information would serve as a basis for the detection of hair-line cracks, should a faulty specimen possess a damping greater than that appropriate to its particular metallurgical state.

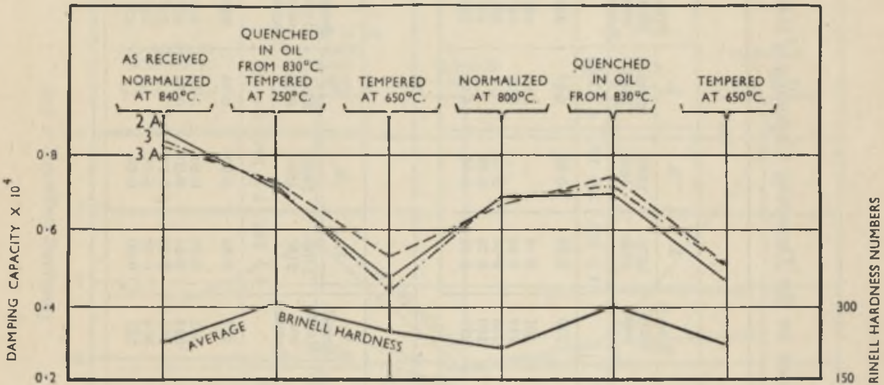


Fig. 10.—Influence of Heat-Treatment. 0·6 per cent. Carbon Steel.

All six specimens were from the same cast containing :

C.	Mn.	Si.	S.	P.
0·59%	0·75%	0·23%	0·048%	0·044%

The bars were marked 1, 1A, 2, 2A, 3, 3A. Examination at both ends by magnetic etching revealed no hair-line cracks, and examination by sulphur printing and microscopic etching showed all bars to be free from micro-cracks. There was, however, evidence of sulphide inclusions near the centre of the cast, of increasing severity from Number 2 to Number 3A; this segregation was not serious. From these examinations only Number 1 and Number 1A could be considered commercially satisfactory, but from the point of view of damping

TABLE XI.—*The Effect of Heat-Treatment on the Damping Capacity of* 0·6 *Per Cent. Carbon Steel.*

Specimen No.	1.				1A.				2.			
Harmonic No.	1.	2.	3.	Brinell Hard-ness Number.	1.	2.	3.	Brinell Hard-ness Number.	1.	2.	3.	Brinell Hard-ness Number.
Frequency Range, cycles/second.	1725–2220	3450–4460	5175–6680		1675–2140	3350–4300	5020–6440		1650–2100	3300–4230	4950–6340	
CONDITION.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.		$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.		$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	
Normalized at 840° C. . . .	0·89	0·95	0·11	230	0·89	0·92	0·97	232	0·875	0·93	0·99	236
Quenched in oil from 830° C. :												
Tempered at 250° C., pickled .	0·70	0·77	0·77	301	0·78	...	1·05	281	0·64	0·73	0·80	300
Tempered at 650° C., pickled .	0·44	0·50	0·55	242	0·54	...	0·70	243	0·52	0·61	0·61	243
Normalized at 800° C., pickled .	0·73	0·82	...	223	0·66	0·75	...	221	0·57	0·64	...	218
Quenched from 830° C., pickled .	0·72	0·80	...	309	0·75	0·78	...	307	0·71	0·79	...	309
Tempered at 650° C., pickled .	0·50	0·64	0·65	222	0·49	0·54	0·60	222	0·49	0·55	...	223

Specimen No.	2A.				3.				3A.			
Harmonic No.	1.	2.	3.	Brinell Hard-ness Number.	1.	2.	3.	Brinell Hard-ness Number.	1.	2.	3.	Brinell Hard-ness Number.
Frequency Range, cycles/second.	1725–2200	3420–4410	5130–6630		1700–2190	3395–4380	4090–6565		1720–2220	3435–4435	5145–6650	
CONDITION.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.		$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.		$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	
Normalized at 850° C. . . .	0·86	0·91	0·96	231	0·84	0·90	0·94	233	0·82	0·90	0·93	229
Quenched in oil from 830° C. :												
Tempered at 250° C., pickled .	0·71	0·72	0·77	301	0·72	0·80	0·84	300	0·72	0·81	0·77	294
Tempered at 650° C., pickled .	0·47	0·52	0·56	243	0·44	0·50	0·52	243	0·53	0·65	0·71	244
Normalized at 800° C., pickled .	0·68	0·75	...	215	0·68	0·77	...	223	0·67	0·75	...	222
Quenched at 830° C., pickled .	0·70	0·74	...	304	0·72	0·78	...	305	0·75	0·81	...	306
Tempered at 650° C., pickled .	0·46	0·53	...	221	0·50	0·65	...	223	0·51	0·60	...	222

measurements the sulphide inclusions in the other bars were not thought to be of any consequence.

The bars were received from the manufacturers in the normalized state, the normalizing temperature being 840° C. The sequence of heat-treatment operations on these specimens is indicated in Fig. 10, with the damping values of three of the specimens as a function of their metallurgical states. Table XI shows the damping values of all six specimens in each of the conditions described, together with the corresponding Brinell hardness values. The damping values obtained for the 1st and 2nd harmonics are shown; the 3rd harmonic measurement is included where this tone could be obtained. In Fig. 10 the damping values refer only to the 1st harmonic, and the subsequent tones are presented in Table XI to confirm the value of the damping at the fundamental. In general, the damping shows a marked increase with frequency; this is not attributed to distinctive features of the steel, but to errors in measurement of the rather short decay times afforded by the higher tones at such damping values. Moreover, it should be pointed out that for a given oscillation amplitude and frequency the stress produced in the steel is about three times that for aluminium alloys, and consequently the departure from exponential conditions may be present during part of the rather short decay times observed. In the absence of a precise knowledge of the variation of damping with maximum fibre stress and the limiting value for exponential decay, no satisfactory conclusions can be reached. An important

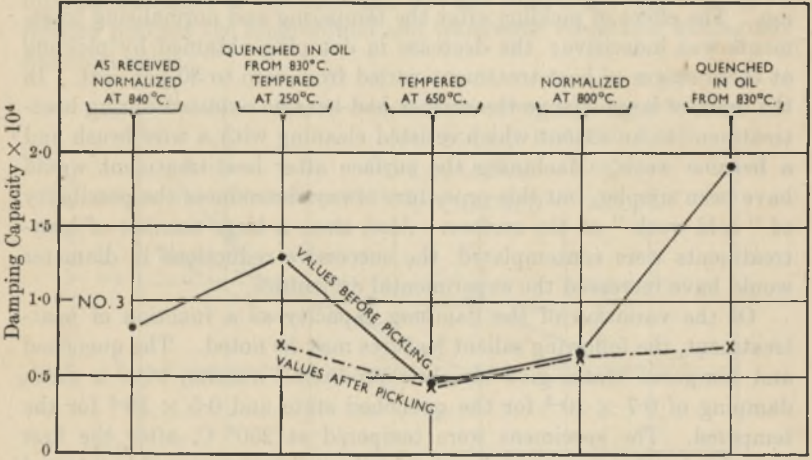


Fig. 11.—The Effect of Surface Scale. 0·6 per cent. Carbon Steel.

feature of the experiments is the marked dependence of damping on surface conditions, and the consequent importance of removing surface scale or rust, &c., from the specimen before a damping measurement. This point is of particular importance after a high-temperature quench in oil, as in the present tests. To illustrate the magnitudes involved, Fig. 11 shows the damping values obtained for Bar Number 3 at the 1st harmonic after each heat-treatment, together with the corresponding damping values after pickling the specimen in a 10 per cent. solution of sulphuric acid to remove the scale. It will be seen that errors which increase the measured damping value by from 2 to 3 times are due entirely to the heterogeneous surface scale caused by oil quenching. The effect of pickling after the tempering and normalizing treatments was indecisive; the decrease in damping obtained by pickling at these stages of heat-treatment varied from zero to 30 per cent. In the cases of large change the surface had become oxidized during heat-treatment to an extent which resisted cleaning with a wire brush and a benzine wash. Machining the surface after heat-treatment would have been simpler, but this procedure always introduces the possibility of " cold work " at the surface. Also, since a large number of heat-treatments were contemplated, the successive reductions in diameter would have increased the experimental difficulties.

Of the variation of the damping capacity as a function of heat-treatment, the following salient features may be noted. The quenched and tempered states give closely reproducible results, with a mean damping of $0{\cdot}7 \times 10^{-4}$ for the quenched state and $0{\cdot}5 \times 10^{-4}$ for the tempered. The specimens were tempered at 250° C. after the first quenching; this was carried out in order to remove possible internal stresses without essentially altering the metallurgical structure. As the Brinell hardness was unchanged by this treatment, it was concluded that at all events the structure was unchanged. Of the two tests in the normalized state, it will be seen that in the first test the normalizing treatment gave an average damping of $0{\cdot}84 \times 10^{-4}$, whilst in the second it gave $0{\cdot}68 \times 10^{-4}$. It seems probable that the difference in normalizing temperatures may be responsible for this, although the first test was made on the specimens as received from the manufacturers without pickling before testing, since it did not appear necessary to clean the specimens beyond normal washing, &c. The relation between the Brinell hardness and the damping is particularly marked in the tempered and quenched conditions, whereas, although the hardness is lowest in the normalized condition, the damping is then practically independent of hardness. Thus, it is indicated that the damping of a material is determined chiefly by its internal disorder, which in the quenched conditions increases its strength. This simple assumption is not substantiated in the normalized condition. Finally, it may be remarked that these results show encouraging uniformity and reproducibility in the tempered and quenched conditions, and these studies might be utilized as a basis for determining whether internal flaws such as hair-line cracks increase the damping sufficiently to make confident predictions possible.

VII.—Detection of Faults.

It can be shown that torsional damping capacity is sensitive to the internal structure of the material, whereas limitations imposed by air friction prevent the longitudinal and transverse vibrations having any practical value.

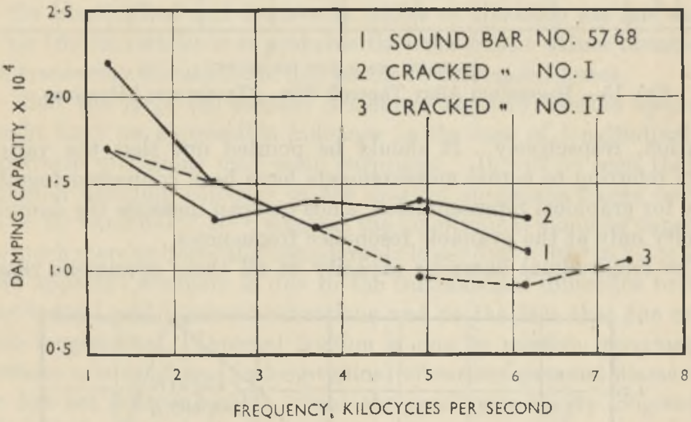


Fig. 12.—Magnesium Alloy Tapered Bars. Longitudinal Vibrations.

The following experiment was carried out on three magnesium alloy bars prepared for press forging, each 80 in. long and of cylindrical cross-section, tapering in diameter from 7½ to 3 in. One of these bars was considered to be sound, whilst the remaining two each contained a crack visible at the surface halfway along the specimen and 8–10 in. in length, parallel to the axis (see Fig. 18, Plate II). Torsional and longitudinal damping-capacity measurements were made upon the three specimens over a wide frequency range at the available resonance frequencies; a similar procedure was adopted for one of the cracked bars and the sound bar in the case of transverse vibrations.

Figs. 12, 13, and 14 show the damping capacity plotted against frequency for the longitudinal, transverse, and torsional modes of

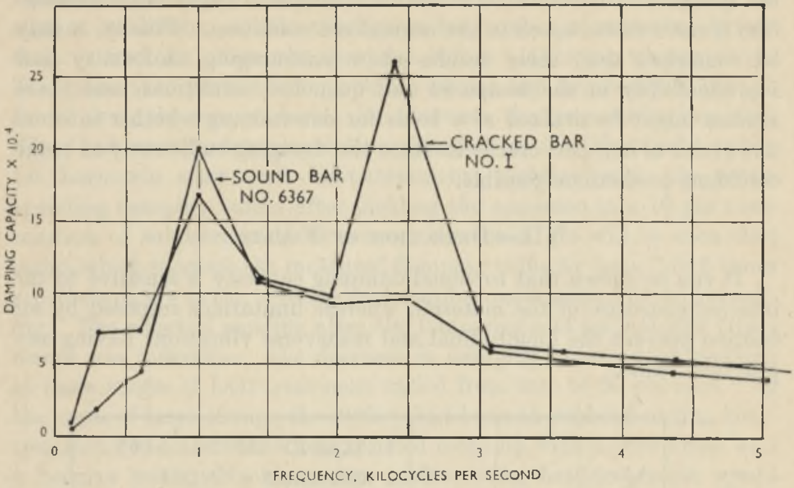


FIG. 13.—Magnesium Alloy Tapered Bars. Transverse Vibrations.

vibration, respectively. It should be pointed out that the various points referring to actual measurements have been connected together solely for graphical representation, since one can measure the damping capacity only at the available resonance frequencies.

The longitudinal damping capacity of all three specimens ranges

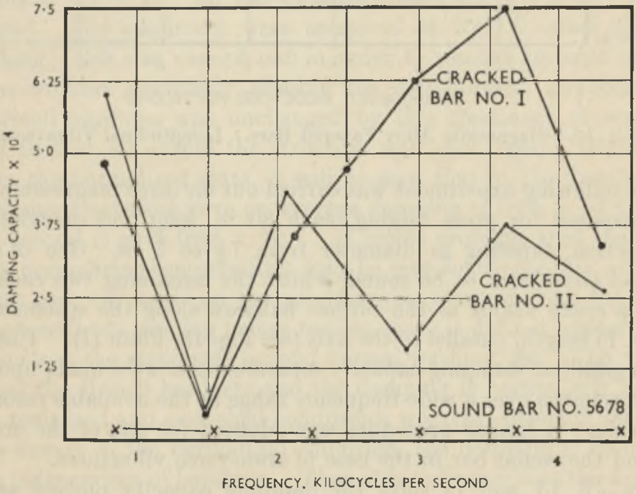


FIG. 14.—Magnesium Alloy Tapered Bars. Torsional Vibrations.

between $0{\cdot}9 \times 10^{-4}$ and $2{\cdot}2 \times 10^{-4}$ over the frequency range of 1000–7000 cycles/second, with no marked differences between the sound specimen and the cracked specimens (Fig. 12).

Fig. 13 shows the transverse damping capacity to be very much higher both for the sound and the unsound specimen; it may be noted that over the frequency range between 100 and 5800 cycles/second there is an erratic variation of damping values between $0{\cdot}6 \times 10^{-4}$ and 26×10^{-4}. Again, there is no clear-cut difference between the sound and the unsound specimen.

The torsional damping-capacity values presented in Fig. 14 show high damping values, whilst the sound specimen is shown to have a consistent damping capacity of $0{\cdot}18 \times 10^{-4}$.

Comparing the damping capacities of the sound specimen in each of the three modes of vibration, one sees that the high values obtained in the longitudinal and transverse modes of vibration are due mainly to air friction, whilst it is probable that the erratic values obtained in the transverse vibration are due partly to suspension losses.

That the large self-evident defects of the two cracked specimens should have no appreciable influence in the case of longitudinal and transverse vibrations may seem surprising. It will be seen that the torsional damping capacity of the cracked specimens varies between $0{\cdot}5 \times 10^{-4}$ and $6{\cdot}0 \times 10^{-4}$, whereas the longitudinal damping capacities are much more uniform and considerably lower ($0{\cdot}9 \times 10^{-4}$ to $2{\cdot}2 \times 10^{-4}$). This apparent anomaly is due to the fundamental difference between longitudinal and torsional vibrations and to the fact that the cracks were longitudinal. Internal friction is due to relative movement of particles of a solid, and in longitudinal vibrations paraxial filaments of the bar act independently. Since the crack was chiefly longitudinal it had little effect on frequency or damping.

In torsional vibrations relative motion between adjacent planes perpendicular to the axis produces shear. The consequent distortion of any crack in the bar probably introduces dissipative forces, thereby increasing the damping.

Finally, the variation with frequency of the torsional damping capacities of the cracked specimens is due to the situation of the defects relative to the nodes and anti-nodes. In the present case the defects were halfway along the specimens. Since there is one single node of vibration at a cross-section halfway along the specimen for the fundamental tone, the defect will have its greatest influence. For the second tone this region is an anti-node and thus the damping capacity is influenced less. Again, at the third tone there is a node at the centre, the remaining two being one-sixth of the length from each end;

thus the damping is again high. This feature is well demonstrated by the cracked bar Number 2 (Fig. 14) and becomes a valuable guide for the location of defects.

The following experiment was designed to investigate the effect of localized defects. Two aluminium alloy ingots of length 24¾ in. were cast so as to contain a pronounced localized defect by pouring drossy material into the mould when half the ingot had been poured and completing with sound material. The ingots were machined to 3 in. diameter and tested; the results are plotted in Fig. 15 (full lines), together with the graph for a sound ingot of cast aluminium alloy (Bar 43). The higher damping obtained at the odd harmonics indicated a central defect. Bar 198 was shortened to 20 in. by cutting 4¾ in. from one end to bring this defect to a region mid-way between the first and second nodes of the new length. At the same time Bar 199 was shortened to 18½ in. to bring the assumed defect nearer to a second node and towards the first node. The subsequent measurements are shown by the broken-line graphs of Fig. 15. The higher values in the first and second tones of Bar 198 and the maximum value at the second tone for Bar 199 confirmed the previous conclusions as regards situation of the defects. Finally, Bar 198 was cut to a length of 12 in. so that the fundamental frequency became 5130 cycles/second and the defect was again central. The 60 per cent. increase of damping ($\lambda = 0{\cdot}54 \times 10^{-4}$) was due to the relative increase in defective volume

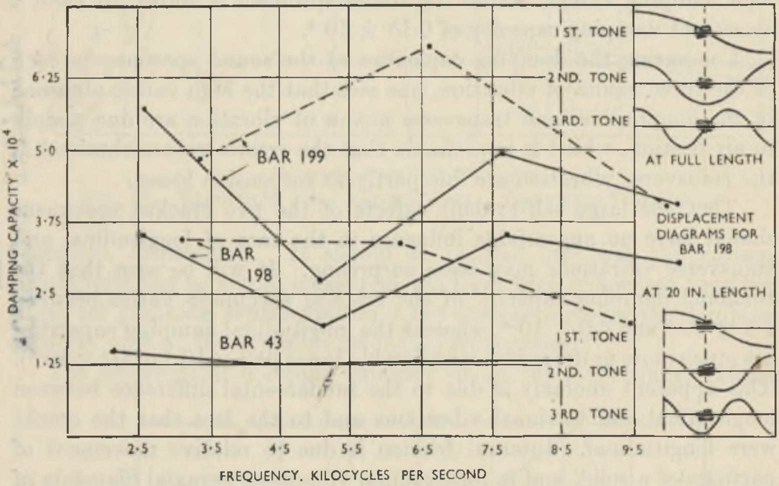


FIG. 15.—Localized Defects.

PLATE II.

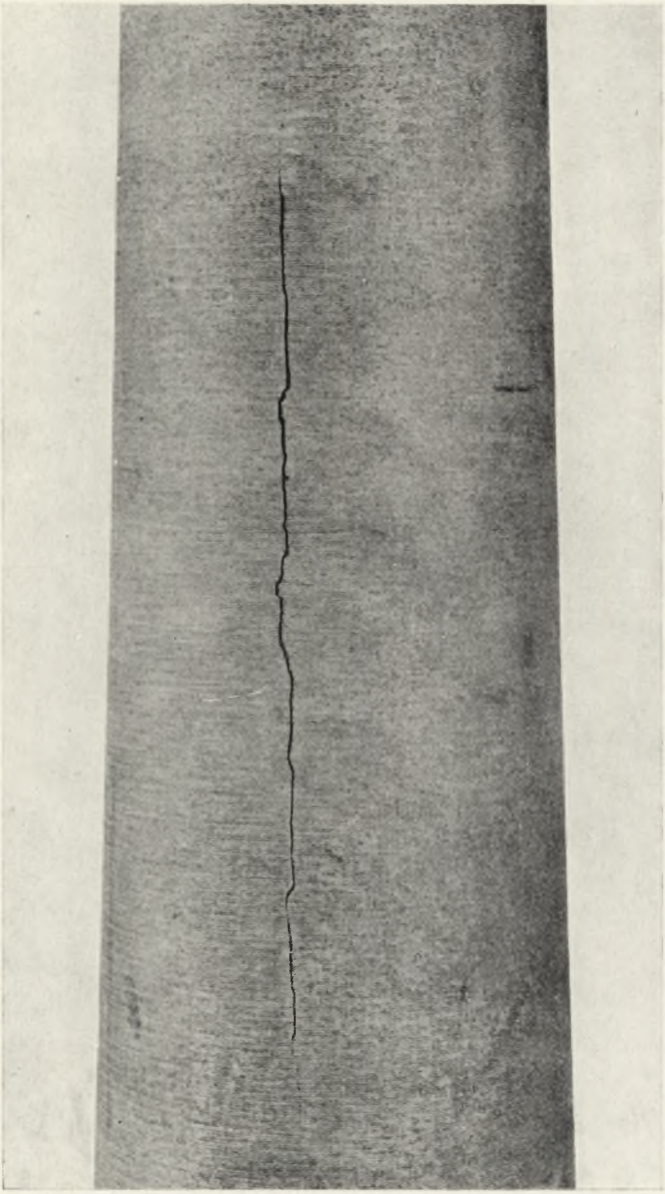


FIG. 18.—Visible Position of Longitudinal Crack in One of the Faulty Magnesium Alloy Bars.

[*To face p.* 40.

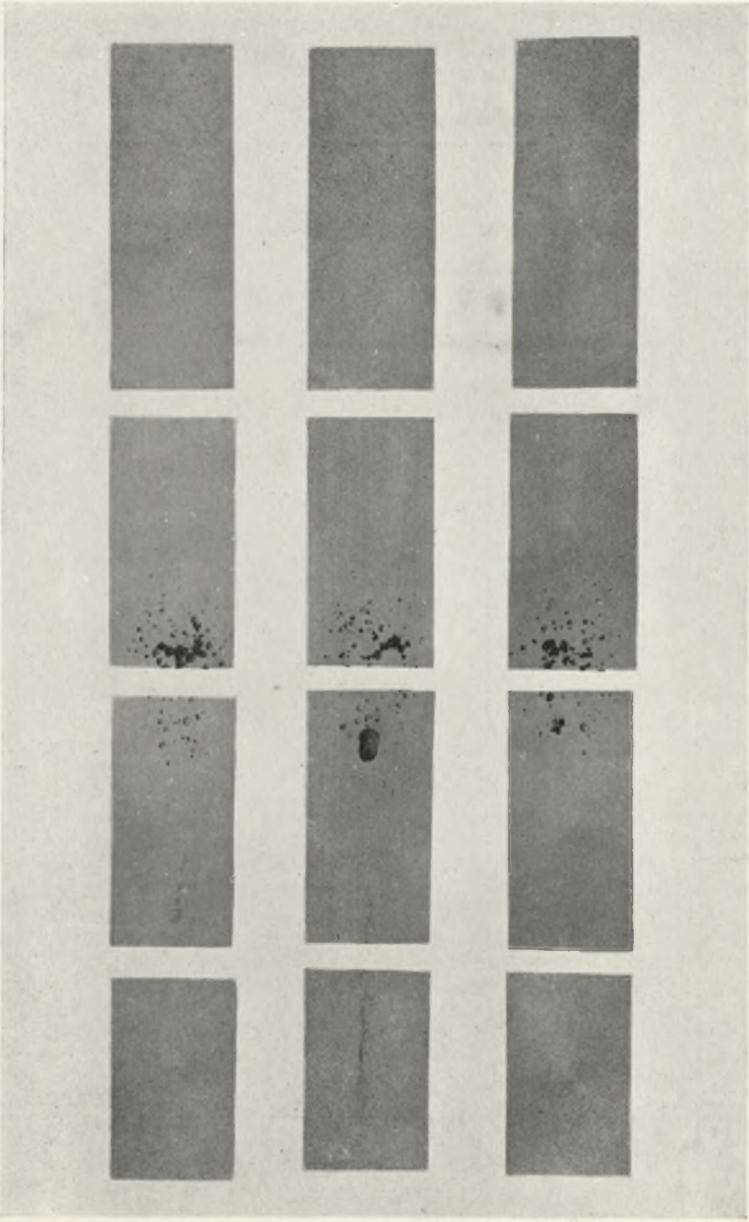


FIG. 19.—Bar 198 Sliced Longitudinally into Three Portions to Illustrate the Magnitude of the Defect.

