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Vol. 1. Part 7.

The Monthly Journal of the

INSTITUTE OF METALS

AUTUMN MEETING, MANCHESTER

It is expected that a considerable proportion of Members attending the Manchester Meeting will desire to stay at the University Hostel, Ashbourne Hall. Applications for accommodation should be made *not* direct to the Warden at the Hostel, but to the Honorary Local Secretary of the Manchester Meeting, Mr. J. A. Tod, The Broughton Copper Company, Ltd., Manchester.

G. SHAW SCOTT, *Secretary.*

and

METALLURGICAL ABSTRACTS

JULY, 1934

 [*Entered at Stationers' Hall*

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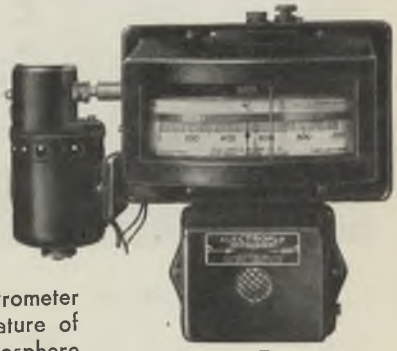

FIG. 1

Fig. 1 shows the Electroflo Indicating Control Pyrometer for the automatic regulation of the temperature of electric furnaces, and the temperature and atmosphere of fuel-fired furnaces, etc. It employs a "knife-edge" method of temperature detection, ensuring control within extremely fine limits, a high resistance, shock-proof moving element and an integral signal system.

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FIG. 2

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THE INSTITUTE'S LIBRARY

Donations of any of the undermentioned would be welcomed to complete the Institute's files :

Encyclopædia Britannica (latest issue).

Sutton H. "A Systematic Handbook of Volumetric Analysis." (J. & A. Churchill.)

"Brass World." Volumes 1–6.

Electrochemical and Metallurgical Industry. Volumes 1–3.

Metallurgical and Chemical Engineering (Chemical and Metallurgical Engineering). Volumes 12–21.

Mineral Industry. Issues since 1932 (incl.)

Foundry Trade Journal. Volumes 1–25.

Journal of the Electroplaters' and Depositors' Technical Society. Volumes 1–3 incl.

Journal of the Iron and Steel Institute. Volumes 1–15.

Metal Industry (London). Volumes 1–4.

Metallwirtschaft. Volumes 1–5.

Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf. Volumes 1–10.

Proceedings of the Institute of British Foundrymen. 1916–17 (Volume 10.)

Revue de Métallurgie. Volume 1.

Transactions of the American Electrochemical Society. Volumes 1–3 and Volume 11.

Transactions of the American Foundrymen's Association. Volumes 1–15, 18–27 incl.

Transactions of the American Institute of Metals (American Brass Founders' Association). Volumes 3–5.

INDEX TO ADVERTISERS

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EDITORIAL OFFICE:
36 Victoria Street,
London, S.W.1.

TELEPHONE:
Victoria 2320.

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

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CONTENTS

METALLURGICAL ABSTRACTS

The monthly issue of *Metallurgical Abstracts* may be cut up for card indexes, as members will receive early in 1935 the year's abstracts in bound form.

INSTITUTE NEWS AND ANNOUNCEMENTS

Autumn Meeting.

Manchester, September 3–6.

The final programme of the Manchester Autumn Meeting was posted to all members on July 2. With the programme was enclosed a reply form that should be returned to the Secretary before August 13 by all members who intend to take part in the gathering.

If any member has not received a copy of the programme and reply form, application for a duplicate of each should be made to the Secretary.

Excursion on September 6.

The whole-day excursion by motor-coach to Froghall, North Staffordshire, promises to be very enjoyable—given good weather—for the scenery on the route selected for the tour is particularly attractive. The following account of the route to be traversed has kindly been contributed by a member of the Local Reception Committee.

The main road from Stockport to Macclesfield passes through the eastern edge of the fertile Cheshire plain, keeping on the left hand the western outliers of the Peak. A climb of four miles brings us to the Buxton–Congleton road at Cleulow Cross, whence from an altitude of 1160 ft. magnificent views of the Staffordshire moorlands are seen, with the Roaches and Morridge ahead, the conical crest of Shutlingslow (1660 ft.) to the left, and the beautiful Dane Valley at our feet. A fall of nearly 600 ft. follows through Wincle to Danebridge, at the head of a horse-shoe of wooded hills, which provide a setting assuredly as fair as that of any village in the kingdom. At the bridge which spans the Dane the route enters Staffordshire.

Near Waterhouses station, some eight miles beyond Leek, the water of the Hamps sinks in a normal summer through the rocky limestone bed of the river. William White (1834) says of the "wild moorland district" of Weaver Hill that the inhabitants formerly used the distich: "Wootton under Wever, where God came never." Yet these limestone moorlands have their own austere beauty.

The descent to the gorge-like Churnet Valley at Alton takes us through scenery of a very different type. Alton Castle stands on the edge of a sandstone cliff, and looks like a stronghold of Rhineland.

The journey from Alton to Froghall, and afterwards to Leek, allows the "works party" to see more of the Churnet Valley. The canal reservoir at Rudyard will be noticed before the Dane Valley is crossed; Cloud End is long a conspicuous feature on the left. A representative idea of the appeal of the gracious plain of Cheshire will be gained on the way from Macclesfield to Manchester.

The "non-works party" soon come to Ellastone, the "Hayslope" of "Adam Bede," where Adam had his workshop and Dinah Morris came to preach. At Mayfield the poet Thomas Moore lived, and heard the bells of Ashbourne. The Dove is crossed at Hanging Bridge, and Ashbourne is soon reached. The Parish Church of St. Oswald dates from 1241; the chancel is the oldest portion of the fabric, and contains twelve finely-proportioned lancet windows; the tapering spire rises to a height of 212 feet.

The winding road through Thorpe brings us to the entrance to Dovedale, where the bare hills of Bunster and Thorpe Cloud stand sentinel. Thence back to the main Ashbourne–Buxton road, from which glimpses are had of beautiful dales on either hand, as far as Newhaven. Passing through Youlgreave, we reach at Alport the lovely Lathkill Dale, one of the fairest of all the Derbyshire dales, and follow closely the Lathkill river to the vale of the Wye near Haddon Hall, which awakes romantic memories of Dorothy Vernon.

The beauties of the Wye Valley, through Bakewell and delightful Ashford-in-the-Water, are deservedly famous. A sharp climb through Taddington and quick descent down Topley Pike bring us back to the Wye opposite the end of Great Rocks Dale, and the gorge-like valley is followed through Ashwood Dale to Buxton. The journey from Buxton to Manchester affords charming views of moorland over the Goyt valley.

Library Gifts.

In the March issue of the *Monthly Journal* a list was printed of books that would be welcomed in the Institute's Library to complete the files. The Council acknowledges with gratitude the presentation to the Library of the following books that were included in the March list :—

Presented by Mr. H. J. H. Drury, Agricola's *De Re Metallica* (Hoover's translation), and *The Smelting of Copper in the Swansea District*. By Col. Grant-Francis.

Presented by Professor C. O. Bannister, *Journal of the Iron and Steel Institute*, Volume 63.

On p. x of the present issue will be found another list of some of the books required in the Library. If members have copies of these they would be gratefully received by the Council as would offers of other books for the Library. Particularly appreciated would be a copy of each new book written by a member. The Librarian will be glad to answer questions, by telephone or letter, regarding books that members may be in a position to present to the Institute.

Annual Subscriptions.

All members—except those who have issued banker's orders—should by now have received letters from the Secretary reminding them that their subscriptions (£3 3*s*., or £1 1*s*. in the case of Student Members) became due on July 1 last. MANY POUNDS WILL BE SAVED TO THE INSTITUTE IN SENDING FURTHER REMINDERS IF MEMBERS WHO HAVE NOT YET PAID THEIR SUBSCRIPTIONS WILL BE GOOD ENOUGH TO FORWARD THEM WITHOUT DELAY.

More than 500 members pay their subscriptions by means of banker's orders. In this way a very considerable saving of labour and expense, and avoidance of risk of loss in the post, is effected. It is the hope of the Council that more members will take advantage of this convenient method of payment. All that the member has to do is to fill in once, a form (to be obtained from the Secretary) instructing his banker to pay his subscription to the Institute's banker every year. This saves the writing of cheques, stamp duty on cheques, addressing envelopes, and postage—on the part of the member; and it saves the Institute the preparation of receipts, addressing envelopes, and postage, for—as the money passes direct from one bank to another—no receipt is necessary. It also obviates the occasional necessity for issuing several notices regarding subscription arrears.

PERSONAL NOTES

Mr. N. Ageew will be leaving Leningrad in July for a tour of Southern Russia (Anapa, on the Black Sea). Correspondence, however, should continue to be sent to him at Leningrad 21, Sosnovka 1/3 Kv. 81–A.

Mr. L. B. Hunt has received the degree of Doctor of Philosophy (London) for research in metallurgy.

Mr. F. N. Rhines has joined the Metals Research Laboratory of the Carnegie Institute of Technology.

Mr. Carl H. Samans has received the degree of Doctor of Philosophy of Yale University and has been appointed Instructor in Metallurgy under Mr. Stoughton Bradley at Lehigh University.

Mr. Arthur W. Trash celebrates this month the 25th anniversary of his appointment as chief chemist to Messrs. H. J. Enthoven & Sons, Ltd. Mr. Trash was for many years assistant to Mr. Geo Patchin, A.R.S.M., Principal of the Sir John Cass Institute. Mr. Trash has carried out a number of experiments dealing with the Harris process of lead refining, and was a member of the sub-panel of the British Standards Institution in compiling the standard methods of lead analysis.

Obituary.

Professor Arvid Johansson of Stockholm died on June 23, after a long illness. He was elected a member of the Institute on February 21, 1929.

PAPER No. 673. This paper is not to be reprinted, wholly or in part, until presented (and then only with due acknowledgment) at a meeting to be held on September 3–6, 1934, in Manchester. The Institute as a body is not responsible for the statements or opinions expressed in this paper, on which written discussion may be sent to the Secretary not later than October 1, 1934.

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This paper will not be reissued in the form of a separate "Advance Copy," a method of publication which has been discontinued.

THE IMPROVEMENT OF WHITE BEARING METALS FOR SEVERE SERVICE: SOME GENERAL CONSIDERATIONS.*

By D. J. MACNAUGHTAN,† Member.

Synopsis.

Development in the internal combustion engine is imposing increasingly severe conditions on the bearings. Consideration is given to the theoretical functions of an ideal white metal, and the manner in which the stresses produced in service tend to cause failure by cracking. Since the normal action of the stresses are compressive, special attention is given to the tension stresses which are shown to lower the fatigue range of the metal and to open up incipient cracks. Based on this analysis the mechanism of crack formation is discussed.

The following directions in which improvement in service behaviour may be secured are considered: (1) diminishing the intensity of the stresses in the metal by modifications in (*a*) certain features of design; (*b*) the material used for the liner: (2) increasing the fatigue-resisting properties of the white bearing metal in respect to which results obtained in preliminary investigations of the fatigue properties of high tin–antimony–copper alloys with and without addition of a further element are given.

Introduction.

It is nearly a century since Isaac Babbitt introduced a bearing comprising two essential parts: a liner of relatively strong and rigid material coated with a thin layer of white metal. The advantages of this combination have proved of great importance in engineering practice but have not even yet revealed themselves clearly in terms of fundamental scientific principles. More attention has been directed to the metallurgy of the white metal coating than to the mechanics of the combination.

The alloy used by Babbitt consisted largely of tin, with small additions of copper and antimony; and in subsequent developments, the additions of copper and antimony in this ternary alloy have been varied within limits to suit different applications. Lead-base alloys with antimony and tin and frequently also with copper, have also

* Manuscript received June 4, 1934.

† Director of Research, International Tin Research and Development Council, London.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LV, 1934. Reference should accordingly be as follows: *J. Inst. Metals*, 1934, **55** (Advance copy).

found extensive use; and more recently, copper-base alloys have been employed in special cases although they possess only certain of the qualities that hitherto have been regarded as essential in bearing metals.

Investigation has proceeded in two distinct directions. On the one hand, engineers have compared different available alloys with special regard to technical and economic considerations under varied conditions of service and manufacture; and on the other hand, metallurgists have studied the structures and properties of the several groups of alloys with special attention to certain physical properties. In recent years, efforts have been made to ascertain what particular physical properties do indeed contribute to the success of bearing metals, and, although progress in this essential direction is difficult, valuable light has been thrown on the problem, and it appears reasonable to expect that material advances will be made as a result. It is natural that efforts in this direction should have been stimulated by difficulties experienced by engineers.

Recent development in the internal combustion engine in particular has produced a combination of three difficult conditions : high bearing pressures, high temperatures, and rapid change of loading. The connecting rod and main crank-shaft bearings in such engines have to face conditions more severe than in any other important class of engine or machine. In view of their superior merits, particularly at elevated temperature, tin-base alloys have been used in preference to lead-base alloys, and have undoubtedly given excellent service under severe conditions. The conditions of service, however, are increasingly advancing to a stage that calls for further improvement in tin-base alloys, or, alternatively, for the substitution of some other type of alloy.

The need for higher bearing pressures arises from two distinct causes : (1) higher maximum gas pressures, required to give higher mean effective pressures, as, for example, when superchargers are used in petrol engines, or to give the conditions required for effective combustion and high economy in the compression-ignition engines now increasingly used in transport; and (2) higher piston speeds. It is an important matter for consideration that whereas the power of an engine increases approximately in proportion to the piston speed, the inertia forces imposed on the bearings and other parts increase with the square of the piston speed. It follows that the efforts that engineers have made to gain more power by increasing the speed of the piston have reacted severely in many directions as well as on the bearings.

The higher temperatures involved arise also chiefly from the higher

speeds, although bearings are in some degree heated from the combustion chambers and valve casings. The chief source of heat in the bearing is friction, and the conditions are eased appreciably when the oil is circulated enough to carry away heat that otherwise would have to be conducted through the white metal and adjacent parts of the engine.

The need for high revolutions and rapidly fluctuating loads on the bearings arises directly from the increasing use of relatively small, high-revolution engines giving high power per unit of weight. Rapid advance in this direction has tended to make fatigue-cracking more important than in former times and has tended to redirect inquiry to ascertain the true theoretical functions of an ideal white metal and the physical properties that it ought to possess.

General Considerations.

Fig. 1, which illustrates a longitudinal section of a bearing, gives an impression of the stresses induced in a white metal coating supported by an ideally rigid liner. The radial pressure p tends to spread the white metal laterally—and also circumferentially—and this spreading tendency is resisted by lateral pressure p', the action of which, since it reduces the shear stress in the white metal, enables it to withstand a greater pressure p than it can resist in a simple compression test carried out on a sample surrounded by air at atmospheric pressure. A graph plotted below the section indicates how the pressures p and p' decrease towards the ends of the bearing where the pressure of the oil is less. The pressure p' is ordinarily less than p, and the difference may be roughly constant when the metal is loaded so severely that it yields in a plastic manner. The gradient in the lateral pressure p', tending to push the white metal out at the ends of the bearing, is resisted by shear stresses acting along the surface between the white metal and the rigid liner. The success of a bearing metal in practice depends largely on its being able to accommodate itself to changes in load, and in accommodating themselves to such changes white metals possess important advantages over other materials. If the changes demanded are unduly severe, however, it appears that white metals as well as other alloys are liable to suffer from fatigue-cracking.

One of the first requirements in a bearing metal is a certain degree of strength, sufficient to carry severe pressure p without undue lateral pressure p' and sufficient to resist the shear stress q without undue displacement from the ends of the bearing. The strength, however, should not be excessive, because it is the very weakness of the metal

that enables it to yield plastically and to flow away from places where the pressure may increase locally. If the bearing metal is not soft enough to flow, or if it does not retain some measure of its original softness in continued service, lubrication may fail locally and the bearing will then seize-up and fail.

It is believed that a capacity for retaining softness after long continued service is intimately related to low melting point, and low

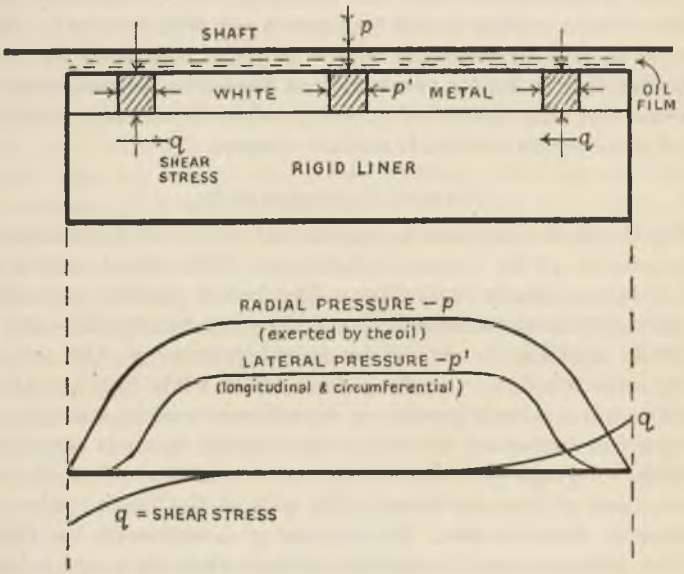

FIG. 1.—Ideal Representation of Radial and Circumferential Pressures and Shear Stresses in a White Metal Coating.

melting point possesses also another great advantage since, in the event of undue increase in temperature, melting out occurs without the bearing alloying itself to the shaft, thereby avoiding complete seizure and irreparable injury to the shaft. When an alloy hardens unduly under cold-work, it tends to score the shaft even when seizure may not immediately result. The merits of the tin-base alloys in these respects are well known. The advantage of melting out when there is a considerable increase in bearing temperature applies also to certain cadmium alloys which have been proposed, but at the present time their general merits as bearing materials have not been evaluated and they certainly present much greater difficulties in casting on steel or bronze liners than in the case of the tin-base alloys.

In addition to the limited degree of strength required to withstand

the normal working stresses already described, some degree of temporary resistance to "cold-working" is desirable to assist the white metal to stand severe pounding caused by excessive vibration or irregular loading, but it is important to distinguish between temporary and permanent hardening by cold-work. Although temporary resistance may be desirable to resist rough treatment, permanent hardening is undesirable and is one of the greater faults to be avoided. A bearing metal that tends to harden permanently may run well enough for a time but will be likely eventually to lose its essential character and then to score the shaft or break in a brittle manner. It is believed that a capacity for self-annealing is one of the more valuable characteristics of a successful bearing metal, and that low melting point tends to afford the quality in question.

It is desirable that a limited degree of hardness, sufficient to withstand normal stresses, should be retained up to the temperatures that the lubricant can withstand without rapid deterioration. Temperatures of 120° to 140° C. have, in the past, been regarded as sufficient, but improved lubricants now permit of higher temperatures up to a possible limit approaching 200° C.

Fatigue-Cracking.

Although failure by pounding is occasionally important, the outstanding difficulty experienced in current severe conditions, particularly in internal combustion engines, is a peculiar form of fatigue-cracking. After a period of service under pulsating stress and high temperature, numbers of fine cracks appear on the surface of the bearing and spread in all directions to form a network similar in appearance to a tesselated pavement. For some considerable time the bearing continues to run in this condition without overheating or other difficulty, but eventually the cracks spread laterally below the surface of the metal, and when one or more pieces become detached the bearing fails by increase of friction and overheating produced as a consequence of the destruction of the surface and faulty flow of oil in the irregular film. The bearing melts out. To cope with this trouble, it is important to ascertain the cause of the initial cracking and the reason why the cracks spread laterally in such a manner that pieces become detached.

In 1930, Sir Thomas Stanton [1] published the results of certain tests in which thin rings of steel with coatings of white metal on their inner surfaces were subjected to repeated bending. The rings were caused to revolve between three rollers that applied forces to the outer surface of the steel, and the white metal was subjected to stresses that acted alternately as tension and compression in the circumferential direction

only. Fatigue produced cracks in the white metal in a pattern corresponding to that observed in practice although the character of the stresses in the test was indeed very different from that of the complex combination of radial and lateral pressures in the bearing. The range of stress used in this investigation is quoted as 20·7 tons/in.^{2} for the steel, but no corresponding figure is given for the range of stress in the white metal. Assuming that the values of the elastic modulus E are taken as a direct measure of the stress without detailed calculations, and that the values for white metal and steel are approximately 8·5 and 26 million lb./in.^{2}, the range of stress in the white metal would be in the order of 6 tons/in.^{2}, which value is greatly in excess of any determined in fatigue tests carried out by other more familiar methods. (Compare results of endurance tests for similar alloys given below.)

When the conditions of loading in a bearing are contrasted with those produced in this or any other ordinary fatigue test, a difficulty in making comparison is immediately evident. Whereas in ordinary fatigue tests the metal is subjected to tensile stresses that tend to open any cracks that may be formed, the normal action of the stresses in white metal in bearings is compressive in all directions. It is difficult to see how fatigue, even if it occurs, can tend to open cracks in the manner that is actually observed. This difficulty might lead to the conclusion that the cracking is really due to bending, as in Sir Thomas Stanton's tests.

Against this view, however, examples have been cited by Ricardo [2] in describing the distribution of cracking in white-metal bearings of connecting rod big-ends in compression ignition engines, in which cracking is most evident immediately below the shank of the connecting rod, where the radial pressure is greatest and the more rigid support tends to reduce flexure to a minimum. It appears necessary, in view of much similar evidence, to consider whether the cracking may not be produced by stresses acting in a different manner from that illustrated in Fig. 1, and particularly whether tension stresses are present in the circumferential and longitudinal directions in the white metal. The stresses to produce fatigue, of course, must vary in magnitude and possibly in direction during each cycle.

The importance of tension in provoking accelerated fatigue in white metal is illustrated in Fig. 2, which is drawn from results of tests carried out by Haigh. The range of stress required to cause failure in direct stress is plotted on a base representing the mean stress applied during the cycle. It is clear that tension reduces the range of stress required, and that compression increases the range in a corresponding degree.

As the action of tension seems necessary before cracks can open, or even before fatigue can be caused by variations of pressure of reasonable magnitude, it is proposed to consider different causes which, in different cases, may tend to produce tension in the white metal. Five possible causes can be recognized. Of these the following are obvious : (1) In some instances, doubtless, tension may be produced by flexure of the liner, *e.g.* in engines with overhanging bearings or big-ends of extremely light construction; (2) Tension may be produced by flexure of the white metal even in cases in which no flexure of the liner occurs. This may arise when the adhesion of the white-metal coating is imperfect and may account for failures under conditions in which the white metal normally is found to function satisfactorily. Less obvious causes of tension are as follows : (3) Although only pressure is initially

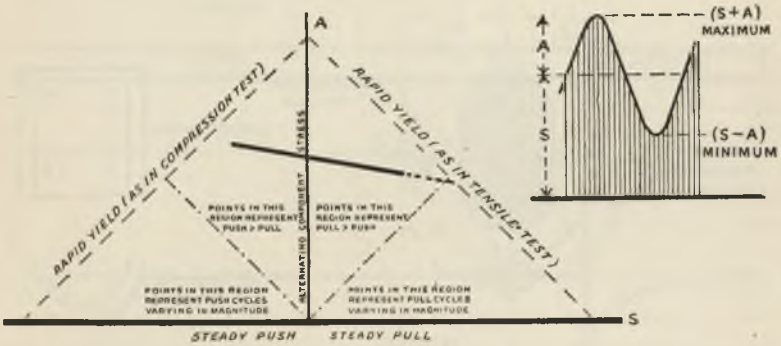

Fig. 2.—The Effect of Altering the Compression/Tension Ratio on the Range of Stress Required to Cause Fatigue in White Metal (Haigh Fatigue Test).

produced in the lateral directions by applied radial pressure it would appear that as a result of the local spread of the metal around the area subjected to maximum pressure, tensions may be produced circumferentially and longitudinally as indicated in Fig. 3. These tensions would diminish to zero on removal of radial pressure which had not exceeded the elastic limit, while residual tensions would remain if the elastic limit had been exceeded. It is to be noted, however, that these tensions are produced around and outside the actual zone of maximum pressure in which there is the greatest tendency for cracking to occur; (4) The friction of the oil upon the surface of the white metal, although chiefly transmitted by shear-stress in the white metal may perhaps in some cases produce circumferential tension. The magnitude of such forces, however, cannot be large. Assuming a nominal pressure of 1000 lb./in.^{2}, giving a peak pressure perhaps as

great as 6000 lb./in.^{2} and a coefficient of friction 0·015 (a high value) the tangential drag on the surface of the white metal is only of the order of 90 lb./in.^{2}; (5) Tension is set up when the white metal cools after solidification or subsequently, and the stress that may be produced in this manner is considerable. Assuming that the white metal and liner cool simultaneously, and that both are free from stress at a temperature $T1$, then the strain that has to be produced by tension

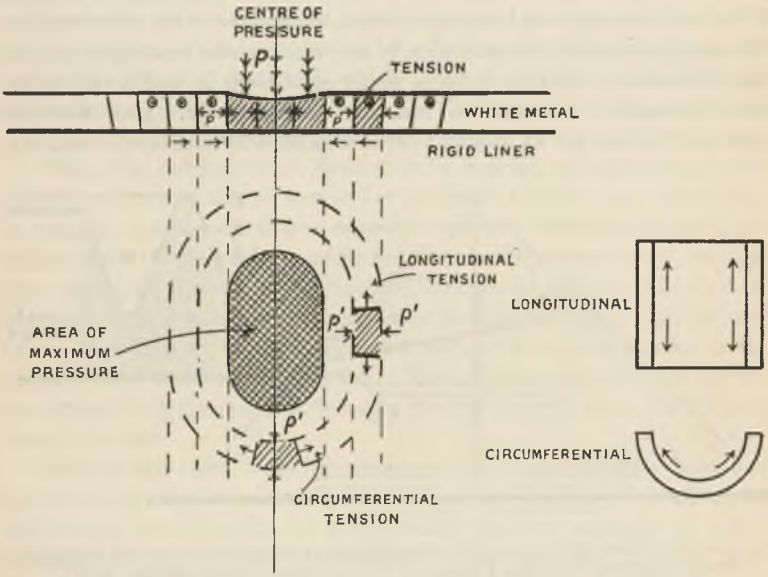

Fig. 3.—Diagram Showing how Circumferential and Longitudinal Tensions may be Produced during Application of Radial Pressure p.

after cooling to $T2$ to neutralize the contraction due to cooling is given by f in the equation that follows :—

$$\frac{f}{E}(1 - \sigma) = (\alpha_{wm} - \alpha_s)(T_1 - T_2)$$

where E denotes Young's modulus and σ Poisson's ratio for the white metal, and α_{wm} and α_s are the coefficients of thermal expansion for the white metal and steel, respectively. In this simple form, the equation neglects the effects of the stress in the steel—which is assumed to be practically rigid. The equation indicates that a difference in temperature of 100° C. would produce approximately 6·8 tons/in.^{2} in the white metal, in circumferential and longitudinal tension if the metal remained elastic. In reality, however, a range of temperature only a

little greater than 50° C. produces tensile stresses reaching the yield-point of any ordinary white metal. The importance of thermal contraction in relation to fatigue is therefore obvious.

The manner in which cracks form in a network on the surface of the white metal appears to be entirely consistent with the idea that tension acts both longitudinally and circumferentially in the manner indicated under headings (2) and (4) above. No evidence has appeared, so far, that the location of the cracks is related to macrostructural features, and the pitch of the network seems to be governed by mechanical considerations. When any one crack forms and opens, the tension is relieved in the immediate vicinity, being absorbed by shear stress between the white metal and liner as indicated in Fig. 4.

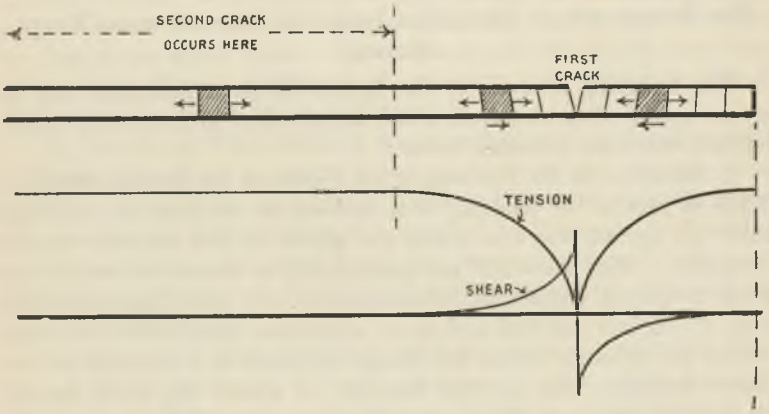

Fig. 4.—Diagrammatic Representation of Possible Mechanism that Determines the Spacing of the Cracks in a Fatigued White Metal Coating.