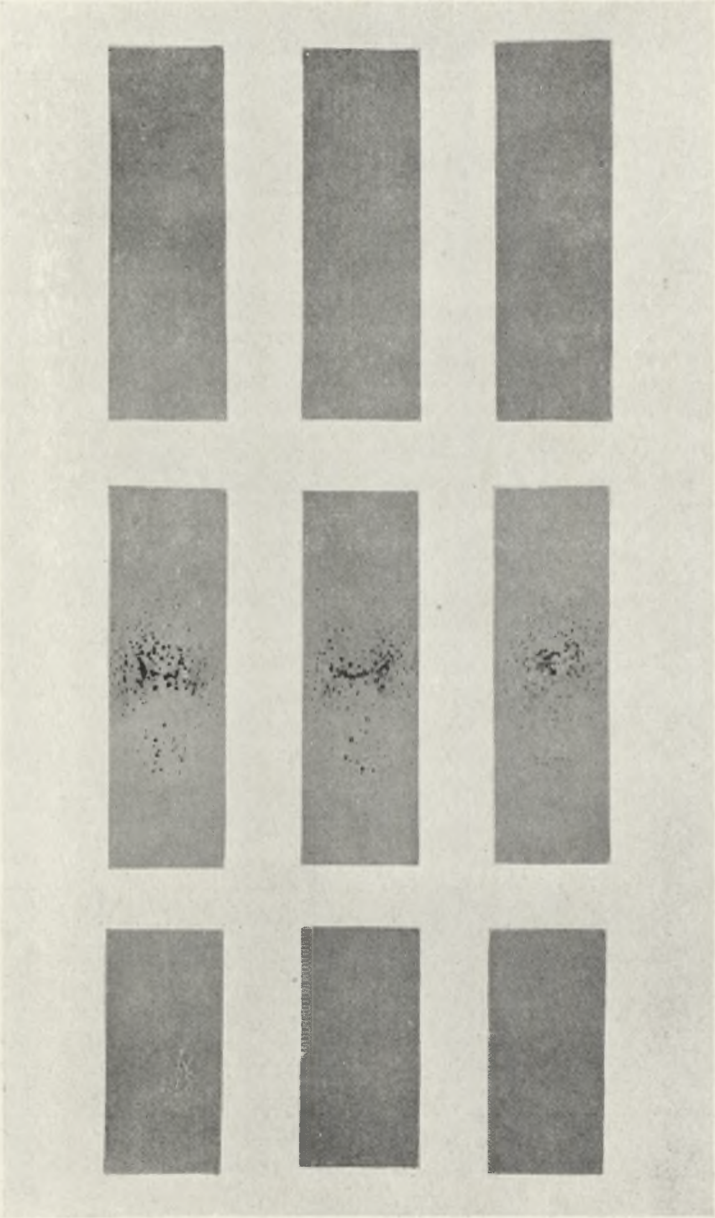


FIG. 20.—Bar 199 Sliced Longitudinally into Three Portions to Illustrate the Magnitude of the Defect.

PLATE V.

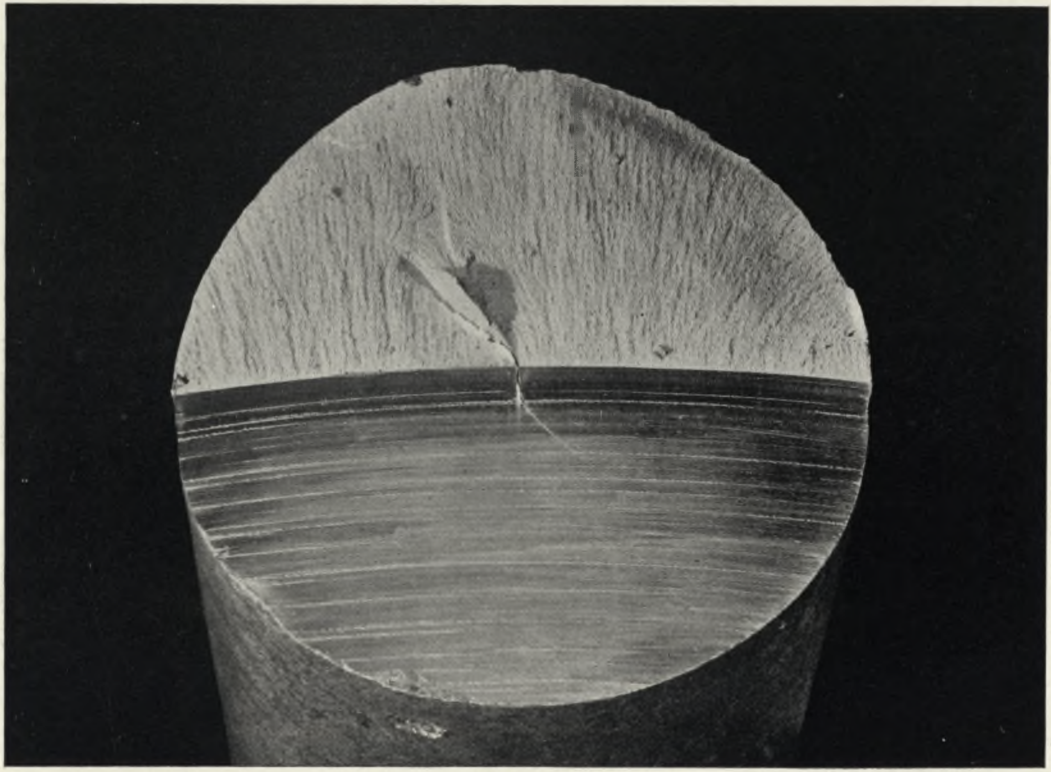


FIG. 21.—Cross-Section of Magnesium Alloy Bar 1431, Half-way along its Length.

of the bar. Figs. 19 and 20 (Plates III and IV) show Bars 198 and 199 sliced longitudinally into three portions to indicate the internal condition. The positions of the defective region of Bars 198 and 199 are evident, whilst the ease of detection of these defects indicates the sensitivity of damping capacity to internal defects.

The Influence of Surface Defects.

Since the stress in a bar executing torsional oscillations is a maximum at the surface, defects situated in the neighbourhood of the surface may be expected to have considerable effect on the damping of the specimen.

For the experiment to be described, six cylindrical cast aluminium alloy ingots were secured in the " as-cast " condition. Apart from the ends being sawn square, the bars were free from machining. Accordingly the surface of each ingot was drossy and therefore likely to have a higher damping. The ingots were numbered 188 to 193 inclusive. In Table XII the measurements are presented under Column *a*, for the " as-cast " condition with drossy surface. Since the specimens gave a fairly uniform damping capacity at the first three tones, the values shown are their average. Under Column *b* are the values obtained when each ingot had been machined just sufficiently to remove the surface dross; it was necessary to machine with a slight taper to conform with the usual shape of an ingot as cast. This machining was not quite complete in the case of ingots numbered 188 and 193, owing to slight eccentricity of the original cast ingot, so that patches of drossy surface were evident along one side of each of these two ingots. The length of each ingot was 29 in. and the diameter $3\frac{1}{4}$ to $3\frac{3}{4}$ in.

TABLE XII.—*Surface Dross Experiment.*

Ingot Number.	*a.* As Cast, before Machining.	*b.* Machined to Remove Dross.	*c.* After Machining to 3-in. Diameter.
	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.
188	0·62	0·215	0·170
189	0·48	0·185	0·190
190	0·45	0·160	0·160
191	0·45	0·157	0·145
192	0·37	0·167	0·180
193	0·60	0·30	0·210

The higher damping values of Ingots 188 and 193 under Column *b* will be noted. Finally, the six ingots were machined to a uniform diameter of 3 in. in order to remove all traces of this normal casting-surface material and thus become the familiar machined cast ingot. The values under Column *c* in Table XII correspond to the ingots at the diameter of 3 in. and with no self-evident defects. It may be mentioned that the final damping-capacity values do not represent particularly sound material, with the exception of Ingots 190 and 191. These results are due to an attempt to cast the six ingots with specified defects; in particular, Ingots 192 and 193 were cast so as to contain shrinkage. However, the gross differences due to the removal of the surface defects may be considered as genuine, so that the orders of magnitude of λ are established.

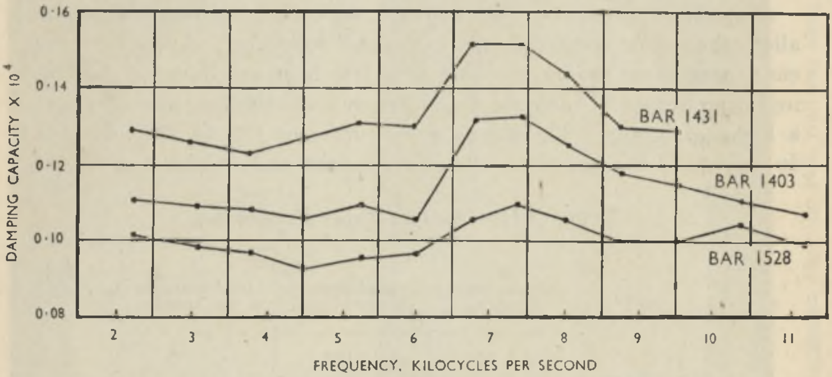


Fig. 16.—Magnesium Alloy Bars.

A Practical Example of Fault Detection.

One of the principal limitations of radiographic technique in the examination of components for internal flaws arises when fissures exist which have a singular orientation. It is evident that only where the X-ray beam is parallel to the plane of the fissure will marked alteration in the beam transmission take place. The damping capacity, however, can be expected to suffer noticeable increase due to fissures, provided the defect is neither very small compared with the volume of the specimen nor confined to the central axis.

An illustration of these points was afforded by the measurements on eight magnesium alloy bars prepared by machining for press forging. All of these bars were submitted to tests because a fracture test on a slice cut from one end of each bar had indicated the presence of fissures formed during hot working. Each bar was 80 in. long and in diameter tapered from 7½ to 3 in. with two moderate irregularities in the rate of taper situated about one-sixth the length from each end. The results of measurements on three of these bars are shown in Fig. 16. Bar 1528 represents the bar with the lowest damping capacity and Bar 1431 that with the highest; all other bars had values which fell within these limits, *e.g.*, Bar 1403. The peak in the damping capacity at the 10th tone of 7450 cycles/second is seen to be most marked where the general damping capacity is highest. Since Bar 1528 does not show this selective behaviour, these values cannot be ascribed to the irregular diameter of the specimens or to limitation of the suspension imposed by the non-uniform mass of the specimen. Moreover, any attempt to explain this peak by assuming a localized defect is opposed by the fact that, since there are as many nodes as the harmonic number, a localized defect may be expected to have considerable influence for several successive harmonics in the range of higher harmonic numbers rather than a peak for a single harmonic. No explanation is offered for these values, but the phenomenon is certainly convenient in that a routine examination of this kind of specimen can be confined to the region of the 10th tone.

In view of these results it was decided to perform a fracture test on Bars 1528 and 1431 at cross-sections spaced every 8 in. along the length. The procedure employed was that of sawing half-way through the bar at each selected cross-section and fracturing the remaining section under a drop-hammer. The fragments of Bar 1528 showed it to have been perfectly sound throughout, whilst Bar 1431 showed fissures evident at every cross-section along the bar. Fig. 21 (Plate V) shows the magnitude of this defect for the cross-section half-way along the specimen, where the diameter is 4 in.; the breadth of the fissure decreases towards the thinner end of the bar. This defective fragment of Bar 1431 was subjected to radiographic examination, three radiographs being taken in directions parallel to the beam, at 45° and 90° to the plane of the fissure. Only where the X-ray beam was parallel to the plane of the fissure was any evidence of a defect recorded.

Since the radiographs were taken over an 8-in. length of the specimen, such a specimen as described would have required a larger number of radiographs to be taken at various angles and over various lengths to be sure of freedom from this type of discontinuity. Finally, it must be admitted that the difference in damping capacity between Bars 1528 and 1431 is not as great as a prior knowledge of the defect would have suggested. However, it will be seen from Fig. 21 (Plate V) that the defect is situated mainly along the central axis, where, owing to the radial distribution of frictional dissipation, the central region is least favourable to crack detection. It is also possible that had these specimens been annealed beforehand the difference would have been greater.

The Influence of Porosity, &c.

It was natural that when a satisfactory and reliable technique for measuring damping capacity had been established, the need for information on the significance of porosity, grain-size, and composition should arise. Of these, porosity has been found to produce marked influence upon the damping capacity, and for this reason data are presented to indicate the order of magnitude.

During experiments designed to assess the value of various degassers used in chill casting, and their subsequent influence upon the forgeability of the material, damping-capacity measurements formed part of the data collected. Among the various groups of ingots forming the particular melts employed, one group is selected for the purpose of showing the relationship between damping capacity and porosity.

In Table XIII the damping capacities and casting conditions for eight ingots from a melt of R.R.59 aluminium alloy are shown, in which the alternate ingots were cast into a chill mould containing a degassing reagent. In each case the damping-capacity values are the average of the first three tones, and it will be noted that the estimated degree of observed porosity coincides with these damping values. The columns under forging results show that when each ingot was cut into three portions to correspond with the top, middle, and bottom of the ingot as cast, and each portion examined, those marked "porous face" were rejected by the normal works judgement as being unsuitable for forging into aero-engine pistons. All remaining sections were forged satisfactorily, whilst in all cases the grain-size was considered to be fine. It will be observed that wherever the damping

Table XIII.—*The Influence of Porosity. Hiduminium R.R.59 Alloy Chill-Cast Ingots, Modified Degassing Procedure.*

Ingot Number.	Condition of Chill Mould.	Porosity Number.*	Damping Capacity, $\lambda \times 10^4$.	Ingot Inspection Results.		
				Top.	Middle.	Bottom.
1	Untreated	6	0·44	Porous face	Porous face	...
2	Treated	10 (free)	0·20	...	...	...
3	Untreated	2	0·40	Porous face	Porous face	...
4	Treated	9	0·19	...	...	...
5	Untreated	6	0·26	Porous face	...	...
6	Treated	9	0·19	...	...	...
7	Untreated	5	0·30	...	Porous face	...
8	Treated	8	0·22	...	...	...

* This number represents the estimated degree of porosity, by inspection of a machined surface, where 10 denotes freedom from porosity.

capacity exceeded $0{\cdot}22 \times 10^{-4}$ the porosity is sufficiently evident to be readily seen on a machined surface. Finally, the remaining damping-capacity values are still high for this alloy, since many ingots of cast R.R.59 alloy have given damping-capacity values of $0{\cdot}140$–$0{\cdot}160 \times 10^{-4}$, and it is concluded that there was still some porosity present, which would not be serious enough to cause, by itself, a failure in forging.

A further example of the influence of porosity is provided by the chill-cast Y alloy ingots Y_1, Y_2, Y_3. The damping capacities obtained (see Table XIV) for these ingots are considerably in excess of the values usually associated with Y alloy, and from the point of view of damping, the bars are definitely defective. Accordingly, each bar was cut into sections and sent to the Metallographic Department for examination. Y_1 and Y_2 were reported unsound to a certain degree, shrinkage and gas cavities being observed. The bars were classified as falling at the lower limit of acceptance for production purposes. Y_3 was rejected on the grounds of "extreme porosity." The facility of detection of this defect is an indication of the sensitivity of damping capacity as a method of non-destructive testing.

Table XIV.—*Chill-Cast Y Alloy, Tested "As Chill Cast."*

Ingot Number.	Harmonic Number.				Average of 2nd and 3rd Harmonics.
	1.	2.	3.	4.	
	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.	$\lambda \times 10^4$.
Y_1 . .	0·202	0·210	0·218	0·228	0·214
Y_2 . .	0·219	0·227	0·237	0·245	0·232
Y_3 . .	0·660	0·690	0·620	0·610	0·655

VIII.—CONCLUSIONS.

It must be remembered that all measurements included in this report were made in air at room temperature, and all conclusions refer only to these conditions.

It has been definitely established that the damping capacities at vanishing amplitudes of aluminium alloys and carbon steel are between 10^{-4} and 10^{-5}, and under the above conditions only results obtained with bars of the shape of solids of revolution employing torsional oscillations have significance. Both longitudinal and transverse oscillations yield excessive acoustic radiation, and the damping due to external losses is far greater than that due to internal dissipation. Suspension losses are also greater for the two latter modes of vibration, and in the case of transverse oscillations are prohibitive in themselves. The damping capacity of the light alloys tested is independent of frequency and also of stress, at least up to a maximum surface stress of 60 lb./in.^{2}. It is important to bear in mind that the damping capacities quoted refer to a more complicated distribution of stress than that in the case of the resonant pendulum. In the latter case the instantaneous stress has a radial variation only, whereas in the case of the heavy "free-free" bar the instantaneous stress has both an axial and a radial variation, and the maximum stress quoted exists only over a limited region in the neighbourhood of the nodes and for only a small fraction of the total time of oscillation. It will be observed that, owing to the sinusoidal stress distribution, the effect upon the total damping capacity of variation of damping capacity with stress will be less evident than in the case of the ideal torsion pendulum. Whilst it has not been fully established that the damping of steel is independent of frequency, the contrary case has not been established either. Observed variations are small and may be due to experimental factors or to departure from exponential decay near the upper limit of the stresses employed.

The damping capacity of complex light alloys in soundest possible condition varies between $0{\cdot}06 \times 10^{-4}$ (annealed material) and $0{\cdot}15 \times 10^{-4}$ (fully aged material); the majority of values lie between $0{\cdot}10 \times 10^{-4}$ and $0{\cdot}15 \times 10^{-4}$. The damping capacity of light alloys seems to depend on the degree of precipitation present. Contrary to reasonable anticipation, the damping of annealed material is not stable at room temperature; over a period of months an increase of 20 per cent. has been observed. Re-annealing restores the original value. The above increase of damping has not been established for all annealed material; cases have occurred in which the measured increases in damping lie within the limits of experimental error.

The damping of 0·6 per cent. carbon steel is $0{\cdot}5 \times 10^{-4}$ and $0{\cdot}7 \times 10^{-4}$ for the tempered and oil-quenched states, respectively. These values, together with corresponding Brinell values, were reproduced through successive cycles of heat-treatment. It is probable that the changes in damping of steel are closely connected with lattice changes in the crystal structure of the material, the tempered and quenched conditions corresponding to the body-centred cubic lattice and the face-centred cubic lattice, respectively.

The method employed in this work provides wide latitude for the dimensions of the specimen, the only limitation being that the specimen must have the shape of a solid of revolution. Measurement of damping for several harmonics affords a valuable check on experimental conditions and yields information regarding inhomogeneity of specimens. Damping values (confined to the exponential range of decay) afford a simple means of comparison of specimens or measuring changes produced by various processes. Damping values are single numbers rapidly calculated while the test is in progress, and the delay associated with the usual photographic recording is eliminated. Thus, this type of testing is rapid and accurate, and applicable to production material and to finished components when they are of the shape of solids of revolution.

At the present stage of development of the technique, the most important application of damping capacity is to the non-destructive testing of production materials. In this connection damping values are in many ways unique. Not only is it possible to distinguish material accepted for production purposes from faulty material (as done by other tests), but accepted material can be classified according to quality. The ability to deal with large specimens, where radiographic examination would be valueless, and to discover fine cracks with facility, together with the speed of operation, render damping measurement a useful method of non-destructive routine testing. Whilst damping measurements cannot always indicate with absolute certainty the presence of fine cracks, owing to selective sensitivity to orientation, serious defects cannot pass undetected and good material is never in doubt. The sensitivity to surface conditions and to defects situated near the surface of a rod or tube may be utilized for plated surfaces or for the study of protective finishes.

Throughout the stress range 0–30 lb./in.^{2} for aluminium alloys and 0–190 lb./in.^{2} for steel, the damping capacity has been found constant, in agreement with previous investigations over similar ranges. This is consistent with the solution of the damped-wave equation, but does not imply accuracy of the original equation, in which it was necessary to assume that the internal frictional force is proportional to the particle velocity and not to the velocity gradient as would be expected. In the case of the torsional pendulum the two assumptions are equivalent, but, owing to the sinusoidal distribution of the displacement, they are quite distinct in the case of the heavy " free-free " bar. Insufficient evidence is available for speculation on the nature of the internal forces.

Some investigators have mentioned the necessity for initial cyclic stressing before decay measurement. Throughout the present work there has been no evidence that pre-stressing has any influence on the damping values obtained: this may be due to the enormous number of stress cycles performed during tuning and to the magnitude of the stresses employed.

The damping capacity of materials has been considered a factor of prime importance with regard to the dissipation of energy in vibrating machinery. It may be fallacious to assume that high damping is beneficial, as, at any rate for low stresses, it is probable that the internal friction is negligible compared with external friction. However, in many machines the oscillatory component of the force on a member may still be sufficient to provide a cyclic stress amplitude capable of fatigue working the metal, and in the absence of knowledge of the relation between damping capacity and fatigue strength no conclusions can be reached. The knowledge necessary to estimate the relative importance of damping capacity of a material used for vibrating machinery in which there are possibilities of resonance, could be provided by a suitable fatigue test by resonance methods which, at the same time, would yield information concerning the relation between damping capacity, stress, and the cyclic history of the material. Another limitation to the energy dissipation possible by internal frictional forces is due to the limited volume of material which actually experiences the maximum stress and the limited time over which this maximum stress operates.

Correlation of the work with that of other investigators is made extremely difficult by the widely different objectives of the experimenters and the diversity of techniques employed. No technique is ideal and many results are open to grave suspicion. The cause of greatest uncertainty is the magnitude of external losses, which has led many investigators to deny the fundamental nature of the damping values obtained, while still attaching importance to variations obtained with changes in temperature and stress.

This point of view assumes the contribution from external friction to the measured damping to be a constant during all changes, so that any measured increase in damping is due solely to internal friction. Thus, the lowest damping observed is regarded as determining the maximum uncertainty due to external friction, irrespective of material or conditions. There is no evidence that the external friction component of the damping is a constant in any experimental procedure, either as a function of stress or of temperature, but it may be assumed constant only for variations in damping for varying metallurgical conditions with physically identical specimens under identical conditions.

Whilst the technique here employed is closely allied to that adopted by Wegel and Walther [1] and later by Zener,[8] it is important to keep in mind that their results refer mainly to longitudinal and transverse vibrations; results obtained with the present technique employing these modes are considered unreliable. Longitudinal damping values of $0{\cdot}36 \times 10^{-4}$ for 99·5 per cent. pure aluminium and torsional values of $0{\cdot}8 \times 10^{-4}$ for a steel drill rod by Wegel and Walther, together with longitudinal values of $0{\cdot}12 \times 10^{-4}$ for 70 : 30 brass by Zener, show that the values obtained by their techniques are of the same order of magnitude as those obtained by the present technique. The comparison cannot be taken further owing to the different conditions of operation. By means of the Föppl–Pertz technique, torsional damping values of $4{\cdot}1 \times 10^{-3}$ at 1000 lb./in.^{2} maximum surface stress for an aluminium alloy similar to Duralumin (Hatfield, Stanfield, and Rotherham [5]), 5×10^{-3} at 750 lb./in.^{2} for Duralumin and $5{\cdot}5 \times 10^{-3}$ at 750 lb./in.^{2} for R.R.56 alloy (Stanton and Thompson [4]) have been obtained. The stresses employed are admittedly larger than those reported in this work, but the damping values quoted are suspiciously high, and it was therefore decided to modify the existing technique to bridge the gap between dampings for stresses up to 30 lb./in.^{2} and those up to 1000 lb./in.^{2}. Experiments were therefore undertaken during the preparation of this report which have established that the damping capacity of a compound pendulum of Duralumin freely suspended with its axis horizontal, in the manner of our normal technique, does not exceed $0{\cdot}6 \times 10^{-4}$ at a maximum surface stress of 700 lb./in.^{2}. At 60 lb./in.^{2} the damping was $0{\cdot}1 \times 10^{-4}$, in agreement with the results obtained with a "free-free" bar. Part of the increase in damping is due to increased losses, but there can be little doubt that a genuine increase of damping occurs with increasing stress in the extended range employed. An important consequence of this is that the dissipation of energy in resonant members will be mainly at the surface and will depend largely on the stresses which obtain in the member.

IX.—ACKNOWLEDGEMENTS.

The authors are indebted to Mr. W. C. Devereux, Chairman of High Duty Alloys, Ltd., for permission to publish this work and for his continued encouragement during the progress of the research, and to Mr. W. E. Prytherch, M.Sc., under whose direction the work was carried out.