As a consequence of this relaxation, the next crack forms at a distance such that tension is present in sufficient degree to affect the fatigue limit adversely.

The sequence of events in the formation of a crack is important because it may indicate the measures required to cope with the trouble. If, as Murphy [3] has implied, the crack originates at the junction between the white metal and liner, and works up to the surface, the solution of the problem may lie in improved adhesion to the liner.

Micro-examination of a number of cracked bearings indicates that the cracks start at the surface and work downwards; an example is shown in Fig. 5 (Plate I). Moreover, as shown in Fig. 6 (Plate I), the circumferential cracks do not necessarily follow the bond between the white metal and liner, but may keep definitely clear of the bond. In the

figure reproduced, details of the microstructure of the alloy are clearly discernable between the crack and junction. More detailed examination of the cracks and structure does not suggest any close relation between the two.

The evidence appears to support the view that the cracks originate at or very near to the surface, and that they are caused by fatigue under the action of wide variation of normal pressure coupled with circumferential and longitudinal tension.

The observed tendency of the radial cracks, after penetrating a certain proportion of the depth of the white metal, to turn laterally is possibly due to the action of pulsating shear stresses acting laterally around the margins of the "tesselations."

The Possibility of Obtaining Improved Service from White Metals.

The foregoing analysis of the factors involved indicates that to secure improved service from white metals there are two chief possibilities, which are discussed below :

I. *Reduction in the Intensity of the Forces on the Bearing Metal.*— While in general the tendency is to increase the loads on the bearings there are certain ways in which the effects of this increase can be mitigated. Thus Ricardo [2] has pointed out in connection with compression-ignition engines the advantages of : (1) providing connecting rods of a lighter material such as an aluminium alloy, which not only reduce the dynamic forces but being composed of a material of low elastic modulus, tend in some measure to absorb the shock forces; (2) suitable design of the manner of attachment of the stem of the connecting rod to the big-end, whereby distribution of the explosion pressure over a wider area of the white metal can be secured; (3) the employment of floating bushes, whereby the shock loading is not always maintained on the same area on the white metal.

It would further appear that a diminution in the intensity of forces on the white metal would be secured if the coating were cushioned with a material of lower elastic modulus than the steel normally used for the liner. In this respect bronze is superior in that it has a considerably lower elastic modulus than steel.

The above are matters of design. The most promising metallurgical contribution appears to be in the direction of reducing the tensile forces that lower the fatigue range of the material. Here the chief possibility would be to secure the minimum stresses in the white metal which result from its contraction during cooling. This involves consideration of : (1) the casting conditions as regards temperature of metal

and liner, to determine the conditions for minimum stress compatible with satisfactory adhesion: in this connection the experimental methods of Müller[4] are of interest; (2) the thermal changes that occur during conditions of service. The ideal type of liner would be one having the same coefficient of expansion and contraction as white metal. The adoption of steel instead of bronze liners has been disadvantageous in this respect, since the coefficient of expansion of the low or medium carbon steel used is of the order of 0·000012, that of bronze 0·000017–0·000018, and that of the white metal 0·000024. Since bronze has been displaced on grounds of lack of strength it is possible that the use of a heat-treated bronze, for example of the type recently described by Wise and Eash,[5] which has greater strength than ordinary bronze, might produce a liner having the requisite physical properties and a coefficient of expansion more closely approximating to that of the white metal. Certain austenitic steels and aluminium alloys which have a coefficient of expansion very similar to that of white metal may also merit consideration.

II. *The Use of White Metals of Superior Fatigue-Resisting Properties.*—The tin-base alloys in general broadly form two groups, one consisting of alloys in which the antimony is below the limit of solubility in tin and in which the hard constituent is supplied by the presence of needles of the copper–tin compound, and the other consisting of alloys in which the antimony exceeds the limit of solubility, so that antimony–tin cubes are also present.

A considerable amount of data has been obtained concerning these two groups with respect to wear resistance, friction under test conditions in bearings, and such physical properties as are revealed by determinations of Brinell hardness, proportional limit in compression, &c. There is, however, almost an entire absence of information concerning fatigue properties. To determine the respective proportions of antimony and copper to give the maximum fatigue properties would require an extensive series of lengthy endurance tests. Short-cut methods, such as the use of ultimate tensile strength/fatigue ratio or a Brinell hardness number/fatigue ratio as are successfully employed for wrought steel, would, therefore, be of great service.

In some preliminary work the effect of increasing the antimony content in a series of alloys in which the copper content was kept constant has been investigated. Fatigue tests were carried out by the rotating cantilever method at the Engineering Department of the National Physical Laboratory and by the Haigh test by Professor B. P. Haigh. The results are shown plotted in Fig. 7. It appears that there is an increase in the fatigue-resisting properties as the

antimony content is raised to about 8 per cent., above which the rate of increase tends markedly to fall off. It would thus appear that the chief governing factor is the amount of antimony in solid solution.

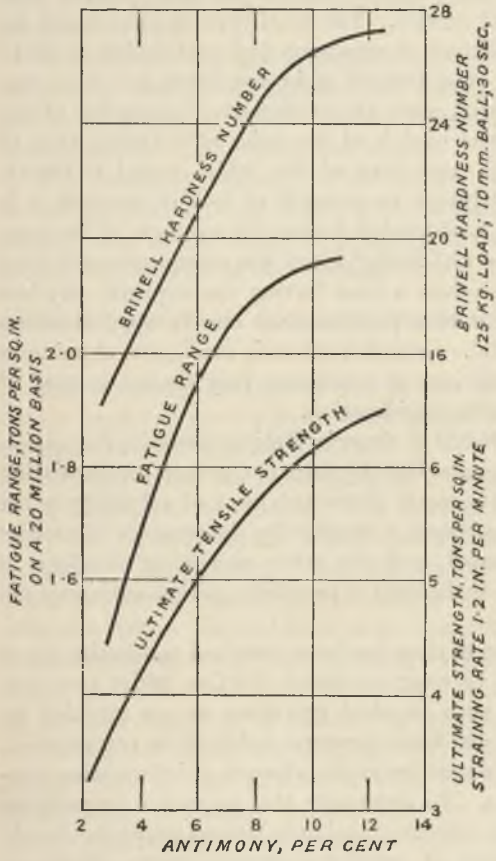

FIG. 7.—The Effect of Increasing Antimony Content in a Series of Copper–Antimony–Tin Alloys of Constant Copper Content (approx. 3·5%) on the Fatigue Range, Brinell Hardness, and Ultimate Tensile Strength. Other Elements Present in Alloys 0·25% Lead, 0·03% Arsenic, Iron trace. Casting Temperature 350° C., Mould Temperature 150° C.

The results of determinations of the Brinell hardness at a constant time of indentation and of the ultimate tensile strength at a standard rate of loading are also shown in Fig. 7. The general similarity in the slopes of the curves gives promise that for exploratory purposes the Brinell hardness and tensile tests are a useful guide to the fatigue-resisting properties.

In view of the statement by Boegehold and Johnson,[6] and Smart,[7] that in alloys of the type under consideration it is disadvantageous to increase the copper content much above 3·5 to 4 per cent. since in service this makes the alloy less resistant to shock at elevated temperatures, an investigation on the effect of copper was postponed and chief consideration has been given to the determination of the effect of the addition of other elements to alloys containing various amounts of antimony but with a constant copper content of about 3·5 per cent. The effect of an addition of 1 per cent. of cadmium [8]

in increasing the Brinell hardness number and ultimate tensile strength is shown in Fig. 8. Consistent with its effect on the tensile properties and the hardness, from actual determination of the fatigue limit of the alloy containing 3·5 per cent. copper and 7 per cent. antimony, made by Professor B. P. Haigh, it appears that the addition of 1 per cent. cadmium increases the fatigue limit from 2·07 tons to 2·47 tons on a 20 million cycle basis. This improvement in the fatigue properties indicates the desirability for further investigations on the effect not only of cadmium but of other elements on the tin – copper – antimony alloys.

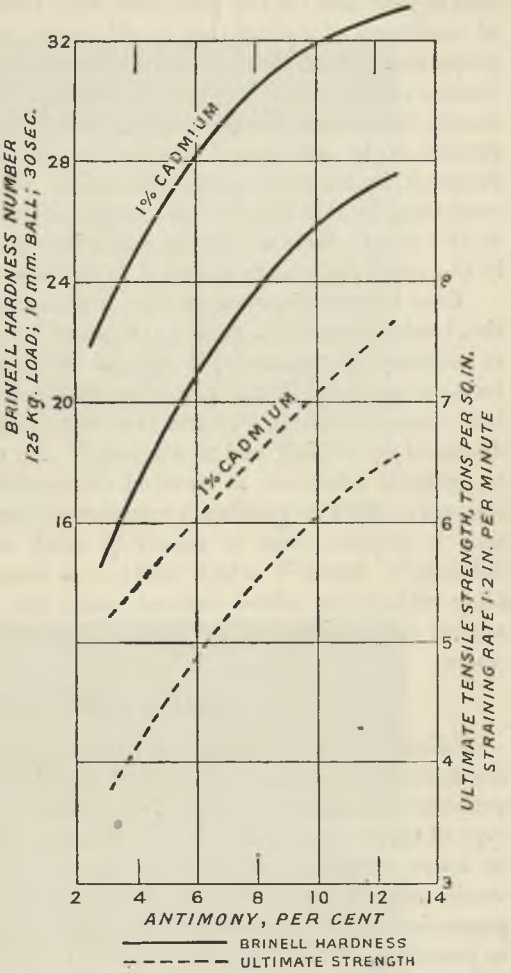

FIG. 8.—Effect of the Addition of 1% Cadmium to Copper–Antimony–Tin Alloys with a Constant Copper Content (approx. 3·5%). Cd Present: Casting Temperature 360° C., Mould Temperature 150° C. Cd Absent: Casting Temperature 350° C., Mould Temperature 150° C. Other Elements Present in Alloys: Lead, 0·04%; Iron and Arsenic, Traces only.

That marked differences in structure and physical properties of white metals can be obtained by varying the casting temperature, and the temperature of the mould has been shown by various investigators, *e.g.* Hudson and Darley,[9] Rolfe,[10] and others. Thus, in the above tests, these conditions were kept constant except that in the case of the addition of cadmium it was found necessary to

raise the temperature somewhat to ensure sound castings. It would thus appear that for any particular alloy there is likely to be a range of conditions of casting that would ensure maximum fatigue-resisting properties. The results of determination of the tensile properties under various casting conditions by Arrowsmith,[11] indicates that variations of tensile strength of the order of at least 10 per cent. are possible. It remains to be ascertained whether this is an index of corresponding variation in fatigue-resisting properties. In any case, the optimum conditions in this respect have to be carefully considered in relation to the other effects of casting conditions on the contraction stresses in the metal and on the adhesion of the alloy to the liner.

Even if determinations of the ultimate tensile strength or indentation hardness serve as a guide to the possible fatigue-resistant properties at ordinary temperatures, it remains to be ascertained whether such tests are as useful in this respect at elevated temperatures. Here the time factor in testing becomes even more important, a matter that is discussed by O'Neill and Kenneford.[12] An obvious consideration as to probable behaviour at elevated temperatures is whether an added element is likely to produce a constituent, *e.g.* the lead–tin eutectic if lead is present even in relatively small amounts (Boegehold and Johnson [6]; Smart [7]), which melts at a lower temperature than the alloy without the added element, since this would tend to result in a more rapid falling off in physical properties as the temperature is raised.

Resistance to Pounding.

Failure due to pounding may occur under service conditions when the maximum pressure on the white metal definitely exceeds the proportional limit in compression. Although at the present time this type of failure is secondary in importance to the cracking which occurs at lower maximum pressures, it clearly requires consideration. It would appear possible that improvement in the fatigue-resisting properties would simultaneously result in improvement in resistance to pounding. This arises from the fact that a white metal of enhanced fatigue properties is likely to have a higher proportional limit not only in tension but in compression. On the other hand, such material is likely to have lower ductility. This raises the question whether the higher strength required to ensure a higher fatigue-resistance may not lead to another kind of cracking, namely, that which would result when the material is deformed beyond the limits of its ductility. To determine whether this may occur, pounding tests are required in addition to endurance tests.

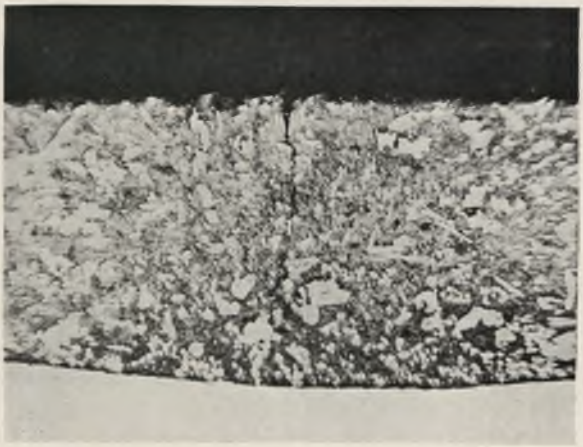

FIG. 5.—Cross-Section of a Cracked White Metal Coating, Showing a Typical Radial Crack. × 50.

FIG. 6.—Cross-Section of a Fatigued White Metal Coating, Showing Separation during Service of a Cracked Section. × 50.

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The results of pounding tests on similar alloys to those considered above are described by Greenwood,[13] and they provide evidence that while a marked decrease in ductility does result in cracking in the material extruded from the bearing it does not cause cracking in the metal remaining in the bearing. At the temperatures at which deformation under pounding becomes severe, such work-hardening as occurs and which tends to lower the ductility of the alloy and therefore encourage cracking under deformation in the case of an alloy of low order of ductility, is counter-balanced by the softening by annealing which takes place at the temperature involved.

Acknowledgments.

The author desires to thank Professor B. P. Haigh, M.B.E., D.Sc., for invaluable discussions on the matters dealt with in the paper, and also for his kind permission to include the results of fatigue tests obtained by him. Thanks are also due to the Director of the National Physical Laboratory for permission to publish the results of fatigue tests carried out for the International Tin Research and Development Council, which results are incorporated in Fig. 7. The experimental work referred to, and in which the author has had the assistance of his colleagues, is part of a programme of research by the International Tin Research and Development Council, who have granted permission to publish this paper.

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[13] H. Greenwood, *ibid* , Part 3.

THE BEHAVIOUR OF WHITE BEARING METALS WHEN SUBJECTED TO VARIOUS DEFORMATION TESTS.

PART I.—INDENTATION TESTS. By A. S. KENNEFORD, M.Sc., STUDENT MEMBER, and HUGH O'NEILL, D.Sc., M.Met., MEMBER. With an Appendix on AN X-RAY EXAMINATION OF BABBITT METAL AND OF THE AGE-HARDENING OF CAST LEAD–ALKALI ALLOY.* By G. S. FARNHAM, B.A., M.Sc., MEMBER.

PART II.—TENSILE TESTS.† By R. ARROWSMITH, B.Met., M.Sc.

PART III.—POUNDING TESTS.† By H. GREENWOOD, M.Sc., STUDENT MEMBER.

Investigations carried out by members of the Metallurgical Department of the Victoria University of Manchester.

INTRODUCTION.

THE following work was undertaken in the first place with a view to obtaining data for assessing the relative merits of different white bearing metals according to various laboratory tests. The need for such information is becoming more urgent owing to the developments taking place in engineering practice which are making more exacting demands on bearing alloys. In the second place it was hoped that the information gained in this way might act as a guide to the production of improved materials.

The tests reported in the present paper might be considered inadequate in themselves since they exclude many of the factors operating under running conditions. Elsewhere, however, studies under such conditions have been made and published. Jakeman and Barr,‡ for instance, examined in an actual bearing at various loads, speeds, temperatures, and conditions of lubrication, a series of alloys of the tin-

* Manuscript received March 14, 1934.

† Manuscript received March 24, 1934.

‡ *Brit. Non-Ferrous Metals Research Assoc.*, Research No. **43**, 1931; *Engineering*, 1932, **133**, 200–202.

Note to Abstractors and Other Readers.—These papers will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LV, 1934. Reference should accordingly be as follows: *J. Inst. Metals*, 1934, **55** (Advance copy).

base, lead-base, and lead-alkali types. Measurements were made of wear, frictional losses, and behaviour with different oils. To provide complementary information, therefore, the present work was carried out on alloys similar to those investigated by Jakeman and Barr, and in Table I such materials are marked with an asterisk.

TABLE I.—*Composition of Alloys.*

Ref. No.	Tin.	Antimony.	Lead.	Copper.	Iron.	Arsenic.	Description.
*I	92·3	3·78	0·30	3·55	0·04	0·03	High tin
*IB	92·8	3·50	0·47	3·21	0·03	trace	
INC	88·8	7·14	0·25	3·74	trace	0·03	
ICd	No. I plus 1% Cadmium.						
II	85·5	9·88	0·33	4·21	0·05	0·03	
IIA	85·0	10·75	0·30	3·90	0·04	trace	
IIMg	No. II plus 0·79% Magnesium						
IICd	No. II plus 1% Cadmium						
IINi	No. II plus 1·96% Nickel						
*IIPb	No. II plus 4% Lead						
	81·7	10·1	4·1	3·99	0·07	0·06	
*IV	39·8	10·5	48·6	1·03	0·04	0·06	Medium tin
*V	5·05	14·9	79·9	0·09	trace	0·06	High lead
*VA	5·40	14·6	79·1	0·04	trace	0·06	
*LA	"Bahnmetall"						Alkali-hardened lead
	Pb 98·65 (sodium 0·6, calcium 0·7, lithium 0·04)						
Tin	"Chempur" brand 99·99%						
Lead	"Tadanac A" brand 99·99%						

Of those which are not marked in this way, attention may be drawn to Nos. ICd and IICd. Additions of cadmium have recently been recommended as enhancing the physical properties of tin-base bearing metals at ordinary and elevated temperatures.

The experimental work may be divided into three groups, and has been reported in sections as follows :

Part I.—Indentation Tests.
II.—Tensile Tests.
III.—Pounding Tests.

ACKNOWLEDGMENTS.

The International Tin Research and Development Council provided financial assistance for these investigations, and gave permission for the results to be published. The authors are indebted to Mr. D. J. Macnaughtan, Director of Research to the Council, for very useful discussions and information. The work was carried out with facilities kindly placed at the authors' disposal by Professor F. C. Thompson, D.Met., and with his constant advice and encouragement.

Part I.—INDENTATION TESTS.

By A. S. KENNEFORD,* M.Sc., Student Member, and HUGH O'NEILL,† D.Sc., M.Met., Member.

With an Appendix on AN X-RAY EXAMINATION OF BABBITT METAL AND OF THE AGE-HARDENING OF CAST LEAD–ALKALI ALLOY.

By G. S. FARNHAM,‡ B.A., M.Sc., Member.

Synopsis.

The effect of viscous flow, ageing, and prolonged heating on the resistance to indentation of tin- and lead-base bearing metals has been investigated. Flow tests with a 120° steel cone at 19° and 96° C. show that Babbitt metal containing 1 per cent. cadmium or 2 per cent. nickel, or a lead–alkali bearing metal, give better indentation results than a plain Babbitt alloy.

The hardness of the different metallographic constituents of bearing metals and their softening on heating to 100° C. have been measured by scratch and micro-indentation tests. The matrices lose 40–45 per cent., and the cuboids 20 per cent. of their hardness, but the cuboids in a Babbitt remain somewhat harder than those in a lead-base alloy.

Two new simple tests are suggested. In the first a lubricated 60° conical casting of the alloy is flattened under 100 kg. load for 30 seconds, and the Mallock hardness number determined. By increasing the duration of loading a flow index may be measured on lines similar to "Hargreaves' analysis." Then, by compressing until cracks appear on the extruded edge, the ductility of the specimen and its cracking stress may be measured. At room temperatures the lead-base alloys show relatively low ductility, and this agrees with their low work-hardening capacity as determined by specially conducted ball tests and repeated impact tests with the scleroscope.

The second method employs an instrument similar to the Herbert pendulum, and measures the damping effect. It may not only be used to give rapid indications of hardness at different temperatures, but is also sensitive to the effect of different lubricants.

Introduction.

The resistance to indentation of soft alloys having lead or tin as their basis, must be considered with reference to the duration of the indenting load. The lead–tin eutectic, for instance, "creeps" continuously under a tensile stress [1] of 0·14 kg./mm.^{2}, whilst the compressive proof stress (0·0005 in.) of Babbitt metal [2] is only 1·3 kg./mm.^{2}. Properties such as these have affected the ball hardness tests of the two cold-rolled pewters represented in Fig. 1. Using a load maintenance of 30 seconds or more, alloy A appears harder than alloy B; whereas at very low times of

* Department of Metallurgy, The University, Manchester.
† Senior Lecturer, Department of Metallurgy, The University, Manchester.
‡ Department of Metallurgy, The University, Manchester.

loading the order of hardness is reversed. In this present case it is obvious that the Brinell value for a standard fixed time of loading is arbitrary, and may be misleading; consequently, unless such graphs as those in Fig. 1 run parallel to each other, it is not justifiable to use the standard Brinell number for making hardness comparisons of soft

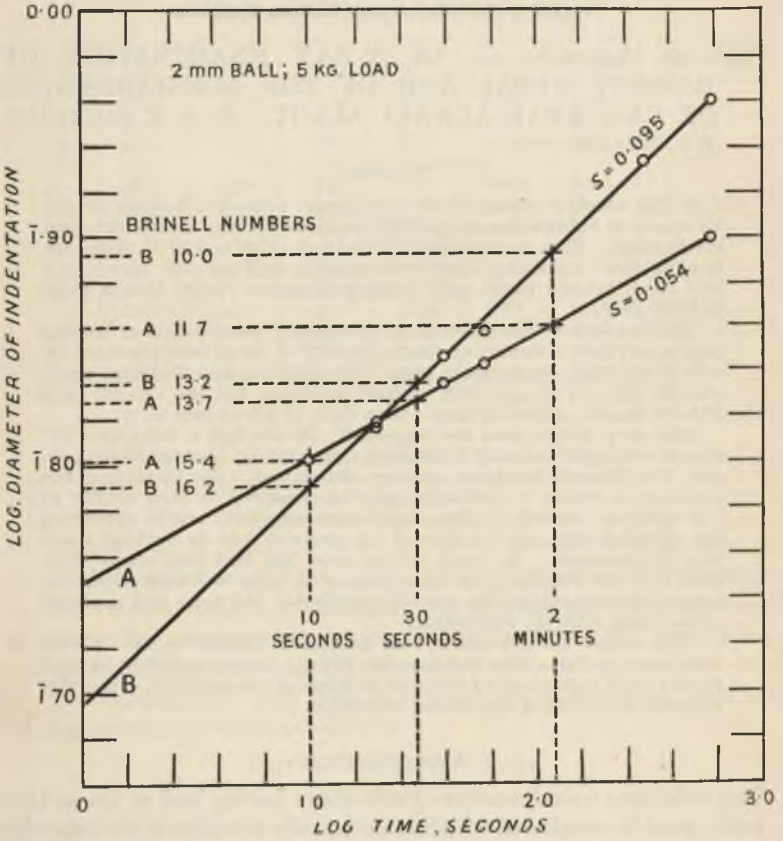

FIG. 1.—Effect of Duration of Load on Two Alloys Having Different S Values.

metals. The present difficulty is due to the different inclination of the two alloy curves, and the work of Hargreaves [3] shows that these slopes depend on the viscous properites of the specimens. Numerically, the inclination is given by the value S in the empirical expression $d = ct^S$, and it appears that *the higher its* S *value, the more a metal is liable to deform by creep.*

The temperature of bearings increases when in use, and their failure

is therefore more likely to depend on properties at elevated than at room temperatures. Whilst the S values of different bearing metals at various temperatures might therefore be of some interest, consideration must first be given to a point concerning their determination by means of ball tests. Just as the Brinell number varies with the test loading ratio (*i.e.*, L/D^2, where D = ball diameter), so the S value may depend on this same quantity. The authors have therefore investigated the point, and with the results shown in Fig. 2. It is evident that

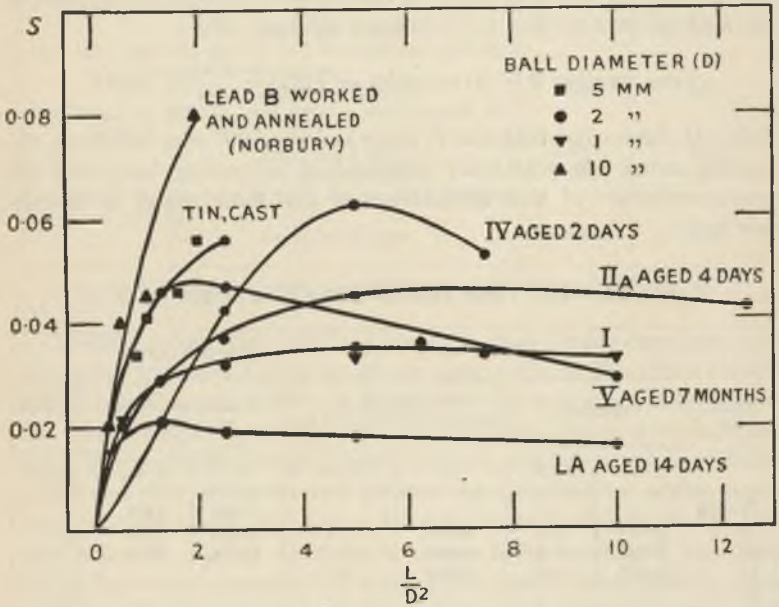

Fig. 2.—Variation of S with $\frac{L}{D^2}$. (See Table I for Compositions of Alloys.)

S is not independent of L/D^2, but passes through a maximum as the loading ratio is increased.

The Use of a Cone for Hargreaves' Analysis.

In many respects cone or pyramid indenters have advantages over the ball, since their angle of indentation is independent of the size of the impression. A given cone or pyramid, therefore, yields hardness values which are truly comparable—though creep effects will still be involved. If the cone obeys Hargreaves' law it ought to be of more general application for this work than the ball indenter. A polished 120° cone of hardened high-speed steel was therefore fitted to the Alfred

Herbert dead-loading machine, and was always lubricated with pure paraffin during tests. A contacting device and lamp were also added to the machine to indicate when the load had been fully applied. The results of many experiments have proved that, in general, Hargreaves' law holds for this cone from 10 up to 600 seconds loading; and in many cases over a very much longer period. Whilst keeping Fig. 1 in mind, hardness comparisons of a sort may conveniently be made on an arbitrary time basis. Lieber [4] recommends not less than 3 minutes loading, but the British Standards Institution's period is 30 seconds, so the authors have worked out results on the basis that:

$$\text{Cone number } (t = 30 \text{ seconds}) = P_c/30 = \frac{4L}{\pi d^2} \text{ kg./mm.}^2.$$

Table II shows that both the S value and the 120° cone hardness of a bearing metal are practically independent of testing load, and the recommendation of this indenting tool for these alloys is thereby justified.

TABLE II.—120° *Cone Tests on Metal Cast at* 400°–200° *C.*

Load, Kg.	Tin (19° C.).				Alloy IB * (19° C.).		Alloy I * (19° C.).
	Unpolished.		Polished on Papers Annealed at 100° C. for 4 Hrs.		Annealed at 100° C. for 5 Days.		
	S.	$P_c/30$.	S.	$P_c/30$.	S.	$P_c/30$.	$P_c/30$.
1·065	...	...	...	...	0·030	18·6	...
5	0·071	6·1	0·054	7·2	0·030	21·5	22·4
10	0·072	5·8	0·060	7·1	0·031	22·3	22·6
15	0·075	4·5	0·063	6·9	...	...	21·9
20	...	...	...	...	...	...	21·9
30	...	...	...	...	0·029	22·2	24·8 (?)

* See Table I.

HARGREAVES' ANALYSIS OF TYPICAL BEARING METALS.

A selection of typical white bearing metals, together with some experimental alloys, have been examined for hardness and flow properties by the 120° cone test. The compositions of the alloys are given in Table I.

Casting conditions are known to play a part in determining the mechanical properties of these alloys. A few tests on one of them in which the mould conditions were varied, are reported in Table III. The cone numbers were calculated for $L = 10$ kg. in all cases.

TABLE III.—*Effect of Casting Conditions on Alloy II.**

Conditions.	120° Cone Values.	
	S.	$P_c/30$ (kg./mm.²).
(*a*) Alloy held at 284° C. for 10 minutes in a graphite mould; cooled in air.		
Aged for 3 days	0·041	27·0
,, 11 ,,	0·041	27·8
(*b*) Cooled slowly from 500° C. in the furnace in a clay crucible.		
Aged for 2 days	...	28·2
(*c*) Alloy held at 284° C. for 30 minutes in a fire-clay crucible; cooled in air.		
Aged for 10 days	0·038	29·0
(*d*) Metal at 400° C. cast into a chill mould at 200° C.		
Aged for 1 day	0·037	27·1
,, 2 days	0·036	26·9
(*e*) Metal re-cast from 400° C. into a chill mould at 100° C.		
Aged for 2 days	0·031	34·2

* Thermal arrests on cooling at 310°, 252° and 234° C.