The authors also wish to acknowledge the assistance afforded by their colleagues, Messrs. R. Tiffen, B.Sc., and F. F. Edwards, in carrying out the experimental work and in the preparation of this paper.

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CORRESPONDENCE ON MR. M. MILBOURN'S PAPER: "THE SPECTROGRAPHIC ANALYSIS OF COPPER AND COPPER-RICH ALLOYS BY THE ARC METHOD."

(*J. Inst. Metals*, 1943, **69**, 441.)

Dr. H. Lowery * (Member): In discussing the spectrographic estimation of impurities in copper and copper-rich alloys, Mr. Milbourn has raised some very important questions connected with the mechanism of the electric arc, and rightly points out that the functioning of a copper arc is not yet properly understood. This fact is all the more surprising when one remembers the immense amount of work that has been done on arc spectra observed under a variety of electrical and special external conditions, not to speak of the extensive researches on electric-furnace spectra by A. S. King,† Hemsalech,‡ Le Comte de Gramont,§ &c. If errors are to be avoided in spectrographic analysis by the arc method, it is clear that information must be available on the possibility of the origination of lines by the various parts of the arc, since it is well known that the electrical conditions are not uniform throughout the arc, the intensity of the electric field even in a steady arc being subject to continuous variation from one pole to the other.

Most spectrographic work is carried out purposely with instruments that do not produce stigmatic images, but this is a disadvantage if the object is to investigate the origination of lines at different points in the arc discharge. With an instrument giving stigmatic images, a point in the spectral image corresponds to a particular point in the source of light, so that it becomes possible to examine exactly the conditions under which a given line has occurred. Thus, in the spectrum of the steady arc discharge, it is possible to distinguish immediately between the lines due to multiple ionization arising from the intense field near the cathode and lines originating from the flame or from the region round the anode. Such a study does in fact reveal pronounced differences in the spectra from the various parts of the arc. The spectrogram from astigmatic instruments would show the "short" lines due to pole effect drawn out into lines crossing the whole width of the spectrum and so becoming confused with other lines originating from the flame of the discharge, which also are drawn out into lines crossing the whole spectrum, thereby increasing the confusion. That a difference between the regions round the poles of the arc and the flame exists may be demonstrated with astigmatic instruments by working with the arc horizontal (see Milbourn, Plate XXXVII, Fig. 5), but this procedure is not sufficiently refined for an accurate study of the conditions prevailing throughout the arc discharge, as the electrical conditions are subject to variation over a relatively small gap. Much useful work has, however, been performed with "astigmatic" instruments in the study of furnace spectra, but here the conditions over fairly large areas of the source are constant, and the spectrograph may be directed towards these areas to obtain a spectrogram under kindred conditions.

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* Principal, South-West Essex Technical College, E.17.

† *Astrophys. J.*, 1922, **56**, 318.

‡ *Phil. Mag.*, 1918, [vi], **36**, 281.

§ *Compt. rend.*, 1920, **170**, 31.

A suitable instrument for the production of stigmatic images * may easily be arranged, using a concave grating in conjunction with a collimator that directs a beam of parallel light on the grating, which in turn focuses the spectral images on a photographic plate. By means of a lens, an image of any part of the arc may be focused on the slit of the collimator, using the method of parallax, and thus its corresponding spectrum may be obtained.

Valuable information on the origin of spectral lines in the arc may be secured by photographing *arc flashes* with a stigmatic spectrograph, especially if the upper electrode carries a screen with an adjustable aperture which enables successive stages in the formation of a flash to be isolated. Electrical conditions are particularly intense when the arc is just being struck; thus, if a potential of 200 v. be applied, the field strength is 20,000 v. per cm. when the gap is 0·1 mm., but will decrease as the poles move apart, finally settling down to an approximately steady value if the arc is allowed to persist. Some spectral lines are broadened under a strong electric field (Stark effect). Such lines occurring in arc spectra will have an Eiffel Tower appearance when arc flashes are photographed; indeed, the shape of the line may be used as a guide to the nature of the variation of the electric field in the flash.

By means of the flash method, Hemsalech † has shown that spark lines (enhanced lines) may occur in the arc under certain electrical conditions. He investigated lead, tin, magnesium, zinc, and cadmium, using a prism spectrograph which gave astigmatic images. The present writer ‡ has studied silver, copper, and gold with a grating instrument mounted stigmatically. In addition to finding enhanced lines as in Hemsalech's work, many "new" lines were also observed. In all cases these latter occurred at the poles, but not all the lines due to the cathode were produced at the anode, and most of the anode lines were different from the cathode lines. Always, more cathode lines were produced than anode lines. With an astigmatic instrument these pole lines would be drawn across the spectrum, and it would not be possible to say whether they were due to the pole effect or the vapour. From the point of view of spectrographic analysis, the value of being able to make the distinction is obvious.

The production of "new" lines by varying the electrical characteristics of the arc seems to be unlimited. With a high initial applied voltage and low circuit resistance giving rise to heavy current densities, the conditions for multiple ionization are particularly favourable, and as a result it is unlikely that any two published lists of spectral lines would agree in their entirety, since exact repetition of electrical characteristics seems to be practically impossible. Moreover, if alleged new lines were due to pole effect, it is conceivable that their wave-lengths when measured would show slight differences from lines observed by other observers owing to the Stark effect shift, and might be interpreted as different lines when in an actual fact they were the same. This is, for example, probably the case with many of the new lines recorded by Catalan in the spectrum of silver, over eighty of which differ but slightly in wave-length from previously recorded lines in spark spectra.

Only three "new" lines were published by the present writer § in the pole spectrum of copper between λ 4500 and λ 3380. These were faint lines due to a field of 8000 v. per cm. and low current density. None of them appears in the Copper I lines given by Mr. Milbourn. Further spectrograms subsequently obtained for the interrupted arc spectrum of copper, using a

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* H. Lowery, *Phil. Mag.*, 1924, [vi], **48**, 1122.

† *Phil. Mag.*, 1922, [vi], **43**, 287, 834.

‡ *Phil. Mag.*, 1925, [vi], **49**, 1176.

§ *Phil. Mag.*, 1925, [vi], **49**, 1176.

heavy current (about 30 amp.) and fields of the order 20,000–40,000 v. per cm., yielded many more previously unobserved lines, especially at the negative pole, some of which appear to be identical with lines observed by Mr. Milbourn, viz., λλ 5710·5, 5236·1, 4734·1, 4354·1, 3837·5, 3753·0. Slight differences in wave-length are probably due to Stark effect.

Copper lines are particularly susceptible to changes in electrical conditions; thus Duffield * found that whereas increased pressure caused the ordinary line spectrum of silver to be partly replaced by a number of bands, in the case of copper, the line spectrum persisted even up to 203 atmospheres with some broadening but very marked displacement, the latter presumably being due to the pronounced change in electric field which caused lines to show the Stark effect.

That care must be taken in interpreting the occurrence of spark lines (enhanced lines) which occur in arc spectra under certain circumstances was shown by Hemsalech,† who noted that spark lines may be developed in the arc when the degree of ionization is actually lowered, as for example by directing a current of air through the arc. Moreover, spark lines (which have sometimes been called high-temperature lines) disappear when the cathode consists of white-hot carbon; on the other hand, they may actually be brought out by making arc flashes in liquid air. With such confusing results as these to explain, it is not surprising that the mechanism of the copper arc, indeed of any arc, is not yet understood. It is likely, however, that any satisfactory explanation will only be found in an examination of the electrical conditions prevailing at the different parts of the arc, and in this connection it is not without interest to note that none of the "new" lines (*i.e.* lines other than enhanced) so far recorded as occurring in the arc due to abnormal electrical conditions, as for example in the pole effect, have been observed in celestial spectra in spite of their multiple ionization; this seems to indicate that they are of a transitory character.

In reference to Mr. Milbourn's observation of the band spectra which form a background to the normal line spectrum of copper, these are invariably brought out by the interrupted arc spectrum in air, among which may be noticed with great prominence the negative bands of nitrogen (heads at λ 3914 and λ 4277), and with weak intensity the positive bands at λλ 3755, 3805, 3943, 3998, 4059, 4269, and 4344. When interrupted arcs are worked in an atmosphere of hydrogen, the four hydrogen lines λλ 6563, 4861, 4340, 4102, are broadened enormously at the beginning of the flashes, when the electric field is most intense (90–120 A. with fields 20,000 v. per cm.). Moreover, the "many lines" or secondary spectrum of hydrogen is also well developed under these conditions.

Mr. D. M. Smith,‡ B.Sc., A.R.C.S., D.I.C. (Member): For the analysis of copper and copper-rich alloys, various modifications of the arc method have been proposed from time to time, the globule arc being favoured for the analysis of copper, and the metallic arc, using a comparatively bulky electrode of the sample, for copper-rich alloys.

In the B.N.F.M.R.A. laboratory, use is still made of a 7-amp. arc between graphite electrodes, the sample being in the form of a globule on the lower (negative) electrode. The arc length is 3 mm., the central third of which is focused on the spectrograph slit by means of a spherical lens. Whilst objections may be raised both to the use of an upper graphite electrode and to the mode of slit irradiation, the method has proved very useful in the analysis of

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* *Phil. Trans. Roy. Soc.*, 1908, [A], **209**, 205.

† *Phil. Mag.*, 1922, [vi], **43**, 287, 834.

‡ Investigator, British Non-Ferrous Metals Research Association, London.

high-conductivity and arsenical coppers (unless phosphorus-deoxidized). The principal advantage of the method is its high sensitivity and, except in the case of arsenic determinations, it gives quite reproducible results for small quantities of impurities. The estimated limits of detection of antimony, bismuth, cobalt, iron, lead, nickel, and tin are 0·0001–0·0002 per cent., approximately. No doubt the high current strength in this form of globule arc favours a reasonably uniform excitation of the lines from pole to pole, thus minimizing any errors which may arise from what is theoretically an unsound mode of slit irradiation. Increasing the current strength above 7 amp. gives no further gain in sensitivity, but increases the density of the spectrum background.

Before making the exposure, the arc is allowed to run until the sample has become completely molten and then partially solidified, after which the discharge is fairly steady. Examination of the globule after exposure indicates that during the stabilizing pre-arcing period the sample is converted into oxide, thus confirming the view that the presence of oxygen is essential for the proper functioning of the arc.

The author refers to the established method of defining the current and arc length and observes that the various techniques hitherto proposed rely more on standardization of the conditions of exposure than on fundamental considerations. This has been due probably to a statement by Nottingham * that the relative intensities of the lines in the copper arc spectrum depend in a definite manner upon the current flowing through the arc. Consequently, in the absence of the data carefully collected and correlated by the author, it has been considered necessary to maintain the current flowing in the arc as constant as possible.

One of the practical advantages of the globule method for the analysis of copper is that the technique is applicable to the analysis of drillings, but in the case of copper-base alloys, such as brasses, cupro-nickels, and gun-metals, for example, this method will give only approximate indications of impurity contents. It is with alloys such as these that the intensity ratios used for the determination of any given element generally depend to a marked extent on the amounts of the major components of the alloy and where marked selective distillation is to be expected.

A spectrographic laboratory which is called upon to analyse samples of widely differing compositions is faced with the necessity of providing a range of standards for each type of alloy to be tested. Thus, in the Association's laboratory use has been made of analytical tables for brass (Brownsdon and van Someren †) and for copper–nickel and copper–nickel–zinc alloys (data kindly provided by the author), supplemented by sundry analysed samples. While suitable ranges of standards will probably still be necessary when the highest accuracy possible by these methods is desired, for a wide range of copper-rich alloys the author has now provided a simple means of control for analytical work of adequate accuracy for practical purposes. Although it is possible to form an idea of the sensitivity of detection for each element from the table in Appendix I, it would be useful if approximate figures for the limits of spectrographic detection could be stated.

The spectrographic determination of selenium, which has recently been of some interest, has presented a number of difficulties, which so far have not been overcome. This question was studied both by the author and in the B.N.F.M.R.A. laboratory, and it was concluded that the main problem was to obtain a photographed spectrum of sufficient density and contrast in the region of short wave-lengths (the most sensitive selenium lines being SeI

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* *J. Franklin Inst.*, 1929, **207**, 299.

† *J. Inst. Metals*, 1931, **46**, 97.

2039·85 and 2062·8 A.). The slope of the calibration curve is so small that, while the element can be detected with certainty, the amount present cannot be estimated with any useful degree of accuracy.

As an instance of the use of the microphotometer in the Association's laboratory, may be cited the determination of tellurium in copper. The graphite arc globule method was used, with the arc length reduced to 2 mm. and no lens between the source and spectrograph slit (distance apart 20 cm.). Using the line pair CuI 2363·2/TeI 2385·8, 39 repeat determinations of the tellurium content of a sample containing 0·04 per cent. gave a standard deviation of 0·0035 per cent., or 8·9 per cent. of the actual content. Whilst this accuracy cannot be considered high, it is much higher than could be obtained visually. Since no photo-electric control was employed in this case, the result obtained supports the author's contention with regard to microphotometric measurement.

It is now generally becoming accepted that the greater part of the total analytical error may be traced to the light source. The author has made a comprehensive study of the arc discharge from both theoretical and practical points of view, and in this way has laid sure foundations for further research on the subject.

The AUTHOR (*in reply*): I am grateful to Dr. Lowery for having amplified certain aspects of the origins of radiations, and of the use of spectrographs, which I had dealt with but briefly.

In order to avoid confusion, it is probably worth reiterating that two types of illumination of the spectrograph slit were used throughout my work. In one, an image of the arc was thrown on to the slit of a quartz spectrograph by a spherical condensing lens, so that a stigmatic spectrum was obtained. Figs. 3 and 5 (Plates XXXV and XXXVII) are typical of this system, and on the former it can just be seen that the two copper spark lines 2837·55 A. and 2877·69 A. (marked as Cu+) are extremely short and completely confined to the electrode regions. In the other system, no condensing lens was used, the arc being 20 cm. from a slit 1½ mm. long. The slit, to all intents and purposes, was uniformly illuminated along its length, giving lines which may be readily compared for density. Figs. 4 and 6 (Plates XXXVI and XXXVIII) were obtained in this way, which is used in all routine work.

Since one endeavours to use as steady a source as possible for analytical work, the transient conditions in an arc flash would pre-judge its usefulness as a means of investigating such problems. Hemsalech's observations, however, do lend general support to the contention that factors which tend to reduce the rate of volatilization of copper increase the intensity of spark radiations.

The electrical conditions during the earliest stages of the formation of an arc have been studied by Fett,* and by Betz and Carrer,† using cathode-ray oscillographs. Their important conclusion that the cathode fall of potential in a copper arc remains constant at 12–13 v. under various conditions of current (0·5–100 amp.), open-circuit voltage (up to 230 v.), and speed of separation of the contacts (7·5–90 in. per second), indicates that one might expect similar radiations from the cathode layers of arcs which have very different overall potential gradients. My work has shown how arc radiations may extend into the column of the discharge under the influence of vapour clouds, the electrical conditions playing only a secondary effect. It is worth pointing out that Dr. Lowery's electrical conditions differ greatly

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* *J. Applied Physics*, 1941, 12, 436.

† *Ibid.*, 1937, 8, 845.

from those usually obtaining in analytical work. There is a possibility that the difference arises because he is quoting open-circuit voltages, which may bear no relationship to the potential in the arc itself.

In assessing differences in lists of observed lines, the importance of minor impurities and of the contrast of the photographic plate, in allowing faint lines to be detected on a continuous background, should not be overlooked. In this connection, I am grateful to Dr. Lowery for his confirmation of some of the lines which I had observed and for the details on bands which he has supplied.

I should also like to express my thanks to Mr. D. M. Smith for the observations which he has drawn from his comprehensive experience of spectrographic methods. The following table gives an approximate indication of the limits of detection which he requests:

Limit of Detection.	Elements.
Less than 0·001 per cent.	Tin, lead, iron, nickel, manganese, bismuth.
About 0·001 per cent.	Arsenic, antimony.
About 0·003 per cent.	Aluminium, silicon.
About 0·007 per cent.	Zinc, phosphorus.

The mention of selenium affords an opportunity for expanding the details previously given for the detection of this element.* It was then suggested that, for studying the region 1960–2073 A., a spectrograph of small dispersion should be used, together with Schumann plates. More recently it has been found that a medium spectrograph may be employed, at any rate for 2040 and 2063 A., and that, in particular, it is not necessary to modify the focus of a flat-field instrument, such as the Hilger E.498 model, in order to bring the lines into focus. While Schumann plates give the greatest contrast, they are not easy to control, and the Ilford Q1 or Kodak B10 plate is probably preferable. Exposure and slit width should be such that the background in the neighbourhood of the lines sought is clearly evident, so that there may be no doubt as to whether the threshold of the plate has been crossed. A solid electrode arc appears to be better than a globule arc, since the former gives more background in the 2000 A. region than the latter. The following conditions allow 0·007 per cent. selenium in copper to be detected:

An arc, 1 mm. long, carrying 7 amp., between the sample (negative) and a pure copper rod; source 20 cm. from the slit, 0·03 mm. wide, of a Hilger E.498 spectrograph; exposure 2 minutes on a Q1 plate.

* M. Milbourn, *J. Soc. Chem. Ind.*, 1937, **56**, 205T.

METALLURGICAL ABSTRACTS

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AUTHOR INDEX TO ABSTRACTS

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 11 JANUARY 1944

I.—PROPERTIES OF METALS

Recent Advances and Developments in the Field of Aluminium and Its Alloys. W. Linicus (*Metallwirtschaft*, 1941, **20**, (20), 505–510).—A general review. In the reduction process, the use of layer cells has given increased efficiency. The development of the 3-layer process for making super-purity aluminium has resulted in greater availability of this material for reflectors and decorative work, and has provided a means of refining contaminated metal. Further advances have been made in purification by fractional solidification and distillation. The shortage of copper has caused a search to be made for alternative alloys, and the aluminium–magnesium–zinc group is being developed. Their liability to stress corrosion can be minimized by addition of manganese or chromium and by appropriate heat-treatment. Specifications have been drawn up for secondary metal, and remelting procedures standardized. Developments have been made in cladding, particularly for reflectors. In draw-press work, advances have been made in die design and the use of rubber. In processing, section rolling and incorporation of heavy-metal inserts call for mention. In riveting, age-hardening is being controlled by varying the composition of the rivets, and explosive rivets are being employed to an increasing extent. Some advances have been made in welding apparatus. For heat-treatment, salt baths are being replaced by air-circulation furnaces.—H. W. L. P.

Hardness of Aluminium Sheet (Tests and Conversion Charts). (Templin.) See p. 24.

Beryllium—Facts About the Metal, Rather than Fancies. —— (*Metal Progress*, 1943, **43**, (6), 904–907, 942; also (abridged) *Met. Ind.*, 1943, **63**, (5), 71–72).—An editorial note describes the development in the U.S.A. of the commercial use of beryllium, and draws attention to the fact that the main obstacle to further development is the scarcity of beryllium ores rather than arbitrary restrictions. A summary is then given of a report to the U.S. War Production Board. The report states that the potential use of the metal exceeds the present supply. Over 90% of the beryllium produced is used for the alloying of copper, the beryllium being introduced in the form of a " master alloy " containing 4–4·5% beryllium; the proportion in the final copper-base alloy is 0·3–2·5%. The copper–beryllium alloys have high fatigue strength, elastic limit, and resistance to creep, wear, and corrosion, and they are much used in small but important control parts in marine, military, and aircraft work. Alloys of aluminium or magnesium with beryllium are in the experimental stage, more progress having been made with the former type. The report also refers to the use of metallic beryllium in X-ray work and to the value of beryllium oxide as a refractory aid in the production of fluorescent elements (" phosphors ") for lamps.—P. R.

***Investigations of Ferromagnetic Impurities. II.—[In Copper, Brass, and Silver.]** F. W. Constant, R. E. Faires, and H. E. Lenander (*Phys. Rev.*, 1943, [ii], **63**, (11/12), 441–445).—Cf. Constant and Formwalt, *Phys. Rev.*, 1939, **56**, 373; *Met. Abs.*, 1939, **6**, 448. The magnetic properties of copper

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* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

magnet wire, brass rod, and silver all showed the influence of ferromagnetic impurities. With copper and brass, heating to 900° and 750° C., respectively, in hydrogen for 2 hrs., followed by quenching, eliminated the ferromagnetism, but with silver this method was unsuccessful. With copper, reheating in an atmosphere containing oxygen caused the ferromagnetic effects to reappear. Diagrams are reproduced showing the ratio of the remanence after heat-treatment to the original remanence. The cause of these effects is discussed, and it is concluded that the heat-treatment results in the ferromagnetic impurity, presumably iron, entering into solid solution in copper or brass, but not in silver. The exact compositions of the materials are not stated. —W. H.-R.

***Electrical Conduction and Recrystallization in Thin Lead Films Deposited at Low Temperatures.** Edgar L. Armi (*Phys. Rev.*, 1943, [ii], **63**, (11/12), 451–454).—Thin films of lead were deposited on glass by evaporation in high vacuum. Films deposited on glass at the temperature of liquid or solid hydrogen showed an appreciable conductivity at thicknesses as small as 7 A., whereas with glass at room temperature a thickness of the order 160 A. was required. This difference is due to the agglomeration of the film into isolated particles which takes place readily at room temperature, whereas at the low temperatures re-grouping is only possible on a very small scale. Experiments on the ageing of the films at different temperatures are described, and confirm these views; they show that there is a critical temperature below and above which ageing decreases and increases the resistance respectively.—W. H.-R.

Magnesium, Its Properties and Production. Walter B. Spellmire (*Gen. Elect. Rev.*, 1943, **46**, (7), 372–375).—Mainly a general description of the electrolytic and thermal processes in use for the production of magnesium. —E. V. W.

***The Effect of High Electrostatic Fields Upon the Vaporization of Molybdenum.** G. B. Estabrook (*Phys. Rev.*, 1943, [ii], **63**, (9/10), 352–358).—The effects of electrostatic fields on the vaporization of molybdenum were studied by measuring the electrical resistance of wires mounted in evacuated glass tubes so that a radial field could be applied while the wire was heated by the passage of a current. The wire was made electro-positive to avoid emission of electrons. Field strengths below about $0{\cdot}52 \times 10^6$ v./cm. had no effect on the rate of vaporization, but on increasing the field strength above this value, the rate of vaporization decreased, at first slowly and then more rapidly, until it became nearly zero at field strengths of the order $1{\cdot}8 \times 10^6$ v./cm. The effect is least pronounced as the temperature is increased. The effect may be due to the evaporated atoms becoming dipoles in the strong fields, and so being attracted back to the wire. In the range where the field does affect the rate of evaporation, there is a sudden increase in resistance when the field is applied.—W. H.-R.

***The Effect of High Electrostatic Fields Upon the Vaporization and Resistance of Molybdenum Filaments.** Walter P. Reid (*Phys. Rev.*, 1943, [ii], **63**, (9/10), 359–366).—Theoretical. The effects observed by Estabrook (abstract above) are explained on the assumption that the decrease in the rate of evaporation caused by the application of an electrostatic field is due to the formation of an adsorbed gas layer on the filament.—W. H.-R.

Remarks on Salvador Velayos' Paper : "Effect of Elastic Compression on the Maximum Magnetic Susceptibility of Nickel." Heinz Bittel (*Z. Physik*, 1940, **116**, (5/6), 349–351; *Chem. Zentr.*, 1940, **111**, (II), 3450).—Cf. *ibid.*, 340–348; *Met. Abs.*, 1941, **8**, 255. V.'s experimental results on the effect of elastic compression on the maximum permeability of nickel rods may be described, not only by V.'s own formula, but also in general terms by B.'s theory, since according to V.'s results both the coercive force and the magnetic field at the maximum permeability are proportional to the internal stresses. B. rejects V.'s empirical formula on account of its limited validity.

***On the Phenomenon of Overheating a Solid Body. [Tin Wires.]** S. E. Khaykin and N. P. Benet (*Compt. rend.* (*Doklady*) *Acad. Sci. U.R.S.S.*, 1939, [N.S.], **23,** (1), 31–35).—[In English.] Experimental evidence is given to show that tin wires of 8–10 mm. diameter and 10–12 cm. length behave differently on melting by careful electric heating, according to whether they are single-crystal wires or not. In polycrystalline wires the melting process starts in the centre of the wire, and penetrates to the surface. On the other hand, single-crystal wires melt first at the surface. Since the temperature increases with depth (an effect intensified by the air-cooling of the surface), it has to be assumed that the internal temperature exceeds the melting point by up to 2° C. Thus, a single crystal may not melt, even though its temperature exceeds the melting point, and the more perfect the single crystal, the greater is the superheating it can undergo. It is concluded that for a solid to melt, not only must the melting point be reached, but certain other specific conditions must be fulfilled.—N. B. V.