Conditions (*e*) (400°–100° C.) gave the best results from the point of view of hardness, but to avoid any zoning effects due to the chill,[5] a mould temperature of 200° C. (400°–200° C.) was eventually decided on. Subsequent ingots were cast in rectangular form and 0·5 in. thick, from an electrically-heated bottom-pouring graphite crucible. Within a few hrs. of casting the test surface was prepared on emery papers from 0 to 000 grade, and the metal was generally allowed to age for a day or more. Ageing effects have always to be considered with these alloys, for room temperature is relatively so near to their melting points as to constitute an annealing temperature on the absolute scale. Examples of various changes are given in Table IV.

The ageing process in cast lead–alkali bearing metal is found to be somewhat irregular.

The specimens prepared as described were tested in an oil-bath at room temperature, and also at an increased temperature. For the latter purpose, the platform of the indenting machine was fitted with a steam-bath, and the specimen remained in paraffin within this bath at 95°–96° C. Results which are considered to be representative are given in Table V.

The effect of the increased temperature on the properties of the alloys may be observed from Fig. 3, and the good qualities of No. IICd are noteworthy. Alloy II retains its hardness better than any of the others, but it appears to be very liable to viscous flow (*S* value) at the

TABLE IV.—*Ageing Effects in Soft Metals.*

Reference No.	Treatment.	120° Cone Tests.	
		S.	$P_c/30$ (kg./mm.^{2}).
Sn	Cast at 400°–200° C. Unpolished	0·072	5·75
	,, 350°–50° C. Cold-rolled and water-quenched from 200° C.		
	Aged for 1 hr.	0·070	6·25
	,, 10 days	0·070	6·25
I	Cast at 400°–200° C.		
	Aged for 1 month	0·039	20·2
	Cold-rolled 50% R.T.		
	Aged for ½ hr.	0·175±	23·5±
	,, 24 hrs.	0·093	18·1
	,, 48 ,,	0·082	16·7
	,, 11 days	0·062	16·3
	,, 22 ,,	0·058	16·4
IINi	Cast at 500°–200° C.	0·056	29·8
	Quenched from 200° C. At once	0·060	31·8
	Aged for 1 day	0·045	30·3
	,, 7 days	0·050	31·8
	,, 14 ,,	...	34·2
	,, 2 months	...	34·2
LA	Cast at 500°–200° C.		
	Aged for 3 minutes	...	23·6
	,, 30 ,,	...	24·4
	,, 50 ,,	...	23·6
	,, 1 hr.	...	24·7
	,, 3 hrs.	...	27·5
	,, 21 ,,	...	29·9
	,, 3 days	...	33·1
	,, 13 ,,	...	34·2

higher temperature. Incidentally, the change of cS values has been plotted as well as that of the S values, since Fell [6] considers the former to be more representative of the viscosity effect. No great difference between the two is to be observed in Fig. 3. The lead–alkali bearing metal—like IICd—remains quite hard at 96° C., but then shows a greater percentage increase of creep value than either Alloy IICd or Alloy V. The addition of 4 per cent. lead to the Babbitt metal raises $P_c/30$ at room temperatures, but this advantage has been lost at 96° C.

The contribution made by the various micro-constituents to the changes in properties reported in Table V was next investigated.

SCRATCH AND FLOW TESTS ON THE DIFFERENT CONSTITUENTS OF BEARING METALS.

By using the ball sclerometer equipment,[7] it has been possible to obtain indentation data for the different phases at different temperatures

TABLE V.—120° *Cone Tests.* (*Most Alloys Cast at* 400°–200° *C.*)

Alloy.	19° C.			96° C.		
	$P_c/30$.	S.	cS.	$P_c/30$.	S.	cS.
Tin (*a*)	5·8	0·072	0·083	...	...	...
(*b*)	5·5	0·038	0·051	3·0	0·077	0·121
I	22·6	0·039	0·029	11·0	0·074	0·063
IB	20·0	0·033	0·023	11·8	0·075	0·061
IB (*c*)	22·3	0·031	0·021	10·9	0·072	0·061
INC	29·2	0·045	0·026	13·0	0·078	0·059
ICd	30·4	0·039	0·023	17·6	0·108	0·063
II	26·9	0·036	0·022	16·9	0·105	0·066
IIA	30·8	0·027	0·016	...	...	...
IICd	41·4	0·054	0·024	18·5	0·074	0·047
IINi (*d*)	31·1	0·034	0·019	15·1	0·077	0·054
	29·8	0·056	0·031	14·7	0·086	0·059
IIMg	32·5	0·046	0·025	15·2	0·078	0·055
IIPb	34·6	0·050	0·025	12·8	0·080	0·061
IV	23·1	0·067	0·040	9·5	0·142	0·102
V (*e*)	25·7	0·047	0·028	11·7	0·076	0·061
LA (*f*)	38·0	0·028	0·015	17·4	0·071	0·048
Lead (*g*)	5·2	0·059	0·076	2·7	0·064	0·111

(*a*) Unpolished; (*b*) cast at 350°–50° C., polished; (*c*) annealed at 100° C. for 5 days, tested at 96° C. without cooling; (*d*) cast at 500°–200° C.; (*e*) cast at 425°–150° C.; (*f*) as received; (*g*) cast, polished, annealed at 100° C. for 4 hrs., aged for 14 days.

of some of the bearing metals. Two types of test have been employed: (*a*) scratch tests with the 0·5 mm. hemispherical diamond * under a load of 0·090 kg., and (*b*) micro-indentations using a sharp 120° diamond cone under a static load of 1·065 kg. Cone flow tests were made under the latter conditions; whilst the resistance to scratching ($P_s = 8L/\pi w^2$) was measured in the former. The appearance of sclerometer scratches may be seen in Fig. 4 (Plate I).

Satisfactory results were difficult to obtain on the fine copper–tin needle constituent of alloy II. Scratch tests have been made on impure liquated needle constituent kindly secured for the authors by Mr. F. Moreland, of Messrs. Fry's Metal Foundries, Ltd., from a somewhat similar alloy (2 per cent. copper). They support the view that the copper–tin constituent is harder than the tin–antimony cuboids. With low copper contents the needles will consist of the CuSn phase (see Appendix), but by increasing the amount of copper, Cu_3Sn first separates during freezing and should change to CuSn by a peritectic reaction.

* This diamond was kindly prepared and presented by Mr. P. Whitaker.

Needles in Babbitt alloys are therefore sometimes observed to have a central core differing from the outer coating. In the present work only homogeneous needles were to be seen.

Synthetic SnSb (50 atomic per cent. tin) has also been prepared, which after annealing at 300° C. for 1 week became free from cores and consisted of a single phase. The test result for this alloy is included with the values for polished and etched bearing metals given in Tables VI and VII.

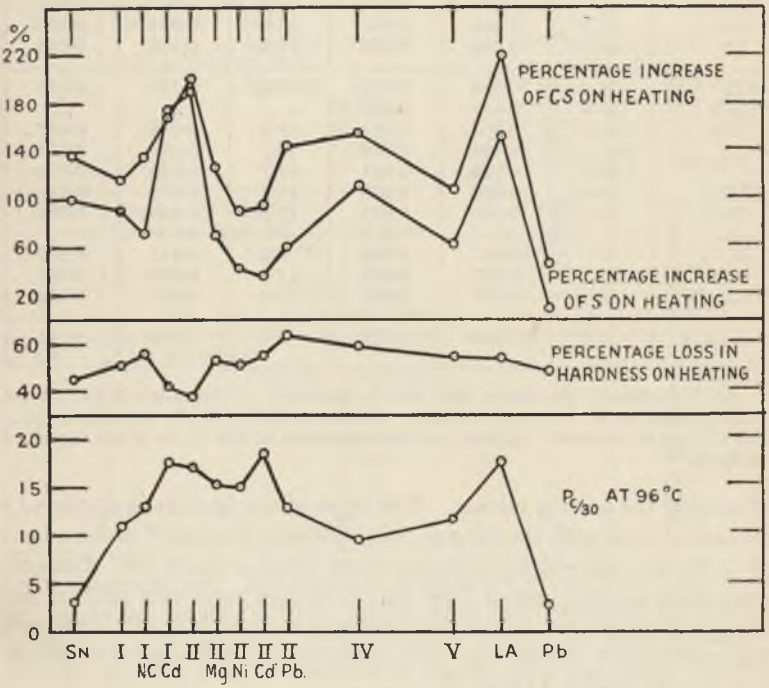

FIG. 3.—Effect on Steel Cone Values of Heating to 96° C.

It will be observed that the softening of the alloys is chiefly due to loss of hardness of the matrix, whilst the cuboids of No. II remain somewhat harder than those of the lead-base alloy No. V. The test on cast antimony indicates that the cuboids in No. V do not consist of this metal alone, but probably of an antimony–tin alloy. The hard constituent of LA metal was too fine to give satisfactory results. Cone flow tests in Table VII indicate that the matrix of No. II is more liable to viscous flow than that of No. V, and this must be responsible for the high *S* value of alloy II (Table V) when heated.

TABLE VI.—*Resistance to Scratching of the Micro-Constituents.*

Alloy.	Constituent.	At 19° C. kg./mm.².	At 100° C. kg./mm.².	Decrease on Heating. Per Cent.
I.—Cast at 400°–200° C.	matrix	32	...	...
II.—Cast at 400°–300° C.	matrix	34	...	...
	cuboids *	127	...	...
Slowly cooled from 500° C.	matrix	33	20	39
	cuboids *	117	92	21
Babbitt alloy (83% tin, 9% antimony, 2% copper). Test on solid separated at 230° C., polished and etched.	needles	260 †	...	...
	cuboids	97–103 †	...	...
SnSb phase.—Cast at 450°–200° C.; annealed at 300° C. for 7 days.	...	104	82	21
	...	109 †	...	...
IV.—Cast at 400°–200° C.	matrix	20	...	...
	cuboids	101	...	...
V.—Cast at 425°–150° C. Slowly cooled from 500° C.	matrix	36	20	44
	cuboids	101	82 ±	19
LA.—As received.	matrix	57	32	44
Antimony.—As Cast.	...	58	...	...

* Scratch parallel to cube edge. Different orientations gave hardness values ranging from 91 to 127 kg./mm.².

† 0·165 kg. load.

TABLE VII.—120° *Cone Flow Tests on the Micro-Constituents.*

Alloy	Constituent.	*S.*			P_c/30. Kg./mm.².		
		At 19° C.	At 100° C.	Increase, Per Cent.	At 19° C.	At 100° C.	Decrease on Heating, Per Cent.
II.—Slowly cooled from 500° C.	matrix	0·036	0·134	270	27	17	37
	cuboids	..	...	...	77	42	45
SnSb phase.—Cast 450° – 200° C. Annealed at 300° C. for 7 days.	...	0	0	0	72	46	36
IV.—Cast 400°–200° C.	matrix	...	...	...	11	...	...
	cuboids	...	...	...	77	...	...
V.—Slowly cooled from 500° C.	matrix	0·040	0·078	95	23	13	43

Effect of Prolonged Heating at 100° *C.*—With long periods of running at temperatures in the region of 100° C., white-metal bearings may undergo the equivalent of annealing treatments. Chilling or coring effects remaining from casting may thus be removed, and the eutectics will tend to coarsen. The authors have investigated the effects of this possible softening influence, certain alloys being tested with the cone, heated in paraffin for 14 days at 100° C., air-cooled in the oil, and then re-tested. The two tin-base alloys, II and IICd, showed no pronounced change, but the lead-rich alloys had softened as shown in Table VIII.

TABLE VIII.

Alloy.	Before Heating.		1 Day after Annealing.		Aged after Annealing.	
	S.	$P_c/30$.	*S.*	$P_c/30$.	*S.*	$P_c/30$.
IV	0·067	23·1	0·038	22·6	...	...
V	0·047	25·7	0·040	18·6	...	...
LA	0·029	36·8	0·021	15·2	0·020	22·6

Freeman and Woodward [8] have reported a similar lowering of compressive proof stress in lead-base alloys.

BALL TESTS AT DIFFERENT LOADS.

The ball test has normally one advantage over the cone in that Meyer analysis may be carried out to determine the work-hardening capacity (n value) of a metal. A knowledge of this property might be of interest as an indication of general ductility, and possibly of resistance to cracking by fatigue. In the present case, the time factor again creates a difficulty, as may be seen from the following experiments.

Certain specimens were indented for four periods of loading (*e.g.* 30, 100, 300, and 600 seconds duration) under weights such as 5, 10, 20, and 50 kg. The results for each period of loading when plotted logarithmically gave the straight lines of the Meyer equation, $L = ad^n$, though the 50 kg. load generally gave unduly high values of diameter. Fig. 5 shows the figures obtained for alloy IIA. The soft metals which have been examined in this way fall into two categories: those having an n value (inclination of the Meyer graphs) practically independent of load-duration (t), and those giving a decrease of n with increase of t. The latter group tend to show an "intersection effect" *on extrapolation, i.e.* the Meyer graphs for various times of loading tend to meet in a point which theoretically would represent a value of load and diameter where time has no effect. The mean stress at such a point should be a limiting creep stress, if any such property exists in a metal. The authors

are not inclined to believe that it does, and have actually found slight creep effects in tin when indented at its observed stress of intersection. Nevertheless, if " intersection " occurs at a relatively high stress value it might indicate a relatively high resistance to creep. For this purpose, such results as have been obtained are included in Table IX.

Norbury [9] has already noticed what the authors have called the " intersection effect " in lead, and his figures have been used for lead B in calculating the values given in Table IX. Incidentally, the authors

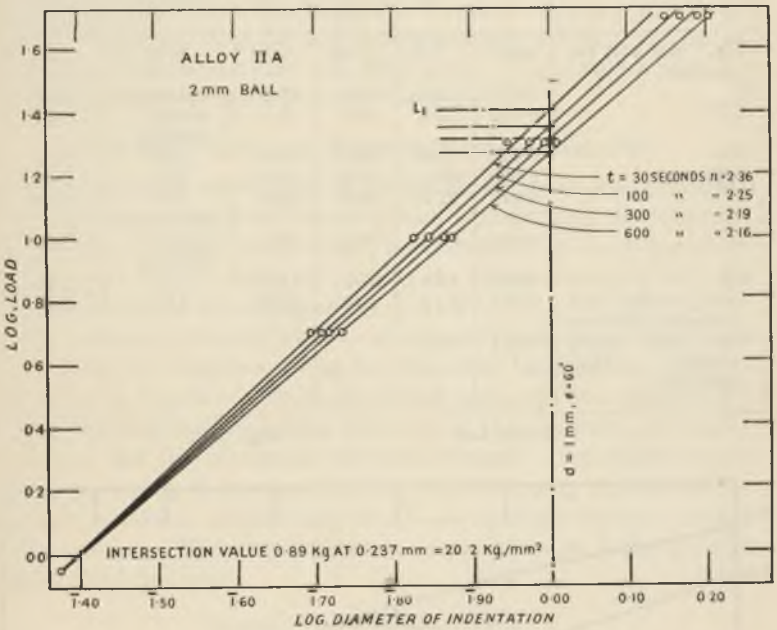

Fig. 5.—Meyer Graphs.

find that Norbury's results for lead A do not obey Hargreaves' law.

To make strict comparisons of ball hardness equal angles of indentation ϕ must be chosen. Introducing the time factor, the authors have therefore measured *the resistance to indentation* (*mean pressure* P_m) *for* $\phi = 60°$ *and unit time of load maintenance* ($t = 1$ *second*). The method used is to interpolate from the Meyer graphs (such as Fig. 5) the values of load (L_1) to give an indentation such that $d/D = \sin \frac{60°}{2} = \frac{1}{2}$. For the authors' 2 mm. ball, this is in fact the load (a) to give $d = 1$. Plotting L_1 against t it is found that the following em-

pirical relation holds quite well: $L_1 = mt^k$, from which m can be obtained by extrapolation. This value m is the load theoretically to give a standard impression ($\phi = 60°$) in 1 second, and on multiplying it by $4/\pi d^2$ the corresponding mean stress, P_m, is obtained. Whether the

TABLE IX.—*Ball Tests.* (2 *mm. Ball.*)

Alloy.	S ($L/D^2 = 1$).	Brinell No. ($L/D^2 = 1$).	Ball Number. P_m for $\phi = 60°$. $t = 30$.	Ball Number. P_m for $\phi = 60°$. $t = 1$.	Mean Stress at "Intersection Point," kg./mm.².	Meyer n Value for $t = 1$ second.
Tin,* cast and unpolished.	0·041	5·30	5·94	8·80	2·78	2·70
I	0·028	18·6	20·8	27·2	curves are nearly parallel	2·22
INC	0·032	23·8	27·2	37·1		2·37
IIA	0·025	25·0	33·8	49·5	20·2	2·60
IINi	0·030	28·2	40·2	62·4	25·4	2·48
IV	0·017	22·3	26·0	29·6	17·3	2·29
V	0·045	26·5	26·5	36·4	curves are nearly parallel	2·00
LA	0·020	33·0	37·1	43·5	do.	2·12
Lead,† worked and annealed (Norbury)	0·055	4·12	4·48	5·70	2·92	2·35
Cast and slowly cooled (Hargreaves)	0·054	3·25	...	...	...	...

* 5 mm. ball. † 10 mm. ball.

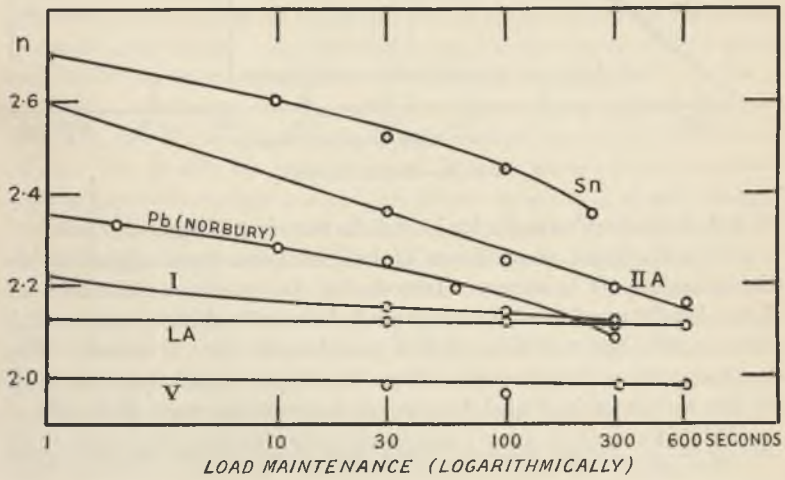

FIG. 6.—Variation of n with t.

hardness value for this short period of time—representing as it does, conditions approaching those of a slow dynamic test—is more useful than that computed after considerable flow of the specimen, it is difficult to say. The values obtained are given in Table IX, and for comparison purposes those corresponding to $t = 30$ seconds have also been calculated. The latter may be compared with the $P_c/30$ values recorded in Table VI, since a 120° cone should give an angle of indentation of (180°–120°) = 60°. The agreement may be considered satisfactory in most cases.

The Meyer n value, which in harder metals than these is a measure of work-hardening capacity, has also to be considered on a time basis. In Fig. 6 there has been plotted the variation of n with t, and an extrapolation back to unit time has been made. The n values for $t = 1$ obtained in this way are included in Table IX.

Dynamic Tests and Work-Hardening Capacity.

The time-factor effect may be mitigated by substituting dynamic tests for those in which an indenting load is maintained for relatively long periods of time; furthermore, measurements of work-hardening capacity may then be made by varying the impact energy of the test, and substituting in the expression $E = a \cdot d^{n1}$.

The authors could only avail themselves of a scleroscope tester, but results with this machine, using the magnifier hammer, are given in Table X. A measure of work-hardening capacity was obtained by making repeated impacts on the same spot of the specimen, and noting the initial and the maximum rebound numbers. According to this method of testing, it appears that the work-hardening capacity of the lead-base materials—particularly No. V—is definitely inferior to that of the tin-base. The extrapolated n values given in Table IX also support this conclusion.

Table X.—*Scleroscope Tests.*

Alloy.	Initial No.	Maximum Induced No.	Increase by Impacting, Per Cent.
Tin.—Cast at 400°–200° C., polished.	4·5	10·5	133
I.—Remelted at 400°–200° C.	14	26	86
IB.—Cast at 400°–200° C.	11	25	127
INC " "	13·5	27	100
IIA " "	22·5	41	82
IV.—Cast at 400°–200° C.	15·5	26·5	71
V.—Cast at 425°–150° C.	21	31	48
LA. As received.	29·5	48	63
Pb. Cast at 400°–200° C.	3	4·5	50

The initial scleroscope numbers put the alloys of Table X in the same hardness series or sequence as that given by the $P_c/30$ values (Table V) and the P_m values for $\phi = 60°$ and $t = 30$ (Table IX).

Application of Mallock's Test to Bearing Metals.

Mallock's hardness test [10] consists of loading a conical piece of the metal to be examined against a smooth hard plate, and measuring the

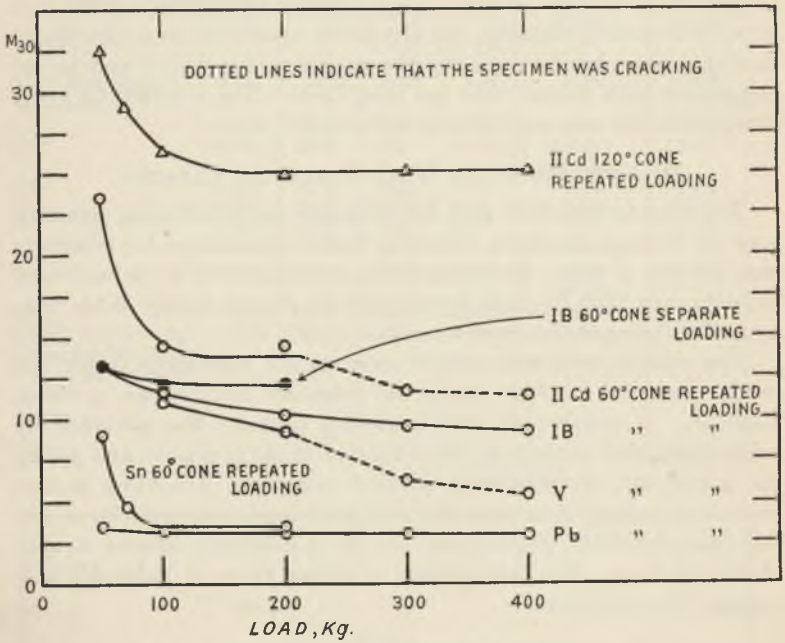

Fig. 7.—Effect of Load on Mallock Number (30 Seconds Loading).

diameter d of the flat produced on the point of the cone. Mallock found for steels that $L \propto d^2$, and so the hardness values given by :

$$\text{Mallock number} = M = \frac{4L}{\pi d^2}$$

should be independent of testing load and truly comparable. Owing to " work-softening " and recrystallization effects, white metals may not behave in quite the same way as ferrous alloys. Two cast-iron moulds were therefore prepared for the casting of 60° and 120° conical test-pieces, and the latter were lubricated with paraffin and flattened against a hard steel plate in a lever machine. Preliminary experiments were

undertaken to investigate the effect of (*a*) cone angle; (*b*) repeated loading with increasing loads on the same specimen, as compared with the separate loading of new cones with the various individual loads; and (*c*) the effect of time of load-maintenance with repeated loading but a constant load.

The results are represented in Figs. 7 and 8. As was expected, the larger cone angle gave higher Mallock numbers. Furthermore, the Mallock number with repeated loading decreased as the load increased from 50 kg., but beyond 200 kg. the decline was not great. For alloys IB at least, separate loading on 60° cones resulted in more constant hardness values than did repeated loading (Fig. 7). Some of the 60° specimens gave an extruded edge to the flat, and with repeated loading at 200 kg. and increasing times this commenced to crack when the deformation became severe. It may be inferred from Fig. 8 that for repeated loading of 100 kg. there is a logarithmic relation between d and t. To be strictly comparable with Hargreaves' experiments and our own work with the 120° steel cone, separate loading should have been used in the time tests. It is possible, however, that repeated loading of a Mallock cone will yield a flow value, S_M, equal in interest to the S values previously discussed. In this way the use of several conical specimens would be avoided.

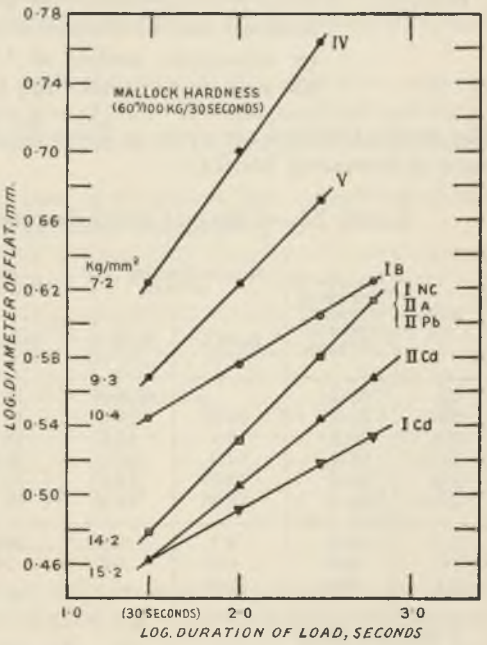

FIG. 8.—Effect of Time of Load-Maintenance with Repeated Loading on 60° Mallock Cones and 100 kg. Load.

The cracking of the edge of the 60° cones seemed to be a useful and simple method of measuring the ductility of the alloys, and the authors have determined the stress, M_c, at which it just became visible during compression on a motor-driven machine. This incipient cracking was

quite easy to observe at a constant straining speed of 0·008 cm./second and Fig. 9 (Plate I) is a photograph of a series of alloys after test. Two experimental methods were tried as follows:

Series I.—Specimens as cast were compressed directly to the cracking point and M_c determined. The Mallock hardness and flow properties had to be measured on a separate set of specimens.

Series II.—A single set of specimens was used, and firstly the Mallock hardness was determined, secondly the flow value S_M by subsequent loading at 100 kg. for periods up to 600 seconds, and finally the cracking values.

The results obtained are given in Table XI, the alloys being listed in order of decreasing ductility.

TABLE XI.—*Tests on Conical Specimens, Cast as Before.*

Alloy.	Diameter of Flat (mm.) at Cracking Series I, 60° Cone.	Stress at Cracking (M_c). 60° Cone.		Mallock Hardness, 100 kg./30 seconds.		S_M Series II. 21° C.
		Series I. 14° C.	Series II. 21° C.	Series I. 14° C.	120° Cone. 14° C.	
IB	25·5+	not	cracked	13·3	19·2	0·060
INC	21·5*	13·8*	13·8	14·2*	20·4	0·104
IIA	20·2	14·1	12·2	14·7	26·9	0·104
IICd	16·3	16·9	16·7	20·4	32·9	0·080
ICd	14·3*	12·0*	12·8	15·2*	22·1	0·054
IIPb	14·1	13·3	11·6	15·7	29·8	0·104
V	11·1	9·7	8·8	10·4	17·5	0·106
IV	9·6*	6·5*	6·9	7·2*	12·4	0·140
LA	9·2†	12·2†	...	...	24·1‡	...

* Tested at 21° C.

† Specimen had previously been subjected to 200 kg. for more than 600 seconds and then aged 25 days before this cracking test.

‡ Aged 7 days after casting and perhaps not fully hardened.

It is believed that this modified Mallock test deserves consideration since (*a*) indentation with a steel ball or cone does not indicate the cracking limit of these alloys, and (*b*), compression tests with cylindrical specimens lack the geometrical conditions of similarity which hold for the Mallock cone.

The Effect of Lubricants.

Tests of bearing metals which ignore the effect of lubricants have only a limited value. So far in the present work, pure paraffin has been used throughout. The Mallock cone test, however, would almost

certainly be sensitive to the application of different lubricants, just as the work of Hankins,[11] and particularly of Kuntze and Sachs,[12] shows how friction effects may be introduced quantitatively into the 120° steel-cone test. The authors have made no experiments along these lines but have investigated a method used by Rehbinder [13] for studying the effect of liquids on the surface energy of mineral crystals. Rehbinder employed a modified Kuznetzov pendulum,[14] and after various experiments the authors have adopted a simple tester very similar to the Herbert pendulum. The latter in fact could almost certainly be used for work of this kind.

The instrument weighs 5 kg. and consists of a rigid 9-in. cross-bar carrying cylindrical weights at each end. A 5 mm. steel ball and holder is fixed rigidly at the middle of the cross-bar, and supports the pendulum

TABLE XII.—*Effect of Lubricant on Pendulum Test. Amplitude of* 10*th Swing from an Initial Amplitude of* 20°.

Alloy.	"Wiped Dry."		Oil 1.		Oil 3.	Oil 7.	
	21° C.	90° C.	21° C.	90° C.	21° C.	21° C.	90° C.
I (Remelted)	3·35	...	3·5	...	...	3·2	...
INC	3·35	0	4·25	...	...	3·5	1·2
IIA	5·8	3·1	5·15	2·1	6·1	5·9	3·0
IICd	8·9	...	8·8	...	...	9·1	...
IV	4·5	2·0	3·9	1·0	...	5·0	1·0
V	5·8	2·5	6·2	2·15	...	6·3	2·9
Glass	19·5	...	...	...	19·35	19·45	...

on the specimen. A pointer, collinear with the ball-holder but on the upper side of the cross-bar, enables the swinging of the pendulum to be read against an adjustable scale. The dimensions of the tester were such that if set to swing on a horizontal glass plate, the time for 10 oscillations was 23 seconds. When the different bearing metals were substituted for the glass plate, this time was practically the same for each specimen, ranging from 22·2 to 22·7 seconds. Observations of the amplitude at the end of each swing for a total of 10 swings were therefore made, and these are the results plotted in Fig. 10. They not only show the different behaviours of the alloys, but also variations due to the type of lubricant applied to the test surface.

Three different oils were chosen: *No.* 1, a light mineral oil of the paraffin-lamp type; *No.* 3, a fairly thick mineral oil, and *No.* 7, the same as No. 3 plus 0·5 per cent. oleic acid. Tests were also made with no applied lubricant but after wiping the specimen and indenter with

benzine. This "wiped" condition does not of course represent a chemically clean surface. Values of amplitude of the 10th swing are given in Table XII. The material which shows least damping is likely

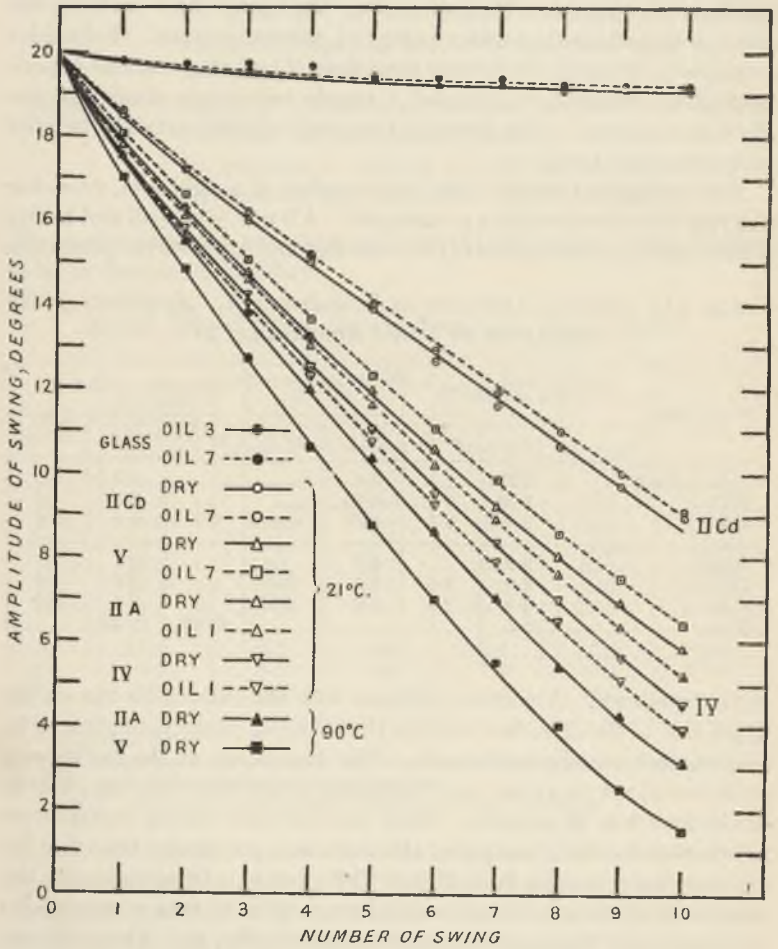

Fig. 10.—Pendulum Tests.

to be the best bearing metal from the present point of view. The lead-base alloy No. V is somewhat superior to the ordinary Babbitt at room temperature, but at 90° C., however, the test indicates that No. IIA is slightly better than No. V. The addition of cadmium improves

No. IIA, apart from the loss of ductility which has been shown in other tests.

These experiments with a pendulum are submitted for consideration because of their simplicity, and because of the way in which they indicate that oils 3 and 7 are superior to oil 1.

APPENDIX.

An X-Ray Examination of the Phases in Babbitt Metal, and of the Age-Hardening of Cast Lead–Alkali Alloy.

By G. S. Farnham, B.A., M.Sc., Member.

(1) *SnSb Phase.*—A synthetic alloy of this composition was examined after annealing for 1 week until free from coring. A spectrogram from an etched plate specimen was obtained by reflection of Cu X-radiation from the surface, as in the Bragg method. The structure proved to be of the NaCl type. By taking a "back-reflection" spectrogram from the same specimen the length of the cube edge was found to be 4·099 A.

This result confirms the work of Morris-Jones and Bowen,[15] who found an NaCl structure with $a = 4{\cdot}092$.

A fine-grained plate specimen of alloy No. II was also photographed by the Bragg type of arrangement. In the complex spectrum obtained the lines corresponding to SnSb ($a = 4{\cdot}099$) were clearly identified. The other lines are reflections from the matrix, a constituent with the spacing of nearly pure tin being identified. This must be the "tin" component of the eutectic.

(2) *Cu–Sn Phase.*—A mass of "needle constituent" was obtained by liquation from a Babbitt alloy. Some brittle needles were carefully broken off, ground in a mortar, and sieved. Portions of ductile alloy remained on the sieve but the fine brittle material passed through. This was packed into a Lindemann glass tube and a Debye–Scherrer spectrogram obtained. The position of spectral lines corresponding to the phase "CuSn" (63 per cent. tin) was calculated from formulæ given by Westgren and Phragmén,[16] and compared with the lines of the spectrogram. The latter were consistent with the assumption that the powder was CuSn, or what Westgren calls the η phase. A few extra lines present seemed to correspond with SbSn, some of which had probably adhered to the needles during liquation.

(3) *The Age-Hardening of Lead–Alkali Alloy.*—A plate specimen of lead–alkali alloy was examined by the "back-reflection" method, both in the newly-cast condition and then after ageing at room temperature for several days. The X-ray spectrum consisted of the lines of

two phases, one of which changed with ageing whilst the other did not. The latter was of the face-centred cubic type with $a = 4{\cdot}889$ A.

Measurements for the former were :—

Phase I.—Newly-cast	F.C.C. . .	4·930 A.
Aged	,, . .	4·937 ,,
N.B. Lead	,, . .	4·94 ,,
Sodium	,, . .	4·24 ,,

The facts could be accounted for as follows: About 0·8 per cent. of sodium can dissolve in lead at 300° C.,[17] but the equilibrium solubility is small at room temperatures. The newly-cast alloy appears to contain supersaturated lead which precipitates a sodium constituent ($?Na_2Pb_5$) during ageing, and brings about age-hardening. The other phase may be $CaPb_3$,[18] since the solid solubility of calcium in lead is said to be very low.[19]

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FIG. 4.—Scratch Tests on Babbitt No. II. × 75.

IB. IIA. IICd. IIPb. VA. LA.

FIG. 9.—Cracking Tests.

[*To face p.* 322

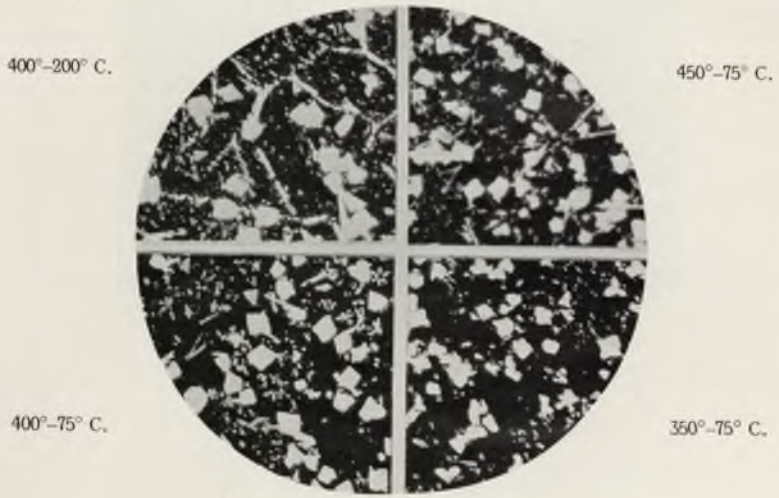

FIG. 14.—Alloy IIA Cast Under Various Conditions.
× 100.

Part II.—TENSILE TESTS.

By R. ARROWSMITH,* B.Met., M.Sc.

Synopsis.

The tensile properties of white metal specimens, prepared by gravity die-casting and without any machining, have been determined at room temperature on a Hounsfield "Tensometer." Various casting conditions were examined for each alloy. Babbitt metal with additions of cadmium gave the highest values of limit of proportionality and ultimate stress. The greatest ductility was obtained from an alloy No. INC containing 89 per cent. of tin.

Tensile tests are not usually carried out on white metal bearings. Although the ultimate strength may be of little obvious importance as a measure of the value of a bearing alloy, yet there is the possibility that it will serve as an indication of the metal's resistance to fatigue.[1] Furthermore, the tensile test provides information as to yield-point and ductility which may throw some light on service failures.

Many bearing troubles are probably due to improper casting conditions. According to Corse,[2] white metals having a coarse-grained structure due to being cast from too high a temperature and then slowly cooled, are unsuitable for bearings. On the other hand, too rapid chilling with resulting fine-grain is equally undesirable. In view of this, the effect of casting conditions on tensile values has been taken into consideration.

Measurements of the tensile properties of *machined* test-pieces of certain white metals have been made by a number of workers, including Smith and Humphries,[3] Mundey, Bissett, and Cartland,[4] and Rolfe.[5] Mundey, Bissett, and Cartland used test-pieces 0·564 in. in diameter and 2 in. long, machined from metal poured into a cast-iron stick mould, which was heated to 100° C., the metal being poured at 350° C. Rolfe included in his work the effect of varied casting conditions on the properties of a typical 85 per cent. tin alloy. He showed that, generally speaking, the tensile strength increases with rise of casting temperature, and decreases as the mould temperature is increased.

Experimental Work.

The chemical composition of the alloys which have been investigated is given in Table I.

The thickness of the white-metal lining of a bearing will not generally exceed 0·25 in. To reproduce as nearly as possible the conditions of the

* Department of Metallurgy, The University, Manchester.

metal in the bearing the diameter of the test-piece should therefore not exceed this figure, whilst in addition it should be cast, rather than machined from a larger ingot. The tests recorded here were made with a Hounsfield " Tensometer " using specimens 0·226 in. diameter and a gauge-length of 0·884 in. These were gravity die-cast in a relatively heavy iron mould preheated to the desired temperature, and were not machined. In order to minimize any possible loss due to oxidation, the alloys were melted rapidly under a cover of carbon, great care being taken to avoid overheating. That very little change occurs in the physical properties of an alloy on such careful remelting, is well illustrated by the following preliminary tests on alloy No. IIA.

TABLE XIII.—*Effect of Remelting Alloy No. IIA.*

Material.	Yield-Point, Tons/in.².	Maximum Stress, Tons/in.².	Elongation, Per Cent.	Reduction of Area, Per Cent.
Received . .	3·70	5·76	11·7	16·0
First remelt . .	3·65	5·86	10·7	13·4
Second remelt . .	3·65	5·88	11·6	14·5
Slow, oxidizing melt	3·70	5·78	10·6	14·5

With the Tensometer, the load is applied to the specimen through a screw-and-lever mechanism, operated by turning a handle. In carrying out a test, the handle was turned either through a complete, or a definite part of a revolution during a given time, and the scale reading of the mercury gauge noted. This method was found to be more accurate than using the autographic system which is fitted to the machine.

As it is now clearly recognized that in the tensile test the time factor may have a profound bearing on the strength of the material, some tests were made on No. IIA alloy, in which the rate of straining was varied.

TABLE XIV.—*Effect of Rate of Straining.*

Time for Complete Revolution of Handle, Seconds.	Yield-Point, Tons/in.².	Maximum Stress, Tons/in.².	Elongation, Per Cent.	Reduction of Area, Per Cent.
60	3·41	5·58	11·3	16·0
30	3·70	5·76	11·7	16·0
(= 0·017 in. per minute)				
15	3·90	5·94	13·1	16·5

In the present work, the 30 seconds rate—equivalent to 0·017 in. per minute—was used in all tests, a stress reading being taken every quarter of a complete revolution of the handle. Some typical stress–strain curves so obtained are shown in Fig. 11. Hooke's law is approxi-

mately obeyed, and for present purposes the apparent limit of proportionality has been termed the "yield-point."

With the exception of the lead–alkali alloy LA, no appreciable ageing effect was observed with the alloys investigated, and the test-pieces were broken approximately 1 hr. after being cast. The tensile strength and ductility of the lead–alkali specimens which were allowed to age for varying times are given in Table XV.

The accuracy of these results is in some doubt, however, as in every case fracture occurred in the shoulder of the specimen. This is believed to be due to cracks existing in the castings, possibly caused by the shape of the specimens.

The results obtained on alloys I–VA, all of which are the mean values of two or more concordant tests, are given in Figs. 12 and 13.

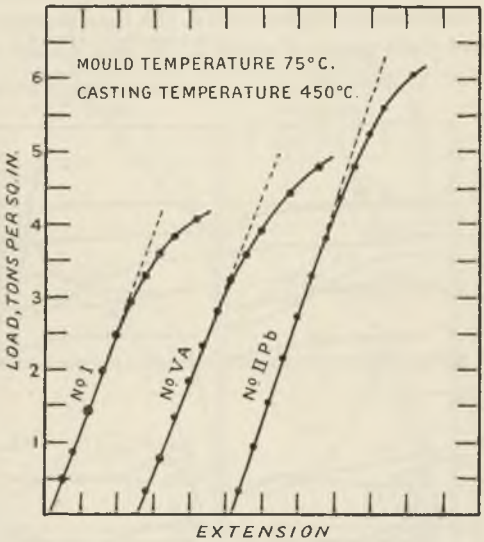

Fig. 11.—Stress–Strain Curves from Tensometer.

Fig. 14 (Plate II) shows the structures resulting from variation in mould and casting temperatures of the best all-round alloy No. IIA.

Table XV.—*Alloy LA. Cast at* 500° *C., Mould Temperature* 200° *C.*

Ageing Time, Hrs.	Yield-point, Tons/in.².	Maximum Stress, Tons/in.².	Elongation, Per Cent.
1	3·12	4·93	7·5
48	3·31	6·07	8·5
144	4·25	6·02	4·8

Discussion of the Results.

It will be seen from Fig. 12 that at room temperature, of all the alloys examined, No. IICd is the strongest. Alloy No. IIPb comes next, whilst No. IIA is but little inferior. With the lower mould temperatures, alloys IIA and IIPb are reversed so far as the yield-point is concerned, that of IIA and IICd being the highest of the series.

As is shown in Table XVI, the hardening effect of 1 per cent. of cadmium on alloys I and IIA is very marked, especially in the case of the former. The improvement, however, is only obtained at the expense of a large amount of ductility. The same may be said for the addition of 4 per cent. of lead to alloy IIA.

The yield ratio—within limits a criterion of the quality of a material—is distinctly higher for No. IIA than for any other alloy. The strength and yield-points of alloys I, IV, and VA are definitely inferior.

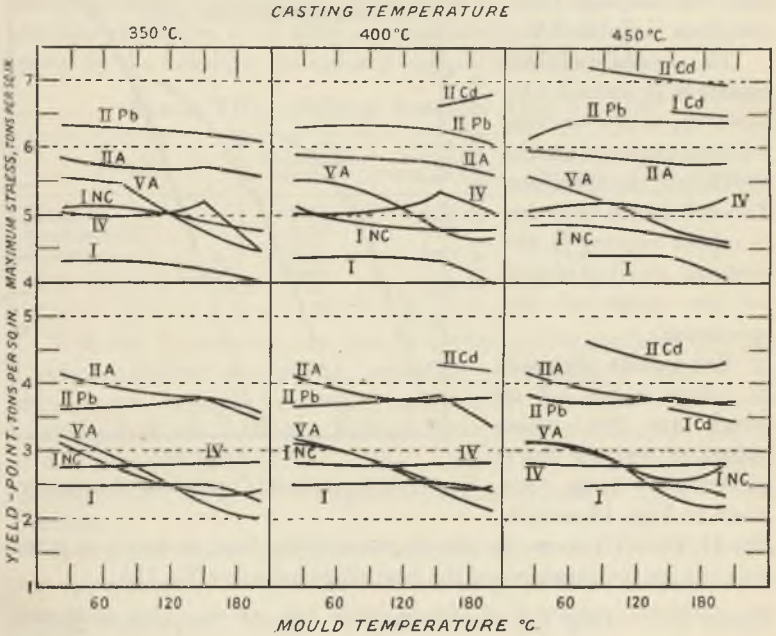

Fig. 12.

Table XVI.—*Effect of* 1 *Per Cent. of Cadmium.*

Alloy.	Mould Temperature, ° C.	Casting Temperature, ° C.	Yield-Point, Tons/in.².	Maximum Stress, Tons/in.².	Elongation, Per Cent.	Reduction of Area, Per Cent.
I	150	450	2·52	4·32	19·0	31·5
ICd	,,	,,	3·65	6·54	6·6	7·5
IIA	,,	,,	3·70	5·74	9·2	15·5
IICd	,,	,,	4·45	7·00	3·2	5·0

Passing to a consideration of the ductility, the high values of the elongation and reduction of area of alloys I and INC are especially

remarkable. The highest elongation figure recorded was for alloy INC cast at 350°–150° C. The elongations of IIA and IV for the colder moulds are much the same, whilst from this aspect No. IIPb and especially VA are much less satisfactory.

The very few tests carried out on the lead-alkali alloy do not justify any dogmatic generalization. From Table XV, however, it appears

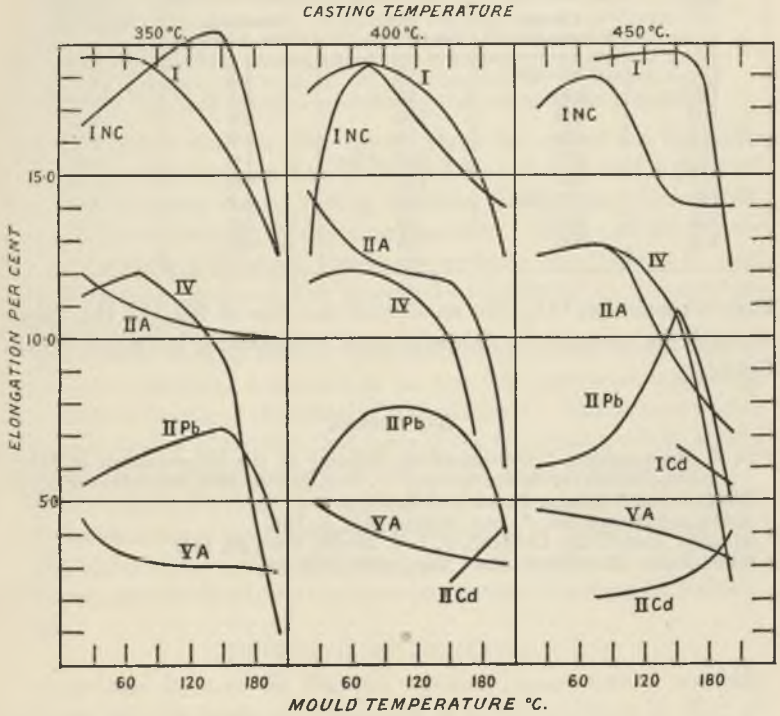

Fig. 13.

that its yield-point is similar to that of No. IIA (see Fig. 12), whilst the elongation is only about one-third that of this alloy.

The best casting conditions simply to give maximum tenacity for bearing metal just under 0·25 in. thick are given in Table XVII, together with minimum values for comparison. It is to be noted that these conditions will not necessarily give optimum all-round results in service; *e.g.* a cold mould will certainly result in poor adhesion between lining and shell.

The chief difference between the values obtained by the author and

those of Mundey, Bissett, and Cartland [4] is in connection with the elongation. The latter reported no elongation on alloys similar to IIPb and IV; a fact for which it is difficult to provide an explanation.

TABLE XVII.

Alloy.	Optimum Conditions.			Lowest Maximum Stress, Tons/in.².
	Casting Temperature, ° C.	Mould Temperature, ° C.	Maximum Stress, Tons/in.².	
I	350–450	75	4·3	4·0
INC	350	75	5·1	4·5
ICd	450	150	6·6	6·5
IIA	450	18	5·9	5·6
IICd	450	200 or less	7·0	6·6
IIPb	450	150	6·4	6·0
IV	400–450	75	5·2	4·5
VA	400	18	5·5	4·5
LA	500	200	6·0	...

Rolfe's conclusion [5] that for an alloy of the type of No. IIA the tensile strength decreases as the temperature of the mould is increased, is confirmed.

REFERENCES.

[1] D. J. Macnaughtan, "Considerations Relating to the Improvement of White Bearing Metals for Severe Service," *J. Inst. Metals*, 1934, **55** (Advance copy).
[2] W. M. Corse, "Bearing Metals and Bearings."
[3] Smith and Humphries, *J. Inst. Metals*, 1911, **5**, 194.
[4] Mundey, Bissett, and Cartland, *J. Inst. Metals*, 1922, **28**, 141.
[5] Rolfe, *Trans. Manchester Assoc. Eng.*, **1929–1930**, 13.

Part III.—POUNDING TESTS.

By H. GREENWOOD,* M.Sc., Student Member.

Synopsis.

A modified form of the Stanton impact tester suitable for the testing of white metals by pounding at different temperatures is described. Results on cylindrical specimens are given, and the unsuitability of this type of test-piece is shown. The use of bearing-shaped specimens with a cylindrical indenter is described. Results are recorded for eight different white-metal bearing alloys and a lead–alkali alloy, cast under various conditions, and tested at 18°, 100°, and 150° C. A Babbitt metal with an addition of cadmium gave the greatest resistance to pounding.

The only earlier work on this subject which the author has been able to trace was that done by Herschman and Basil † who used a modified form of the Stanton impact testing machine, the specimens being chill-cast cylinders 0·8 in. long by 0·4 in. in diameter. These test-pieces were subjected to only 1000 blows, the energy per blow being 0·33 ft.-lb., and the deformation produced was measured at intervals by means of an optical micrometer.

The results showed that at temperatures up to 100° C. the rate of deformation gradually decreased as the test was continued, suggesting that work-hardening of the material had occurred. This is a surprising conclusion in view of the fact that some of the materials used are known to anneal spontaneously after cold-work, even at room temperatures.

In the present investigation it was felt that more useful information would be obtained if the specimen was subjected to 100,000 blows.

The materials investigated were similar in composition to those used by Herschman and Basil, and their compositions will be found in Table I, p. 302.

Description of Apparatus.

A modified form of the Stanton repeated impact testing machine was used for this work, a photograph of which is shown in Fig. 15 (Plate III). The apparatus for holding the normal Stanton specimen was removed from the anvil, the steel weight on the hammer was replaced by lighter lead ones, and by altering the gearing on the machine the frequency of the blows was increased (except in the preliminary tests) to 250 per minute. In order to accommodate a small furnace on the anvil, the lifting mechanism was removed and placed at a point 2 in. along the hammer shaft, a new lifting arm being made 2 in. shorter than that of the standard model, so that when working it did not come in contact with the furnace.

* Metallurgical Department, The University, Manchester.

† *Proc. Amer. Soc. Test. Mat.*, **1932, 32,** (II), 536–555.

The first tests, for comparison with Herschman and Basil's results, were carried out on chill-cast lead cylinders 1 in. high by 1 in. in diameter, and on chill-cast white-metal specimens of the same height and 0·8 in. in diameter. Both metals were poured at 300° C. By means of a short brass bolt the specimens were securely fastened to a plate of hard asbestos, which was bolted on to the anvil. The asbestos was intended to serve as a heat insulator. A loosely fitting steel cap was placed on the top face of the specimen so that the energy of the hammer might be the more evenly distributed.

The deformation of the specimen was measured by means of the apparatus visible on the right of Fig. 15 (Plate III).

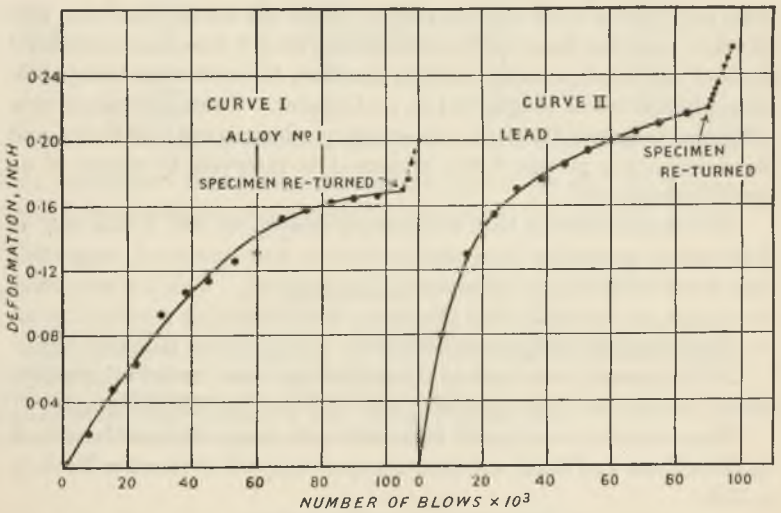

Fig. 16.—Tests at 200° C. on Cylindrical Specimens Cast at 300° C.

Through a hole near the top of the hammer-head a short steel rod $\frac{1}{4}$ in. in diameter was fastened, the end of which came in contact with the short arm of a system of levers giving a magnification of 100. At the end of the final lever arm of the system, a barograph pen recorded the movement in a vertical plane on a revolving drum driven through reduction gearing by a synchronous-speed gramophone motor. As the specimen decreased in height, therefore, the first lever was progressively depressed and the pen raised 100 times this distance. The drum was rotated once in each hr., one revolution of the drum corresponding to 15,000 blows on the specimen. The curve thus drawn, shows therefore, decreases in height against the number of blows. The weights of the lever arms were so arranged that there was no tendency for the first

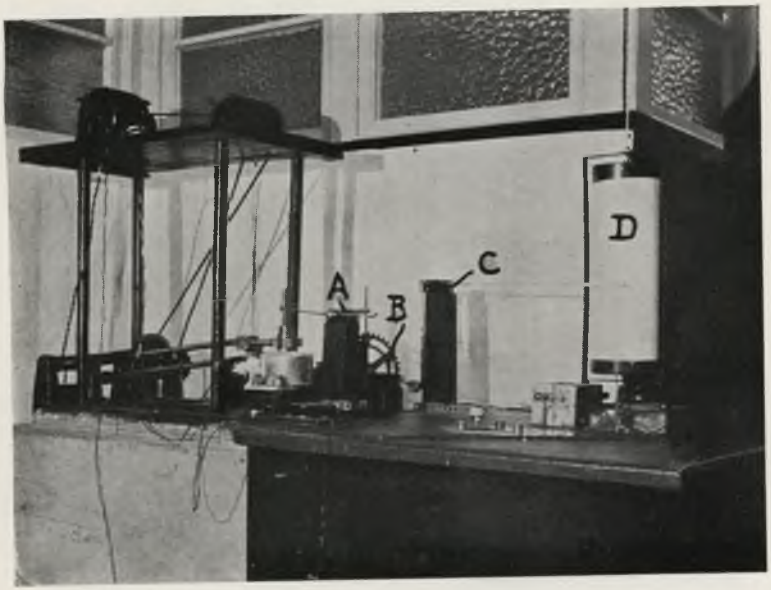

FIG. 15.—Pounding Apparatus.

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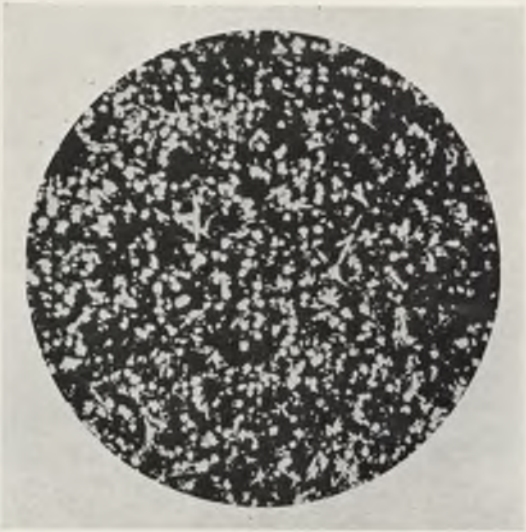

FIG. 22.—Alloy No. 2. Casting Temperature 450° C. Mould Temperature 18° C. × 100.