***The Effect of High Electric Fields on the Conductivity of Tungsten.** Peter Louisa Vissat (*Phys. Rev.*, 1943, [ii], **64,** (3/4), 119–125).—A grounded tungsten wire, 0·0078 mm. in diameter, was mounted co-axially with a cylinder which was made negative to the wire. A potential difference was then applied between the cylinder and the wire, and the change in resistance of the wire was measured. With a vacuum of the order of 10^{-6} mm. of mercury, and fields of the order of 10^6 v./cm., an increase in resistance was observed when the field exceeded a certain value, and this increase became greater as the field increased. Possible causes of the phenomenon are discussed, and it is concluded that it is due to ionization currents in the space between the wire and the cylinder passing to the filament, and so heating it and increasing the resistance.—W. H.-R.

***Energies for Self-Diffusion in Zinc.** H. B. Huntington (*Phys. Rev.*, 1943, [ii], **63,** (9/10), 383–384).—A note. Experiments by Miller and Banks (*Phys. Rev.*, 1942, **61,** 648; *Met. Abs.*, 1942, **9,** 235) show that in the self-diffusion of zinc, the energy of activation is always smaller for diffusion along the hexagonal axis than for diffusion in the basal plane. If the hypothesis of vacancy diffusion is accepted, the diffusing atom half-way between two vacancies in the same basal plane would appear to be in a position of higher energy than an atom half-way between vacancies in adjoining planes. Calculations of the electrostatic energy of the two situations have been made on the assumption that the two valency electrons per atom are uniformly distributed in space, and give qualitative confirmation of the difference in activation energies.—W. H.-R.

***Investigation of Electrocapillary Phenomena on Various Liquid Metals.** S. Karpatschoff and A. Stromberg (*Acta Physicochim. U.R.S.S.*, 1942, **16,** (5/6), 331–335; *C. Abs.*, 1943, **37,** 3322).—Cf. K. and S., *ibid.*, 1940, **12,** 523; *Met. Abs.*, 1941, **8,** 342. Electrocapillary curves for silver, antimony, bismuth, aluminium, gallium, and tellurium were obtained, using fused mixtures of KCl + LiCl of eutectic composition as the electrolyte. A table is given for the potentials of the maxima of the electrocapillary curves against the lead electrode for the metals studied. In a number of cases the p.d.s at the maxima of the electrocapillary curves for different metals coincide with the p.d. between these metals at their points of zero charge in aqueous solutions. Such agreement is not found for silver.

The Behaviour of Metals Under Alternating Stresses. E. Siebel (*Metallwirtschaft*, 1941, **20,** (17), 409–414).—A review of recent work on fatigue and the phenomena associated with it, with particular reference to the effect of notches and corrosion on the fatigue behaviour of stressed parts, the effects of two types of stresses acting simultaneously, methods of determining fatigue damage, and means for improving the resistance of constructional materials to fatigue failure.—A. R. P.

Metals at High Temperatures. N. A. de Bruyne (*Aircraft Eng.*, 1943, **15**, (174), 223–226).—Published data on the strength of metals at high temperatures are examined in relation to expressions used by Andrade and by Dushman for flow and fracture at high temperatures. Where the strain energy becomes appreciable, a correcting term is necessary to allow for interaction between strain energy and activation energy. De B. examines the use of a relationship of the type suggested by Becker and previously used by himself in describing viscous flow, by application to results obtained by Martin (*J. Inst. Metals*, 1924, **31**, 124) for the ultimate strength of aluminium at high temperatures. Results obtained by Dickinson (*J. Iron Steel Inst.*, 1922, **106**, 103) on a number of commercial steels at high temperatures are given, plotted in the form of the log of time to fracture at constant stress against the reciprocal of the absolute temperature; they show a linear relationship.—H. S.

***A Note on the Thermoelectromotive Force.** Karl F. Herzfeld (*Phys. Rev.*, 1943, [ii], **64**, (1/2), 37–38).—Theoretical. An analogy exists between the state of electrons in a temperature gradient and a gas at low pressure in a capillary in which a temperature gradient exists. Equations are derived and compared with the usual expressions.—W. H.-R.

The Scientific Significance of Ferromagnetism. Francis Bitter (*J. Washington Acad. Sci.*, 1943, **33**, (8), 235–238).—A review of the development of the scientific interpretation of ferromagnetism by means of theoretical and experimental investigations.—E. A.

Ferromagnetism and the Metallic State. Louis Néel (*J. Phys. Radium*, 1941, [viii], **1**, 242–250; *Chem. Zentr.*, 1942, **113**, (I), 1603; *C. Abs.*, 1943, **37**, 3309).—The old Weiss hypothesis of the molecular field can be extended by slight additional assumptions to metals with incomplete intermediate shells (transition metals) to interpret many experimental phenomena. Furthermore, these phenomena can be readily classified for calculation. For the ferromagnetic phenomena the molecular field is positive. Certain difficulties, such as the existence of a Curie range, or a ferromagnetic and a paramagnetic Curie point, can be removed by assumptions based on possible fluctuations of the molecular field. For the anti-ferromagnetic metals, such as manganese or chromium, the molecular field is negative. By assuming that fluctuations of the molecular field are possible here also, one can calculate a susceptibility–temperature curve which is horizontal over a wide range, and is, on the whole, in agreement with experimental results. Further, the molecular field should depend very markedly upon the mutual distances between the magnetic atoms. These deductions are supported experimentally, since ferromagnetism appears only for definite separations of the atoms. The case of manganese is especially interesting, because manganese lies close to the boundary of ferromagnetism, and only a slight enlarging of the lattice (*e.g.*, by embedding nitrogen atoms) serves to make it ferromagnetic.

***On the Thermomagnetic and Thermoelastic Phenomena in Ferromagnetic Metals. [Nickel and Iron.]** D. I. Volkov (*Zhur. Eksper. i Teoret. Fiziki* (*J. Exper. Theoret. Physics*), 1939, **9**, 444–450; *Chem. Zentr.*, 1940, **111**, (II), 3157).—[In Russian.] Cf. *ibid.*, 1939, **9**, 798; *Met. Abs.*, 1943, **10**, 341. V. investigated the Thomson–Nernst thermomagnetic effect and the thermoelastic effect in nickel and iron in weak magnetic fields. The experiments showed a rapid increase of the thermo-e.m.f. with a gradual transition to saturation, which occurs at the same value of H as the magnetic saturation. The change of the thermoelectric properties is thus limited in relation to the anisotropy by the orientating effect of the field in the region of spontaneous magnetization. The thermo-e.m.f. of nickel increases, and that of iron decreases, with the increase of tensile stress.

The Short- and Long-Term Order in Ferromagnetic Bodies. L. S. Stilbans (*Zhur. Eksper. i Teoret. Fiziki* (*J. Exper. Theoret. Physics*), 1939, **9**, 432–437; *Chem. Zentr.*, 1940, **111**, (II), 3309).—[In Russian.] S. discusses the thermodynamic characteristics of ferromagnetic bodies. The usual methods of calculation, which do not take into consideration the short-term order, give incorrect results at temperatures above the critical. S. carried out calculations taking into account the short-term order, which are therefore also valid at temperatures in excess of the critical. Formulæ derived in calculations embracing the long-term order confirm the former ones.

On the Change of the Resistance of Metals in a Magnetic Field. A. Akhieser (*Zhur. Eksper. i Teoret. Fiziki* (*J. Exper. Theoret. Physics*), 1939, **9**, 426–431; *Chem. Zentr.*, 1940, **111**, (II), 3156).—[In Russian.] The effect of the magnetic field on the resistance of metals at low temperatures was studied theoretically. A marked periodicity of the dependence of the resistance on the magnetic field was observed, similar to that shown experimentally, *e.g.*, for bismuth.

Statistical Theory of Liquids.—II. G. Jaffé (*Phys. Rev.*, 1943, [ii], **63**, (7/8), 313–321).—Cf. *Met. Abs.*, 1943, **10**, 105.

II.—PROPERTIES OF ALLOYS

Recent Advances and Developments in the Field of Aluminium and Its Alloys. (Linicus.) See p. 1.

***Ageing in the Solid Solution of Silver in Aluminium.** A. H. Geisler, C. S. Barrett, and R. F. Mehl (*Metals Technology*, 1943, **10**, (2); *A.I.M.M.E. Tech. Publ.* No. **1557**, 20 pp.; and *Trans. Amer. Inst. Min. Met. Eng.*, 1943, **152**, 182–200; discussion, 223–225).—The ageing of solid solutions of silver in aluminium has been studied for ageing temperatures up to 303° C., using alloys containing 10, 20, and 30% silver. Laue X-ray diffraction photographs show Guinier–Preston streaks, indicating that platelets form on the (111) planes of the aluminium solid-solution matrix. The initial precipitate has the γ' structure, which at a later stage begins to change to the equilibrium γ structure. The γ' and γ structures are both close-packed hexagonal, and are oriented alike; they differ only in interatomic distances. Microscopic examination shows that the γ' to γ transformation is accompanied by a discontinuous type of reaction nucleated at the grain boundaries, which probably involves the recrystallization of the strained matrix. Measurements of hardness and electrical resistivity were also made. Hardening is caused by the precipitation of γ' and the stresses in the matrix involved in keeping the γ phase in this strained γ' condition, and the electrical resistance is also regarded as affected by these stresses. The general problem of ageing is discussed.—W. H.-R.

***Mechanism of Precipitation from Solid Solutions of Zinc in Aluminium, Magnesium in Aluminium, and of Some Magnesium-Base Alloys. [Lattice Spacings of Mg_2Pb and Mg_2Sn.]** A. H. Geisler, C. S. Barrett, and R. F. Mehl (*Metals Technology*, 1943, **10**, (2); *A.I.M.M.E. Tech. Publ.* No. **1558**, 22 pp.; and *Trans. Amer. Inst. Min. Met. Eng.*, 1943, **152**, 201–223; discussion, 223–225).—X-ray, microscopic, and hardness-test methods were used to investigate the precipitation of zinc from aluminium–zinc alloys containing 12 and 25% zinc. Coherent platelets form parallel to octahedral matrix planes in the early stages of precipitation, but they break away from the matrix before they are thick enough to diffract as 3-dimensional gratings. Age-hardening occurs during the formation and growth of the coherent platelets, but softening occurs when the non-coherent zinc structure appears. Similar investigations were made with aluminium–magnesium alloys containing 10 and 14% magnesium; coherent platelets form on (100) matrix planes, followed by growth to a well-defined Widmanstätten figure with plates on (100), and later on (120) matrix planes. Age-hardening takes place throughout the entire decomposition. The precipitation of Mg_2Sn and Mg_2Pb from magnesium–tin and magnesium–lead alloys was studied; coherent platelets may form, but if so they do not grow very large. The lattice spacings of the precipitated Mg_2Sn and Mg_2Pb were 6·744 A. and 6·836 A., respectively. —W. H.-R.

***Some Observations on the Age-Hardening of Aluminium Alloys Containing Zinc.** W. Feldmann (*Metallwirtschaft*, 1941, **20**, (20), 501–504).—Although it has long been known that aluminium alloys containing magnesium and zinc are capable of giving excellent mechanical properties when heat-treated, their commercial development has been hindered by their liability to stress-corrosion. It is now known that this liability can be removed by suitable heat-treatment. A study was therefore made of the age-hardening of an alloy containing zinc 4, magnesium 2, manganese 1% in sheet form. Samples were solution-treated for 2 hrs. at temperatures in the range 380°–500° C., quenched in cold water, and then aged for periods up to 81 days at room temperature and at temperatures in the range 75°–160° C. With ageing temperatures below 100° C., there was a general increase of hardness with time; with higher temperatures the hardness rose to a maximum and then decreased. Greatest hardness was obtained with a solution temperature of 500° C., Brinell numbers up to 120–130 being reached (9 days ageing at 140° C.). Proof-stress values up to 19 tons and ultimate stress up to 25 tons with 13% elongation were recorded. Ageing at room temperature followed by ageing at elevated temperatures resulted in maximum hardness being reached more quickly. After ageing at elevated temperatures, some ageing at room temperature occurred but was not pronounced. Lowering the solution temperature made the ageing slower, and lower hardness values resulted; for every quenching temperature there is an ageing temperature below which no hardening occurs. A study was also made of the hardening of a binary alloy of aluminium with 7% zinc at temperatures in the range − 71° C. to 100° C. Age-hardening was quite appreciable at 0° C. and was more rapid at lower temperatures.—H. W. L. P.

***On the Conditions of Formation and the Habit of Segregates Formed on Ageing Aluminium Alloys Containing Zinc, Copper, and Magnesium.** H. Röhrig and J. Roch (*Metallwirtschaft*, 1941, **20**, (16), 383–386).—Studies were made of the early stages of precipitation in aluminium-base alloys containing copper 0·7, magnesium 0·5%, with zinc content varying between 0 and 15%. Cast samples were given a solution-treatment of 18 hrs. at 540° C. and were then hot-rolled; they were then re-treated for 24 hrs. at 540° C., quenched in cold water, and given precipitation-treatments for various periods of time at temperatures from 250° C. upwards. The resulting microstructures are described in detail, and several typical micrographs are reproduced. Precipitation commences at the grain boundaries and later appears in the body of the crystals; there is frequently a zone, comparatively free from precipitate, adjacent to the boundaries. Appreciable precipitate appears after 2 hrs. at 250° C., and the particles increase in size and number with time. They tend to appear as small needles oriented in specific directions, and tend to be smaller and more rounded with higher zinc contents. They are larger, the higher the temperature. The Brinell hardness increases with zinc content, more rapidly the higher the temperature. The ultimate tensile stress shows a well-defined minimum at 250° C.—H. W. L. P.

The System Aluminium–Zinc. O. Tiedemann (*Z. physikal. Chem.*, 1942, [A], **191**, 133–144; *Brit. Chem. Abs.*, **1943**, [A I], 59).—The work of Röhrig and Roch and of Feldmann (abstracts above) is discussed, and is shown to support the existence of a metastable region of aluminium–zinc alloys with up to 29% zinc.

***On the Effect of Iron on the Age-Hardening of Wrought Aluminium–Copper–Magnesium Alloys.** K. L. Dreyer and H. J. Seemann (*Metallwirtschaft*, 1941, **20**, (25), 625–629).—A study was made of the age-hardening of a Duralumin-type alloy with additions of iron in the range 0·3–1·3%. Samples in the form of 2-mm. sheets were given a solution-treatment at various temperatures in the range 480°–540° C., quenched in water, and tested after ageing at room temperature for periods up to 12 days. The results are given in graphical form, and show that the mechanical properties decrease with iron contents in excess of 0·5%. The rate of age-hardening decreases with increasing iron content; improvement resulting from increasing the solution temperature becomes less pronounced. Conductivity measurements taken at intervals during ageing show that specific resistance is lowered with increasing iron content—in other words, that the iron is removing copper from solid solution.—H. W. L. P.

***The Prevention of Coarse Grain Growth in Aluminium [Alloy] Sheets for Deep Drawing.** A. Schroeder and K. Matthaes (*Metallwirtschaft*, 1941, **20**, (25), 631–636).—After preliminary experiments with tapered test-pieces, series of tests were made on the recrystallization of a clad Duralumin-type alloy during solution-treatment. In general, specimens were rolled or stretched by amounts varying between 0 and 30%, treated at 500° C., re-rolled or stretched, and re-treated at 500° C. Additional experiments were made on selected samples of very coarse- and very fine-grained material after the initial treatment. Special attention was paid to finding the critical lower limit of prior strain at which maximum grain growth took place and below which recrystallization did not occur. Final grain-size was found to depend primarily on the degree of prior deformation, initial grain-size and mode of deformation being relatively unimportant. The strain corresponding with the critical lower limit is greater, the larger the original grain, and the higher the critical limit, the coarser the corresponding grain. Curves are given showing final grain-size and critical limit as functions of the original grain-size; their point of intersection gives the original grain-size for which no grain growth occurs on re-treatment. By selecting the initial treatment so as to give this grain-size, the problem of subsequent exaggerated grain-size is eliminated.—H. W. L. P.

***Some Effects of Temperature on a High-Strength Aluminium Alloy.** A. G. H. Damerell (*Metal Treatment*, 1943, **10**, (35), 139–145).—The effects of ageing Hiduminium R.R. 59 (copper 2·2, magnesium 1·5, silicon 1·0, iron 1·0, nickel 1·0, titanium 0·5%, aluminium balance) at 100°, 150°, 170°, 200°, 225°, and 250° C. on the Brinell hardness, 0·1% proof stress, and ultimate stress are shown in a series of curves. The normal heat-treatment is for 15–20 hrs. at 170° C. or 10 hrs. at 200° C., and produces the best combination of properties. After this treatment, the alloy is likely to be best able to retain its properties in service at high temperatures. Curves are given showing the effect on the Brinell hardness of heating fully aged and fully annealed specimens for 1–200 hrs. at temperatures up to 400° C. The results of short-time tensile tests at elevated temperatures are also recorded. Fully heat-treated material remains appreciably stronger than annealed material even after 200 hrs. at 250° C.; but above 300° C. the effect of heat-treatment is largely transient.—J. C. C.

Refrigerating Aluminium Alloy Rivets and Parts. (Fletcher.) See p. 30.

***On the Creep Strength of Dural Sheet Rivets.** E. Hottenrott (*Luftfahrtforschung*, 1940, **17**, 247–249; *Chem. Zentr.*, 1940, **111**, (II), 3400).—H. reports investigations carried out on the creep strength of Dural-riveted joints of 6 different kinds. The determining factors for the explanation of differences in the creep strength values are recapitulated. The general importance of these preliminary experiments is briefly dealt with.

***The Electrical Conductivity and Isothermal Hall Effect in Cuprous Oxide.** William Feldman (*Phys. Rev.*, 1943, [ii], **64,** (3/4), 113–118).—The electrical conductivity and isothermal Hall effect in cuprous oxide were studied at temperatures up to 700° C. At the higher temperatures the conductivity may be represented by an equation of the type $\sigma = Ae^{-\epsilon/kT}$, where T is the absolute temperature, but this law is not obeyed below 300° C. There is no evidence that any intrinsic conductivity exists in cuprous oxide. The variation of the Hall coeff. with temperature suggests that n, the number of carriers, cannot be represented by a relation of the type $n = n_0 \exp. (-\epsilon/kT)$. There is no evidence for a change in sign of the Hall coeff. The general theory of semi-conductors is discussed; the simple theory requires considerable extension to explain the data.—W. H.-R.

***The Hardness of Certain Primary Copper Solid Solutions.** J. H. Frye, Jr., and J. W. Caum (*Metals Technology*, 1943, **10,** (2); *A.I.M.M.E. Tech. Publ.* No. **1554,** 8 pp.; and *Trans. Amer. Inst. Min. Met. Eng.*, 1943, **152,** 75–82).—The hardness of primary solid solutions of zinc, gallium, germanium, and arsenic in copper was studied for alloys containing up to 5·1 atomic-% of solute. Meyer analyses were made, and the values of the Meyer constants a and n are tabulated. The relation between lattice distortion and increase in hardness is discussed. If comparison is made between alloys containing equi-atomic percentages of solute, there is a roughly linear relation between the increase in the ultimate Meyer hardness number and the increase in lattice spacing, but no simple relation exists between lattice distortion and increase in hardness when alloys having different proportions of solute atoms are compared.—W. H.-R.

***Stress-Relief Annealing of Cold-Worked, Hardenable Copper Alloys.** J. Wortmann (*Metallwirtschaft*, 1941, **20,** (21), 531–536).—Copper-base alloys containing (*a*) nickel 0·5, silicon 0·25%, (*b*) iron 0·8, silicon 0·4, aluminium 0·05%, or (*c*) tin 1, iron 0·15, manganese 0·2, phosphorus 0·1%, are usually hardened by annealing for 2 hrs. at 860°–900° C., quenching, cold-working, and ageing at 400° C., whereby despite the removal of work-hardness, the strength and hardness remain practically unchanged owing to precipitation effects. Softening, however, occurs when the hardened alloys are kept at 400° C. for prolonged periods, *e.g.*, the Brinell hardness, which is (*a*) 105, (*b*) 107, and (*c*) 135 immediately after ageing, falls to (*a*) 74, (*b*) 98 and (*c*) 70 after 120 hrs. at 400° C. This softening can be avoided by reducing the homogenizing temperature to 550°–700° C. and prolonging the time of homogenizing. For example, after heating for 24 hrs. at 700° C., quenching, cold-working to 50% reduction, and tempering at 400° C., the Brinell hardness of (*a*) rises to 121 in 24 hrs., and only slowly decreases after 264 hrs., reaching 102 after 1512 hrs.; the corresponding figures for (*b*) are 128 and 110, and for (*c*) 107 and 90. After 1512 hrs. at 400° C., the tensile strength of (*a*) is 35·7, of (*b*) 39·4, and of (*c*) 31·4 kg./mm.^{2}, the corresponding elongations being 24, 18, and 38%. Very much lower values for tensile strength and hardness are obtained if the cold-working step is omitted.—A. R. P.

Cartridge Brass: an Elementary Introduction. L. E. Gibbs (*Metal Progress*, 1943, **43,** (6), 897–900).—The physical properties of cartridge (70 : 30) brass, a single-phase α-alloy, can be modified only by cold-working or annealing, the extent and effects of which are closely interrelated. The various "temper designations" of brass strip (quarter-hard, half-hard, &c.) are tabulated with the corresponding nominal reduction in the B. and S. system, and with the approximate percentage reduction for (*a*) sheet and strip and (*b*) rod and round shapes. The gauge system is explained. Annealed material is classified according to grain-size; comparison charts at a standard magnification have been made available by the American Society for Testing Materials. A chart correlating tensile strength, elongation, grain-size, and copper content shows that the optimum relationship between ductility and tensile strength is attained in the 70 : 30 region; the specification limits are usually 68·5–71·5% copper. The effects of cold-working and annealing on the hardness, tensile strength, elongation, and apparent elastic limit of cartridge brass are shown graphically.—P. R.

***Effect of Antimony on Some Properties of 70 : 30 Brass.** Daniel R. Hull, H. F. Silliman, and Earl W. Palmer (*Metals Technology*, 1943, **10**, (2); *A.I.M.M.E. Tech. Publ.* No. **1552**, 11 pp.; and *Trans. Amer. Inst. Min. Met. Eng.*, 1943, **152**, 127–137; discussion, 137–143).—Tests on the effect of antimony on the rolling properties of 70 : 30 brass were made on a laboratory scale, and then under full-scale commercial conditions. Both hot- and cold-rolling properties were examined, and impact tests were also carried out. Antimony affects the impact strength of 70 : 30 brass, and under some conditions this is shown by lengthwise splitting of cold-rolling bars, by edge cracking, and by a brittle shear fracture. Impairment of impact strength in cast brass is measurable at 0·01% antimony; at about this concentration the effect is apparent in rolling, and 70 : 30 brass cannot be cold-rolled with 0·10% antimony. The presence of lead in amounts appreciably less than 0·10% greatly accentuates the effect of antimony. Fired small-arms cartridge cases, when melted, may yield castings containing about 0·007% antimony and 0·07% lead, and the difficulties of using this kind of scrap are discussed; cold work followed by annealing improves the impact strength of such material. The paper is followed by a lengthy and interesting discussion.
—W. H.-R.

***X-Ray Line Broadening by Cold-Working Alpha Brass.** Max Petersen and C. W. Tucker (*Phys. Rev.*, 1943, [ii], **63**, (9/10), 385).—According to Niemann and Stephenson (*Phys. Rev.*, 1942, **62**, 330) the broadening of X-ray diffraction lines from cold-worked alpha brass is enhanced by speed of working, although the internal friction introduced by cold-working is not. Experiments were made by P. and T. with annealed cartridge brass extended at different rates, including slow stretching, and extension by a falling weight at a speed of 30 ft./second. The X-ray back-reflection photographs showed no significant differences in line broadening, and the supposed disparity between internal friction and line-broadening is not confirmed.—W. H.-R.

***Investigations of Ferromagnetic Impurities. II.—[In Copper, Brass, and Silver.]** (Constant, Faires, and Lenander.) See p. 1.

Special Brasses. H. E. Arblaster (*Australasian Eng.*, 1943, **43**, (324), 16–16*b*, 45–48).—A survey of the compositions and physical and mechanical properties of special brasses, prepared by the addition—separately or in various combinations—of iron, silver, phosphorus, tin, manganese, aluminium, nickel, silicon, and lead to copper–zinc alloy " parent brasses." The effect of the different additions is discussed. Silver solders are included in the survey.
—E. A.

Leaded Brasses. Robert S. Burpo, Jr. (*Metals and Alloys*, 1943, **17**, (6), 1215).—A tabular digest of U.S.A. specifications.—J. C. C.

***Experiments on the Substitution of Nickel for Tin in Tin Bronzes and Red Brass.** A. H. Hesse and J. L. Basil (*Amer. Foundryman*, 1943, **5**, (8), 2–4).—H. and B. report that the substitution of nickel for tin in alloy G (copper 88, tin 9, zinc 3%) results in a decrease in the amount of intercrystalline shrinkage. In the cases of alloy M (copper 88, tin 6·5, zinc 4, lead 1·5%) and red brass (copper 85, tin 5, zinc 5, lead 5%), the intercrystalline shrinkage is little affected by nickel substitution. Physical properties are not materially changed by replacements of less than 7·5% tin by nickel. Corrosion tests conducted in still river water showed no variation in the corrosion rate of modified G and M alloys, although a slight increase was noted in the corrosion rate of red brass in which 2·5% tin had been replaced by nickel. With moving river water, fairly rapid corrosion rates were noted in all three alloys when modified by addition of nickel.—J. E. G.

***Magnetic Properties of Solid Solutions. III.—The Paramagnetic Alloys of Copper and Nickel.** A. R. Kaufmann and C. Starr (*Phys. Rev.*, 1943, [ii], **63**, (11/12), 445–450).—Cf. *ibid.*, 1941, **60**, 134; *Met. Abs.*, 1942, **9**, 40. The susceptibilities of copper–nickel alloys containing 0–50% nickel by weight have been measured at temperatures between 14° and 1300° K. An equation of the Curie–Weiss type does not represent the results, and an empirical equation of the type $\chi = aT + b + (c/T)$ is found to be satisfactory. The variations of the constants in this equation for the different alloys are discussed from the viewpoint of modern theory. Alloys in the range 30–38% nickel show a considerable field dependence of the susceptibility at low temperatures. —W. H.-R.

***An X-Ray Study of the Dissociation of an Alloy of Copper, Iron, and Nickel.** Vera Daniel and H. Lipson (*Proc. Roy. Soc.*, 1943, [A], **181**, (987), 368–378).—The alloy Cu_4FeNi_3 is single phase (face-centred cubic) above about 800° C., and at lower temperatures its equilibrium condition consists of two phases of similar structure. A specimen was heat-treated at 650° C. for 1 hr., and an X-ray powder photograph then showed sharp diffraction lines, each surrounded by two slightly diffuse, but quite strong, side bands. These are interpreted as indicating that there is a modulation in the structure, which is parallel to the cube planes, the period of the modulation being about 50 unit cells. The modulation is presumably due to the segregation of the different kinds of atoms, and the periodic structure may be the first step in the dissociation into two phases. The theory of periodic variations in a lattice is examined, but does not yet account completely for all the experimental data. —W. H.-R.

***On Binary Systems with Germanium. II.—Germanium–Arsenic, Germanium–Antimony, Germanium–Bismuth.** Herbert Stöhr and Wilhelm Klemm (*Z. anorg. Chem.*, 1940, **244**, 205–223; *Chem. Zentr.*, 1940, **111**, (II), 3602).—Cf. *ibid.*, 1939, **241**, 305; *Met. Abs.*, 1939, **6**, 354.—The systems germanium–arsenic, germanium–antimony, and germanium–bismuth have been investigated. (1) In the system *germanium–arsenic* two compounds, GeAs and $GeAs_2$, appear with wide ranges of homogeneity. Both the melting-point maxima, at 732° and 737° C., are very flat. The solubility of the germanium in arsenic at 685° C. is 16 ± 1 atomic-%; the limit of solubility of arsenic in germanium is ~3%. The α-solid-solution field is followed by a heterogeneous region extending up to about 23 atomic-% germanium. This is followed, up to 59%, by the homogeneous fields of the phases $GeAs_2$ and GeAs, without a detectable two-phase region. Next comes a heterogeneous region up to 97% germanium. There is a further small region of solubility on the germanium side. While the hexagonal lattice constants of arsenic are: $a = 3{\cdot}754$ and $c = 10{\cdot}52$ A., the constants of the saturated α solid solution were found to be: $a = 3{\cdot}701$ and $c = 10{\cdot}71$ A. Hence the expansion of the lattice takes place in the direction of the *c*-axis. Arsenic is practically without effect on the lattice constants of germanium. Magnetic measurements show that the diamagnetism of both metals is considerably increased by the presence of the other. (2) The systems *germanium–antimony* and germanium–bismuth are quite simple, being both eutectic systems with low solubility in the solid state. X-ray investigations show that the solubility of germanium in antimony lies between 2·2 and 4·6 atomic-%, and that of antimony in germanium between 2·5 and 3·9 atomic-%. The lattice constants of antimony are:

$a = 4{\cdot}296$ and $c = 11{\cdot}24$ A., and those of the solid solution saturated with germanium are: $a = 4{\cdot}266$ and $c = 11{\cdot}30$ A. The lattice constants of the solid solution of antimony in germanium remain unchanged within the limits of error, although the density is increased markedly. Magnetic measurements show that the magnetism of germanium is only slightly changed by the presence of the antimony. On the other hand, the magnetism of antimony is strongly affected by the solution of germanium. The antimony exhibits an abnormally great diamagnetism; the saturated solid solution is, however, slightly paramagnetic. (3) In the system *germanium–bismuth*, the eutectic temperature is 271° C., and the eutectic composition practically at 100% bismuth. The solubility regions are small on both sides. The solubilities, determined by X-ray analysis, are: germanium in bismuth $\leq 1{\cdot}5$ atomic-%, and bismuth in germanium ≤ 2 atomic-%.

***A Magnetic Study of the Two-Phase Iron–Nickel Alloys.—II.** K. Hoselitz and W. Sucksmith (*Proc. Roy. Soc.*, 1943, [A], **181**, (986), 303–313).—Cf. Sucksmith, *Proc. Roy. Soc.*, 1939, [A], **170**, 551; *Met Abs.*, 1940, **7**, 365. The method of using measurements of magnetic saturation intensity to determine equilibrium phase boundaries is extended, and is used to determine the $\alpha/\alpha + \gamma$ and $\alpha + \gamma/\gamma$ boundaries in iron–nickel alloys containing up to 34 atomic-% nickel. The method is suitable for the study of phase segregation, and the results show that when γ crystallizes from α, γ of equilibrium composition is formed, whilst the α continuously changes composition until equilibrium is finally reached. The speed of approach to equilibrium is assumed to be proportional to the difference between the composition of the uniformly changing α phase from its equilibrium composition, as in radio-active decay. The heat of activation is of the order of 34,000 cal./mol. At 325° and 300° C. the "half-value" times would be about 10 years and 40 years, respectively, so that there is a lower practical limit of temperature in the study of these alloys.

—W. H.-R.

***Diffusion Rates of Carbon in Iron–Molybdenum and Iron–Tungsten Alloys.** R. Smoluchowski (*Phys. Rev.*, 1943, [ii], **63**, (11/12), 438–440).—Experiments on the diffusion of carbon in iron–tungsten and iron–molybdenum alloys at 1000° C. are described. Both elements retard the diffusion of carbon, the effect of tungsten being about twice that of molybdenum at equivalent atomic percentages. This is in contrast to the behaviour of cobalt, which accelerates the diffusion of carbon in iron (*Phys. Rev.*, 1942, **62**, 539; *Met. Abs.*, 1943, **10**, 106).—W. H.-R.

***The Diffusion of Air Through Monel Metal.** H. S. Coleman and H. L. Yeagley (*J. Chem. Physics*, 1943, **11**, (3), 135–139).—The diffusion of the gases of the atmosphere through the walls of a Monel metal tube (nickel 69·70, copper 28·00, iron 2·57, and carbon 0·1%) was measured. The rate of diffusion shows a marked discontinuity at about 900° C., and dilatometric observations confirm the existence of some physical change at that temperature. This physical change may be associated with the formation of a solid solution, NiO–Ni, or the occurrence of an order–disorder transformation. The gases diffuse in the atomic form and leave the inside surface of the tube as diatomic molecules.—S. J. K.

The Effect of Low Temperatures on the Mechanical Properties of Monel Metal. N. G. Neuweiler (*Schweiz. techn. Z.*, **1940**, 479–483; *Chem. Zentr.*, 1940, **111**, (II), 3400).—N. discusses the effect of low temperatures on the mechanical properties of industrially important alloys of the Monel-metal type, with reference to the experimental results of various investigators. Evidence is presented that the most important mechanical properties of Monel metal remain practically unchanged or even improve at temperatures down to the temperature of liquid air.

Contribution to the Evaluation of Bearing Metals on the Basis of the Results of Tests and Their Constructive Interpretation. O. Hummel (*Metallwirtschaft*, 1941, **20**, (22), 559–563).—In lubricated bearings the frictional resistance can be calculated by the expression $W = z \, . \, fv/d$, where z is the absolute viscosity of the lubricant, f is the area of the lubricated surface, v is the speed of the moving part, and d is the thickness of the lubricant film. Since the determination of z under practical bearing conditions presents considerable difficulties, it is suggested that the behaviour of bearing metals can be better represented from a practical point of view by a v–p–t (speed–load–temperature) characteristic which can be represented diagrammatically. Methods of determining and evaluating these diagrams are discussed at some length. —A. R. P.

On the Volume Changes of Alloys in the Heterogeneous Liquid–Solid Range.—I. F. Sauerwald (*Metallwirtschaft*, 1941, **20**, (17), 405–408).—The volume changes which occur while an alloy is cooling through the temperature range between the liquidus and solidus depend on the volumes of the liquid and solid phases and the changes that take place in these due to temperature and concentration variations which may be deduced from the volume isotherms and the equilibrium diagram. This is illustrated by examples taken from the iron–carbon, copper–zinc, copper–tin, and copper–aluminium systems. —A. R. P.

Lattice Constants, Atomic Radii, and Valency Electron Concentrations. H. Perlitz (*Metallwirtschaft*, 1941, **20**, (22), 555–557).—A lecture on the Hume-Rothery rule and its implications.—A. R. P.

[Contribution] to the Theory of Solid Solutions. I.—Correlation in Solid Solutions. II.—X-Ray Scattering by Solid Solutions. I. Livshits (*Zhur. Eksper. i Teoret. Fiziki* (*J. Exper. Theoret. Physics*), 1939, **9**, 481–499, 500–511; *Chem. Zentr.*, 1940, **111**, (II), 3307).—[In Russian.] [I.—] The correlation between the arrangement of the various atoms in the lattice of a solid solution may be defined by a " correlation parameter " which can either be calculated from the free energy of the solid solution, or else determined on the basis of abstract considerations of probability. In the case of a three-dimensional lattice, only an approx. determination is possible, which is, however, equivalent to Kirkwood's approximation in the calculation of the free energy. The resulting expression for the free energy of solid solutions may be used for the determination of the curve of Curie points in the c, T diagram, the decomposition curve of the solid solution, the changes in specific heat, &c. [II.—] On the basis of the results of [I], the intensity of the scattered lines for the linear case has been calculated first without and then with reference to lattice distortion. The calculations were then extended to the three-dimensional lattice. Equations were derived for the maximum and the width of the Bragg lines.

[Contribution] to the Theory of the Decomposition of Binary Alloys. B. N. Finkelstein (*Zhur. Eksper. i Teoret. Fiziki* (*J. Exper. Theoret. Physics*), 1940, **10**, 341–345; *Chem. Zentr.*, 1940, **111**, (II), 3307).—[In Russian.] In continuation of recent investigations of Becker (*Ann. Physik*, 1938, **32**, 128; *Met. Abs.*, 1938, **5**, 539), and Livshits (cf. abstracts above) equations were derived for the change of the free energy ΔF, the linear dimensions L_0 of the nuclei present in equilibrium, and their work of formation A.

***The Propagation of Order in Crystal Lattices.** J. Ashkin and W. E. Lamb, Jr. (*Phys. Rev.*, 1943, [ii], **64**, (5/6), 159–178).—Theoretical. Part I gives an outline of the general matrix theory in three dimensions applied to the problem of the propagation of order in a binary crystal alloy, and shows that states of long-range order are not possible over a range of temperatures unless the maximum characteristic value of the associated matrix is degenerate over this same range. Part II discusses the propagation problem in two-dimensional crystals. The approximation of Zernike (*Physica*, 1940, **7**, 565; *Met. Abs.*, 1941, **8**, 226) is better for a two- than for a three-dimensional crystal. —W. H.-R.

***Statistics of Two-Dimensional Lattices with Four Components.** J. Ashkin and E. Teller (*Phys. Rev.*, 1943, [ii], **64**, (5/6), 178–184).—Theoretical. Statistical methods are used to investigate a two-dimensional square lattice consisting of four kinds of atoms, subject to the simplifying assumptions that only nearest neighbours interact, and that there are only two distinct potential energies of interaction, one between like, and the other between unlike atoms. The partition functions are obtained in two forms, and predictions can be made regarding the nature of the transition point from order to disorder. —W. H.-R.

***Some Remarks on the Statistics of Binary Systems.** Gregory H. Wannier (*Proc. Roy. Soc.*, 1943, [A], **181**, (987), 409–411).—A discussion of results obtained by Fuchs (*Proc. Roy. Soc.*, 1942, [A], **179**, 340; *Met. Abs.*, 1942, **9**, 244).—The method used should and does partly cover both the two-phase system and the case of superstructure. The quantitative results must be accepted with caution, as the method contains important errors of both type and magnitude.—W. H.-R.

On the Statistics of Binary Systems. Klaus Fuchs (*Proc. Roy. Soc.*, 1943, [A], **181**, (987), 411–415).—A reply to the criticisms of Wannier (abstract above).—W. H.-R.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

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

Hints for Polishing and Etching, with Special Reference to Soft Metals. [Solubility of Sodium in Lead.] E. Schulz (*Metallwirtschaft*, 1941, **20**, (17), 418–424).—Methods of polishing and etching aluminium, lead, and their alloys to reveal the macro- and micro-structure are briefly described, and characteristic micrographs of annealed and aged structures are reproduced. Micrographic examination of sodium–lead alloys shows that the limiting solid solubility of sodium in lead at room temperature does not exceed 0·2%, whereas resistance measurements indicate a limit of over 0·4%.—A. R. P.

***Electrolytic Polishing of Copper.** W. Engelhardt (*Metallwirtschaft*, 1941, **20**, (15), 349–356).—Recent work on the electrolytic polishing of copper is critically reviewed on the basis of the results obtained by E. in a repetition of the work of Jacquet, Elmore, and Benedicks and Ljunggren; an explanation is also offered of the phenomena observed in Jacquet's process. The effects ascribed by B. and L. (*Korrosion u. Metallschutz*, 1940, **16**, 17; *Met. Abs.*, 1940, **7**, 291) to the presence of oxide inclusions are shown to occur also with deoxidized copper under certain conditions; E. considers them to be due to disturbances set up by adherent gas bubbles. Some commercial uses for electrolytic polishing of copper are suggested.—A. R. P.

Surface Replicas Containing Dye for Use in the Light Microscope. Vincent J. Schaefer (*Metal Progress*, 1943, **44**, (1), 72–73; also (abridged) *Met. Ind.*, 1943, **63**, (20), 312–313).—References are given to accounts of the early use of transparent replicas in the microscopic study of surfaces. The method has recently been developed for use in conjunction with both the electron microscope and the ordinary microscope: a transparent synthetic resin is allowed to flow on to the prepared surface, and later removed by transparent adhesive tape, which is closely pressed into the resin during solidification.

By dissolving a dye in the resin before use, the variations in the thickness of the resin film, and hence in the depth of attack by the etching reagent, are automatically reproduced in a photograph taken by transmitted light. The technique adopted is described, and examples are illustrated.—P. R.

The Significance of the Etch Figures on the Crystal Faces of Aluminium. I. N. Stranski (*Ber. deut. chem. Ges.*, 1942, [A], **75**, 105–113; *C. Abs.*, 1943, **37**, 3314).—A lecture. Cf. Mahl and Stranski, *Z. physikal. Chem.*, 1942, [B], **51**, 319; *Met. Abs.*, 1943, **10**, 141.

***The Structure of Electrodeposited Chromium.** William Hume-Rothery and Malcolm R. J. Wyllie (*Proc. Roy. Soc.*, 1943, [A], **181**, (987), 331–344).—The visual appearance and crystal orientation of electrodeposited chromium were studied for deposits prepared at current densities from 50 to 3000 amp./ft.^{2}, and temperatures from 12° to 85° C., using a standard chromic acid bath containing 250 grm. CrO_3 per litre, and a ratio of CrO_3 to sulphate ion of 100 : 1. Some measurements were also made at 95° C. The brightest deposits have a (111) preferred orientation, and are confined to a definite range of temperature and current density. With increasing variation of the conditions of deposition (temperature or current density) from those characteristic of the brightest deposits, two effects are produced: (*a*) an increasing proportion of particles of random orientation are present, and (*b*) the perfection of alignment of the particles of preferred orientation becomes less. The hardness of electrodeposited chromium has been measured for deposits prepared over the range 25°–90° C. at current densities of 500, 1000, 1750 amp./ft.^{2}. The brightest deposits have the greatest hardness, and this maximum hardness is the same for all three current densities, although the temperatures of deposition at which the maximum occurs is different. The residual stress present in electrodeposited chromium has been measured by the method of Stoney (*Proc. Roy. Soc.*, 1909, [A], **82**, 172), and is as high as 27 tons/in.^{2} for some of the deposits, but is almost zero for the bright deposits. [*Note by Abstractor:* The equation of Stoney for the residual stress used by H.-R. and W. appears to be in error by a factor of 4, and the ordinates in Fig. 5 of their paper should be divided by 4; this has been done in giving the value 27 tons/in.^{2} above.]
—W. H.-R.

***X-Ray Studies of Electrodeposits of Copper.** (Maitak.) See p. 19.

***Preliminary Spectrographic and Metallographic Study of Native Gold.** Welton J. Crook (*Metals Technology*, 1943, **10**, (2); and *Trans. Amer. Inst. Min. Met. Eng.*, 1943, **152**, 255–268).—Specimens of native gold from different sources were analysed spectrographically, and etched sections were examined microscopically. All the specimens contained copper, silver, and iron. The copper and silver are probably present as a definite alloy with the gold, whilst the iron is thought to be present in the form of iron sulphide or as oxide inclusions. There is some evidence that placer nuggets from " new " deposits show strain lines, whilst those from " old " deposits do not, thus suggesting that recrystallization occurs over long periods of time.—W. H.-R.

***The Structure of Liquid Mercury.** J. A. Campbell and J. H. Hildebrand (*J. Chem. Physics*, 1943, **11**, (7), 330–333).—The structure of liquid mercury at − 38°, 0°, 50°, 100°, 150°, and 200° C. was examined by means of the diffraction of monochromatic molybdenum K_a X-radiation. The first and second main peaks, at 3·0 and 5·7 A., respectively, remain constant in position, but become lower and broader as the temperature is raised, whilst small peaks in the neighbourhood of 4 and 7 A. not only broaden but shift rapidly and finally disappear. The number of atoms in the first co-ordination layer varies between 6·0 and 5·3.—S. J. K.

***The Reflection of X-Rays from the " Anti-Phase Nuclei " of $AuCu_3$.** A. J. C. Wilson (*Proc. Roy. Soc.*, 1943, [A], **181**, (987), 360–368).—Jones and Sykes (*Proc. Roy. Soc.*, 1938, [A], **166**, 376; *Met. Abs.*, 1938, **5**, 485) have shown that the superlattice lines in X-ray photographs of $AuCu_3$ are not always as sharp as the main lines, and that the broadening depends on the indices of the line. This is the result of the existence of " anti-phase nuclei," in which the superlattice is organized in different ways. The theory of the subject is developed, and detailed calculations are made of the broadening to be expected from five different ways in which the nuclei can " change step." None of the models assumed explains all the facts, but the best agreement is obtained by assuming that the changing step occurs so that gold atoms avoid each other.—W. H.-R.

Crystallography for Routine Analysis. C. H. Walker (*Metropolitan-Vickers Gaz.*, 1943, **20**, (340), 167–173).—The principles and method of obtaining X-ray diffraction patterns, and some of the applications of crystal analysis in routine testing, are discussed. The production of X-rays and of X-ray patterns with the powder camera and the universal camera, is described and illustrated.—E. A.

V.—POWDER METALLURGY

On the Historical Development of Sintered Hard Metals. F. Skaupy (*Metallwirtschaft*, 1943, **20**, (21), 537–538).—A review of the patent literature. —A. R. P.

***The Micro-Hardness Tester—a New Tool in Powder Metallurgy.** (Steinitz.) See p. 25.

***Copper–Lead Bearings by Powder Metallurgy.** W. D. Jones (*Metallurgia*, 1943, **28**, (168), 255–260).—Three powder compositions, containing 16·5, 25·5, and 36·5% of lead and having extremely good cold-pressing properties, were examined. Percentage solidities in excess of 80% were obtainable without the addition of lubricants, with compacting pressures as low as 5 tons/in.^{2}. Practically non-porous bearing metals were obtained, using these powders, by employing pressures of the order of 5 tons/in.^{2}, sintering temperatures over the range 650°–850° C., and coining pressures of 10 tons/in.^{2}. The treatments desirable in order to obtain porous alloys which could be oil-impregnated if desired, were also investigated; and similar results were obtained with copper–tin–lead alloy powders. No difficulties were experienced in bonding the alloys by conventional methods to a steel backing.—J. W. D.

VI.—CORROSION AND RELATED PHENOMENA

***The Behaviour of Compound Parts Made from Cast Iron and Silumin in Artificial Sea-Water and in Salt Solution.** G. Schikorr and K. Alex (*Metallwirtschaft*, 1940, **19**, 777–779; *Chem. Zentr.*, 1940, **111**, (II), 3261).—Experimental evidence is provided which shows that: (1) Silumin is " nobler " than cast iron in sea-water and less noble in 3% salt solution; (2) in compound pieces the less-noble metal is accordingly more attacked, and—at its expense—the " nobler " more protected; (3) consequently corrosion tests of aluminium alloys carried out in salt solution instead of in artificial sea-water may give results exactly opposite to those obtained in sea-water in practice.

***On the Action of Ozone on Powdered Metals. [Gold and Lead.]** Heinz Schütza and Irmgard Schütza (*Z. anorg. Chem.*, 1940, **245**, (1), 59–66; *Chem. Zentr.*, 1940, **111**, (II), 3165).—Compact gold and lead were atomized by H.-F. sparks in oxygen containing ozone. Gold yielded a brown-black oxidation product which gave up ozone on heating to 160°–200° C. The analysis of the product, stored in a desiccator over sulphuric acid, showed the following composition: metallic gold 58·9, Au_2O_3 (determined by conversion with oxalic acid) 36·1, ozone 2·2, and water 2·5%. Thus, the ozone must be either absorbed exceptionally strongly, or evolved by decomposition of a higher oxide. No light could be thrown on this question by either radiographic or magnetic investigations. Lead yields a brown oxidation product, consisting mainly of PbO_2 and of some lower oxides, and giving up 4% ozone on heating. Care has to be taken regarding the purity of the oxygen used, which must be especially free of nitrogen, as the nitrogen oxides formed would accumulate in the atomized products. The pure oxides Au_2O_3 and PbO_2 yield on heating oxygen only and no ozone, and do not precipitate iodine from a KI solution. Previous contradictory statements (by Brunk) are attributable to traces of nitrogen compounds difficult to remove.

***Rate of Solution of Magnesium in Acids.** T. H. James (*J. Amer. Chem. Soc.*, 1943, **65**, (1), 39–41).—The rate of dissolution of magnesium in sulphuric, hydrochloric, formic, acetic, valeric, and glycolic acids was determined at 20° C. by shaking an excess of the metal in the form of shavings with a standard volume of acid; the measured rates are apparently those of the chemical reaction. The undissociated organic acids react at a smaller rate than H_3O^+, but the rates of all those tested are of the same order of magnitude and are not affected by addition of sodium chloride to the acid.
—A. R. P.

Thermodynamic Considerations in the Corrosion of Metals. J. C. Warner (*Electrochem. Soc. Preprint* No. 5, 1943, (Apr.), 67–80; (abridged) *Metallurgia*, 1943, **28**, (164), 61–66).—From a review of available thermodynamic data, the spontaneity of corrosion reactions for most of the common metals in deoxygenated water and in water saturated with carbon-dioxide-free air is calculated, and the results are tabulated and briefly discussed. A thermodynamic discussion of the mechanism of the corrosion of zinc in moist air containing carbon dioxide, and of the tarnishing of silver in air containing sulphur vapour, hydrogen sulphide, or sulphur dioxide, is also offered. The condition for the steady state or limiting corrosion rate is defined by a method analogous to the application of Bernoulli's theorem to fluid flow problems.
—A. R. P.