FIG. 23.—Alloy No. 2 + 1% Cadmium. Casting Temperature 450° C. Mould Temperature 18° C. × 100.

Structures of Alloy Cast in Brass Shell.

FIG. 24.—Alloy INC after Pounding. × 500.

FIG. 25.—Alloy II after Pounding. × 250.

PLATE V.

Alloy No. IV. Alloy No. 1.

FIG. 26.—Linings after Pounding.

lever to spring back after it had been struck by the rod on the hammer, nor for the pen to creep up the paper due to the vibration induced.

The test-piece was mounted on the anvil as described above, its top face covered with a layer of stiff grease to correct the tendency of the cap to bounce off the specimen, and the steel cap placed in position. For tests at elevated temperatures the specimen was surrounded by a small electric furnace and was in contact with a copper–Constantan thermo-couple for temperature measure-ment. The hammering commenced when the test-piece had been at the desired temperature for 30 minutes. An automatic switch was incor-porated so that the whole apparatus was shut down after 100,000 blows had been delivered.

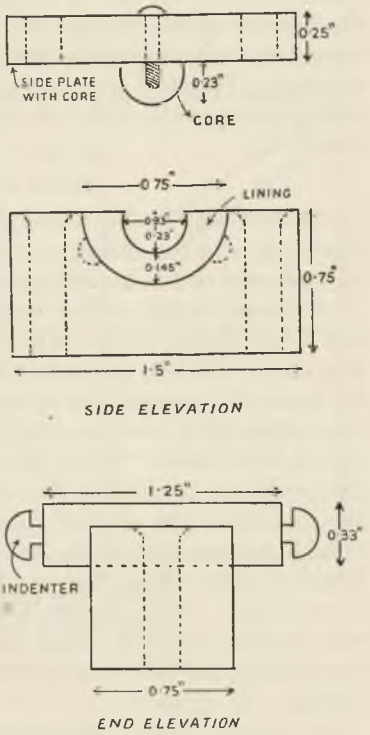

Fig. 17.

The results obtained from these specimens of alloy No. 1 and lead, both tested at 200° C., are given in Fig. 16. For alloy No. 1, the energy of the hammer was 0·42 ft.-lb. per blow, the deformation after 100,000 blows being 17 per cent., whilst for lead the energy per blow was 0·0625 ft.-lb., and the deformation after 90,000 blows, 22 per cent. The deformed specimens spread con-siderably at the ends, and it is reasonable to suppose that this spreading is the cause of the de-creasing rate of deformation as the test proceeds, and of the curve be-coming less steep than at the start.

In order to examine this hypo-thesis, as compared with that of the work-hardening of the test-pieces, the two deformed specimens were turned down to their original diameter and re-tested at the same tempera-ture as before. In both cases it was found that the rate of deformation was much greater than just before the test was interrupted, as is shown in the dotted portion of curves I and II (Fig. 16).

On the grounds, therefore, of the small number of blows, and of the possibly misleading nature of the results, it was felt that the type of

test adopted by Herschman and Basil was unsuitable. The use of cylindrical specimens was therefore discontinued.

As an alternative, tests were carried out on specimens shaped like half a bearing as shown in Fig. 17. The brass shell or mould was not tinned, the white metal being keyed in by means of small holes drilled into the sides of the semi-circular groove. After casting the white metal, the brass mould was fastened to the anvil. As a result of many preliminary tests, the actual indenter finally took the form of a case-hardened steel rod, 1·25 in. long and 0·33 in. in diameter, on to which the hammer of the machine fell. With an indenter such as this, immersed up to its horizontal diameter, the angle of indentation remains constant. Therefore the amount of deformation produced in one test is *strictly comparable* with that produced in any other test on the same machine.

Casting Procedure.

The following casting technique was used exclusively in all the work described, with the exception of that done in the few tests carried out on specimens cast in tinned moulds.

A definite weight of new metal (20 grm. in the case of alloys 1, 2, and 3, and 25 grm. in that of alloys 4 and 5) was melted under charcoal in a small crucible in an electric furnace, and its temperature measured by means of a copper–Constantan thermocouple. For mould temperatures above 18° C. the brass shell was heated in a small oven to the required temperature. When the melt was at the casting temperature, the mould was taken from the oven, a small " dozzle " placed on top, the contents of the crucible vigorously stirred with a graphite rod in order to prevent segregation, and the alloy poured into the mould until a head of metal 0·25 in. high was formed. The mould was then allowed to cool in air. When cool the brass block with the white-metal casting was removed, the feeder head filed off, and a small hole drilled along the top edge for the thermocouple. The specimen was then ready for testing.

Description of Test.

With these specimens, the problem of chilling by contact with the anvil is much less than in the case of the cylindrical specimens, so that the hard asbestos plate was replaced by one of mild steel. In the centre of the latter was fastened a small steel block to which the brass mould was secured, bringing the test-piece to the middle of the furnace.

The indenter rod was then inserted along the groove in the specimen, a small projecting upper lip of bearing metal on each side of the indenter helping to keep it in position. This was re-enforced by two light springs,

which were stretched from the base-plate to the ends of the indenting tool. The projected horizontal area of the bearing was 0·248 in.^{2}.

After some trials, the energy of the blow was fixed at 0·44 ft.-lb. per blow, being the equivalent of a $6\frac{1}{2}$-lb. hammer falling 0·8 in. As before, for all tests above room temperature the pounding was started 30 minutes after the test temperature had been attained, 100,000 blows being then given.

Tests on Tinned Specimens.

Since bearings are almost invariably tinned on to the brass or steel shell, tests were carried out on four castings in tinned moulds. Samples

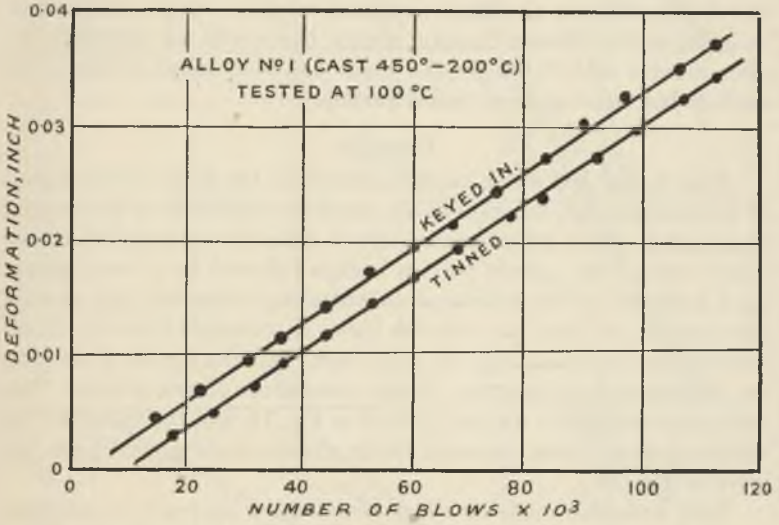

Fig. 18.—Tinned Lining and Keyed Lining.

of alloy No. 1, cast at 300° C. into a mould at 100° C., when pounded at a temperature of 200° C. gave considerable variations in the rate of deformation in the four tests. This trouble was almost certainly due to variations in the adhesion of the white metal to the brass block. After the pounding test had been completed each specimen was removed, when it was possible to correlate the resistance offered in the test to the extent of the adhesion. In the case of the smallest amount of deformation it was shown that the adhesion had been effective over the whole area of contact.

It is not improbable that the low pouring temperature employed may have exercised a considerable influence in giving the poor results of some of these tests. In another set of comparative tests as between tinned

and keyed-in specimens, the results of which are shown in Fig. 18, the casting temperature was therefore increased to 450° C. and that of the mould to 200° C. Using these conditions, the tinning appeared to be perfectly satisfactory in all cases. As will be seen, the graph of deformation is practically linear, and almost the same as regards rate of deformation in the two sets of determinations.

In view then of this proof that the deformation under the conditions of these tests was the same for tinned as for keyed-in test-pieces, coupled with the possibility of erratic results arising from imperfect tinning at the lower casting temperatures, it was felt preferable to employ the keyed-in specimens and to abandon the practice of tinning. Since the aim of the work was to obtain comparative results on the resistance to pounding of the different bearing metals, the results are believed to be more reliable with the technique which has been adopted than if the castings had been made in tinned moulds.

Results.

With the method which has been described, the graph of the amount of deformation as a function of the number of blows is at first curved to an extent which differs appreciably in different tests and introduces a zero error. The curved portion is then followed by a linear graph. As a measure of the resistance to pounding, therefore, the average deformation in inches per 100,000 blows is computed from the linear relationship by eliminating the zero error. All the figures given later are the mean of at least two, closely concordant determinations. Results corrected in this way are plotted in Fig. 19, and the values for the different alloys, when prepared under various casting conditions, are given in Fig. 20.

Tests were also made on alloys containing 1 per cent. of cadmium, and on a specimen of alkali-hardened lead (LA). These are recorded in Table XVIII, and may there be compared with results for INC and II.

Table XVIII.

Alloy.	Casting Conditions.	Deformation (In. per 100,000 Blows) at the Following Testing Temperatures.			
		18° C.	100° C.	150° C.	200° C.
INC	300°–100° C.	0·0047	0·012	0·046	...
	350°– 75° C.	...	...	0·012	...
ICd	400°– 75° C.	0	0·004	0·008	...
II	350°– 75° C.	...	...	0·009	...
IICd	400°–100° C.	0	0	0	0·001
LA	500°–200° C. Aged for 6 days	0·010	0·018	0·025	...

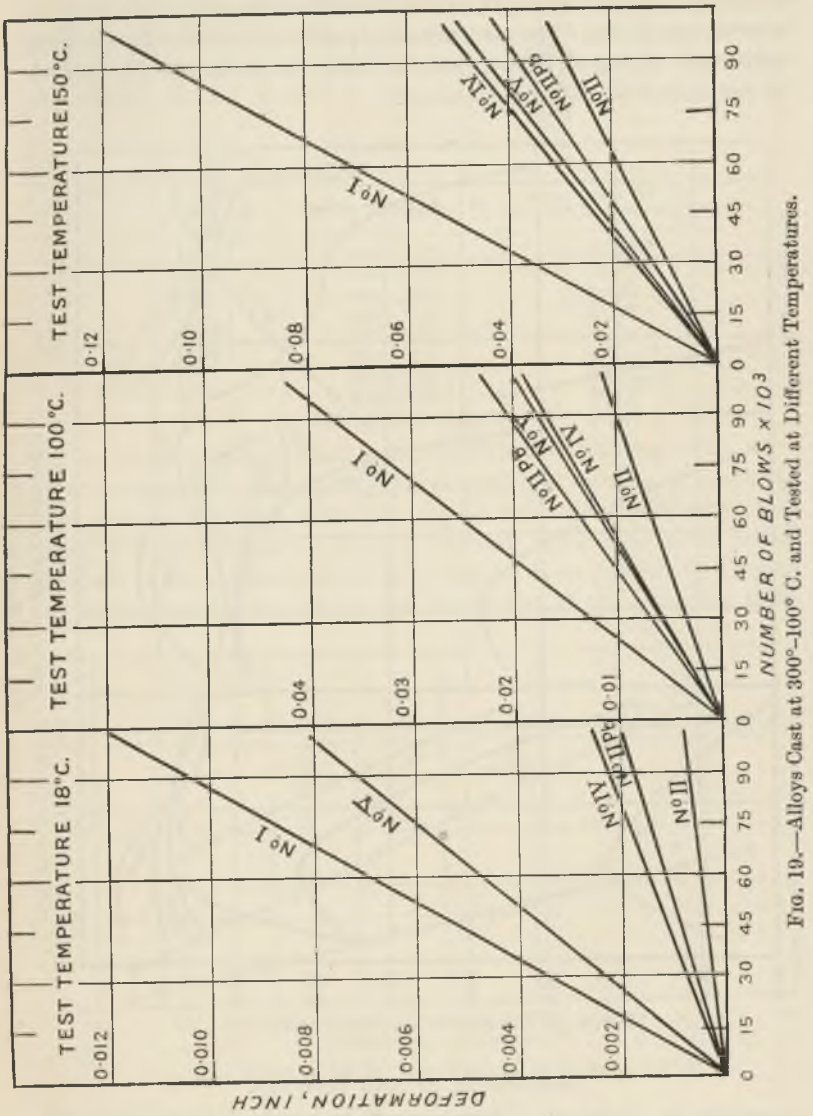

FIG. 19.—Alloys Cast at 300°–100° C. and Tested at Different Temperatures.

EFFECT OF INTERRUPTED POUNDING.

In an actual bearing, periods of rest interrupt those of pounding during service. The extent, if any, to which these rests affect the behaviour of the metal is clearly one of some interest, and in Fig. 21 the

results of a few interrupted tests on alloys Nos. II and V when tested at 150° C., are shown. The tests were stopped for periods of 12 hrs., during which the specimens cooled down to room temperature. The periods of rest caused no important change.

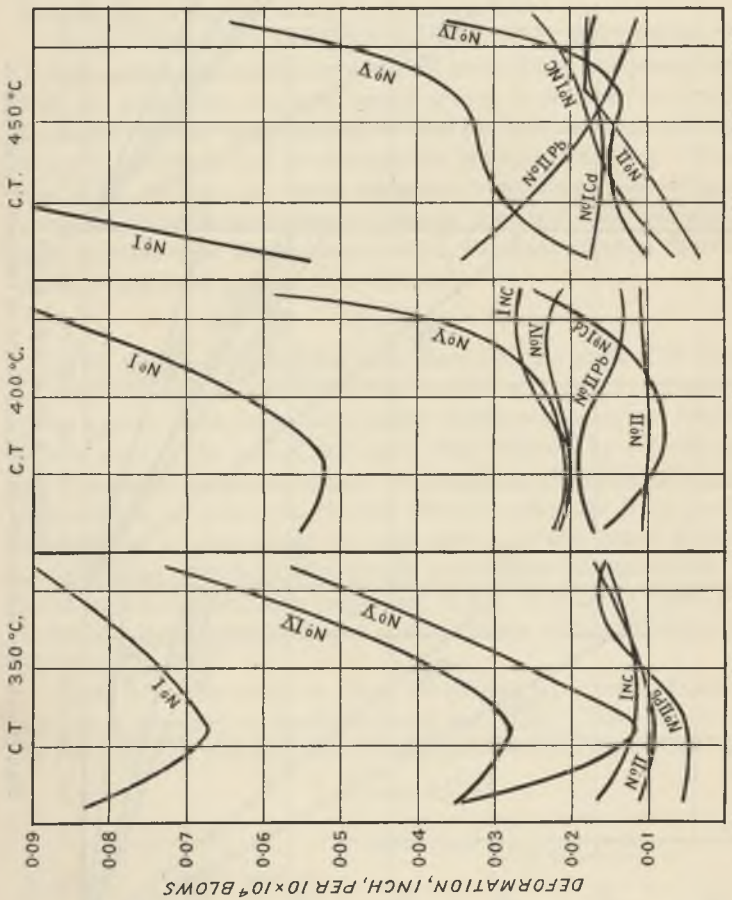

FIG. 20.—Tests at 150° C.

Discussion of the Results.

From an examination of Figs. 19 and 20 it is possible to draw up Table XIX giving the optimum resistance to pounding of the various alloys. The good qualities in this respect of No. II and the great resistance offered by No. IICd are very much in evidence. It is also to be noted that No. INC is very satisfactory when cast at 350°–75° C.

Part III.—Pounding Tests

Considering the effect of the casting and mould temperature on the results for No. II, it will be seen that, when tested at 150° C., the greatest deformation is given by the test-piece cast at 300° C. and the least when the metal is poured at 450° C. into a cold mould. The casts at the

TABLE XIX.

Alloy.	Casting Conditions, ° C.	Deformation (In. per 100,000 Blows) at 150° C.
I	400°– 75°	0·052
INC	450°– 18°	0·007
ICd	400°– 75°	0·008
II	450°– 18°	0·003
IICd	400°–100°	0
IIPb	350°– 75°	0·005
IV	450°– 18°	0·010
V	350°– 75°	0·012
LA	500°–200° C. Aged	0·025

lower temperatures into cold moulds showed cold lapping, to which the poor results under these conditions may be due. An additional possible cause of variation is to be found in the wide differences in the microstructure of the samples, but so far it has not been possible to discover any correlation between these and the results of the pounding tests.

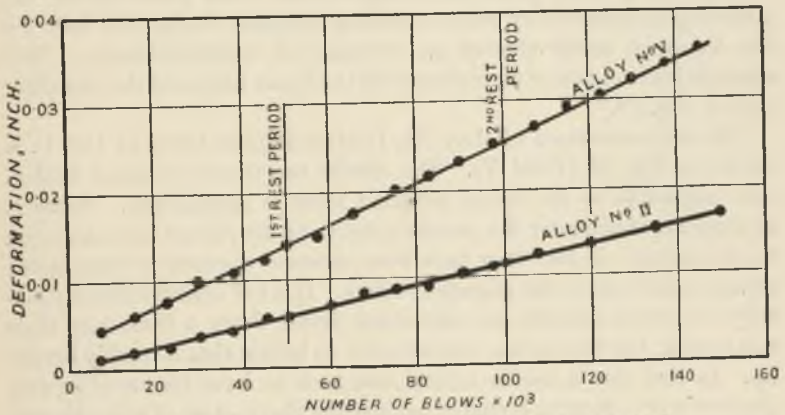

FIG. 21.—Effect of 12-Hr. Rest Periods on Tests at 150° C.

Unless the yielding stress of the material is exceeded, no permanent deformation will result from pounding, and since alloy IICd has completely resisted the hammering (Table XIX), its yield-point should be higher than that of any of the alloys. This is fully confirmed by the results given in Part II of the present paper (p. 326) and the same relative

generalization may be applied to alloys ICd and I. Figs. 22 and 23 (Plate IV) make it evident that the addition of 1 per cent. of cadmium to alloy No. II enormously increases the amount of the needle constituent at the expense of the cuboids.

The normal structure of alloy INC (450°–200° C.) may be seen in the *lower* part of Fig. 24 (Plate V). The upper portion of this photomicrograph shows, in section, the appearance of the deformed surface layer of the alloy after pounding with 100,000 blows at 150° C. The break-up of the fine needle network into small particles is apparent. This effect is not due to any chilling by the metal core during casting, for examination of the upper underformed portion of the lining showed that it had the same structure at the surface as in the body of the alloy. A similar casting of this material was also sectioned and examined after a standard pounding at 18° C. The microstructure was exactly similar to Fig. 24. Scratch tests with the Ball sclerometer made along the sectioned faces of these specimens gave the following results :

Resistance to Scratching, Alloy INC.

	Pounded at 18° C.	Pounded at 150° C.
At pounded surface . .	42 kg./mm.^{2}	41 kg./mm.^{2}
Inside	42 ,,	41 ,,

Apparently such strain-hardening as may take place during the pounding is removed by some annealing influence during the test, for the deformed metal showed no evidence of work-hardening. This observation is of course consistent with the linear nature of the pounding curves, Fig. 19.

The microstructure of alloy No. II after 100,000 blows at 150° C. is shown in Fig. 25 (Plate V). The needle constituent becomes broken into fragments as the upper pounded layer is approached. There is no evidence that under the present conditions the cuboids are shattered to any extent : in fact they have been observed apparently unimpaired though quite near to the pounded surface. It is not unlikely that favourably orientated cuboids are sometimes driven down a little into their soft matrix, but the needle constituent is so brittle that it readily breaks up. In one case a needle crystal was seen to have fractured in two places where it became pounded against the sharp edges of two adjacent cuboids.

Cracking.—Most of the deformed test-pieces showed signs of cracking at the two ends immediately beneath the indenter. In all cases, however, these cracks were confined to the extruded portions and were never, as far as could be determined, propagated into the main body of the specimen.

Part III.—Pounding Tests

Although there was a considerable amount of deformation in samples of alloy No. I no cracks were produced in this material. No. INC cracked slightly, but not as much as No. II for instance. All the other alloys showed some evidence of cracking, the extent of which was in general proportional to the total amount of deformation. In Fig. 26 (Plate VI) photographs of deformed specimens of alloys No. I and No. IV, both tested at 150° C. are given. The total amount of deformation was about the same in each case. Alloy No. V behaved very similarly in this respect to No. IV.

In order to ascertain whether there were any cracks just below the surface of the test-pieces, many deformed specimens were etched electrolytically in a dilute solution of nitric acid, but no fissures were ever revealed.

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This paper will not be reissued in the form of a separate "Advance Copy," a method of publication which has been discontinued.

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SOME PROPERTIES OF TIN CONTAINING SMALL AMOUNTS OF SILVER, IRON, NICKEL, OR COPPER.*

By Professor D. HANSON, D.Sc.,† Vice-President, E. J. SANDFORD, B.Sc.,‡ Member, and H. STEVENS, M.Sc.,§ Member.

Synopsis.

The tin-rich ends of the silver–tin, nickel–tin, and copper–tin equilibrium diagrams have been investigated. With the first, the eutectic occurs at 3·5 per cent. of silver, at 221·3° C.; with the second, at 0·18 per cent. of nickel at a temperature which does not vary appreciably from the melting point of pure tin; with the last, between 0·70 and 0·75 per cent. of copper at 226·9° C. The solid solubility of silver in tin is shown to be approximately 0·02 per cent. at room temperature, increasing to 0·06 per cent. at 210° C. The solid solubility of nickel is less than 0·005 per cent., and that of copper less than 0·01 per cent. at 220° C.

The method of making additions to tin is discussed, and it is shown that no particular difficulties are met with in the case of silver, iron, copper, and nickel.

The influence of additions of these metals on the tensile strength of tin is discussed. A great increase produced by quenching silver–tin alloys is not permanent at room temperature, whilst with the other three alloys quenching has no effect. Additions of iron above 0·4 per cent. are without effect, although up to this percentage an increase of 40 per cent. in the tensile strength is found.

Nickel up to 0·3 per cent. produces an increase up to 2·1 tons/in.^{2}, but further additions have no influence. Copper up to 2 per cent. greatly increases the tensile strength after all heat-treatments investigated.

Silver is shown to refine the grain of tin, but not to prevent grain-growth at high temperatures. The addition of iron above 0·05 per cent. or of nickel above 0·06 per cent. prevents such grain-growth, although below these compositions germination takes place. 0·35 Per cent. and more of copper prevents recrystallization of cold-rolled tin at room temperature, but annealing at temperatures from 110° C. upwards produces larger grains than in alloys of slightly lower copper content.

Introductory.

Tin alloys readily with most of the common metals, although, in some instances, small quantities only can be dissolved in liquid tin at tem-

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† Professor of Metallurgy, University of Birmingham.
‡ Research Student, Metallurgy Department, University of Birmingham.
§ Research Student, Metallurgy Department, University of Birmingham.

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peratures near the melting point of the pure metal. Intermetallic compounds are freely formed, particularly with metals of high melting point, and some of these compounds have a very definite metallurgical importance. The solid solubility of other metals in tin has been little investigated, and most of the published equilibrium diagrams fail to disclose any solid solubility at all. Even less knowledge is available regarding the influence of added elements on mechanical and other physical properties of the metal. The investigation described in this paper has been undertaken in order to ascertain the effects of alloying silver, iron, nickel, and copper with tin, and special attention has been paid to the constitution and tensile properties. The investigation has been made possible by a grant from the International Tin Research and Development Council, to whom the authors wish to express their indebtedness both for the help received and for their permission to publish the results obtained. In particular, they would like to refer to the interest taken in the work by Mr. D. J. Macnaughtan, Director of Research to the International Tin Research and Development Council.

Part I.—The Constitution of Alloys of Tin with Silver, Iron, Nickel, and Copper.

(a) *Silver–Tin Alloys.*

The work of Murphy [1] and others has shown that the compound Ag_3Sn forms a eutectic with tin. Murphy found that the solid solubility of silver in tin was less than 0·1 per cent. at 206° C.

An accurate determination of the liquidus and eutectic from 0 to 6 per cent. of silver has been made by means of cooling curves. The tin and silver used had a purity of 99·99 and 99·97 per cent., respectively. Cooling curves were taken on 150 grm. of metal, melted in a Salamander crucible and covered with charcoal. The rate of cooling was 1° C. per minute, and this, together with stirring, reduced supercooling to the order of 0·5° C. At least two cooling curves were taken on each alloy, and the maximum difference between duplicate curves was 0·5° C.

From Fig. 1, which shows the tin-rich end of the constitutional diagram plotted from these results, it will be seen that the eutectic occurs with 3·5 per cent. of silver at a temperature of 221·3° C. An accurate determination of the solid solubility of silver in tin has yet to be made, but the results of mechanical tests (to be discussed later) justify the insertion of a tentative solubility line in Fig. 1.

(b) *Iron–Tin System.*

Edwards and Preece [2] found that the compound $FeSn_2$ forms a monotectic with tin and that the solid solubility of iron is less than 0·01 per cent. This was confirmed by Ehret and Westgren.[3] On account of the very low solid solubility, it was not expected that these

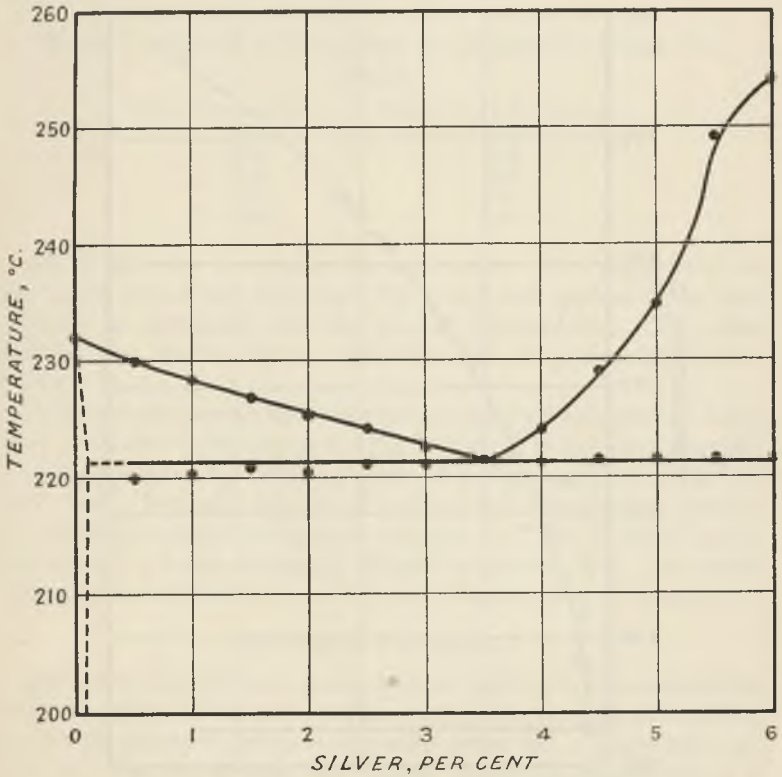

Fig. 1.—Tin-Rich End of the Silver–Tin Equilibrium Diagram.

alloys would be amenable to heat-treatment, and, therefore, no work has been carried out on the constitution.

(c) *Nickel–Tin System.*

Previous workers have agreed that the compound Ni_3Sn_2 forms a eutectic with tin, but have not agreed as to its composition and temperature of formation. The tin-rich end of the diagram has therefore been determined. The materials used were " Chempur " tin and pure Mond nickel shot. Cooling curves were taken on alloys containing

up to 2·1 per cent. of nickel, using an iron–Constantan couple for low temperatures and a Chromel–Alumel couple for high temperatures.