Laws Governing the Growth of Films on Metals. U. R. Evans (*Electrochem. Soc. Preprint* No. 10, 1943, (Apr.), 129–136; also (abridged) *Metallurgia*, 1943, **28**, (165), 133–135).—From a review of recent work on the growth of films on metals, the three laws expressing the rates of growth are derived and discussed. The linear law, $y = k_1t$, occurs with porous films on light metals which allow oxygen to leak towards the metal surface. The parabolic law, $y^2 = k_2t + k_3$, occurs with non-porous films having ionic and electronic conductivity, and is governed by outward ionic migration under a potential gradient. The logarithmic law, $y = k_4 \log (k_5t + k_6)$ occurs when the conditions needed for parabolic thickening are absent, and is due to the outward passage of interstitial matter through flaw-paths or zones of loose structure.—A. R. P.

VII.—PROTECTION

(Other than by Electrodeposition.)

†**Protective Chemical and Surface Finishes for Scientific Instruments and Apparatus.** H. Sutton (*J. Sci. Instruments*, 1943, **20**, (6), 86–92).—The general problem of the protection of metal surfaces against atmospheric attack is discussed, special attention being paid to " immersion treatments," and the preparation of metal surfaces which are to be painted. The paper deals with the treatment of steel surfaces, zinc-base alloys, cadmium, aluminium and its alloys, magnesium-rich alloys, and electrodeposited coatings. Possible sources of corrosion in instruments are electrochemical action between

different metals, and a table of electrode potentials with respect to a saturated calomel electrode of different metals immersed in sea-water is given. Unsuitable packing materials are also sometimes a source of corrosion.—W. H.-R.

Surface Protection of Aluminium and Aluminium Alloys. W. Linicus (*Werkstatt u. Betrieb*, 1940, **73**, 146–151; *Chem. Zentr.*, 1940, **111**, (II), 3260).—A review of the known methods for protection of aluminium and its alloys by metallic and non-metallic coatings, and of the application of aluminium to the surface protection of steel.

Behaviour of Various Magnesium Alloys During Anodic Oxidation. Max Bräuer (*Z. Metall- u. Schmuckwaren-Fabrik. Verchrom.*, 1941, **22**, 392–393; *Chem. Zentr.*, 1942, **113**, (I), 2062; *C. Abs.*, 1943, **37**, 3352).—The properties of anodic oxide coatings on magnesium alloys are, to a great extent, dependent on the constituents of the alloys. In general, the coatings are bright, but they are darkened by a high percentage of aluminium. Light-yellow or light-grey coatings are produced on alloys which are rich in manganese. Zinc in amounts exceeding the aluminium content produces coatings unpleasant in appearance. A coating 15 microns thick on alloy AZM has a dielectric strength of 290 v. Additions of zinc and aluminium have a considerable effect on the hardness of the coatings. Magnesium–manganese alloys approach Duralumin in their wear-resistance.

***Determination of Tin Coating Weights.** (Bendix, Stammer, and Carle.) See p. 23.

Protection Against Rust by Hot-Galvanizing. Heinz Bablik (*Oberflächentechnik*, 1940, **17**, 95–96, 101–103, 109–111, 117–119; *Chem. Zentr.*, 1940, **111**, (II), 3260).—A comprehensive description of the importance of zinc coatings for the protection of iron, and of the chemical and metallurgical conditions in hot-galvanizing.

Metal Spraying. —— (*Aircraft Production*, 1943, **5**, (59), 445–447).—Applications in America are described for the protection of foundry patterns and core boxes and air-cooled engine cylinders. Reference is made to sprayed bearing bushes and liners, and to reclamation of worn parts by spraying.—H. S.

Metal Spraying. C. K. Wilson (*Steel*, 1943, **112**, (19), 98–100).—The application of metal spraying to flat and irregular surfaces is described. The importance of the proper preparation of the surface to be sprayed is stressed. Readily accessible, machinable surfaces of hardness <58 Rockwell C may be prepared by grit-blasting and special machining. But the new electrical method of " fuse-bonding " is suitable for preparation of inaccessible surfaces of any hardness. In this latter process a special electrode alloy (composition not given) is fused to the surface by electric resistance heating in such a way as to form a metal froth on solidifying which provides remarkably good bonding for the sprayed metal on the base material.—E. A.

Sprayed Metal Reduces Maintenance Costs. B. Granowski (*Australasian Eng.*, 1943, **43**, (225), 16–17, 48, 50–51).—The applications and advantages of metal spraying in plant maintenance are discussed, and the spraying process is compared with welding. Tests were carried out in the laboratory and on crankshafts, and the wear resistance, hardness, machinability, bond strength, and microstructure of various sprayed metal deposits, were determined. Wet-grinding proved to be the most suitable method for finishing the sprayed surfaces. G. recommends the use of dissolved acetylene as the fuel gas, in conjunction with an inert gas or deoxidized air as the impending medium in the spraying process, and a suitable heat-treatment after spraying.
—E. A.

Metallizing for Profit. Clyde B. Clason (*Weld. Eng.*, 1943, **28**, (6), 34–37).—Metal spraying is stated to be used to build up worn parts, undersized components, and defective castings; to increase resistance to corrosion and scaling; bond metals to non-metallic materials; and to provide decorative or reflective finishes. Among the metals used are: aluminium, lead, tin, zinc, copper, bronzes and bearing metals, nickel, nickel alloys, and stainless steels. Data are included on grit-blasting and other pre-metallizing treatments, spraying speeds, and finishing operations.—E. G. W.

VIII.—ELECTRODEPOSITION

Surface Protection by Electrodeposited Coatings. Richard Springer (*Werkstatt u. Betrieb*, 1940, **73**, 123–126; *Chem. Zentr.*, 1940, **111**, (II), 3259).—A survey of the electrodeposition of zinc, copper, brass, and hard chromium.

***The Structure of Electrodeposited Chromium.** (Hume-Rothery and Wylie.) See p. 14.

Chrome-Plated Parts. H. G. Conway (*Aircraft Production*, 1943, **5**, (53), 109).—The plater is often not allowed enough latitude. Working limits for the unplated part, the plated part, and the finished part are indicated in relation to flash chroming and heavy-deposit chroming.—H. S.

The Hard-Chromium Plating Process. G. Elssner (*Feinmechanik u. Präzision*, 1940, **48**, 199–204; *Chem. Zentr.*, 1940, **111**, (II), 3402).—A review.

Hard-Chromium Plating. Harry M. Dean (*Australasian Eng.*, 1943, **43**, (320), 13–14).—After a brief description of the history of chromium and of the properties of chromium deposits, the methods for hard chromium plating—as applied in Australian plants—are described, with special reference to precautions to be observed, and to economics of the processes.—E. A.

***Electrolyte for Chromium Plating.** G. M. Kuperman and L. D. Melikadze (*Trudy Tbilis. Khim. Inst.*, 1940, **2**, 207–216; *Khim. Referat. Zhur.*, 1941, **4**, (2), 78; *C. Abs.*, 1943, **37**, 3351).—[In Russian.] The object of the experiments was to devise a method for obtaining chromium electrolyte from available raw materials. The following technical scheme was used: production of $CaCrO_4$ from fused $Na_2Cr_2O_7$ and the separation of CrO_3 from it by decomposition with H_2SO_4. The optimum concentration of the initial $Na_2Cr_2O_7$ is 10%. Increasing the concentration of $Na_2Cr_2O_7$ increases the amount of NaOH formed from the reaction: $Na_2Cr_2O_7 + 2Ca(OH)_2 = 2CaCrO_4 + 2NaOH + H_2O$; this increases the solubility of $CaCrO_4.2H_2O$. The process must be carried out at 90° C., at which temperature a higher yield of the fine-grained $CaCrO_4$ precipitate is obtained, and the $CaCrO_4$ is less soluble than at lower temperatures. The excess CaO required for a complete precipitation is 15–20%. The precipitate formed contains $CaCrO_4.2H_2O$ 81% and CaO 19%. The $CaCrO_4$ is filtered, washed, dried, and transformed into CrO_3 with H_2SO_4 (400 grm./litre) by mixing and heating. The gypsum is separated by settling or filtering, the solution containing 60–70 grm. of CrO_4/litre is evaporated, the excess H_2SO_4 neutralized with $CaCrO_4$, and the gypsum formed is separated, to leave a solution containing CrO_3 300, H_2SO_4 up to 2·5, and CaO up to 5 grm./litre. The solution is suitable for chromium plating. The relative amounts of the substances used per unit of CrO_3 are: $Na_2Cr_2O_7.2H_2O$ 2·127, H_2SO_4 (monohydrate) 1·858, and CaO 1·270. The adaptation of the method to plant conditions is described in detail.

Possible Applications of Heavy Copper Plating in the Production of Coatings on Parts of Machine and Apparatus. H. M. Forstner (*Metallwirtschaft*, 1940, **19**, 803–809; *Chem. Zentr.*, 1940, **111**, (II), 3259).—F. defines heavy copper plating as an electrodeposited, non-porous copper coating of $\nless$ 0·10 mm. thickness, 24–28 kg./mm.^{2} strength, 40–60% elongation (on 100 mm.), and 65–85 Brinell hardness. Its possible applications are surveyed.

Production of Copper Patterns by Electroforming. (Laukel.) See p. 28.

***X-Ray Studies of Electrodeposits of Copper.** G. P. Maitak (*Zapiski Inst. Khim. Akad. Nauk U.R.S.R.* (*Mem. Chem. Inst. Acad. Sci. U.S.S.R.*), 1941, **7**, 527–536; *Chem. Zentr.*, 1942, **113**, (I), 3176; *C. Abs.*, 1943, **37**, 3350).—[In Russian.] The copper electrodeposits were obtained at various c.ds. from N-$CuSO_4$ solution and from N-$CuSO_4$ + N-H_2SO_4 solution. At c.d. 0·05 amp./cm.^{2} the lattice parameter was 3·610 A., which agrees with the value obtained electrochemically. At 0·05 to 0·025 amp./cm.^{2} deposits from either solution gave the highest overvoltage. At c.d. higher than 0·05 amp./cm.^{2} spongy deposits were obtained which had larger lattice parameters. At 0·6 amp./cm.^{2} the parameter reached a maximum. At the very start of copper-sponge deposition the same parameter was obtained at 0·6 amp./cm.^{2} (and the same overvoltage) as at 0·05 amp./cm.^{2}. In some of the spongy deposits X-rays revealed the presence of Cu_2O. The size of the primary particle was 200 A., no matter whether the deposit was solid or spongy.

***Hydrogen Overvoltage of Various Electrolytic Copper Deposits.** G. P. Maitak (*Zapiski Inst. Khim. Akad. Nauk U.R.S.R.* (*Mem. Inst. Chem. Acad. Sci. U.S.S.R.*), 1941, **7**, 537–550; *Chem. Zentr.*, 1942, **113**, (I), 3176; *C. Abs.*, 1943, **37**, 3351).—[In Russian.] The electrolyte used was N-$CuSO_4$ in N-H_2SO_4. The c.d. varied from 0·001 to 1·0 amp./cm.^{2}. At 0·1 amp./cm.^{2} the overvoltage was 0·64–0·66 v. The lowest overvoltage obtained was for spongy deposits at 0·6 amp./cm.^{2}.

Electro-Tinning and Detinning of Steel Sheet. Josef Teindl (*Hornický Věstník*, 1941, **23**, 95–97; *Chem. Zentr.*, 1942, **113**, (I), 2192; *C. Abs.*, 1943, **37**, 3350).—Clean and smooth steel sheet is necessary to produce bright tin coatings. Commercial methods for hot and electrolytic tinning are described. Electro-tinning causes no loss of tin by oxidation, is more economical, and can produce a sheet having 30 grm. of tin/m.^{2} on one side and 5 grm./m.^{2} on the other, whereas 40 grm./m.^{2} on each side is given by hot tinning. Sheet having approx. 3 grm./m.^{2} of tin is satisfactory for lacquering. Porosity in tin coatings cannot be eliminated by either method. Sheet for use in food cans should have $\ngtr$3–5 pores/cm.^{2}, although up to 17 have been allowed.

The Electrodeposition of Zinc. E. Werner (*Metallwirtschaft*, 1940, **19**, 655–656; *Chem. Zentr.*, 1940, **111**, (II), 3259).—Comprehensive description of the present state of the technique.

***Electroplating with Three Electrodes. Application to Bright Deposits of Zinc and Cadmium.** J. Guzmán and L. Quintero (*Anales. Soc. españ. Fís. Quím.*, 1936–1939, [v], **35**, (1), 24–40; *Chem. Zentr.*, 1940, **111**, (II), 3402).—In G.'s indicator potential method the metal deposits are precipitated electrolytically by a current of ions; this current is maintained constant by a potential which is controlled in a definite way by three electrodes. The method was applied to electrodeposition, where control of the c.d. is unnecessary. Bright zinc and cadmium deposits have been prepared by this method from cyanide solutions containing colloids and some nickel. In order to obtain a bright zinc deposit, an indicator potential of 410 mv. has to be applied, with a soluble anode and without agitation of the electrolyte. To produce a bright cadmium deposit, the same indicator potential of 520 mv. has to be applied and under similar conditions to those used for an ordinary cadmium deposit.

Flexibility of the Cuprous-Oxide Rectifier for Automatic Control Equipment in Electroplating. G. E. Huenerfauth (*Electrochem. Soc. Preprint* No. 7, 1943, (Apr.), 97–104; also (abridged) *Met. Ind.*, 1943, **63**, (2), 26–28).—The cuprous-oxide rectifiers now on the market are much more flexible sources of current for plating than are motor generators, and may readily be provided with automatic control mechanisms for plating and anodizing. Various types of timers and relays coupled with control of the low-wattage 110-v., single-phase current on the magnetic contactor coil built into the rectifier unit, and the use of parallel and series operation allow ease in working out automatic control not previously obtainable; several examples are quoted with reference to wiring diagrams.—A. R. P.

Grinding and Polishing in Electrodeposition. Hugo Krause (*Schleif- u. Poliertechn.*, 1940, **17**, 131–135; *Chem. Zentr.*, 1940, **111**, (II), 3259).—A comprehensive survey.

IX.—ELECTROMETALLURGY AND ELECTROCHEMISTRY

(Other than Electrodeposition.)

The Cerium Amalgam Electrode and the Thermodynamics of Aqueous Cerium (III) Sulphate Solutions. [Solubility of Cerium in Mercury.] George C. Walters and Thomas De Vries (*J. Amer. Chem. Soc.*, 1943, **65**, (1), 119–122).—A semi-solid amalgam containing 2·7% of cerium was obtained by electrolysis of a saturated solution of $CeCl_3.H_2O$ crystals in absolute alcohol. The potential of the cell Ce–Hg (two-phase) | M-$Ce_2(SO_4)_3$ | Hg_2SO_4,Hg was found to be 1·4275, 1·4373, and 1·4473 v. at 15°, 25°, and 35° C., respectively, from which it appears that the potential of metallic cerium in a solution containing cerous ions is 1·6824 v. at 25° C. Measurements of the potentials of cells with various cerium contents of the amalgam indicate that the solubility of cerium in mercury is 0·312% at 25° C.—A. R. P.

***On the Electromotive Behaviour of Nickel in the Presence of Hydrogen.—III.** Bruno Foresti (*Gazz. chim. ital.*, 1940, **70**, 349–359; *Chem. Zentr.*, 1940, **111**, (II), 3451).—The electromotive behaviour of massive nickel electrodes (98·8–99·55% nickel) in the presence of hydrogen was investigated within the p_H range 5·8–12·27. Electrodes annealed in a nitrogen atmosphere for 12 hrs. at 800°–900° C. did not reach the potential of the hydrogen electrode, but remained more " noble " than the latter. On the other hand, electrodes polished with Al_2O_3 became activated and reached the potential of the hydrogen electrode. Eckell found the same result in a similar experiment with cold-worked nickel electrodes. The polishing effects lattice deformation on the metal surface, and at the same time imparts catalytic activity, as a result of which a direct relation is set up between the formation of " active centres " and the lattice distortion. This not only yields zones of atoms topochemically suitably ordered for the activation adsorption, but at the same time also puts these atoms into an excited state in connection with the deformation. It may be assumed that the " active centres " consist of groups of excited atoms of definite order, which would explain the heterogeneous structure of catalytically active surfaces.

***Studies on Overvoltage. XV.—A Study of Decomposition Potentials. Cathodic and Anodic Polarization of a Platinized Platinum Cathode Near the Reversible Value in Hydrogen-Saturated Acid Solutions.** A. L. Ferguson and Myron B. Towns (*Electrochem. Soc. Preprint* No. 8, 1943, (Apr.), 105–117).—Further evidence is put forward in support of the proposition that the electrode phenomena at, and on either side of, the reversible value are all the same, and that the electrode potential is determined by the activities of the hydrogen atoms and ions at the electrode-solution interface, and can be calculated by the Nernst equation if these activities are known. From this it follows that hydrogen ions may be discharged at potentials more positive than the reversible value, and that the potential depends largely on the material and physical condition of the electrode.—A. R. P.

***Studies on Overvoltage. XVI.—Cathodic and Anodic Polarization of a Platinized Platinum Cathode Near the Reversible Value in Nitrogen-Saturated Acid Solutions.** A. L. Ferguson and Myron B. Towns (*Electrochem. Soc. Preprint* No. 9, 1943, (Apr.), 119–128).—Anodic and cathodic polarization curves obtained in nitrogen-stirred acid solutions under various conditions support the theory proposed in previous papers for the mechanism of electrode potential and overvoltage.—A. R. P.

X.—REFINING

The Possibilities of Improving Commercial Lead. Willy George (*Metall u. Erz*, 1940, 37, (7), 253–256; *Chem. Zentr.*, 1940, **111**, (II), 3257).—The preparation of the purest possible lead can be carried out by decreasing the bismuth content in the refined lead, either by suitable choice of the melting charge, or by the use of known metallurgical working methods, the application of which must be adapted to each individual case. The other impurities (copper and antimony) can be reduced by extracting first the copper with sulphur by the Colcor method, and then removing the antimony by refining in the reverberatory furnace. For the removal of zinc from lead, the most suitable method is a pre-treatment used in conjunction with Parkes' process, consisting of treating the lead with NaOH and at the same time poling with water vapour or with NaOH and water, in cast-steel kettles at 800° C. The poling with NaOH not only removes all the zinc except a few units in the fourth place of decimals, but also effects an after-refinement in which (except for copper and bismuth) all other impurities are removed down to the same order of magnitude as the zinc content.

XI.—ANALYSIS

†A Review of Spectrographic Analysis of Some Metals and Alloys.—II. Jacob Sherman and J. W. Jenkins (*J. Amer. Soc. Naval Eng.*, 1943, 55, (3), 404–469).—Cf. *Met. Abs.*, 1943, **10**, 329. The calibration of photographic plates and the preparation and purification of graphite electrodes are described, and the spectrographic analysis of Al alloys, steels, steel solution, Zn spelter, Zn-base die-casting alloys, ingot Cu, pig Pb, Pb and Pb battery materials, is discussed in detail, with special reference to the method used, the elements to be determined, the spectrograph used, the photographic plate, the excitation or source, the preparation of the specimen and standards, the electrodes (upper and lower) used, the reference lines for the elements in Angstrom units, the densitometer used, if any, and the analytical procedure.—J. W. D.

Sampling for Spectrographic Analysis. H. H. Simmons (*Metals and Alloys*, 1943, **17**, (6), 1221).—Molten metal is drawn by a syringe bulb into a glass tube. The glass cracks away, leaving a clean rod which is readily formed to the correct shape for electrodes.—J. C. C.

***Estimation of Aluminium as Phosphate.** Herbert Blumenthal (*Metall u. Erz.* 1940, **37**, (8), 315–316; *Chem. Zentr.*, 1940, **111**, (II), 3230).—Neutralize the Al solution (50 mg. Al), containing HCl or H_2SO_4, with NH_3 so as just to produce a slight precipitation of $Al(OH)_3$. Dissolve this in as little HCl as possible, add 25 c.c. of a cold saturated SO_2 solution, 20 c.c. of 10% $(NH_4)_2HPO_4$ solution, and 15 c.c. acetic acid (1 : 3). The SO_2 solution must be sufficient to prevent the precipitation of $AlPO_4$. Make up to 400 c.c., boil for 20 minutes with some filter paper, and filter through a S. & S.-Weissband-filter. Wash the precipitate until free of Cl′, dry, and calcine at 1250° C. to a constant weight. In the case of a Zn alloy containing Al, dissolve 10 grm. of sample in (1 : 1) HCl with addition of $KClO_3$ and make up to 1 litre. Transfer 100 c.c. of this solution to a 500-c.c. measuring flask, and add NH_3 and H_2SO_4 until the solution is just acid to methyl orange. Then make up to 400 c.c. and pass in H_2S. Except for negligible traces, all the Zn will be thus precipitated, and also any Cu present. Make up to 500 c.c., filter 250 c.c. of it boil off the H_2S, and treat the solution as above.

Quantitative Determination of Antimony, Bismuth, and Gold in Red Copper by the Logarithmic Method. A. L. Ostashevskaya (*Zavod. Lab.* (*Works' Lab.*), 1938, **7**, 958–963; *Chem. Zentr.*, 1940, **111**, (II), 3231).—[In Russian.] O. examined the accuracy of the log. method, and found the magnitude of errors to be similar to those in microphotometry. Although the minimum concentrations determinable of Sb, Bi, Au, and Cu are somewhat higher than in microphotometry, they can be reduced by the use of high-sensitivity plates.

***Method for the Quantitative Spectrographic Analysis of Solutions. IV.—Estimation of Cadmium and Zinc.** A. K. Rusanov and V. M. Alexeeva (*Zavod. Lab.* (*Works' Lab.*), 1938, **7**, 963–967; *Chem. Zentr.*, 1940, **111**, (II), 3231).—[In Russian.] The Cd and Zn in solutions are estimated by visual comparison of the intensity of the lines: Cd 4799·91 A. and Mn 4823·50 A.; Zn 4722·16 A. and Mn 4783·43 A.; Zn 4810·53 A. and Mn 4823·50 A. The determination may be carried out in 10 minutes with an accuracy of ±4·5% for Cd in the concentration range of 0·03–1%, and ±2·7% for Zn in the concentration range of 0·01–1%.

***Polarographic Analysis of Copper and Zinc in Brass Plate. A Rapid Control Method.** Willard P. Tyler and Walter E. Brown (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1943, **15**, (8), 520–523).—The plate is removed from Fe or steel by means of ammoniacal $(NH_4)_2S_2O_8$, the solution is added to a supporting solution containing NH_4OH, NH_4Cl, Na_2SO_3, and gelatin, and, after the Na_2SO_3 has reduced the excess of $(NH_4)_2S_2O_8$, polarographed in the usual way. By measuring only the ratio of the diffusion currents of Zn and Cu, exact temperature control, extreme accuracy in measuring the volume of the solutions, and a standard capillary tube, are unnecessary. An analysis takes only 20 minutes, half of which time is occupied in allowing the reducing action of the sulphite to go to completion. The original must be consulted for full manipulative details and the method of calculating the results.
—A. R. P.

***Preliminary Spectrographic and Metallographic Study of Native Gold.** (Crook.) See p. 14.

***Rapid Method for the Determination of Magnesium, Calcium, and Barium Ions.** N. K. Senyuta (*Zavod. Lab.* (*Works' Lab.*), 1939, **8**, 721–723; *Chem. Zentr.*, 1940, **111**, (II), 3370).—[In Russian.] Precipitate the Ba with an excess of standard Na_2CO_3 solution, the Mg with an excess of standard alkali solution, and the Ca with a standard Na oxalate solution. Separate the precipitates from the precipitating solutions by means of an inert layer (CCl_4) heavier than the precipitating solution, and titrate back the excesses, in the case of Ba and Mg with acid, and in the case of Ca with acid $KMnO_4$ solution. The results are not quite as accurate as those obtained by means of gravimetric analysis; each estimation takes, however, only 20–30 minutes.

***Investigation of the Solubility of Nickel Dimethylglyoxime in Alcoholic Solutions in the Determination of Nickel by the Dimethylglyoxime Method.** F. Nussbaumer (*Metallwirtschaft*, 1941, **20**, (24), 599–600).—Ni dimethylglyoxime is slightly soluble in dilute C_2H_5OH, so that only a slight excess of the usual 1% alcoholic solution of the reagent should be used; 70% C_2H_5OH instead of the usual 95% is preferred as the solvent for the reagent. Not more than 0·08 grm. of Ni should be present in the solution to be precipitated, and a volume of 500 c.c. is recommended; if $Fe^{\cdots}$ is present, 10 grm. of tartaric acid should be added before making the solution just alkaline with NH_4OH. The reagent should be added at 70° C. and the precipitate collected in a porous glass filter after 1–2 hrs.—A. R. P.

***Methods for the Quantitative Spectrographic Analysis of Solutions. III.—Estimation of Thallium and Indium.** A. K. Rusanov and B. I. Bodunkov (*Zavod. Lab.* (*Works' Lab.*), 1938, **7**, 573–579; *Chem. Zentr.*, 1939, **110**, (II), 691).—[In Russian.] It is shown that the spark discharge is applicable not only in the visual quantitative spectrography of metals, but also for solutions. An analytical method has been developed, which is suitable for the quantitative estimation of Tl and In in solutions, based on the comparison of the intensities of the following lines: Tl 5350·47 A. with Fe 5270·361/5269·54 A., and In 4511·31 A. with Cs 4555·3 A. Fe and Cs are added to the solution as comparison elements. The estimation is carried out in 10 minutes with an accuracy of ±5·5% for Tl (concentrations 0·006–0·1%) and of ±7·0% for In (concentrations 0·0008–0·2%).

***Volumetric Method for the Estimation of Tin and Antimony in the Presence of One Another.** G. A. Pevtsov (*Zavod. Lab.* (*Works' Lab.*), 1938, **7**, 916–917; *Chem. Zentr.*, 1940, **111**, (II), 3231).—[In Russian.] The estimation of $Sn^{\cdot\cdot}$ and $Sb^{\cdot\cdot\cdot}$ is based on titration with bromate in the presence of indigo carmine as the indicator. The method may also be applied for estimation of Sb alone.

***Determination of Tin-Coating Weights.** G. H. Bendix, W. C. Stammer, and A. H. Carle (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1943, **15**, (8), 501–504).—A square sample (2 × 2 in.) of the tinplate is suspended vertically in a 400-c.c. beaker by means of a magnet so as not to mask any of the tinned surface; on either side of the sample is placed a porous cylinder containing a carbon cathode immersed in 1 : 4 HCl. Into the beaker are poured 200 c.c. of 1 : 7 HCl and 20 c.c. of a standard KI–KIO_3 solution (50 grm. of KIO_3, 280 grm. of KI, and 0·1 grm. of NaOH in 18 litres) and a current of 3 amp. is passed between the electrodes for 2–5 minutes; the I remaining in the solution is then titrated with thiosulphate.—A. R. P.

XII.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

Interference Fringes for the Measurement of Surface Micro-Topography. J. F. Kayser (*Metal Treatment*, 1943, **10**, (35), 153–156, 172).—The quality of highly-finished surfaces which are smooth enough to be reflecting may be evaluated by observing the interference fringes produced when a glass cover slip is fastened to the surface and illuminated with monochromatic light by means of the optical train of a metallurgical microscope. The interference fringes may be regarded as contour lines spaced at intervals of half the wavelength of the light. A source of monochromatic light from sodium or mercury vapour lamps gives the most clearly defined fringes, but filtered light from a Pointolite lamp gives brighter and more critical illumination. Photographs of some glass rods and lapped steel surfaces are reproduced.—J. C. C.

Roughness of Metallic Surfaces, with Special Reference to Castings. Hugh O'Neill and R. T. Insley (*Metal Treatment*, 1943, **10**, (35), 181–187).—Methods of measuring surface roughness are briefly reviewed. The preparation and use of a set of five specimens of cast bronze (the L.M.S. Roughness Comparascope) as a reference standard is described, and the effect of particle size of moulding sand on the surface finish of castings is discussed.—J. C. C.

The Problem of the Heavy-Current X-Ray Tube and Its Solution by Means of a Multi-Dimensionally Rotated Spherical Anode.—II. H. Stintzing and H. Meub (*Metallwirtschaft*, 1941, **20**, (19), 469–474).—Cf. *ibid.*, p. 45; *Met. Abs.*, 1943, **10**, 360. Details are given of the behaviour of the tube under heavy loads. It is possible to give exposures of 12 seconds at 500 milliamp. without undue heating. The speed of revolution of the spherical copper anode about the two axes must be so adjusted that the surface is adequately scanned. Methods of outgassing the tube are described fully, and reference is made to the choice of copper as a target material on account of its thermal properties, cost, and workability. Brief reference is made to the steps necessary to avoid scattered radiation.—H. W. L. P.

Simplified Electron Microscopy. C. H. Bachman (*Electronics*, 1943, **16**, (2), 78–81).—A brief survey of the history of the development of electron microscopes is given, followed by a description of a modern instrument with horizontal electron path and electrostatic lenses.—E. V. W.

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

A Rotating Cantilever Machine for 200-Kg. Tensile-Compressive Stresses. E. Erlinger (*Metallwirtschaft*, 1941, **20**, (17), 414–416).—The machine is designed to apply a permanent tensile or compressive load of 100 kg. and an alternating load of 100 kg. to give a maximum loading in each cycle of 200 kg., and is so constructed that the amplitude of the vibrations can be varied to suit the elasticity of the metal tested. Both loads are applied by means of springs, and tests can be made up to 50×10^3 reversals. Diagrams and a full description of the construction of the machine are given.—A. R. P.

The Useful Data to be Derived from Fatigue Tests. J. O. Almen (*Metal Progress*, 1943, **44**, (2), 254–261).—Fatigue data obtained by laboratory tests on specimens of high finish prepared under carefully standardized conditions have only limited application to problems of mechanical design. The relatively rough finish of machine parts permits local concentrations of stress which are largely eliminated in laboratory specimens. Stress calculations must be reviewed in the light of individual conditions; direct measurements by photoelastic or extensometer methods give the statistical average of the stress over the region involved, whilst fatigue tests relate to the weakest element present. Operating loads cannot be accurately known and are rarely constant. Fatigue curves on a number of materials are reviewed with a view to correlating " laboratory " tests with tests on actual machine parts: the curves differ in direction rather than in form, and some degree of correlation is shown to be possible, given a sufficient number of observations. The most industrially interesting portion of the fatigue curve lies beyond the fatigue endurance limit, *i.e.*, in the region representing a finite life period. A series of graphs illustrates the influence of the form of specimen both on fatigue strength and on the degree of scatter among the results. Such graphs, representing different types of finish, are found when plotted on log–log paper to converge towards a point corresponding with the ultimate tensile strength of the material at a considerable number of stress cycles, and it is shown that log–log curves of this type may be used in the evaluation of effective stress.
—P. R.

Hardness of Aluminium Sheet (Tests and Conversion Charts). Richard L. Templin (*Metal Progress*, 1943, **44**, (1), 86–88; also (abridged) *Met. Ind.*, 1943, **63**, (23), 357).—The essential procedure in the Brinell, Vickers, Rockwell, Barcol, Webster, and Shore hardness tests is briefly summarized. Satisfactory and comparable results depend on a close standardization of test conditions; results are influenced by the thickness of the specimen, the type of support, and sometimes by surface preparation. Hardness conversion tables can apply only within a limited range, *i.e.*, between two types of test and on a single material in standardized condition. In attempts to use the hardness test (Brinell) to estimate tensile strength in light-alloy sheet, it has been found that the ratio hardness/tensile strength varies widely for different alloys, whilst no simple ratio can be said to exist between hardness and fatigue strength. Hardness forms, however, a satisfactory check on heat-treatment provided that the type of alloy is known.
—P. R.

Hardness Tests. Robert S. Burpo, Jr. (*Metals and Alloys*, 1943, **17**, (6), 1217, 1219).—Characteristics of the common hardness-testing instruments are tabulated.—J. C. C.

***The Micro-Hardness Tester—A New Tool in Powder Metallurgy.** Robert Steinitz (*Metals and Alloys*, 1943, **17**, (6), 1183–1187).—A square-ground diamond penetrator is substituted for a microscope objective, after the specimen has been adjusted so that a selected spot is seen at the junction of the cross-hairs in the eye-piece. The diamond is then lowered into contact with the specimen by the microscope focusing screws, pressures of 25–300 grm. being applied through a calibrated spring. The use of the instrument for measuring the hardness of metal powders mounted in Bakelite and of the grains in compacts is illustrated.—J. C. C.

Testing the Hardness and Softness [of Metals] with a Pre-Loading Machine. K. Frank (*Metallwirtschaft*, 1941, **20**, (17), 416–417).—Modifications of the usual hardness-testing machines (Brinell, Rockwell, Vickers) are described to allow of their being used for testing the hardness of awkwardly shaped objects, such as shell-cases, by measuring the difference in depths of impression made by 10- and 150-kg. loads.—A. R. P.

Hardness Testing with the Barcol Impressor. J. H. Hrucka (*Iron Age*, 1943, **152**, (16), 84–87).—The Barcol tester is a hand-size portable impressor in which a hardened truncated cone penetrator is held down by a spring-headed plunger. Experiences in using this impressor for testing the hardness of aluminium and its alloys, brass, copper, steel, and certain plastics, are described. The instrument is almost fool-proof, but a certain manual dexterity is required for testing the hardness of plastics. For copper and aluminium alloys constantly reproducible values are obtained.—J. H. W.

Hardness Determinations According to Rockwell, Brinell, and Vickers with a Single Apparatus. J. H. Kimman (*Polytech. Weekblad*, 1941, **35**, 321–323; *Chem. Zentr.*, 1942, **113**, (I), 412; *C. Abs.*, 1943, **37**, 3378).—The development of hardness determinations and the procedures for determining the Rockwell, Brinell, and Vickers hardness values are reviewed, and the universal instrument of Frank is described.

Progress in Micro-Testing. D. W. Rudorff (*Metallurgia*, 1943, **28**, (168), 273–277).—A new method for investigating thermoelasticity devised by Chevenard is described, and the type of thermoelastic curve obtained and its applications are discussed. Consideration is also given to micro-testing technique, and apparatus for micro-tensile testing, micro-shear testing, micro-static-torsional testing, micro-torsional-fatigue testing, and micro-high-temperature-creep testing, are described.—J. W. D.

A New Method of Non-Destructive Testing. Rudolf Berthold (*Metallwirtschaft*, 1941, **20**, (17), 425–426).—A series of substances which undergo colour changes on heating has recently been placed on the market in Germany. Some of these may be used for detecting flaws in finished articles, *e.g.*, lack of adhesion between bearing metal and shell, laps and elongated blow-holes parallel to the surface of a metal article, and the presence of inclusions. The article is painted on one side with a film of the substance, and heat is applied to the other side; in the absence of flaws, &c., the colour change takes place uniformly on the unheated side, but if flaws exist, their presence is revealed by a retardation in the colour change in the neighbourhood of the flaws due to the much smaller rate of heat transmission through gases than through metals.—A. R. P.

Electrical Measurement of Stresses. A. Theis (*Aircraft Eng.*, 1943, **15**, (170), 106–109).—Translated from *Z. techn. Physik*, 1941, **22**, (11), 273–280. The technique of strain gauging with the use of strip and ring-shaped gauges, is described.—H. S.

Rapid and Accurate Inspection of Spot Welds [in Aluminium Sheet]. L. L. Anderson (*Metal Progress*, 1943, **44**, (3), 433–434, 462).—An illustrated description is given of a hand-operated tensile-testing apparatus for use on welded aluminium sheet. The U.S. Navy requirements, which include maximum as well as minimum values, are summarized in respect of shear tests on overlapping joints and tensile tests on spot welds. The machine is adaptable for both types of test; its design permits the use of exceptionally long specimens, and the considerable space within the frame allows the machine to be used in testing a large variety of finished pieces.—P. R.

Quality Inspection of Beryllium Copper. Wayne Martin (*Metals and Alloys*, 1943, **17**, (6), 1203–1207).—The suitability of beryllium–copper wire for spring making may be predicted from tests of electrical conductivity and tensile strength; the best heat-treating temperature should be determined for each batch. For strip, inspection is best carried out by tests of elastic modulus and hardness. The grain-size is an indication of the temperature at which solution heat-treatment was carried out; stringers of β phase indicate segregation in the ingot and cause difficulties in spring fabrication; and grain-boundary precipitates of γ phase, which are said to be caused by slow heating during batch-annealing, reduce the amount of beryllium available for hardening, and give rise to distortion in hardening. For best physical properties a short-time heat-treatment at a higher temperature than normal is recommended.
—J. C. C.

RADIOLOGY

X-Ray Inspection of Castings (Army Air Forces' Requirements). Robert Katz (*Metal Progress*, 1943, **44**, (1), 89–94; and (abridged) *Found. Trade J.*, 1943, **71**, (1423), 249–250).—A description is given of the procedure adopted by the U.S. Army Air Forces in the X-ray examination of structural castings in which the ultimate design load produces stresses between 20 and 100% of the permissible stress. The presence of certain defects leads to immediate rejection; in other cases the test castings are subjected to a static loading test, the frequency of tests on subsequent batches depending on the results obtained in the first test batch. Radiographs of aluminium alloys are reproduced to show various types of defect, the nomenclature, cause, and characteristic appearance of which are given.—P. R.

X-Rays in Industry. J. K. Allen (*Siemens Mag.* (*Eng. Suppt.*), 1943, (**211**), 1–4; (**212**), 1–4).—An historical survey of the discovery and application of X-rays is given, followed by some modern uses of the X-ray shadowgraph.
—E. V. W.

XIV.—TEMPERATURE MEASUREMENT AND CONTROL

Temperature Regulation of All Kinds of Metallurgical Furnaces. C. Sieber (*Metallwirtschaft*, 1941, **20**, (24), 603–610).—Various modern types of automatic temperature controllers for numerous types of melting and annealing furnaces are described with reference to wiring diagrams, and the principles underlying their construction are outlined.—A. R. P.

Temperature Measurement and Control with Solid Photoelectric Cells. Marlin E. Fogle (*Electrochem. Soc. Preprint*, No. **14**, 1943, (Apr.), 183–191; also (abridged) *Metallurgia*, 1943, **28**, (166), 162; and *Met. Ind.*, 1943, **63**, (5), 82).—Various types of photo-electric pyrometers using solid cells are described and compared with optical and total-radiation pyrometers for measuring and controlling high-temperatures in steel furnaces and ceramic kilns.—A. R. P.

XV.—FOUNDRY PRACTICE AND APPLIANCES

The Melting and Pouring of Alloys. S. Simpson (*Australasian Eng.*, 1943, **43**, (322), 16–17, 37, 38–39).—S. deals with the classification and selection of the various furnace types for a given job, composition of the charge and its effect on melting, furnace atmosphere control, function and composition of fluxes, and precautions to be observed in pouring.—E. A.

Metallurgical Factors of Importance to the Practical Aluminium Founder. S. A. E. Wells (*Found. Trade J.*, 1943, **71**, (1420), 179–184; discussion, (1421), 207–210; (1422), 225–228; also *Met. Ind.*, 1943, **63**, (8), 114–117; (9), 139–140).—A paper read before the London and Lancashire Branches of the Institute of British Foundrymen. An outline is given of precautions to be adopted in melting aluminium-base alloys. The technique of grain refinement using titanium or niobium is described. The effect of dissolved gases giving rise to " pinholes " is described, and suggestions are made for the elimination of this defect. W. reports that a serious loss of magnesium can occur from a repetition of the flux degasification treatment on Ceralumin " B," resulting in a softening of the alloy. Repeated melting of this alloy in the absence of flux does not lead to any loss of magnesium. In the case of " Alpax Gamma," repeated flux treatment leads to substantial magnesium loss, with corresponding decreases in Brinell hardness and proof stress.—J. E. G.

Melting, Alloying, Heating Aluminium and Alloy Ingot. R. R. LaPelle (*Metal Progress*, 1943, **44**, (2), 276–282).—This short description of the equipment and methods employed in the production of high-strength aluminium alloys includes an illustrated account of an oil-fired reverberatory furnace for remelting ingots and scrap. Factors influencing the choice of fuel are reviewed. The procedure of alloying and of casting different types of ingot is described, and a brief account is given of " homogenizing " treatment and of cladding operations.—P. R.

Aluminium Cylinder Heads for Aircraft Engines. G. Eldridge Stedman (*Steel*, 1943, **112**, (15), 102–105; (16), 114–116).—The foundry practice at an American aluminium foundry is reviewed, in the casting of cylinder heads with a remarkably low value of scrap.—E. A.

***The Casting of Aluminium-Alloy Power Gears.** N. I. Mirusev (*Liteynoe Delo* (*Foundry Practice*), 1941, **12**, (3), 29; *Chem. Zentr.*, 1942, **113**, (I), 2817; *C. Abs.*, 1943, **37**, 3378).—[In Russian.] Experiments with the aluminium alloy " ASWP," containing copper 9–12, silicon 1·2, zinc 0·5, magnesium 0·5, and nickel + manganese 1%, showed that cracking difficulties could be reduced 80% by modifying the composition to copper 7·5, iron 0·55, and silicon 1·62%. Welding repairs must be checked by X-rays, and the strength by rotation at 8000–9000 r.p.m. for 5 minutes and 80 hrs. at 6500 r.p.m.

Some Causes of Gas Unsoundness [in Copper Alloys] **and How to Eliminate Them.** H. L. Smith (*Trans. Amer. Found. Assoc.*, 1942, **50**, (2), 490–497; discussion, 497–498).—S. points out that faulty melting practice is one of the most important factors causing porosity and other casting defects in copper-base alloys. It is submitted that in fuel-fired furnaces the water vapour formed reacts with carbon contained either in the fuel, the crucible, or the charcoal covering, to give carbon monoxide and hydrogen, the latter dissolving readily in the melt. On pouring, the exposed metal surfaces are oxidized, and the dissolved hydrogen rapidly reduces this oxide, forming water vapour which, being entrapped in the metal, leads as it cools to the production of gas holes. In the crucible melting of copper and copper-base alloys, carbon may be absorbed from the crucible which, during pouring, forms carbon monoxide and carbon dioxide. In electric-arc-furnace melting it is suggested that the cumulative effect of carbon gas porosity is due (*a*) to the reaction of carbon monoxide with the metal to form carbon and metallic oxide, (*b*) to the reaction

of the metallic oxide with more carbon monoxide to form minimum amounts of carbon dioxide, and (*c*) to the reduction of these minute amounts of carbon dioxide in the arc, thus permitting the reaction to proceed from the start.
—J. E. G.

Producing Bomber Castings. J. A. Oates (*Aircraft Production*, 1943, **5**, (56), 292–296; (57), 307–312).—A mechanized foundry is described, and details are shown in numerous illustrations of the equipment and of the moulding technique for the Stirling undercarriage gear-box.—H. S.

Roughness of Metallic Surfaces, with Special Reference to Castings. (O'Neill and Insley). See p. 23.

Gravity Die-Casting.—I. —— (*Aircraft Production*, 1943, **5**, (59), 434–442).—The organization and casting methods used in the production of aluminium alloy parts of the Rolls-Royce Merlin engine as gravity die-castings, are described. These include gear-case cover, coolant pump body, boost-control casing, cylinder skirt, &c.—H. S.

The Venting of Die-Casting Dies. H. K. Barton (*Machinery* (*Lond.*), 1943, **63**, (1616), 386–388).—Methods of designing die-casting dies to ensure adequate venting are described. In dies with simple parting lines, it is often sufficient to finish the die faces with rather coarse shaper cuts, the direction of the cut on one die surface being at right angles to that on the other. Recesses may be vented by undercut plugs. When deep cavities are cut on one side only of the die, a modified gate should be used to slow down the incoming metal stream and allow more time for air to escape.—J. C. C.

Continuous Casting. Leslie H. Day (*Metal Treatment*, 1943, **10**, (35), 173–180).—Descriptive. In continuous casting machines the metal is poured either through a stationary mould or between rolls. In the Junghans and Williams machines, water-cooled moulds of good thermal conductivity are used, the heat being withdrawn laterally. In the Edred and Poland–Lindner machines the moulds are of relatively poor conductivity. If metal is cast on a rotating roll, as in an early machine designed by Bessemer and the Hazelett A machine, folding occurs, and low-melting constituents are segregated. This difficulty is overcome in the Hazelett B continuous casting-rolling mill by the use of a cooling member on which the metal solidifies before passing between the rolls. Reference is made to the Merle machine.
—J. C. C.

Use of Ultrasonics in Metallurgy [for Producing Homogeneous Alloys]. W. Becker (*Novosti Tekhniki* (*Tech. News*), 1941, **10**, (4), 25–26; *Chem. Zentr.*, 1942, **113**, (I), 2579; *C. Abs.*, 1943, **37**, 3376).—[In Russian.] The addition of lead to alloys, for instance to aluminium and zinc alloys, for the purpose of improving workability, is often difficult because of irregularity in distribution. High-frequency sound-waves, applied by a method similar to the one used in the production of stable emulsions such as mercury–water and water–oil emulsions, were utilized in the production of aluminium and zinc alloys containing 10% and 7%, respectively, of lead. These alloys were so stable that even repeated remelting did not cause segregation. The apparatus used is described. The process is also adapted for the introduction of constituents which have low solubility or high melting point and for the removal of gas inclusions from castings.

Production of Copper Patterns by Electroforming. A. K. Laukel (*Trans. Amer. Found. Assoc.*, 1942, **50**, (2), 394–401; discussion, 402–404).—L. stresses the importance of choosing suitable pairs of metals for plate and pattern if corrosion is to be avoided. The production of copper patterns using moulds made in plaster of Paris is described in detail. The limitations and advantages of this process are outlined.—J. E. G.

Correlated Abstract of Literature on Flowability and Deformation of Sands. P. E. Kyle and F. R. Evans (*Amer. Foundryman*, 1943, **5**, (1), 4–8).—A critical

survey is submitted of methods of measuring flowability, with particular reference to a test, devised by K. and E., dependent upon the hardness gradient of a mould. On the basis of data available it is submitted that flowability and deformation are interdependent within any one mould, that flowability should be related to the preparation of the mould, and that deformation should be related to the ability of a mould to withstand loads imposed upon it either by handling or by molten metal during pouring.
—J. E. G.

A Study of the Flowability of Foundry Sands. Erik O. Lissell and Eugene J. Ash (*Trans. Amer. Found. Assoc.*, 1942, **50**, (2), 637–653; discussion, 653–656).—L. and A. suggest that a distinction should be made between (1) autoflowability or flow under conditions of freedom from any external force other than gravitation, and (2) the flowability which is exhibited when sand is subjected to an applied force. In this second type of flowability it is possible to distinguish between (*a*) compression flow due to the movement of the binder between the sand grains, and the general movement of the sand grains principally in the direction of the applied force, and (*b*) true flowability, that is, the flow of the sand grains in a direction other than that of the applied force. L. and A. consider that by means of the Dietert method a satisfactory measurement of compression flow may be made.—J. E. G.

***Progress Report—Comparison Data on the Durability of Naturally-Bonded and Synthetic Moulding Sands by the Repeated-Pour Test.** Jack CoVan (*Trans. Amer. Found. Assoc.*, 1942, **50**, (2), 539–561; discussion, 561–567).—It is considered that the most satisfactory durability test for moulding sands is the Nevin repeated-pour test. The durability of three synthetic sands and two naturally-bonded sands were examined. C. reports that in the case of the naturally-bonded sands the amount of natural clay bond required to maintain a green compression strength of 6 lb./in.^{2} throughout the series was at least twice as much as that required to maintain this strength in the synthetic sands. It is therefore concluded that, in the case of the sands examined, the synthetic sands are more durable than the natural sands.
—J. E. G.

***A Foundry Investigation of Bond Clay Properties.** A. S. Nichols, F. W. Hintze, and F. L. Overstreet (*Trans. Amer. Found. Assoc.*, 1943, **50**, (4), 1257–1290; discussion, 1291–1300).—An investigation into the effect of bonding clays upon the durability of moulding sands, and the relation of casting defects to sand properties.—J. E. G.

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

Similar British and American Secondary Aluminium Alloys are Compared. —— (*Amer. Foundryman*, 1943, **5**, (9), 19–20).—A comparison of alloy D.T.D. 424 with an American counterpart. Points mentioned include foundry technique, composition limits, and mechanical properties.—J. E. G.

Mechanical Ingoting of Aluminium and Magnesium Turnings. Max Stern (*Iron Age*, 1943, **152**, (7), 90–92; also (abridged) *Met. Ind.*, 1943, **63**, (20), 313).—A description is given of a method, nearing the production stage, of recovering aluminium and magnesium turnings and grindings by briquetting them into nearly solid blocks. Complete evaporation of water and oil and precise temperature control eliminate oxidation and contamination risks. The ingots can be used for melting, for deoxidizing and alloying, or for direct extrusion and forging.—J. H. W.