In spite of such precautions as slow rates of heating and cooling, inoculation, and stirring, the only arrest found coincided with the melting point of pure tin. Altogether, 28 cooling curves, and 12

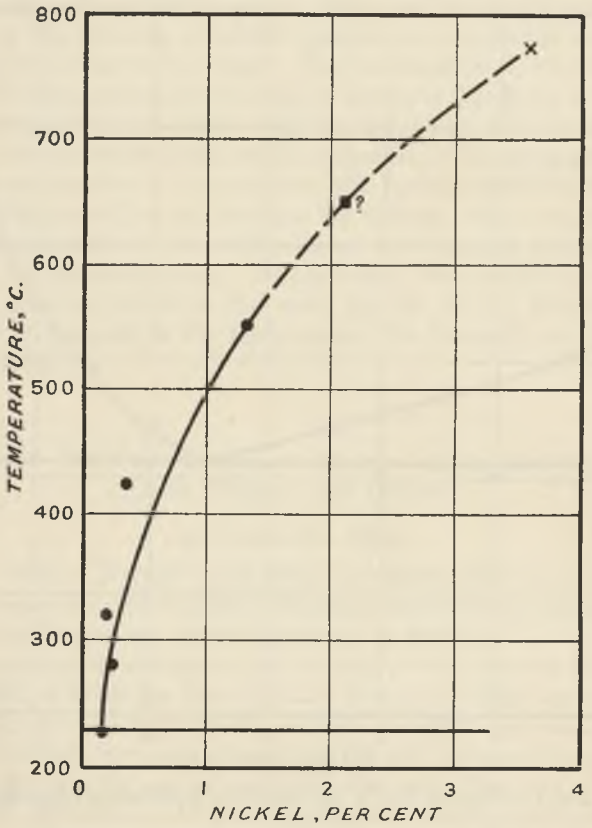

Fig. 2.—Tin-Rich End of the Nickel–Tin Equilibrium Diagram.

heating curves were taken, on varying amounts of metal, at rates varying between 2° and 30° C. per minute. By means of heating curves taken at the rate of 1° C. per minute it was ascertained that the solidus does not vary appreciably from the melting point of tin. Cooling curves having failed, the liquidus was found by segregation experiments. A quantity of metal (about 250 grm.) was heated to 850° C. for 1 hr. (at this temperature about 3·5 per cent. of nickel

would be in solution in the liquid), cooled to a suitable temperature and maintained at that temperature for 24 hrs. The crucible was then lowered carefully into water. The excess solid compound had segregated to the bottom of the melt, so that an analysis of the top layer gave the composition of the liquid phase at the temperature of the experiment. The results are given in Table I.

TABLE I.—*Results of Segregation Experiments on Nickel–Tin Alloys.*

Constant Temperature ° C.	Nickel in Top Layer, Per Cent.
240	0·18
280	0·23
320	0·19
425	0·31
550	1·29

Fig. 2 embodies the results discussed above. The upper point on the broken line is one determined by Voss,[4] and appears to be substantially in agreement with the present determination. The other point on the broken line is a doubtful one obtained from thermal analysis.

A microscopic examination showed that the solid solubility of nickel in tin is less than 0·005 per cent. Fig 3 (Plate I) is a photomicrograph of an alloy containing 0·005 per cent. of nickel, annealed at 228° C. for 7 days. Definite evidence of undissolved compound is present. The markings of the background are due to "dirt" picked up in preparation, it being extremely difficult to prevent this. It demonstrates, however, that the second phase is harder than the matrix.

(d) *Copper–Tin System.*

Agreement has not been reached in the past as to the composition and temperature of formation of the copper–tin eutectic, although it is generally accepted that it is formed between the ε constituent and pure tin. Various workers have placed the composition between 1 and 2·5 per cent. of copper, and the temperature of formation between 225° and 227° C.

Gurevich and Hromatko,[6] as the result of a careful investigation, found that the eutectic occurred at 1 per cent. of copper and at 227·1° C. However, between pure tin and 1 per cent. of copper they investigated only the liquidus, and beyond 1 per cent. obtained only the eutectic points on their cooling curves. Haughton [5] accepted their value for the eutectic composition, but placed the temperature of formation at 227·4° C. In the discussion on Haughton's paper, Rooney gave reasons for supposing that the eutectic composition is less than 1 per

cent. On this account, the present authors have made a careful determination of the point.

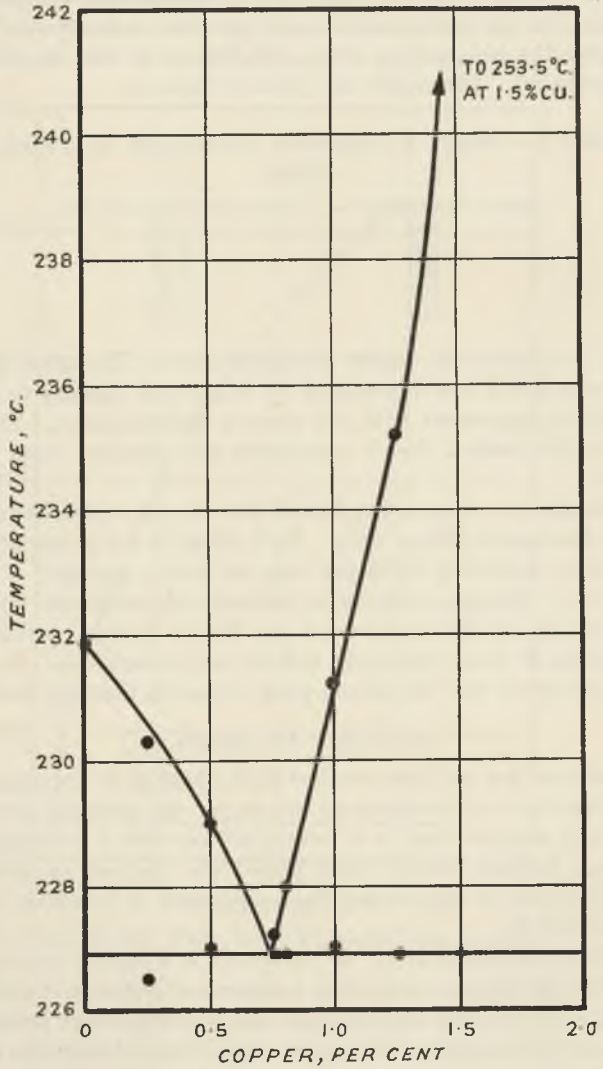

Fig. 4.—Tin-Rich End of the Copper–Tin Equilibrium Diagram.

Alloys containing up to 1·5 per cent. were made for cooling curve experiments and the compositions confirmed by analysis. Stirring

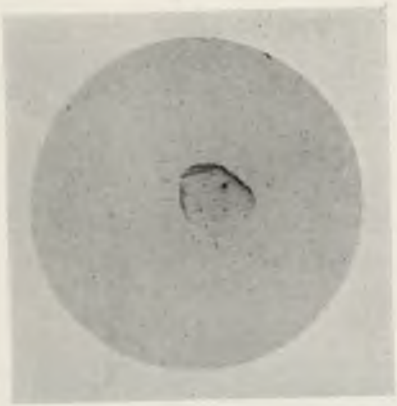

FIG. 3.—0·005% Nickel. Annealed at 228° C. for 7 days and Quenched. × 1000.

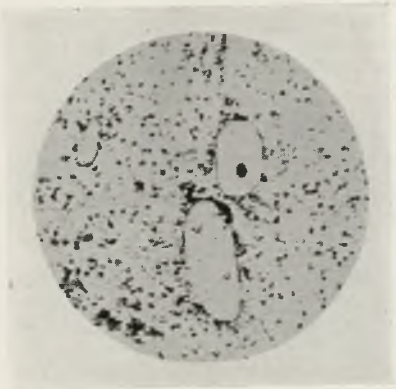

FIG. 5.—0·11% Copper. Annealed at 220° C. for 17 Days and Quenched. × 500.

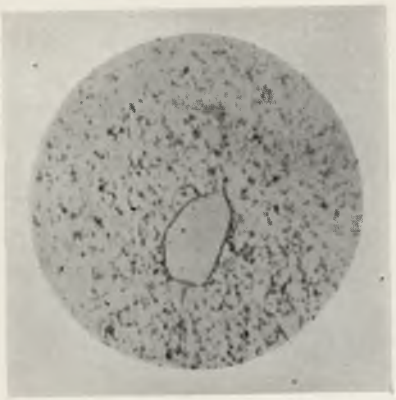

FIG. 6.—0·01% Copper. Annealed at 220° C. for 15 Days and Quenched. × 500.

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FIG. 11.—(Above) Equi-Axed Grains Usually Found in Tin Alloys. (Below) Elongated Grains in Copper–Tin Alloy. (0·45% Copper. Annealed at 222° C.)

reduced super-cooling to a very small amount and, in the case of the hyper-eutectic alloys, produced definite liquidus points on the cooling curves.

Fig. 4 shows the tin-rich end of the copper–tin equilibrium diagram. The eutectic composition is between 0·70 and 0·75 per cent. of copper and occurs at a temperature of 226·9° C. The figure thus found for the composition is considerably lower than that of Gurevich and Hromatko, although there is good agreement as to the temperature. A comparison of the results of the two investigations shows complete agreement as to the liquidus temperatures of individual alloys. The difference lies, therefore, in the interpretation of the results. Had Gurevich and Hromatko determined the liquidus of the hyper-eutectic alloys, they would have seen that the point on their diagram for the alloy containing approximately 0·8 per cent. of copper lies, not on the falling liquidus line between pure tin and the eutectic, but on the rising liquidus of the hyper-eutectic alloys. With this alteration, their diagram would agree with the one now presented.

The results of tensile tests on heat-treated alloys indicated that the solid solubility of copper was not as great as was found by Haughton (*viz.*, 0·2 per cent.) and therefore a microscopic determination has been made. Specimens of alloys containing up to 0·21 per cent. of copper were roughly prepared, annealed for 17 days in a salt-bath at 220° C., and quenched in water. Fig. 5 (Plate I) is a photomicrograph of an alloy of 0·11 per cent. copper thus treated. That there was an excess of the ε constituent is clearly visible. Finally an alloy containing 0·01 per cent. of copper was annealed at 220° C. for 15 days, quenched and examined. Again an excess of the ε phase was found (Fig. 6, Plate I).

The solid solubility of copper in tin is therefore less than 0·01 per cent. at 220° C.; that is to say, is negligible for practical purposes.

Part II.—The Preparation of Certain Alloys of Tin.

The work discussed here involved the addition of several metals of high melting point to tin; a few notes on the method of making the alloys are therefore given. It is fortunate that, in spite of its low melting point, tin has a very high boiling point (over 2000° C.); this made possible the use of high temperatures without an attendant risk of loss by volatilization.

(a) *Silver.*

Silver is readily soluble in tin at 600° C., 6 per cent. dissolving in 2 hrs., while charcoal is sufficient to prevent oxidation. Analysis showed that alloys can be made synthetically with a good degree of

accuracy; for example, an alloy intended to contain 6 per cent. of silver, gave 5·94 per cent. on analysis.

(b) *Iron.*

The liquidus of the iron–tin system rises steeply from the melting point of tin to over 1000° C. when 5 per cent. of iron is present. Armco iron, in the form of turnings, dissolves fairly rapidly in tin at 1000° C., charcoal being sufficient to prevent oxidation; 5 per cent. of iron dissolves in 2 hrs., and analysis showed that 4·75 per cent. was present in the cast alloy. On account of the long freezing range (nearly 800° C.), it is advisable to cast such a temper alloy into thin strips to prevent segregation as much as possible.

(c) *Nickel.*

Solid nickel is readily soluble in molten tin at 900° C., up to 21 per cent. having been added at this temperature. Segregation occurs in this series, but severe chilling eliminates this as a source of trouble.

(d) *Copper.*

No special difficulties are encountered in the preparation of tin-rich copper alloys. Copper wire dissolves readily at 600° C., and more rapidly at higher temperatures.

Part III.—The Mechanical Properties of Several Tin-Rich Alloys.

The tests described below were carried out on alloy strips 0·1 in. thick, cold-rolled from 0·5 in. Since the average room temperature is above the recrystallization temperature of pure tin and many of its alloys, the cold-rolled strips were allowed to self-anneal for 15 days before any tests were made. Variations in the speed of testing have a great influence on the ultimate tensile strength of metals of great ductility, and throughout this work the constant rate of strain of $1\frac{5}{32}$ in. per minute was used, this being the maximum attainable. Loads were read to 0·001 tons, and duplicate tests never varied by more than 0·002 tons. The results are shown here as graphs, while the various heat-treatments adopted are indicated thereon.

(a) *Silver–Tin Alloys.* (Fig. 7.)

After the following heat-treatments: (i) self-annealing at room temperature; (ii) annealing at 100° C.; (iii) annealing at 210° C., the addition of silver up to 0·2 per cent. causes a gradual increase in tensile strength up to 50 per cent., although with the last heat-treatment, a maximum strength is found when 0·1 per cent. of silver is present.

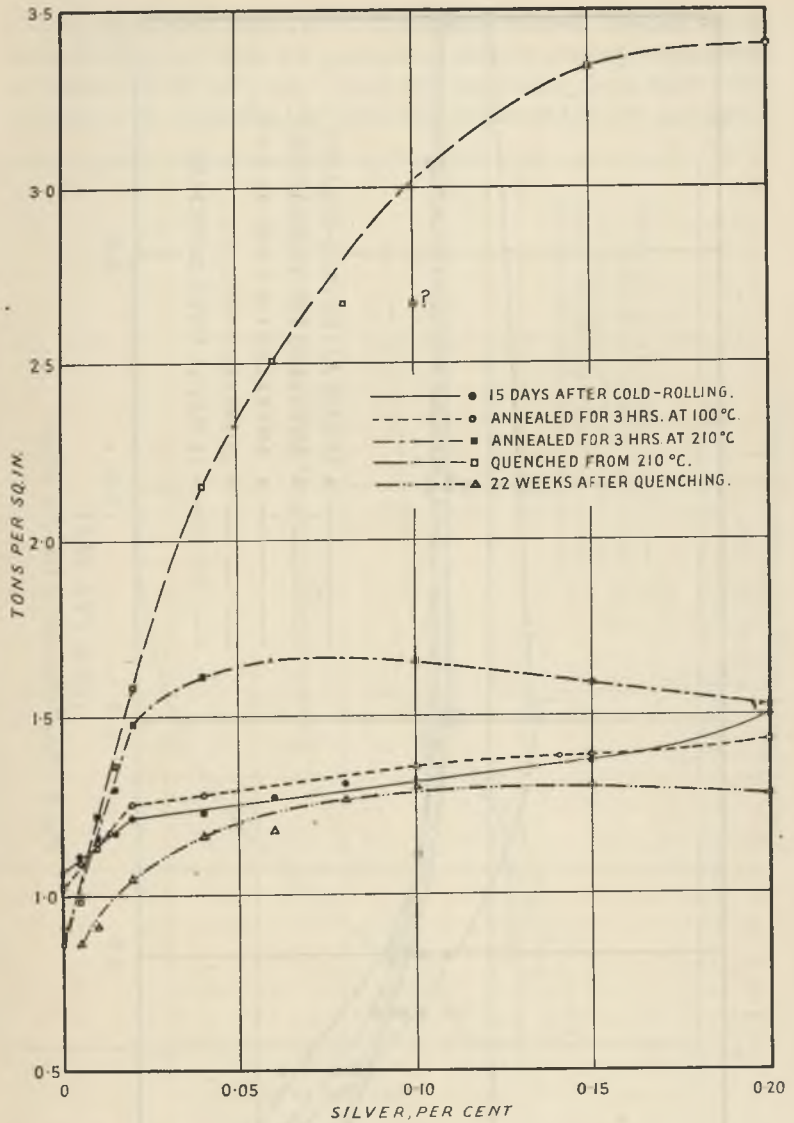

Fig. 7.—Tensile Strength of Silver–Tin Alloys.

The marked discontinuity on these curves, occurring around 0·02 per cent. of silver, is an indication of a limit of solid solubility; the limits thus obtained are shown on Fig. 1.

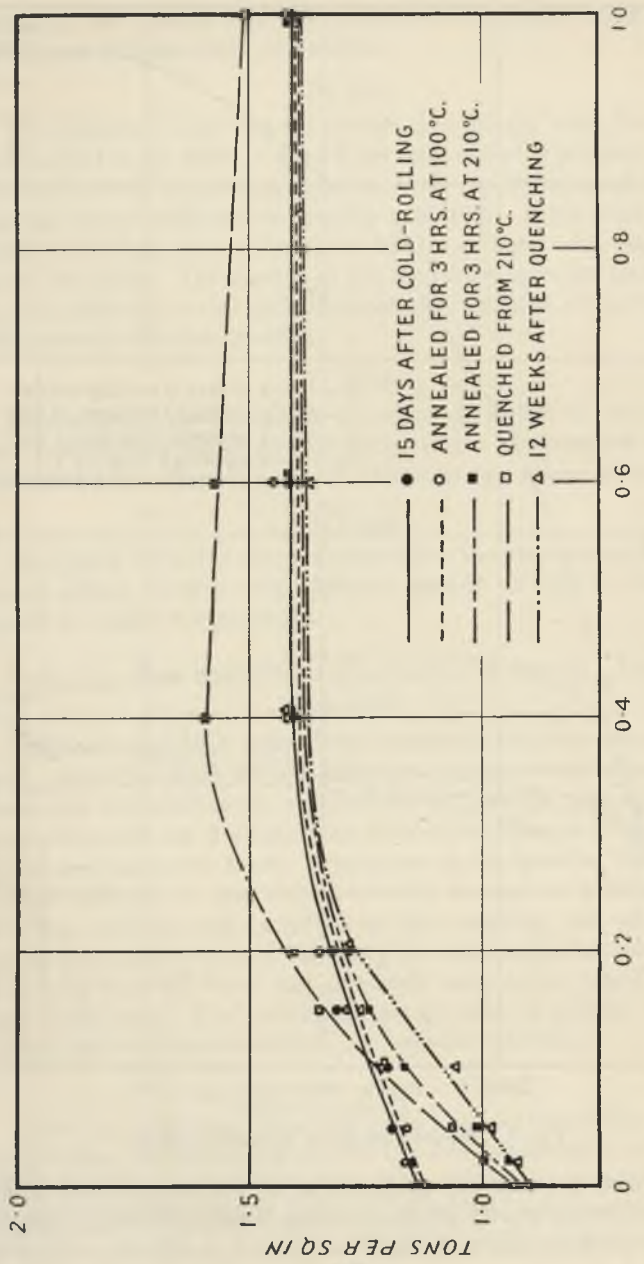

Fig. 8.—Tensile Strength of Iron–Tin Alloys.

After quenching from 210° C. the tensile strength increases rapidly up to 3·5 tons/in.², when 0·2 per cent. of silver is present, representing an increase of 250 per cent. The curve connecting these results does not show a discontinuity, but attention is directed to the apparently

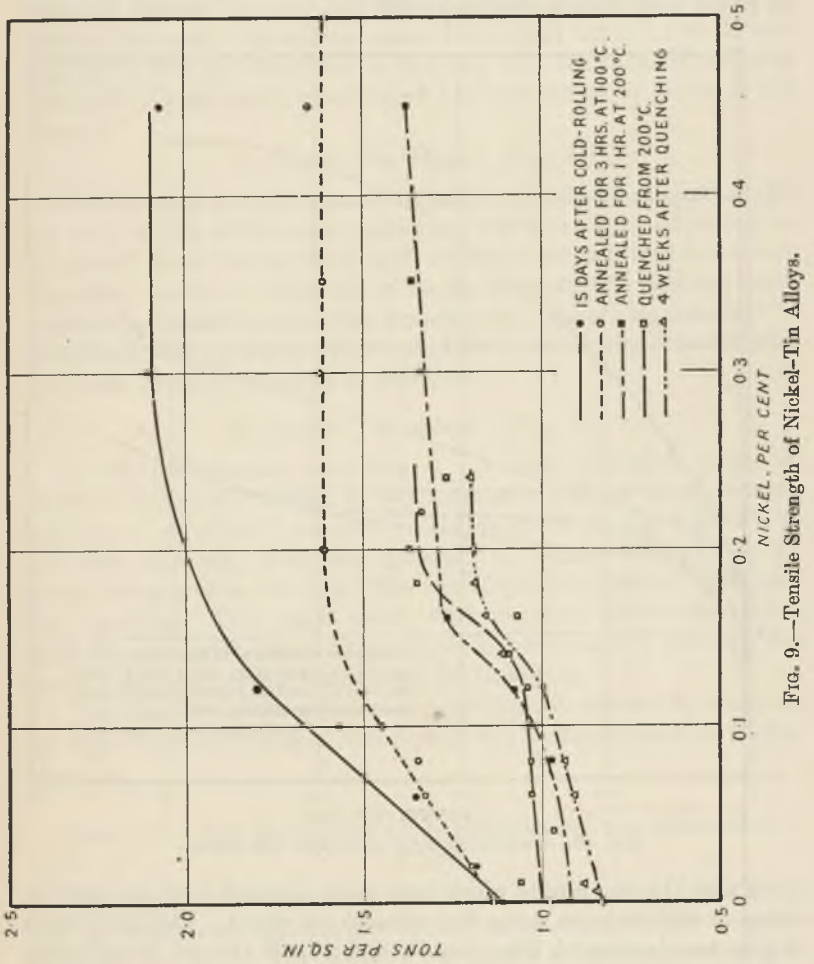

Fig. 9.—Tensile Strength of Nickel-Tin Alloys.

inconsistent results shown by the alloy containing 0·1 per cent. of silver. It is possible that the curve actually shows a discontinuity at 0·07 per cent. of silver, and then ascends to 3·5 tons/in.². Unfortunately, the effect of quenching is not permanent, since after 22 weeks at room temperature, the enhanced tensile strength completely dis-

appears, leaving the alloys somewhat weaker than before any heat-treatment.

High-temperature annealing greatly reduces the ductility of these alloys, from an average of 90 per cent. in the self-annealed condition to 40 per cent. after annealing at 210° C.

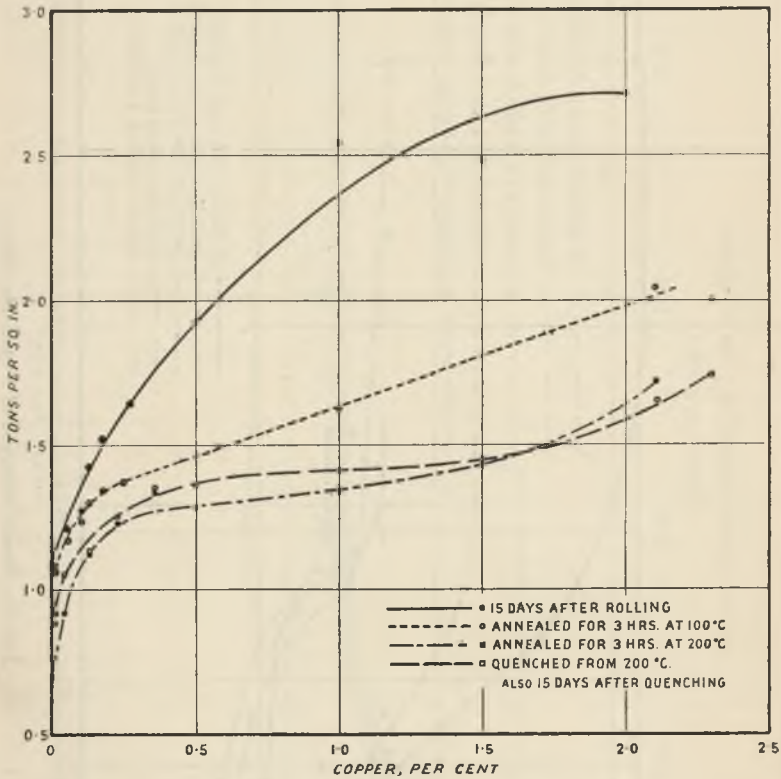

Fig. 10.—Tensile Strength of Copper–Tin Alloys.

Table II gives results which have been obtained from the eutectic alloy of the silver–tin series (3·5 per cent. of silver). This alloy has a higher tensile strength than pure tin and is little affected by annealing at 100° C.

Table II.

Condition.	Ultimate Tensile Strength Tons/in.².
15 days after rolling	3·63
Annealed for 3 hrs. at 100° C.	3·50
Annealed for 3 hrs. at 210° C.	2·34
Quenched from 210° C.	3·70

(b) *Iron–Tin Alloys.* (Fig. 8.)

After the following heat-treatments: (i) self-annealed at room temperature; (ii) annealed at 100° C.; (iii) annealed at 210° C.; (iv) quenched from 210° C., the addition of up to 0·4 per cent. of iron, causes a gradual increase in tensile strength, but further additions have no influence. Quenching causes but a small increase over annealing, which may be attributed to the fact that the solid solubility of iron in tin is very small, a fact which has been shown by Edwards and Preece.[2]

(c) *Nickel–Tin Alloys.* (Fig. 9.)

0·2 Per cent. of nickel causes an increase in tensile strength of 100 per cent. in the self-annealed condition, but there is no advantage to be gained from further additions whatever be the heat-treatment. Annealing produces a decrease in tensile strength, the decrease being greater the higher the annealing temperature. Quenching from 200° C. is without effect, a result which would be expected when the probable low solid solubility of nickel is considered.

(d) *Copper–Tin Alloys.* (Fig. 10.)

In the self-annealed condition, 1 per cent. of copper causes an increase in tensile strength of approximately 120 per cent., but the addition of a further 1 per cent. of copper produces only a further 10 per cent. increase. Annealing decreases the tensile strength, the decrease being greater the higher the annealing temperature; quenching has no effect. This result agrees with the fact, previously stated, that the solid solubility of copper in tin is less than 0·01 per cent. and not 0·2 per cent. as was maintained by Haughton.

The ductility in the self-annealed condition is reduced by additions of copper up to 1·0 per cent., but beyond this amount there is no further decrease.

Part IV.—The Influence of Impurities on the Grain-Size of Tin.

The experiments described below were carried out on alloy strips 0·1 in. thick, cold-rolled from 0·5 in. In the case of the silver–tin and iron–tin alloys, the ends of the tensile specimens were etched, without previous preparation (this was unnecessary) in dilute nitric acid. With the nickel–tin and copper–tin alloys it was more convenient to use separate specimens; these were cut from strips used for the tensile tests, and were 1·5 in. × 2 in., the shorter length being the direction of rolling; they were etched in a similar manner after

the required heat-treatments. In all cases, the grains were counted by the intercept method; *i.e.* the number of grain boundaries crossed in traversing a given length in each of two directions at right angles was ascertained by means of a travelling microscope. The product of the two readings was the number of grains in the area given by the product of the distances traversed. With grain-sizes of the order of 10,000 per cm.^{2}, a distance of 1 cm. was sufficient, but where the grains were large, or where mixed sizes were found, several counts were made over the whole length and breadth of the specimen. In a few cases, where very large grains existed, the intercept method was checked by counting the individual grains on the complete surface of the specimen; complete agreement was always found.

(a) *The Influence of Silver.* (Table III.)

The effect of silver on the grain-size produced by recrystallization at room temperature after severe cold-work is most marked with 0·015 to 0·02 per cent. Between these compositions, a decrease takes place which appears to coincide with the limit of solid solubility and the appearance of a second phase. Further additions of silver cause a small reduction.

TABLE III.—*Grains per cm.*^{2}.

Silver. Per Cent.	A.	B.	C.
Nil	7,200	8,400	23
0·005	8,300	5,300	28
0·01	8,700	8,700	40
0·015	6,000	10,200	41
0·02	18,100	18,900	53
0·04	19,200	14,800	101
0·06	22,300	...	101
0·08	25,600	...	255
0·10	27,200	17,500	240
0·15	24,600	19,200	240
0·20	24,200	14,400	255

A.—15 days after cold-rolling.
B.—Annealed for 3 hrs. at 100° C.
C.—Annealed for 3 hrs. at 210° C.

Annealing for 3 hrs. at 100° C. causes no increase in grain-size when less than 0·02 per cent. of silver is present, but whereas there was previously a further slight reduction with silver contents above this amount, there is now no change.

Annealing at 210° C. causes a marked grain-growth in all alloys containing up to 0·2 per cent. of silver (the maximum investigated), although additions of silver do cause a slight reduction from 25 grains per cm.^{2} with pure tin, to 250 grains per cm.^{2} when a little more than 0·1 per cent. of silver is present.

(b) *The Influence of Iron.* (Table IV.)

Additions of iron up to 0·05 per cent. increase the grain-size of tin, recrystallized after cold-work, from 13,000 to 6000 grains per cm.^{2}, but further additions, up to 1 per cent., are without effect.

TABLE IV.—*Grains per cm.*^{2}.

Iron, Per Cent.	A.	B.	C.	D.
Nil	13,500	400	180	55
0·02	10,000	3	3	4
0·05	6,000	2,800	1,400	2½
0·10	6,000	3,300	2,400	700
0·15	6,000	3,100	2,700	1,700
0·20	6,000	2,800	2,200	1,700

A.—15 days after cold-rolling.
B.—Annealed for 3 hrs. at 180° C.
C.—Annealed for 3 hrs. at 214° C.
D.—Annealed for 3 hrs. at 224° C.

Annealing for 3 hrs. at 100° C. causes a slight grain-growth in alloys containing less than 0·05 per cent. of iron, of such a magnitude as to produce a constant grain-size throughout the series, from 0 to 1 per cent. of iron. The grain-growth found to take place in pure tin at 100° C. does not agree with what was stated when discussing the silver–tin alloys, in which series no growth was found in pure tin at that temperature. It is extremely difficult, however, to reproduce the exact conditions of strain and temperature, &c., but it is believed that constant conditions existed throughout each series of alloys.

On annealing at temperatures from 180° to 224° C., germination is found to take place when 0·02 per cent. of iron is present, resulting in the production of grains having areas of 1·5 cm.^{2}, while in one case, an area of 8 cm.^{2} was found.

When the iron concentration is more than 0·02 or 0·05 per cent. when annealing at 224° C., the grain-size rapidly diminishes to a figure around 2000 grains per cm.^{2}.

(c) *The Influence of Nickel.* (Table V.)

The influence of nickel on the grain-size of tin recrystallized after cold-work, is small. Additions up to 0·15 per cent. effect a slight refining, but beyond this composition there is no change.

Annealing for 24 hrs. at 128° C. causes grain-growth in alloys of low nickel content; with 0·005 per cent. the increase is from 10,000 to 500 grains per cm.^{2}. After this heat-treatment the addition of nickel refines the grain, the maximum effect being with 0·06 per cent., beyond which there is no further change; grain-growth is practically arrested at 128° C. by such nickel contents.

TABLE V.—*Grains per cm.*^{2}.

Nickel. Per Cent.	A.	B.	C.
0·005	10,000	560	10
0·01	9,900	1,540	12
0·02	18,100	10,000	1·2
0·04	20,400	6,000	1·2
0·06	30,100	11,500	0·5
0·08	21,000	14,000	114
0·10	18,400	17,500	159
0·12	39,200	13,500	228
0·14	40,800	17,000	1,120
0·16	27,600	17,000	2,370
0·18	28,900	19,000	3,040
0·20	28,900	18,500	3,520

A.—Self-annealed at room temperature.
B.—Annealed for 24 hrs. at 128° C.
C.—Annealed for 24 hrs. at 211° C.

Annealing for 24 hrs. at 211° C. produces grain-sizes of the order of 10 grains per cm.^{2} with 0·005 per cent. of nickel, but compositions between 0·02 and 0·06 per cent. cause germination, resulting in the production of large grains averaging 1 cm.^{2} in size. Beyond 0·06 per cent. a sudden refinement takes place which is continued up to 0·2 per cent. (the maximum investigated), when a grain-size of 3500 grains per cm.^{2} results.

(d) *The Influence of Copper.*

The results obtained from a study of the grain-size of copper–tin alloys are given in Table VI.

TABLE VI.—*Grains per cm.*^{2}.

Copper, Per Cent.	Self Annealed.	24 hrs. at 110° C.	24 hrs. at 222° C.
0·03	4,400	4,400	3
0·04	3,500	3,300	3
0·07	3,000	3,200	100
0·13	5,900	6,800	12
0·17	5,800	7,800	1,700
0·23	11,200	10,100	370
0·25	9,800	9,500	1,600
0·27	7,400	7,200	46
0·35	N.R.	2,100	175
0·45	N.R.	360	116

N.R. = not recrystallized.

The results show that copper exerts a refining action on the grain-size produced by recrystallization at room temperature. With 0·35 per cent. only a portion of the alloy had recrystallized, while with 0·45 per cent., recrystallization had not commenced. This led to peculiar results when the effect of annealing was considered.

Annealing for 24 hrs. at 110° C. has little effect on these alloys,

except in those containing 0·35 per cent. and more of copper, *i.e.* those which do not completely recrystallize at room temperature. In this case, elongated crystals are produced instead of the more usual equi-axed ones found in the other alloys. The same phenomenon occurs after annealing for 24 hrs. at 222° C. It seems that these grains are produced by the re-orientation of the original cold-worked structure and not by growth following recrystallization at room temperature; a larger grain-size is produced in the alloy richer in copper than in that which was partly recrystallized before annealing. Fig. 11 (Plate II) illustrates the difference between the equi-axed grains usually found in the recrystallized tin alloys, and the elongated grains in the alloy containing 0·45 per cent. of copper.

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AUTHOR INDEX TO ABSTRACTS

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 1 JULY 1934 Part 7

I.—PROPERTIES OF METALS

(Continued from pp. 285–290.)

Properties of High-Conductivity Oxygen-Free Copper. C. A. Stanwick (*Bull. Nat. Elect. Light Assoc.*, 1932, **19**, 558–560, 574).—Electric furnace melting of cathode copper under carefully controlled conditions, and casting into water-cooled moulds, is now practised in order to produce material containing the minimum of oxygen and assaying 99·98% of the metal. All the shapes are cast vertically. The superior quality and remarkable uniformity of the oxygen-free bars are reflected in the wires rolled from them. They withstand the attack of reducing gases at elevated temperatures, and one of the tests demanded is subjection to bending after annealing in hydrogen at 850° C. With adequate protection of the liquid metal from oxidation during welding, it is anticipated that the use of oxygen-free copper should result in welds of better tensile strength and ductility. Hard-drawn oxygen-free copper wire withstands about 80% of the number of bends obtained with annealed electrolytic copper wire. Similar advantages are shown in results for twisting and tensile tests.—W. A. C. N.

†**A Review of Work on Gases in Copper.** O. W. Ellis (*Trans. Amer. Inst. Min. Met. Eng.*, 1933, **106**, 487–512; discussion, 512–514).—All the most important work on the solubility of gases in copper and their effects on the properties of the metal are critically reviewed, an excellent summary is given of our present knowledge of the subject, and many suggestions are made for future work to clear up the doubtful points. Although most of the evidence at present available indicates that hydrogen is the chief cause of the troubles met with in the casting of copper under foundry conditions, it is considered that a great deal of evidence has been put forward to show that nitrogen, carbon monoxide, and sulphur dioxide are by no means innocuous.—A. R. P.

***Diffusion of Hydrogen Through Platinum and Nickel and Through Double Layers of These Metals.** W. R. Ham (*J. Chem. Physics*, 1933, **1**, 476–481).—The flow of hydrogen through single sheets of nickel and platinum with atmospheric pressure on the ingoing side and a pressure of 0·1 mm. on the outgoing side follows the empirical relation

$$R = A \cdot ((p_0^{\frac{1}{2}} - p_i^{\frac{1}{2}})/x) \cdot T^{-\frac{1}{2}} \cdot \varepsilon_{-b_1/T}$$

similar to that given by Borelius, where p_i is small compared with p_0, but apparently proportional to p_0; with double layers of these two metals the b_1 of the exponential is dependent only on the metal at the outgoing surface, and is the difference between the work of escape from the outgoing surface and the heat of solution of hydrogen in that metal. The kinetic theory flow equation is sufficient to explain the p_i, and the variation of p_i with temperature may be used to compute the work-function at the outgoing surface, and also to obtain values of m/k, where m is the mass of the hydrogen atom and k the Boltzmann constant.—S. G.

***The Freezing Point of Rhodium.** Wm. F. Roeser and H. T. Wensel [with Edward Wichers] (*U.S. Bur. Stand. J. Research*, 1934, **12**, 519–526; *Research Paper* No. **676**).—The freezing point of rhodium was determined by

* Denotes a paper describing the results of original research.
† Denotes a first-class critical review.

measuring with a disappearing filament type of optical pyrometer the ratio of brightness of black bodies immersed in freezing gold and freezing rhodium. The rhodium was melted and frozen *in vacuo* to prevent the absorption of gases during melting. Attempts to operate with the rhodium in atmospheres of air and of nitrogen were not successful. The ratio of brightness of black bodies at the freezing points of gold and rhodium was found to be 751 for wave-length 0·6527 μ. This gives 1966° C. for the temperature of freezing rhodium when the gold point is fixed at 1063·0° C. and C_2 at 1·432 cm.deg. The value 1966° C. is probably accurate to ± 3° C. E. W., in an appendix, deals with the preparation and purity of the rhodium used in this investigation.—S. G.

The Nuclear Spin of Tin. S. Tolansky (*Proc. Roy. Soc.*, 1934, [A], **144,** 574–587).—From spectroscopic evidence it is deduced that the nuclear spins of the two main odd isotopes of tin, 117 and 119, are each — ½.—J. T.

Technical Data on Tantalum, Tungsten, and Molybdenum. Fansteel Products Co. (*Fansteel Bull. R.M.* **16, 17, 18**; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 9).—Three leaflets giving tables of physical data, wire sizes and diameters, &c. The leaflet on tantalum also deals briefly with corrosion-resistance to various chemicals.—S. G.

***Optical Constants of the Alkali Metals.** J. Hurgin and N. Pisarenko (*Nature*, 1934, **133,** 690).—The values calculated, using the free electron gas model and taking into account the collisions of the electrons with the atomic lattice, are in satisfactory agreement with previously measured values.—E. H.

†**Crystalline Structure in Relation to Failure of Metals—Especially by Fatigue.** Herbert John Gough (*Proc. Amer. Soc. Test. Mat.*, 1933, **33,** (II), 3–114).—The Edgar Marburg Lecture. This lecture provides an admirable and lucid summary of the present state of our knowledge of the crystalline structure of metals and its relation to fatigue. The 9 sections into which it is divided discuss the following aspects of the subject: the nature of fatigue, the preparation of single metallic crystals, crystal structure of metals, the distortion of single metallic crystals under simple static stressing systems, the influence of the intercrystalline boundary on static strength and distortion, the effects of cold-working on single crystals and polycrystalline aggregates, cold-working in relation to crystal structure, failure under repeated cycles of stress in relation to the crystalline structure, comparative behaviour of single crystals and polycrystalline aggregates. A *bibliography* of 175 references is appended.—A. R. P.

***Dependence of the Yield-Stress (Streckgrenze) of Metals on Temperature in the Neighbourhood of the Melting Point.** W. D. Kuznetzov and N. A. Bolschanina (*Physikal. Z. Sowjetunion*, 1934, **5,** 31–39).—[In German.] Results obtained by pressing a steel sphere into polycrystalline samples of the metals tin, bismuth, cadmium, and zinc at various temperatures show that the yield-stress of the metal at the melting point is approximately nil.—J. S. G. T.

†**General Properties of Materials at High Temperatures.** H. J. Tapsell (*Science et Industrie*, 1934, **18,** 106–110).—Following a discussion of the influence of temperature on plasticity, tables are given showing the effect on tensile strength of 5 rates of applying the load, and the effect of prolonged loading at specified temperatures over stated testing periods, for Duralumin, 60:40 brass, lead sheet, a magnesium–manganese alloy, and 3 steels. Load–extension curves are quoted to illustrate the variation with temperature of plastic deformation, and the varying effects of time in conjunction with temperature are also shown graphically. General observations on plasticity are illustrated by a number of generalized time–deformation curves. The phenomenon of "negative slip" or "creep recovery" is briefly considered. Variations in ductility are correlated with inter-crystalline cleavage in certain instances, and the effects of shock and of chemical attack are reviewed briefly.—P. M. C. R.

†**Phenomena Associated with the Prolonged Heating of Metals.** H. J. Tapsell (*Science et Industrie*, 1934, **18**, 141–145).—The work of Bailey and Roberts appears to favour an exponential rather than a linear relationship between time of stressing and reciprocal of absolute temperature. The possibility of thermally induced alterations in structure, as in spheroidization and precipitation phenomena, is an important consideration. The effects of the condition of the material at the outset of testing are reviewed; forged non-ferrous materials are stated to show a lower resistance to deformation than cast, below the recrystallization temperature, the latter itself being affected by the degree of cold-working. The influence of grain-size is discussed, with reference to a light alloy and 2 steels. Factors affecting recrystallization temperature are analyzed and summarized. From the difficulty of complete standardization of conditions has arisen the conception of limiting creep stress. A linear relation exists between the logarithms of minimum speed of deformation at points of inflection of creep curves, and logarithms of times required to effect fracture. Time to produce fracture = $\frac{a \text{ (a constant)}}{(\text{minimum speed})^n}$. Typical creep curves are shown for 8 steels, and limiting creep curves (time — % creep) are given for 12 ferrous and non-ferrous materials. The National Physical Laboratory creep-testing procedure is summarized and some results of accelerated tests are tabulated.—P. R.

***The Diffusion in Metals.** W. Seith, E. Hofer, and H. Etzold (*Z. Elektrochem.*, 1934, **40**, 322–326).—The rate of diffusion of magnesium, cadmium, nickel, and mercury in lead, and of lead and mercury in cadmium has been determined. The diffusion of lead in tin was also investigated, but no numerical results were obtained. The mobility in lead of the metals investigated up to the present decreases in the order: gold, silver, magnesium, cadmium, mercury, bismuth, thallium, zinc.—J. H. W.

Action at a Distance by Metals on Micro-Organisms. G. A. Nadson and C. A. Stern (*Zentr. Bakt.*, 1933, II Abt., **88**, 320; and (abstract) *J. Inst. Brewing*, 1933, **39**, 660–661).—See *J. Inst. Metals*, 1933, **53**, 614, and *Met. Abs.*, this volume, p. 165. Evidence was obtained of the toxic action of metals placed near, but not in actual contact with, micro-organisms. Experiments were made with aluminium, copper, and lead. The toxic influence diminished rapidly with increase in distance between metal and culture; it was significant at 2 mm. for aluminium and 5 mm. for lead. Metallic salts possessed a similar, but less intense, action to their metals. As an explanation of the action, it is suggested that electrons are given off by the metal under the influence of the radio-activity of the surrounding medium.—H. W. G. H.

Safeguarding Ancient Buildings—The Death-Watch Beetle. A. N. Cathcart (*Keystone*, **1933**, (2), June, 7 pp.).—Lead is not a satisfactory covering for roofs and gutters, since it usually allows moisture to penetrate into the woodwork, and damp wood is essential for the development and multiplication of the death-watch beetle. Well-laid copper with welted joints and efficient ventilation of the timbers will effectually prevent the attacks of the beetle.
—A. R. P.

Safeguarding Ancient Buildings. Some Notes on Roof Decay and Its Prevention. A. N. Cathcart (*Keystone*, **1934**, (3), April, 6 pp.).—Examples are quoted of lead roofing being perforated by the death-watch beetle. Copper sheet is never touched by the beetle, and copper also appears to be toxic towards the insect; the substitution of this metal for lead in roofing work is therefore strongly advocated.—A. R. P.

Fourth Report of the Atomic Weights Commission of the International Chemical Union. G. P. Baxter, (Mme.) P. Curie, O. Hönigschmid, P. Lebeau, R. J. Meyer (*Ber. deut. chem. Ges.*, 1934, [A], **67**, 47–67).—Revised values for

atomic weights are accepted for potassium, arsenic, selenium, indium, tellurium, cæsium, ytterbium, osmium. Summarized accounts are given of investigations bearing on the atomic weights of the foregoing elements, and also on those of carbon, nitrogen, silicon, sulphur, thallium, lead, tantalum, and niobium.—P. M. C. R.

***The Atomic Weights of Radioactive Substances.** Forrest Western and Arthur E. Ruark (*J. Chem. Physics*, 1933, **1**, 717–722; *C. Abs.*, 1934, **28**, 405).—The atomic weights of lead isotopes, 206, 207, and 208 are obtained in 3 independent ways from chemical and mass-spectrograph data. They are 205·98, 206·98, and 207·98 $\pm$ 0·03. By adding the mass lost in disintegration in the form of α- and β-particles and γ-rays, atomic weights of all known radioactive substances are obtained.—S. G.

The Theory of Liquid Metals. S. Schubin (*Physikal. Z. Sowjetunion*, 1934, **5**, 81–105).—[In English.] The significance of the presence of conductivity electrons in liquid metals and the interpretation of the existence of a residual resistance of metals independent of temperature in the case of liquid metals are discussed mathematically.—J. S. G. T.

Electrical Conductivity at Low Temperatures. S. V. Vonsovsky and A. A. Smirnov (*Physikal. Z. Sowjetunion*, 1934, **5**, 115–130).—[In English.] Using the model of a metal proposed by Kronig and Penny, the authors show that, for low temperatures the resistance of a metal at $T°$ is given by an expression of the form $aT^5 + bT^4 + cT^3$.—J. S. G. T.

The Explanation of Supraconductivity. J. Frenkel (*Nature*, 1934, **133**, 730–731).—Theoretical.—E. S. H.

The Laws of Variation of Resistance of Metals with Temperature: Their Application to Industrial Measurements. —— Jouaust (*Bull. Soc. franç. Élect.*, 1934, [v], **4**, 437–445).—The work of Matthiessen, Onnes, Brillouin, and others is reviewed. J. considers that dimensional variations and local and general straining vitiate resistivity determinations, and advocates the substitution in specifications of temperature coefficients for those of resistivity. —P. M. C. R.

II.—PROPERTIES OF ALLOYS

(Continued from pp. 290–298.)

***The Fatigue Properties of Light Metals and Alloys.** R. L. Templin (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 364–380; discussion, 381–386).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 489. In the discussion *J. A. Crann* presented a table showing the fatigue-endurance values of magnesium alloys based on 500 million cycles as well as the ordinary tensile properties and the ratio endurance limit (L_E)/tensile strength (S_T). In the aluminium–manganese–magnesium alloys L_E increases with the percentage of aluminium both in cast and wrought alloys, whilst L_E/S_T varies for the cast alloys from 0·2 to 0·4 with a mean value of 0·25, and for wrought alloys from 0·31 to 0·38 with a mean value of 0·35; this ratio also tends to increase with increasing aluminium content. Heat-treatment appreciably increases S_T, but has little influence on E_L in the case of the ternary alloys with 8–12% aluminium. Weight for weight, magnesium alloys have a better fatigue-endurance limit than have aluminium alloys. Further discussion took place on the relative value of long and short time endurance tests and on the need for making fatigue tests under more than one type of stress.—A. R. P.

Hiduminium R.R. 53 B. Anon. (*Met. Ind.* (*Lond.*), 1934, **44**, 257; and *Aircraft Engineering*, 1934, **6**, 50).—A short note. The particular applications of Hiduminium R.R. 53 B, a slightly modified alloy of the " R.R. 53 " type, are for fast-moving parts in the electrical industry and for smaller castings in aircraft construction. Its proof stress, maximum stress, elongation %, and

Brinell hardness for sand-cast test-bars "as cast," solution treated, and artificially aged are tabulated. Its composition is: copper 2·5, nickel 1·5, magnesium 0·8, iron 1·2, and silicon 1·2%. Its density is about the same as that of " R.R. 53."—J. H. W.

***Influence of Heavy Metals on Aluminium Alloys.** P. Röntgen and W. Koch (*Light Metals Research*, 1934, **2**, (48), 11–18).—Translated from *Z. Metallkunde*, 1934, **26**, 9–13. See *Met. Abs.*, this volume, p. 168.—J. C. C.

***The Influence of Heat-Treatment and Long-Period Ageing on the Properties of an Aluminium Alloy.** W. Schwinning and E. Dorgerloh (*Light Metals Research*, 1934, **2**, (49), 3–7).—Translated from *Z. Metallkunde*, 1934, **26**, 91–92. See *Met. Abs.*, this volume, p. 291.—J. C. C.

***The Hardness of Aluminium-Rich Binary Alloys in Relation to the Concentration of the Addition Metal.** K. Roth (*Light Metals Research*, 1934, **2**, (49), 8–21).—Translated from *Z. anorg. Chem.*, 1930, **191**, 181. See *J. Inst. Metals*, 1931, **47**, 8.—J. C. C.

***The Cobalt–Tungsten System.** W. P. Sykes (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 385–421; discussion, 421–423).—A tentative constitutional diagram has been constructed from data furnished by micro-examination, diffraction patterns, thermal analyses, and determinations of electrical resistance. Cobalt dissolves 35% tungsten at 1465° C., the temperature of the eutectic. The solid solubility decreases to about 3% tungsten at 550° C. The eutectic occurs at a composition near 46% tungsten and consists of the cobalt-rich solid solution (β) + an intermediate phase (δ) represented by the formula WCo (75·7% tungsten). This latter phase is formed on cooling by a peritectic reaction between the tungsten-rich solid solution (dissolving 0·2–0·3% cobalt) and the cobalt-rich liquid. A second intermediate phase (ε) forms at 1100° C. as the result of a peritectoid reaction between δ and the cobalt-rich solid solution β. It approximates in composition to the formula Co_7W_2 (47·1% tungsten). The cobalt-rich solid solutions are subject to age-hardening above 500° C. A maximum hardness of Rockwell C 65 (Brinell 770) has been observed as a result of ageing at 600° C. for 200 hrs. a rolled alloy containing 35% tungsten. The hardness developed by ageing is unusually persistent at temperatures as high as 700°–750° C.—S. G.

†**Development of Adnic. A Corrosion- and Heat-Resisting White Metal Alloy.** William B. Price (*Metals and Alloys*, 1934, **5**, 71–73). **Adnic. A White Metal Alloy for Corrosion-Resistance and for Moderate Temperature Heat-Resistance.** William B. Price (*Ibid.*, 77–81).—(I.—) An account of the research work which resulted in the production of Adnic. (II.—) The best physical properties of Adnic are obtained with a composition of nickel 29, copper 69–70, tin 1, manganese 0·1–0·25, iron not more than 0·25, silicon less than 0·05, and carbon less than 0·04%. Recrystallization of the severely cold-worked metal starts at 560° C. The 70 : 29 : 1 Adnic alloy in the form of ½-in. hard-rolled rod has an elastic limit of 85,000, a yield-point of 107,000, and tensile strength of 113,200 lb./in.² with an elongation of 10%, a reduction in area of 56·5%, and a scleroscope hardness of 31. The coeff. of thermal expansion is 0·0000163; melting point 1205° C., and the density 0·321 lb./in.² at 68° F. (20° C.). Other data are shown graphically, and include the effect of annealing and cold-drawing on the various properties, and the creep characteristics at high temperatures. Data on corrosion tests in various media are tabulated and comparisons made with the behaviour of bronzes and plain cupro–nickel alloys.—A. R. P.

***Influence of Silver on the Softening of Cold-Worked Copper.** H. C. Kenny and G. L. Craig (*Metals Technology*, **1934**, (Jan.), 1–8, *A.I.M.M.E. Tech. Publ.* **525**).—The temperature at which cold-worked copper softens on annealing is raised by very small amounts of silver, and this effect has been studied for various Lake coppers containing from 0·048 to 0·068% of oxygen. Rockwell

hardness tests and tensile tests on wire specimens were carried out on alloys after long and short anneals at temperatures between 150° and 325° C. The loss in strength by softening during tinning was investigated by immersing tensile specimens for 10 seconds in a 60 : 40 lead–tin bath at 360° C. The softening temperature increases rapidly with the silver content up to 10 oz. per ton (0·034%), and then comparatively slowly. Cold-worked copper free from silver is almost completely softened after a few days at 150° C., whilst copper of the same hardness but containing 10 oz. of silver per ton is not greatly softened after 1 year. These small amounts of silver do not affect the mechanical properties, and have no appreciable effect on the conductivity.
—W. H.-R

***Transformations in the Copper–Tin Eutectoid Alloys.—I.–II.** (I.) I. Isaitchew and G. Kurdjumow. (II.) W. Bugakow, I. Isaitchew, and G. Kurdjumow (*Physikal. Z. Sowjetunion*, 1934, **5**, 6–21, 22–30).—[In German.] (I.—) By annealing copper–tin eutectoid alloys, the β-phase is not changed directly into the α- and γ-phases; an intermediate γ′-phase is first produced. This γ′ phase is characterized by a cubic lattice cell having a parameter approximately half that of the γ-phase; it is, however, possible that it is characterized by an hexagonal axis; in that case the axial ratio is 0·35. The orientations of the respective phases are briefly discussed. (II.—) The effect of temperature of annealing on the crystal structure, minute structure, and electrical resistance of the copper–tin alloys is investigated. The production of an intermediate, γ′, phase from the β-phase during annealing is marked by the lower electrical resistance and greater corrodibility characterizing this intermediate phase. The martensitic intermediate β′ phase is produced by quenching under definite conditions; it is not produced from the β-phase by annealing. Temperatures at which structural changes occur are about 75° C. lower when powders are used than when massive samples or single crystals are used.
—J. S. G. T.

***Strength and Ageing Characteristics of the Nickel-Bronzes.** E. M. Wise and J. T. Eash (*Metals Technology*, **1934**, (Jan.), 1–25, *A.I.M.M.E. Tech. Publ.* **523**).—The mechanical properties of nickel–bronzes have been investigated for alloys containing up to 20% nickel and 13% tin. Tensile properties, Brinell hardness, and fatigue strengths were investigated for (*a*) sand-castings, (*b*) alloys homogenized at 1400° F. and aged at lower temperatures, and (*c*) rolled alloys prepared from specimens annealed at 1400° F., and aged at different temperatures. With the prices of copper, nickel, and tin at the ratios of 9 : 35 : 50, the replacement of part of the tin in bronze by nickel offers attractive savings in cost, together with equal or better mechanical properties. Remarkable tensile strengths of the order 135,000 lb./in.^{2} for annealed and aged alloys, and 170,000 lb./in.^{2} for hard-rolled and aged alloys, can be obtained. Curves are given showing properties for alloys of constant cost based on the above price ratio. The effects of small additions of zinc, chromium, iron, silicon, and lead to the 7·5% nickel, 8% tin alloy were also studied.—W. H-.R.

The Effect of Sulphur and Iron on the Physical Properties of Cast Red Brass (85 Cu, 4 Sn, 5 Zn, 5 Pb). H. B. Gardner and C. M. Saeger, Jr. (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 448–458; discussion, 459–461).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 492. In the discussion *O. E. Harder* made suggestions for improving the foundry technique so as to avoid irregularities in the mechanical properties of this type of alloy. In reply, H. B. G. suggested that the irregularities were due to unsuitable pouring temperatures.—A. R. P.

***Note on Frictional Resistance of Steel and Brass in Shrink Fits.** W. H. Swanger (*Amer. Soc. Test. Mat. Preprint*, **1934**, June, 1–7).—The making of shrink fits by refrigerating the inner member offers an easily accomplished alternative when the converse method of expanding the outer member by heat is not practicable or permissible. S. presents data on the resistance to axial

slip developed between cylindrical rings 1 in. long and 1 in. in diameter assembled on pins which at room temperature were about 0·0015 in. larger in diameter. Prior to assembly the pins were contracted by cooling to — 80° C. in a bath of acetone containing dry ice. Three combinations of material were used: (1) a brass ring on a brass pin; (2) a steel ring on a brass pin; and (3) a steel ring on a steel pin. The resistance to slip was in part dependent on the amount of "oversize" of the pin but was considerably increased when seizing occurred between the contacting surfaces.—S. G.

Silicon–Brasses. W. Dickie (*Met. Ind.* (*Lond.*), 1934, **44**, 510).—A short letter casting doubt on the real cheapness of silicon–brasses owing to contamination of other non-ferrous borings and scrap.—J. H. W.

Kunial Alloys. [H. W.] Brownsdon (*Met. Ind.* (*Lond.*), 1934, **44**, 211–212).—An abstract of an address. The principal physical properties of Kunial brass and copper in the quenched, quenched and tempered, cold-rolled, and cold-rolled and tempered states, and their tempering temperatures and corrosion-resistance, are given in diagrams.—J. H. W.

A New Series of Copper Alloys [Kunial]. Anon. (*Met. Ind.* (*Lond.*), 1934, **44**, 189–190; also *Metallurgia*, 1934, **9**, 113; *Machinist* (*Eur. Edn.*), 1934, **78**, 81–82 E; *Overseas Eng.*, 1934, **7**, 220).—Describes the properties of Kunial brass, copper, nickel–brass, and bronze alloys, which are said to have 3 times the hardness and twice the tensile strength of ordinary copper alloys when annealed at 400°–600° C.—J. H. W.

***Refining [the Structure] of Lead–Antimony Alloys.** V. Montoro (*Met. italiana*, 1933, **25**, 741–747; *Chem. Zentr.*, 1934, **105**, I, 2646).—Addition of 0·2% of sodium to antimonial lead containing 6–16% antimony results in a considerable increase in hardness and a change in the microstructure. Apparently a ternary eutectic is formed which is harder than the binary lead–antimony eutectic.—A. R. P.

Improved Magnesium Alloys. Anon. (*Iron Steel Canada*, 1934, **17**, 23).—A short note briefly describing the properties of ternary magnesium alloys containing aluminium 4–10 and zinc 3–1%.—J. H. W.

***Alloys of Iron, Manganese, and Carbon. V.—Microscopic Studies of Binary Iron–Manganese Alloys.** V. N. Krivobok and Cyril Wells (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 807–820).—Deals with the characteristic microstructures of a series of fairly pure iron–manganese alloys, varying in composition from 100% iron to 100% distilled and remelted manganese. The nature of the constituents is described and illustrated by photomicrographs. Thus the proof is offered, augmenting the dilatometric and X-ray studies of the same alloys already published, that the iron–manganese system does not form a continuous series of solid solutions, but contains several phases, not all of which, however, have been distinguished microscopically—S. G.

***Alloys of Iron, Manganese, and Carbon. VI.—Factors Affecting Transformations in the Binary Iron–Manganese Alloys.** Francis M. Walters, Jr. (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 821–829).—There are a number of factors which affect the completeness of an allotropic transformation and its temperature range. This paper gives the effect on the binary iron–manganese alloys of 3 of these factors, namely, heterogeneity, deformation and heating rate through the α to γ transformation range.—S. G.