XVII.—FURNACES, FUELS, AND REFRACTORY MATERIALS

***Melting and Refining of Zinc in the Electric Furnace.** H. Bille (*Elektrowärme*, 1941, **11**, 198–200; *Chem. Zentr.*, 1942, **113**, (I), 1551; *C. Abs.*, 1943, **37**, 3349).—Experiments were carried out on zinc alloys containing copper, aluminium, and magnesium in an 80-kw. resistor furnace and in a 120-kw. low-frequency induction furnace. Results in the resistor furnace were satisfactory, except that power consumption was high. Difficulties were encountered in the induction furnace owing to short life of the lining, but these difficulties were overcome by proper selection of refractory and mode of application. The main advantage over fuel-fired furnaces is constancy of composition of the alloy made, owing to low zinc losses.

A New Type of Low-Frequency Induction Furnace for Light Metals. H. Capitaine (*Metallwirtschaft*, 1941, **20**, (24), 610–611).—Cf. *Aluminium*, 1942, **24**, 69; *Met. Abs.*, 1943, **10**, 188. A new type of low-frequency induction furnace for melting aluminium and its alloys consists of a broad rectangular charging chamber connected by three narrow channels to a smaller rectangular chamber provided with a pouring spout; the primary coil is embedded in refractories between the channels, which therefore act as the secondary. In melting scrap the dross collects in the charging chamber and the clean metal flows into the casting chamber. The furnace will melt 10 charges of 2 tons per 24 hrs., and when melting charges consisting of 40% of briquetted lathe turnings the channels require cleaning out every 4–5 days by means of a special steel plunger, an operation which takes only 15 minutes. A photograph and plan and elevation diagrams of the furnace, are included.—A. R. P.

XVIII.—HEAT-TREATMENT

Refrigerating Aluminium Alloy Rivets and Parts. B. J. Fletcher (*Metals and Alloys*, 1943, **17**, (6), 1178–1182).—Ageing of aluminium alloys 17S (copper 4, manganese 0·5, magnesium 0·5%) and 24S (copper 4·5, magnesium 1·5, manganese 0·6%) does not commence until the lapse of 16 hrs. at 32° F. (0° C.) and requires 2 weeks for completion. At 0° F. (— 16° C.) no ageing takes place for one week. Equipment for refrigerating aluminium alloy rivets, after quenching in order to retard ageing, is illustrated. The rivets are rinsed in alcohol after quenching to remove moisture which would freeze the parts together.—J. C. C.

***Stress-Relief Annealing of Cold-Worked, Hardenable Copper Alloys.** (Wortmann.) See p. 8.

XIX.—WORKING

Cartridge Brass (Cold Working and Annealing). L. E. Gibbs (*Metal Progress*, 1943, **44**, (2), 243–248, 292).—A series of charts shows the influence of " ready-to-finish " grain-size on the tensile properties of 70 : 30 brass (*a*) after varying amounts of cold rolling, and (*b*) after a stated amount of cold rolling followed by annealing at various temperatures; similar results are then summarized graphically for 70 : 30 rod. The grain-sizes resulting from the final annealing are shown in both cases. The relations between hardness, cold work, and grain-size are illustrated by photomicrographs showing brass in various stages of cold working and recrystallization, and the influence of these factors on the result of the final annealing is reviewed in detail in its application to industrial processes.—P. R.

Drop-Stamping, Using the Cecostamp to Speed-Up Production of Sheet-Metal Parts. —— (*Aircraft Production*, 1943, **5**, (51), 6–9).—The production of compound-curvature parts in sheet metals is described. Zinc alloys are used for the lower die and hardened lead for the punch. The dies are cast in sand moulds, with the use of a pattern made in wood or plaster.—H. S.

Drop-Hammer Technique. —— (*Aircraft Production*, 1943, **5**, (52), 57–60).—Some notes on the production by an aircraft company of compound curvatures in sheet metal.—N. B. V.

Rubber Dies for Small Presses. A. Bernard (*Aircraft Production*, 1943, **5**, (59), 415–417).—A description of bench-type fly-press practice in blanking and forming operations with the rubber pad, is given.—H. S.

Plastic Punches. —— (*Aircraft Production*, 1943, **5**, (54), 166–169).—The plastic punch is moulded directly upon the die. The metal die and plastic punch are used in a drop-hammer or hydraulic press for forming parts in light alloy sheet. The plastic may be worked with hand wood-working tools and is capable of being re-used.—H. S.

Aircraft Sheet-Metal Work. Wilfred E. Goff (*Aircraft Production*, 1943, **5**, (55), 219–229).—Methods of production of sheet-metal equipment for Bristol engines, especially manifolds and cowlings, are described. Nickel plating and subsequent heat-treatment of exhaust rings are described.—H. S.

Sheet-Metal Working. W. S. Neville (*Aircraft Production*, 1943, **5**, (53), 129–133).—Processes evolved for the production of aircraft components are described. These include rubber die practice, flanging, bending, stretching, and drilling.—H. S.

Elastic Theory in Sheet-Forming Problems. F. R. Shanley (*Aircraft Eng.*, 1942, **14**, (164), 293–299; (165), 325–328).—[I.—] The term elastic theory is used here to cover all theories relating to change of shape resulting from the application of stress. S. discusses maximum elongation in relation to gauge length, and also permanent strain, combined stresses, triple tension, shear stresses, pure shear, intermediate conditions, Poisson's ratio, and matters related to forming properties of metal sheets. He then deals with forming processes, giving special attention to bending, spring-back, curved flanges, " cut-outs," stretching, and double curvature. [II.—] Applications of the double-acting press are discussed. The method of gripping the sheet is important in relation to the range of forming that can be done. Drawing of hollow parts from sheet and the use of a draw ring to prevent wrinkling, permissible strains, dimensional relationships of blank to cup, and other features are mentioned with examples. The use of the wedge-draw test at Lockheed is described. Material properties which are of importance to formability are given for a number of aluminium alloy sheets.—H. S.

Machinability of Metals. A. M. Portevin (*Metal Progress*, 1943, **44**, (1), 107–108).—Factors influencing machinability include the following: (1) hardness of the material in relation to the tool; (2) hardness attainable by the material as a result of cold work; (3) force exerted by the tool; (4) working temperature at the point of the tool; (5) presence of non-abrasive or of very hard inclusions; (6) homogeneity or otherwise of the structure of the material; (7) nature of the machined surface. Each factor is discussed in some detail.—P. R.

***Method of Determining the Machinability of Metals.** I. A. Oding and P. R. Virrilep (*Zavod. Lab.* (*Works' Lab.*), 1940, **9**, 1025–1029; *Chem. Zentr.*, 1942, **113**, (I), 261; *C. Abs.*, 1943, **37**, 3379).—[In Russian.] A device for testing the machinability of iron, steel, and non-ferrous metals is described. The instrument is easy to operate, and the effect of structural inhomogeneities is eliminated by the use of small specimens. The machining mechanism, and the effects of structure and tool dimensions, can be studied. The instrument permits the determination of cutting indexes at room and elevated temperatures, and the measurement of the tool temperature. The cutting indexes at a speed of 0·4 m./minute have been determined for cast iron, steel, alloy steels, brass, and bronze.

XX.—CLEANING AND FINISHING

Metal Degreasing. —— (*Aircraft Eng.*, 1942, **14**, (165), 329–330).—The properties of trichlorethylene and other solvents used in vapour-bath degreasing plant are compared, with special reference to fire hazard, danger to health of operators, latent heat of vaporization, and corrosive action on various metals. Brief mention is made of acidity of the solvent and its removal, and to the use of inhibitors.—H. S.

[**Technical and Economic Aspects of Metal Cleaning and Finishing.—60.**]

Metal Cleaning Before Processing. Kenneth D. Kahn (*Iron Age*, 1943, **152**, (11), 62–65).—In an article summarizing research and development since 1917, the advantages and disadvantages, and the equipment and functions, of the principal metal-cleaning methods are described, and the solvent vapour degreasing process is discussed.—J. H. W.

The Seophoto Process. N. Budiloff and K. Hahn (*Metallwirtschaft*, 1941, **20**, (16), 387–392).—In this process, the anodic film on aluminium is impregnated with some material sensitive to light, and the product is exposed, developed, fixed, &c., as usual. Aluminium or aluminium–magnesium alloys of high purity are used: alloys containing copper are unsuitable. For anodizing, the sulphuric, oxalic, or chromic acid process is used, depending on the colour and finish required; chemical dips, such as the M.B.V., are unsuitable. Special precautions have to be taken in processing to avoid superficial imperfections, and thorough cleanliness is essential. Impregnation is done by dipping or rolling, a double process being needed where the light-sensitive substance is insoluble (*e.g.*, silver halides). Ferrogallic or Prussian blue processes may be used. The sensitive material is deposited in the pores of the film; no medium such as albumen or collodion is used, and the product consequently possesses the corrosion- and heat-resistant properties of the anodic film. Impregnation, exposure, and development do not affect the absorptive capacity of the film: the process may therefore be repeated or the picture dyed if required. The process may be used for notices, placards, instrument scales, map reproductions, half-tone work, &c.—H. W. L. P.

XXI.—JOINING

Bonding Plastic and Metal. —— (*Aircraft Production*, 1943, **5**, (52), 55–56).—The Plastel process is described briefly, with reference to the properties of the joints and possible applications of the process in aircraft work.—H. S.

Silver Alloy Brazing with High-Speed Localized Gas Heating. J. I. Butzner (*Iron Age*, 1943, **152**, (13), 38–44).—The technique and equipment for gas–air brazing, which has the advantages of fast localized heating and exceptional flexibility, are described with many examples.—J. H. W.

***The Metallurgy of Fillet Wiped Soldered Joints.** E. E. Schumacher, G. M. Bouton, and G. S. Phipps (*Metals Technology*, 1943, **10**, (2); *A.I.M.M.E. Tech. Publ.*, No. **1566**, 6 pp.; and *Trans. Amer. Inst. Min. Met. Eng.*, 1943, **152**, 291–296; discussion, 296–297).—The causes of porosity in wiped soldered joints are discussed, and the solidification process of a solder is described. In joining lead pipes to cable sheaths by wiped soldered joints, a saving of more than 60% of solder can be made, if, instead of the customary full-sized wiped joint, only a wipe of fillet proportions is formed. This method also eliminates many causes of porosity. The possible saving of tin by the use of new solder alloys is briefly mentioned, and is referred to in the discussion on the paper.—W. H.-R.

***Safe Substitute Solder for Food Cans.** H. W. Gillett, E. J. Cameron, and Robert F. Griggs (*Metal Progress*, 1943, **44**, (3), 420, 421, 454; also *Met. Ind.*, 1943, **63**, (24), 373–374).—A report to the U.S. War Production Board. Tests carried out in the U.S.A. between 1938 and 1942 showed that in respect of mechanical properties and suitability for automatic soldering a lead–silver solder containing 2·5% silver was satisfactory. Possible dangers to health lay in absorption of lead by the food and in the presence in the latter of spattered droplets of solder. Cadmium and bismuth solders are unsuited for food containers, as cadmium has some toxic action and supplies would in any case be insufficient, whilst the bismuth solders have a long freezing range and hence do not form sound seams unless the latter are held under pressure. Experiments on lead absorption were carried out on a variety of foods at 98° F. (36·7° C.) with 3 alloys, the 2½% silver solder and 2 lead–tin–silver solders. Determinations of lead absorption at 3-month intervals showed a negligible increase in lead content over the period, the absorption immediately after canning being above the safe maximum in one case only: experiments at room temperature showed only negligible lead content after 4 months. It increased in the presence of large numbers of solder pellets, but not to a serious extent.—P. R.

***Spot-Weld Joint Efficiency for Aluminium Alloys.** C. W. Steward (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 528s–532s).—The factors governing joint efficiency and production economy were studied for Alclad 24ST, 0·040 in. thick, and the results are summarized. Spots parallel to the joint at distances ¼–1½ in. showed that a spacing less than ½ in. resulted in low strength, and a similar result was obtained with varying distances (¼–¾ in.) between spots in the direction of the load. Efficiency tests on specimens of varying sizes showed that a maximum joint efficiency of 100% could be produced with an average of 93%. The maximum stress on a standard specimen obtained was 61,800 lb./in.^{2}, with an average of 59,800 lb./in.^{2}. The best spot pattern was ½ in. in each direction, and a.c. welds were found to be better than d.c. welds, probably owing to the slight annealing effect.
—E. G. W.

Spot Welding [of Light Alloys]. T. M. Roberts (*Aircraft Production*, 1943, **5**, (57), 338–343).—Spot-welding developments with condenser-type equipment for the resistance welding of light alloys are described. The merits of the high-voltage and medium-voltage condenser discharge types of welding machine are discussed, the latter being preferred by R. for welding the lighter gauges. The high-lift head, electrode design, refrigeration, surface preparation, and weld strength are interesting features to which special attention is given.—H. S.

Spot Welding Light Alloys. —— (*Aircraft Production*, 1943, **5**, (51), 3–5).—Modern types of machine, methods of preparation of the work, electrodes, and manipulation are discussed briefly.—H. S.

Observations on the Repair of Cast Light Metals by Welding. K. F. Zimmermann (*Metallwirtschaft*, 1941, **20**, (15), 361–365).—Light metal castings are easily repaired by oxy-acetylene welding, if the parts are first thoroughly cleaned, a suitable flux is used and the residue completely removed after welding, and the alloy used for building-up the worn or broken parts has a similar composition to that of the parts. Several examples are given with illustrations.—A. R. P.

Rapid and Accurate Inspection of Spot Welds [in Aluminium Sheet]. (Anderson.) See p. 26.

Modern Welding Methods for Copper and Copper Alloys. J. J. Vreeland (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 784–792).—This long survey includes procedure data for the gas and arc welding of copper and copper alloys, together with test results and microstructures. Tough-pitch copper

$\frac{1}{16}$–$\frac{3}{8}$ in. thick can be carbon-arc welded, using phosphor-bronze filler rod, but above $\frac{3}{8}$ in. thickness this is not possible, as multiple-bead welds tend to crack. Deoxidized copper may be oxy-acetylene welded with phosphorus-deoxidized (with or without silver) copper rod or silicon–copper filler. It is also possible to carbon-arc weld deoxidized copper with silicon–copper rod or phosphor-bronze filler of a suitable grade. High copper brasses (to 15% zinc) are preferably welded with silicon–copper (1·5% silicon) by the oxy-acetylene process or with 3% silicon–copper rod and suitable flux by the carbon-arc method. Brasses containing 58–80% copper are preferably carbon-arc welded with 3% silicon–copper, although oxy-acetylene welding or carbon arc welding with brass rods may be used. Bronzes are welded satisfactorily with phosphor-bronze or silicon–copper rods by the carbon-arc and also by the metallic-arc process, the latter method being advisable for aluminium-bronze and beryllium-bronze. The carbon arc can be used for aluminium-bronze and beryllium-bronze with high silicon–copper rods. Some examples are illustrated.—E. G. W.

The Welding of Copper by Direct Electric Heating, Using Phosphor-Copper Deoxidizers and Fluxes. A. N. Alimov and S. A. Gorbunov (*Avtog. Delo* (*Autogenous Ind.*), 1940, **11**, (3), 6–10; *Chem. Zentr.*, 1940, **111**, (II), 3400).—[In Russian.] A welding method for copper wire or strip is described by which the copper parts to be joined are heated to welding temperature by the direct passage of current between carbon electrodes, and the welding is carried out with the application of a quick-acting deoxidizer and flux consisting of phosphor-copper with 7·5–8% phosphorus. The mechanical properties of these copper welds were superior to those made without the phosphor–copper flux.

Repair of Copper Vessels and Boiler Parts by Welding. H. Schnedler (*Metallwirtschaft*, 1941, **20**, (15), 357–360).—The value of oxy-acetylene welding for repairing copper boilers, electrical apparatus, locomotive fire-boxes, and similar large articles is illustrated by several examples. A neutral flame and a good coating of a borax flux are essential for obtaining sound welds.
—A. R. P.

Locomotive Parts Fabrication and Welding of Bronze Bearing Surfaces. J. W. Kenefic (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 799–805).—Among a number of typical applications of welding to repair and fabrication, are included illustrated examples of building-up bearing surfaces with lead-bronze electrodes or the carbon arc, the bronze welding of cast-iron parts, and the facing of fabricated driving boxes with bearing brass.—E. G. W.

***The Flash Welding of Nickel and High-Nickel Alloy Rod.** Wendell F. Hess and Albert Muller (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 532s–544s).—Satisfactory flash-welding conditions were established for $\frac{1}{4}$- and $\frac{3}{8}$-in. diameter rods of "A" nickel, Monel, "K" Monel, and Inconel. Effects of welding variables investigated—cam shape, flashing time, upset, current during forging, and energy input—are described, and the fundamental considerations are discussed. During the work a method of measuring energy input and distribution was developed, using a high-speed recording wattmeter. Welds of optimum strength were obtained at short-circuit power levels just sufficient to maintain uniform fine flashing at the butted surfaces. Lower power resulted in erratic welds of low strength and higher power resulted in reduced weld strength owing to entrapped oxide. Current must be maintained during the initial stages of upset to facilitate forging. Satisfactory microstructures are illustrated, and the three major defects in flash-welded high-nickel alloys are listed as: (i) oxide at the interface, (ii) trapped dendritic material at the interface, (iii) partial fusion in the weld region. Alteration of the clamping dies is required in cases where current conduction from one side only of the clamp is provided in order to avoid "die burns." Other machine data are included.—E. G. W.

On the Present Position of Welding Technique for Hard-Metal Alloys. R. Kottisch (*Metallwirtschaft*, 1941, **20**, (15), 365–368).—Methods of welding hard-metal (cobalt alloys and sintered carbides) inserts and tips to steel articles are briefly described, and some new uses are mentioned.—A. R. P.

Welding in the Construction of Aircraft. James W. Cowie (*Australasian Eng.*, 1943, **43**, (325), 20–22).—After a brief description of the development of welding in aircraft, C. discusses the distortion in welded parts due to: (1) residual stresses in the metal released by heat; (2) contraction of metal in the heated zone; and (3) contraction of the weld deposit. The methods to overcome or reduce distortion, used singly or in combination, are given as: (1) contra heating; (2) weld procedure; (3) pre-stretching; and (4) uniform heating.—E. A.

Electric Welding of Wire. V. N. Voskresenski (*Tochn. Ind.* (*Precision Ind.*), 1940, **11**, (4), 17–19; *Chem. Zentr.*, 1940, **111**, (II), 3259).—[In Russian.] A comprehensive survey of the various methods, circuit layouts, and apparatus for electric welding of ferrous and non-ferrous wires for contacts, &c., with examples of satisfactory and defective welding. Scale-proof chromium–nickel, chromium–aluminium–iron, and chromium–cobalt–aluminium–iron alloys are best welded by means of electric discharges, and not by a.c. or d.c. arc. Wires or wire + strip are welded with the best results in two stages: (1) by first thickening the ends to be welded by strong discharges, and (2) then carrying out the welding operation proper. The strength of the discharges in these operations has to be adjusted according to the diameter of the wire in order to maintain the voltage $\not< 30$. The above method is unsuitable for welding of aluminium wire, which has to be done by the usual lap-welding method.

Welding of Metals with Bronze. —— (*Commonwealth Eng.*, 1943, **30**, (10), 231–236).—Fusion and non-fusion welding with coated aluminium-bronze electrodes are discussed, as applied to metals and alloys having a higher melting point than that of the welding rod, such as wrought, cast, and malleable iron, carbon and alloy steels, copper–zinc alloys in general, manganese bronzes, &c. Composition and properties of the various aluminium-bronze welding rods are tabulated, and the process of welding and some of its special applications are described in detail.—E. A.

Atomic Hydrogen Welding. L. G. Pickhaver (*Weld. Eng.*, 1943, **28**, (6), 42–45).—This general account of the atomic hydrogen welding process includes a reference to multi-arc welders.—E. G. W.

***Establishment of Cooling Curves of Welds by Means of Electrical Analogy.** V. Paschkis (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 462s–483s).—This paper applies a method developed earlier, in which it was shown that certain electrical circuits follow exactly the same mathematical laws as apply to transient heat flow. The heat and mass analyzer was used to study the mechanism of heat transfer from a metallic arc to a plate, and two general curves were obtained, one for each of the two components of energy transfer—radiation and heat in the metal melted from the electrode. The possibilities of the method were established, but further work is required to obtain more curves and to correlate the data with direct thermal measurements. Full details of the curves and the experimental work must be obtained from the paper.—E. G. W.

Why the Weld Recorder? J. R. Fletcher and J. Van Den Beemt (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 815–818).—The weld recorder (or ampere-squared-second recorder) provides the most accurate method of checking the value of I^2t in the formula: Heat $\propto I^2Rt$. The apparatus and circuit are briefly described, and its application to a stainless steel spot weld is summarized. It is stressed that weld recorders must be used only with timers giving perfect synchronous control, and must be employed with proper weld procedure and test weld examination. The variables which affect weld strength but not the recorder are noted, as well as those which affect both weld strength and the recorder.—E. G. W.

Shrinking Galvanized Steel. C. R. Goetjen (*Weld. Eng.*, 1943, **28**, (5), 40). —In shipbuilding it is sometimes necessary to flame-shrink galvanized steel plates after welding in order to overcome distortion, and a special technique has been worked out to reduce the removal of the zinc coating. A highly oxidizing flame, with a central cone $\frac{5}{32}$ in. long, is used, in conjunction with a quench spray. The flame is withdrawn from the metal when the first sign of colour (dull red) appears.—E. G. W.

Reclamation by Hard Facing. F. G. Jones (*Weld. J.* (*J. Amer. Weld. Soc.*), 1943, **22**, (10), 797–798).—In a general review of hard-facing methods, the non-ferrous alloys—chromium–boron–nickel and chromium–tungsten–cobalt—are mentioned as being of particular value for resistance to wear and corrosion, and also to erosion at high temperatures. Typical applications are noted briefly.—E. G. W.

Health Aspects of Welding. A. G. Cranch and B. L. Vosburgh (*Metal Progress*, 1943, **44**, (2), 253, 290; also *Canad. Metals*, 1943, **6**, (10), 35–37, 44).—From a pamphlet issued by the National Safety Council. The principal hazards to health in welding operations are those arising from (*a*) radiation (intense light and, in some cases, ultra-violet radiation), and (*b*) toxic gases and fumes. Radiation hazards can be combated by protective gear (goggles, screens, &c.) and the use of non-reflecting paint. Poisonous gases, mainly oxides of nitrogen, can be eliminated by proper ventilation. Protection from lead or cadmium fumes should be afforded by air-supplied masks: zinc fumes do not constitute a permanent hazard, but cause acute poisoning ("zinc fever") over short periods. Ventilation of welding shops should ensure good visibility at the point of operation and permit a comfortable working temperature; in confined spaces exhaust ventilation is usually desirable.—P. R.

XXV.—BOOK REVIEW

Reports of the Progress of Applied Chemistry. Volume XXVII, 1942. Demy 8vo. Pp. 545. 1943. London: The Society of Chemical Industry, 56 Victoria St., S.W.1. (Members, 11*s.* 6*d.*; non-members, £1.)

This volume covers, in 26 reports, progress in the whole field of applied chemistry, mainly as recorded in *British Chemical Abstracts* during the year 1942. An analysis of the papers referred to in the course of the two chapters which are of especial interest to the members of this Institute, reveals clearly the difficulty of attempting to give a balanced survey of progress in metallurgy in the third year of the war. Thus, of 106 papers mentioned in the report on "Non-Ferrous Metals" (by Dr. E. S. Hedges), 21 are British, 45 American, 19 German, 6 Russian, and 15 from other countries; in that on "Electrochemical and Electrometallurgical Industries" (by Dr. J. W. Cuthbertson), the predominance of American papers is much greater, viz., 65 per cent. of the total. The figures are: British 23, American 52, German 1, Russian 1, Indian 3. This disproportion reflects two facts: first, the difficulty that has existed of obtaining, since May 1940, the literature of enemy countries and, since 1941, the Russian literature; and second, that in the period under survey the United States had only just begun a reduction in the number of scientific papers published. The other reports have not been examined in detail, but the same tendency appears to prevail in them too.

This analysis is not to be interpreted as serious criticism of the reports or of the two authors specifically mentioned; it is given only to show that really comprehensive surveys must wait upon access being gained to literature that is not at present available and upon the publication of much matter at present suppressed. As interim reports—the best, no doubt, it is possible to make at this date—the two reports, and indeed the volume as a whole, are admirable, and they deserve to be widely read, particularly by those who find little time nowadays for keeping their technical reading up to date.

The volume is provided with name and subject indexes, and the standard of production of former years is well maintained.


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