***Alloys of Iron, Manganese, and Carbon. VII.—Influence of Carbon on Thirteen Per Cent. Manganese Alloys.** Cyril Wells and Francis M. Walters, Jr. (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 830–845).—The 13% manganese section of the ternary phase diagram has been determined by the examination of specimens brought to substantial equilibrium at crucial temperatures. It was found that a soak of at least 8 hrs. near the solidus was necessary to bring about a satisfactory distribution of manganese in the forged alloys. ε as well as α was found as a low-temperature decomposition product.—S. G.

***Alloys of Iron, Manganese, and Carbon. VIII.—Influence of Carbon on Ten Per Cent. Manganese Alloys.** John F. Eckel and V. N. Krivobok (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 846–864).—This investigation deals with pure alloys containing iron, 10% manganese, and carbon, the latter varying from 0·01 to 1·4%. These alloys represent the 10% manganese section of the iron–manganese–carbon ternary system. The phase diagram at substantial equilibrium was determined, and is included in the paper. The phases present are the γ-solid solution, α-solid solution, and carbides. The ε-phase found in some alloys in small amounts is not included in the phase diagram. The methods used for the determination of the boundary limits for various fields are described. In addition, extra diagrams are given showing the influence of composition and previous heat-treatment on the decomposition of the γ-phase. No mechanical properties have as yet been determined, but a summary of variation in hardness brought about by different treatments is included.—S. G.

***Alloys of Iron and Manganese. IX.—Transformations and Heterogeneity in the Binary Alloys of Iron and Manganese.** Francis M. Walters, Jr. (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 1002–1013; discussion, 1013–1015).—See *J. Inst. Metals*, 1933, **53**, 624.—S. G.

***Alloys of Iron and Manganese. X.—Thermomagnetic Analysis of the Binary Alloys of Iron and Manganese.** F. M. Walters, Jr., and John F. Eckel (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 1016–1020).—The variation of magnetism with temperature was observed with a ballistic galvanometer. The effect of manganese on ferrite is to decrease its magnetism moderately. Alloys containing 16% manganese and above are practically non-magnetic because the two phases of which they are composed, γ and ε, are non-magnetic. Evidence, hitherto lacking, was found for an ε–α transformation.—S. G.

***Alloys of Iron and Manganese. XI.—The Variation of Electrical Resistance with Temperature in Binary Alloys of Iron and Manganese.** F. M. Walters, Jr., and Cyril Wells (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 1021–1027).—The electrical resistance of binary alloys of iron and manganese containing between 0 and 29% manganese was measured from 25° to 1000° C. It was found that manganese greatly increases the resistance and decreases the temperature coeff. of α-iron. Manganese was found to have very little effect on the resistance of γ-iron, which at 1000° C. is almost independent of the manganese content.—S. G.

***Alloys of Iron and Manganese. XII.—Alloys of Iron and Carbon with 2·5 and 4·5 Per Cent. Manganese.** M. Gensamer (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 1028–1034).—The 2·5 and 4·5% manganese sections of the constitutional diagram of the ternary system iron–manganese–carbon, with carbon up to 1·3%, have been drawn from data obtained by the study of 12 alloys prepared with great care from materials of high purity. The results show that the recent work of Bain, Davenport, and Waring (*Trans. Amer. Inst. Min. Met. Eng.*, 1932, **100**, 228) on alloys of commercial purity are substantially correct—no important differences were observed between their results for alloys of commercial purity and the much purer alloys used in this study.—S. G.

***A Comparison of Certain White-Metal Bearing Alloys, Particularly at Elevated Temperatures.** C. E. Swartz and A. J. Phillips (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 416–425; discussion, 426–429).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 495. In the discussion *L. C. Blomstrom* and *E. R. Darby* reported the results of some tests made on an antimonial zinc–cadmium alloy in an American car; the tests showed that this alloy was much superior to tin-base Babbitt metals in continuous running at high speeds. *H. W. Crillett* suggested that adverse criticism of the behaviour of zinc–cadmium bearing metals was directed solely against the eutectic alloy, which contained no hard constituent such as was present in tin-base bearing metals; this constituent could be introduced by addition of antimony, whereby structures closely resembling those of tin-base Babbitts could be obtained.—A. R. P.

***The Effect of the Addition of Lead on the Hardness of Certain Tin-Base Bearing Alloys at Elevated Temperatures.** J. N. Kenyon (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 430–444; discussion, 445–447).—For abstract of the paper, see *J. Inst. Metals*, 1933, **53**, 495. In the discussion *H. K. Herschman* pointed out that hardness values do not always indicate the suitability of a bearing metal for service, and questioned the effect of lead on the hardness at 75°–100° C. In reply J. N. K. quotes figures showing that 3–4% lead increases the hardness of copper–antimony–tin alloys by about 10–20% at 25° C. and by 3–8·8% at 100° C. Tabulated results on the effect of mould temperatures of 25°, 76°, 176°, and 206° C. on the hardness of tin-base Babbitts with and without lead are given, which show that mould temperature has little effect on the temperature–hardness relations except in the case of alloys with a high antimony content. More than 2% lead was found to cause crumbling at 200° C. in an alloy of tin 89, antimony 7·5, and copper 3·5%.—A. R. P.

Special White Metal Alloys. E. Richards (*Metallbörse*, 1934, **24**, 17–18, 49–50, 81–83, 113–114, 146).—An alphabetical list of tin- and lead-base bearing metals giving compositions and uses.—A. R. P.

The White Alloys of Tin. III.—Pewter. Anon. (*Tin*, **1934**, (April), 19–22).—See *Met. Abs.*, this volume, p. 174. Although old pewters contain a very varied amount of tin, modern pewter usually contains not less than 95% tin. The properties of such alloys, to which small quantities of copper and antimony are added as hardeners, are described.—J. H. W.

***A Microscopic Examination of Iron–Tin Reaction Products.** W. D. Jones and W. E. Hoare (*Iron Steel Inst. Advance copy*, **1934**, May, 1–8).—The existence of 3 intermetallic compounds in the iron–tin system has been confirmed. These are considered to be of compositions indicated approximately by the formulæ: Fe_2Sn, FeSn, $FeSn_2$. The existence of the compound FeSn is supported by evidence additional to that advanced by the work of Edwards and Preece. The γ-phase of Ehret and Westgren has not been confirmed. The investigation indicated that the iron–tin system requires further elucidation.—S. G.

***The Intermediate Phases of the Iron–Tungsten System.** W. P. Sykes and Kent R. Van Horn (*Trans. Amer. Inst. Min. Met. Eng.*, 1933, **105**, Iron Steel Div., 198–212; discussion, 212–214).—For abstract of the paper see *Met. Abs.*, this volume, p. 125. In the discussion *O. E. Harder* and *W. P. S.* consider the merits of the sintering process of making alloys for investigating phase equilibria, and point out the necessity for very prolonged heating to ensure complete diffusion of the constituents and the attainment of stable equilibrium—A. R. P.

***Contribution to the Knowledge of the System Iron–Tungsten.** Otto Landgraf (*Forschungsarb. Metallkunde u. Röntgenmetallographie*, 1933, (**12**), 33 pp.; *Chem. Zentr.*, 1934, **105**, I, 2971–2972).—The alloys were made by melting the constituents in an atomic hydrogen flame using tungsten electrodes to avoid absorption of carbon. Heat-treatment was carried out in a surface combustion furnace. X-ray and micrographic examinations established the existence of the following fields: (i) α-iron containing 0% tungsten at 20° C. to 23% tungsten at 1530° C.; (ii) a closed γ-field; (iii) the compound Fe_3W_2; (iv) a eutectic between α-iron and Fe_3W_2 containing 33% tungsten; (v) tungsten containing a small quantity of Fe_3W_2 in solid solution, and (vi) a duplex field containing tungsten and Fe_3W_2. Notes on the Brinell hardness, density, and microstructure are given.—A. R. P.

***Zinc Die-Casting Alloy Ageing Data.** E. A. Anderson and G. L. Wesley (*Metals and Alloys*, 1934, **5**, 97–99, 102).—Modern zinc-base die-casting alloys made from 99·99% zinc and containing aluminium 4·1, magnesium 0–0·04, and copper 0–2·9% shrink steadily at 20° C. during the first 4–5 weeks after casting, but at 95° C. shrinkage is completed in a few hours. Certain of the alloys aged at room temperature expand again after 6 months to 2 years, but when aged at higher temperature subsequent expansion is prevented; on the other hand,

other alloys may be permanent after normal ageing, but subject to growth after accelerated ageing. In any case, the changes are very small, and of importance only when the tolerance is of the order of 0·0001 in. Changes in tensile strength and ductility during ageing are relatively small after the first few hrs. The steam test for intergranular corrosion has been critically examined, and the results obtained with several alloys within the above composition range are discussed.—A. R. P.

***Dimensional Changes in Die-Casting Alloys. Metastable Beta Phase in Aluminium–Zinc Alloys.** R. G. Kennedy, Jr. (*Metals and Alloys*, 1934, **5**, 106–109, 112).—The properties of β-aluminium–zinc alloy (21·7 : 78·3) made from aluminium containing less than 0·02% of impurities and zinc with less than 0·0001% of impurities have been investigated. After prolonged annealing at 350° C. and quenching in ice-water, the temperature increases slowly for 2 minutes, then sharply to a maximum at 4 minutes; in alloys with more zinc than corresponds with pure β this heat evolution takes place more rapidly. Similar changes occur in the hardness of the β alloy after quenching, maximum hardness being attained in 6 minutes; this maximum is followed by a sharp decrease to the value after quenching in 15 minutes, then by a slow decrease during several days. Practically no contraction occurs after the first 1–2 days at room temperature. X-ray examination of β at above 350° C. indicates a cubic lattice and a simple solid solution, not the compound Al_2Zn_3.—A. R. P.

Heat-Resistant Alloys. —— Piwowarsky (*Congrès du Chauffage Industriel* (Preprint), *Group* 1, *Sect.* 3, **1933**, 8 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 15). —A survey of recent research. A useful tabular summary is included of compositions of various Continental heat-resistant alloys, giving the name of the manufacturer and the special property claimed. Alloys mentioned are Sicromal, Contracid, Megapyr, Thermax, Alferon, Pyrodur, Niresist, Ferrotherm, and Nicrotherm.—S. G.

Special Alloys. Anon. (*Z. ges. Giesserei-Praxis : Das Metall*, 1934, **55**, 78, 122, 164).—Cf. *Met. Abs.*, this volume, pp. 125 and 172. The composition, preparation, and properties of the alloys Elektrum, Elephanten-S-bronze, Elinvar, Elmarid, Emerald-bronze, Elkonit, Elektron, Engestrium, Emperor bronze, and Erhards' War Bronze (Kriegsbronze) are described.—J. H. W.

Notes on the Ageing of Metals and Alloys. Albert Sauveur (*Trans. Amer. Soc. Metals*, 1934, **22**, 97–113; discussion, 114–119).—See *J. Inst. Metals*, 1933, **53**, 627.—S. G.

†Thermal and Electrical Conductivities of Metals and Alloys. J. W. Donaldson (*Metallurgia*, 1934, **10**, 17–19).—In a review of recent work which has been carried out on the thermal and electrical properties of ferrous and non-ferrous alloys, consideration is given to the relationship between the two properties as expressed by the Lorenz law $K\sigma = T$ constant, where K = thermal conductivity, σ = electrical resistivity, and T = absolute temperature. In general, it is concluded that the law holds approximately for pure metals and for alloys such as steel and the alloys of copper and of aluminium, it also holds with a considerable degree of accuracy, but that it varies for cast iron. The practical application of such a relationship, if definitely established for metals and alloys, is also discussed.—J. W. D.

†The Mechanism of Phase Transformations in Eutectoid Alloys. G. Kurdjumow (*Physikal. Z. Sowjetunion*, 1933, **4**, 488–500).—[In German.] Experimental work relating to phase transformations in various alloys, including steel, is critically reviewed. The significance of (1) transformations not involving the process of diffusion; (2) destruction of intermediate phases and (3) the direct production of phases of the solid solution is discussed. A *bibliography* of 34 references is appended.—J. S. G. T.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

(Continued from pp. 298–301.)

***On Grain-Size and Grain-Growth.** M. A. Grossmann (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 1079–1104; discussion, 1105–1111).—The paper records observations of the manner in which grain-size develops in a carburizing test and, in particular, the relationship of the McQuaid–Ehn carburizing test (usually carried out at 925° C. for 8 hrs.) to the austenite grain-sizes which may develop at other temperatures or in other periods of time.—S. G.

The Mechanism of Crystal Growth. Wheeler P. Davey (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 965–996; discussion, 997–1001).—See *J. Inst. Metals*, 1933, **53**, 628.—S. G.

***Slip-Bands and Twin-Like Structures in Crystals.** Constance F. Elam (*Nature*, 1934, **133**, 723).—Slip bands agreeing with traces of {110} planes have been observed in the β constituent of brass. Twin-like structures are produced when slip occurs on two planes equally inclined to the axis (in a tensile test) in different parts of the same crystal. The structures persist when the crystal is repolished and re-etched.—E. S. H.

***Deformation Structure of a Drawn Brass Tube.** V. Montoro (*Met. italiana*, 1933, **25**, 825–831; *Chem. Zentr.*, 1934, **105**, I, 2646).—The crystallite orientation in a drawn brass tube (copper 73·3, zinc 20, aluminium 6·7 atomic-%) has been determined during various stages of drawing. Most of the crystallites are oriented in the [111] direction, tangent plane (011); but a few are oriented in the [001] direction, tangent plane (100). The distribution of the crystallites in these groups and the tendency of the fibre axes to lie in the geometrical axis of the tube depend on the dimensions of the tube and the working conditions.—A. R. P.

***Multiple Laue Spots from Aluminium Crystals.** A. Komar and W. Obukhoff (*Nature*, 1934, **133**, 687).—The distribution of intensity in Laue spots from thick (6 mm.) deformed aluminium crystals depends greatly on the degree of plastic deformation.—E. S. H.

***An X-Ray Study of the Gold–Iron Alloys [and Some Magnetic and Age-Hardening Properties].** Eric R. Jette, Willard L. Bruner, and Frank Foote (*Metals Technology*, **1934**, (Jan.), 1–14, *A.I.M.M.E. Tech. Publ.* **526**).—The gold–iron system has been investigated by X-ray analysis, and the lattice constants have been determined for specimens annealed and quenched from different temperatures. The system contains the two terminal solid solutions, and no intermediate phases or compounds. The solid solution in gold varies from about 3·5% of iron by weight at 300° C. to 17·2% at 724° C., so that age-hardening precipitation is to be expected, and was studied for an alloy containing 15% of iron. The solubility of gold in α-iron is small at low temperatures, and increases to about 2% of gold by weight at 700° C., but accurate photographs were not obtained. The homogeneous gold-rich alloys retain the diamagnetic properties of pure gold up to about 0·1% iron, when they become paramagnetic, whilst the 10% and 15% iron alloys are ferromagnetic when quenched from high temperatures, even though they still consist of the homogeneous solid solution in gold. In the iron-rich alloys the γ structure could not be retained by quenching.—W. H.-R.

***X-Ray Studies on [and Solid Solution Limits in] the Nickel–Chromium System.** Eric R. Jette, V. H. Nordstrom, Barnard Queneau, and Frank Foote (*Metals Technology*, **1934**, (Jan.), 1–11, *A.I.M.M.E. Tech. Publ.* **522**).—Nickel–chromium alloys were prepared from pure electrolytic metals, and X-ray powder photographs were taken after annealing and quenching from different temperatures up to 1150° C. The system consists of the two terminal solid

solutions with an intervening two-phase area, but no intermediate compounds were detected. The solubility of nickel in chromium is small at low temperature, but increases markedly at high temperatures to 8·4% nickel by weight at 1113° C. The solubility of chromium in nickel increases almost linearly with the temperature from about 32·4% chromium by weight at 524° C., to 52·2% at 1113° C. This last value is beyond the eutectic composition of the previously accepted equilibrium diagrams, but these are based on less pure materials. Some of the supposed nickel–chromium compounds reported in previous X-ray work are probably due to oxide and nitride contamination.—W. H.-R.

***Crystal Orientations Developed by Progressive Cold-Rolling of an Alloyed Zinc Containing 1 Per Cent. of Copper, and 0·01 Per Cent. of Magnesium.** M. L. Fuller and Gerald Edmunds (*Metals Technology*, **1934**, (Jan.), 1–8, *A.I.M.M.E. Tech. Publ.* **524**).—Cast bars of the above alloy were rough rolled by the usual hot-rolling practice, and then annealed, cold-rolled with a total reduction of 50%, reannealed, and "finish-rolled" cold, with total reductions of 30, 50, and 80% to a final thickness of 0·04 in. The crystal orientation was investigated by the method previously used (F. and E., *Trans. A.I.M.M.E.*, 1932, **99**, 75). The crystals deform, like those of pure zinc, by the gliding of blocks of the crystal parallel to the basal plane in a direction of closest packing of the lattice, and by twinning on planes of the form {102}. The two preferred orientations known for zinc were observed, and also a third type with the basal plane perpendicular to the rolling direction. In this last position crystals tend to remain fixed in orientation during rolling. This type of preferred orientation has not been reported for pure zinc, and this is probably because the pure metal recrystallizes during rolling much more readily than the alloy.—W. H.-R.

***On the Binding Forces in the Alkali and Alkaline Earth Metals According to the Free Electron Theory.** O. K. Rice (*J. Chem. Physics*, 1933, **1**, 649–655). —A full account of this work, previously published only in abstract (see *Met. Abs.*, this volume, p. 13).—S. G.

†**The X-Ray Investigation of Microstructure: Problems and Methods.** W. E. Schmid (*Arch. tech. Messen*, 1934, **3**, (34), T48–T49).—A survey of current applications of the X-ray examination of crystal structure. These are summarized thus: general investigation of microstructure, measurement of grain-size, determining orientation, demonstrating the presence of elastic stresses and internal strain, comparison of different crystalline bodies, and hence estimation of effect of alloying ingredients, and determination of the atomic arrangement in the space-lattice. The fundamental principles of the process are stated, and the standard methods of Laue and of Debye–Scherrer and Hull are described, with some recent modifications.—P. M. C. R.

***Segregation of Polonium in Bismuth Crystal [Evidence for Secondary Structure in Crystals].** William W. Eaton (*Phys. Rev.*, 1934, [ii], **45**, 647–648).—The results of Focke (*Phys. Rev.*, 1934, **45**, 219) are confirmed.—W. H.-R.

IV.—CORROSION

(Continued from pp. 301–304.)

***Corrosion-Resistance of Structural Aluminium.** E. H. Dix, Jr. (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 405–412; discussion, 413–415).—Since the mechanical testing of thin-sheet specimens as a means of evaluating the relative corrosion-resistance of metals does not afford satisfactory data for obtaining a true conception of the mechanical permanence of thick structural shapes, an extensive series of tests is being made on aluminium alloys by the Aluminum Research Laboratories, involving outdoor and accelerated corrosion exposures of full-sized structural shapes in comparison with sheet and plate specimens. The results up to the present on Duralumin 17 ST (copper 4–4·3,

manganese 0·6, magnesium 0·5, iron 0·5, and silicon 0·2–0·5%) indicate that the corrosion is "self-stopping," and therefore tensile tests made on thin specimens given an entirely misleading idea of the behaviour and stability of structural sections. Beam and column tests on full-size sections show no decrease in the load-supporting capacity of the alloy after exposure to severe corrosive conditions, which produced marked deterioration of the mechanical properties of thin sections. The depth of penetration of the corrosion appears to be independent of the thickness, and on sections of 0·2 in. and thicker the effect of corrosion on the mechanical properties is negligible. In the discussion further evidence of the stability of thick sections of Duralumin 17 ST under corrosive conditions was given by *L. B. Tuckerman* and by *H. S. Rawdon* and *W. H. Mutchler*.—A. R. P.

***Effect of Methyl Alcohol on Magnesium, Aluminium, and Their Alloys.** J. Formánek (*Automobiltech. Z.*, 1934, **37**, 190–192).—The corrosive action of anhydrous methyl alcohol on certain light alloys is inhibited by water, but this renders the "methanol" unsuitable for use in benzene–ethyl–methyl alcohol mixtures. The effect of 3 grades of methyl alcohol was investigated on pure magnesium powder, commercial magnesium ribbon, 5 types of Elektron (analyses given), pure powdered aluminium, Lautal, Silumin, and Hydronalium. Additions of anhydrous ethyl alcohol, or its presence up to 50% in the mixture, inhibited corrosive attack; with more than 50% methyl alcohol certain materials are attacked, but this action is checked if 0·5% of acetone is added. Commercial "methanol," containing traces of sulphur, phosphorus, zinc, and arsenic, may cause severe attack.—P. M. C. R.

***Outdoor Test Results on Bare and Metal-Coated Ferrous Specimens.** C. D. Hocker (*Amer. Soc. Test. Mat. Preprint*, **1934**, March, 1–19).—The time required for the development of the first rust spots on hot-dipped galvanized-iron sheets and the subsequent progressive rusting in several test localities is illustrated graphically. Similar graphs are given for hardware coated with zinc (by plating, by hot-dipping, and by Sherardizing), cadmium (by plating), aluminium and lead (by hot-dipping). Hot-dipped zinc coatings are superior to Sherardized and plated zinc coatings, which appear to be of equal merit except in the case of deeply recessed articles, where the plated deposit does not throw well. Plated cadmium deposits are inferior to zinc as a protection for steel. Hot-dipped aluminium coatings afford good protection to steel in all types of atmosphere; so far little difference has been detected in the behaviour of aluminium coatings (1·55 oz./ft.^{2}) and hot-dipped zinc coatings (2·2 oz./ft.^{2}). Lead coatings are on the whole unsatisfactory rust preventatives except in industrial atmospheres; pinholes are the chief cause of this unsatisfactory behaviour.—A. R. P.

***The Harmony of Outdoor Weathering Tests [Corrosion of Zinc and Cadmium-Coated Steel].** R. F. Passano (*Amer. Soc. Test. Mat. Preprint*, **1934**, March 49–61).—Outdoor corrosion tests in 5 different types of atmosphere show that zinc coatings of a given weight last longer than cadmium coatings of equal weight, and that the amount of zinc coating required for a given amount of protection varies considerably with the type of atmosphere. The underside of galvanized sheets on test racks is fairly well protected by the zinc coating in all atmospheres, but zinc coatings afford little protection to steel when moisture is allowed to accumulate between the plates. This latter fact is of importance, in that it explains failures at laps in construction of corrugated galvanized iron.—A. R. P.

***Galvanic Corrosion by Contact of Dissimilar Metals.** C. L. Hippensteel (*Amer. Soc. Test. Mat. Preprint*, **1934**, March, 39–48).—The corrosion of other metals in contact with them is accelerated by the following metals in the order given (most active metal first): nickel, tin, copper, iron, lead, aluminium. The common metals may be rated from best to worst according to their sus-

ceptibility to acceleration of corrosion by galvanic action as follows: nickel, copper, tin, lead, aluminium, iron. Data are given of the behaviour of couples of all the above metals in various types of atmosphere.—A. R. P.

***How Soon is it Safe to Draw Conclusions? (A Discussion of the Early Interpretation of Test Results in the Atmospheric Corrosion of Non-Ferrous Metals and Alloys.)** W. H. Finkeldey (*Amer. Soc. Test. Mat. Preprint*, **1934**, March, 20–38).—An analysis is given of the data collected by a sub-committee of the A.S.T.M. which has been making atmospheric corrosion tests on 24 non-ferrous metals and alloys in 9 different atmospheres, and the difficulties encountered in interpretating the data are discussed. The results so far obtained show that the initial rate of corrosion of most non-ferrous metals and alloys, whether measured by loss in weight or a loss in tensile strength or ductility, decreases after exposure for 1–2 years, and the time required to reach a more or less normal rate of corrosion varies with the metal or alloy and with the type of atmosphere. Size and shape of materials and variations in the tensile strength and ductility of the different parts of the specimen are of importance in interpreting the results. A critical examination of the data so far obtained leads to the following conclusions. In industrial atmospheres the greatest resistance to corrosion is shown by antimonial lead, chemical lead, pure tin, copper-rich alloys, commercial copper, commercial aluminium, and a 1% manganese–aluminium alloy, and least resistance by nickel, zinc, Duralumin, and a 1 : 0·6 silicon–magnesium–aluminium alloy. Manganese–bronze, 70 : 30 brass, and 70 : 30 nickel–copper alloy are less resistant to industrial atmospheres than commercial copper. In marine atmospheres nickel and nickel–copper alloys, chemical lead and antimonial lead show the greatest resistance to corrosion, and zinc, tin, and Duralumin the least; high-copper alloys and commercial copper are less resistant than nickel–copper alloys, and aluminium alloys in general show a low resistance to corrosion in marine atmospheres except aluminium-coated Duralumin. Corrosion of all the non-ferrous alloys tested in rural atmospheres is very slight.—A. R. P.

Corrosion by Sea and Ozone. Anon. (*Met. Ind.* (*Lond.*), 1934, **44**, 300).—Briefly describes the work of the Mersea Island Testing Station.—J. H. W.

The Use of Bureau of Standards Soil Corrosion Data in the Design and Protection of Pipe-Lines. K. H. Logan (*Amer. Soc. Test. Mat. Preprint*, **1934**, June, 1–15).—In 1922 the U.S. Bureau of Standards undertook to determine whether serious corrosion could occur underground in the absence of stray electric currents. The existence of such corrosion is demonstrated by the data, but the solution of the problem of economically reducing the corrosion is incomplete. Soils rather than materials control the corrosion of existing pipelines. The Bureau of Standards data on the corrosiveness of soils must be modified by coefficients or factors which take account of conditions not represented in the Bureau tests. Further work is required to determine the significance of certain tendencies shown by the data; notably, the effects of the size and age of the specimen on which pit measurements are made, the protective effects of corrosion products, and the results of departure from homogeneity of the soil with respect to its physical characteristics. An economic solution of the problem of protecting pipes against corrosion cannot be found until numerical values can be assigned for the life of unprotected pipes and the life extension to be expected as the result of the use of a protective coating. Ideas as to the necessary qualities of a satisfactory coating have been developed, but there are no satisfactory ways of measuring these qualities or of determining the amounts of each property which are necessary.—S. G.

†Report on Bureau of Standards Soil Corrosion and Pipe Coating Investigation. Leonard P. Wood (*J. Amer. Water Works Assoc.*, 1934, **26**, 176–188).—A review, with some individual comments, of the scope, progress, and results of

the soil corrosion investigation of the U.S. Bureau of Standards (cf. *Met. Abs.*, this volume, p. 242).—J. C. C.

The Corrosion of Metal Pipes by Stray Currents in the Soil. Anon. (*Bull. tech. Suisse Romande*, 1934, **60**, 117–118).—A brief criticism and correlation of work published by O. Scarpa (*Energia elettrica*, **1934**, Jan.), and by R. Gilrat (*Rev. gén. Élect.*, **1934**, Feb. 17 and 24).—P. M. C. R.

Field Tests on Corrosion. J. C. Hudson (*Met. Ind.* (*Lond.*), 1934, **44**, 415–418, 441; discussion, 441–443).—Read before the Midland Metallurgical Societies (Birmingham Local Section of the Institute of Metals, Birmingham Metallurgical Society, and Staffordshire Iron and Steel Institute). The field tests carried out by more or less national organizations in Germany, America, Sweden, and Holland are briefly described, and a fuller account of the work being done in this country is given.—J. H. W.

The Usefulness of Corrosion Tests to the Chemical Engineer. A. S. White (*Indust. Chemist*, 1934, **10**, 98–101).—A general discussion.—E. S. H.

The Assessment of Corrosion Damage. A. S. White (*Indust. Chemist*, 1934, **10**, 170–172).—W. considers the relative effects of (*a*) general and uniform surface attacks; (*b*) pitting; and (*c*) intergranular attack.—E. S. H.

V.—PROTECTION

(Other than Electrodeposition.)

(Continued from pp. 304–306.)

The Fight Against Corrosion. L. Labiesse (*Arts et Métiers*, 1934, **87**, 74–83).—The methods of protecting iron and steel from corrosive attack are summarized, and include coating the base metal with aluminium, zinc, tin, lead, cadmium, nickel, and chromium, by immersion, spraying, cementation, and electrolysis.—J. H. W.

Surface Protection of Metals. Leonard F. Hirsh (*Machinist* (*Eur. Edn.*), 1934, **78**, 252–253E).—The methods of application and the advantages and limitations of the 6 more commonly used rust-proofing processes, namely, hot galvanizing, Sherardizing, zinc, and cadmium plating, Parkerizing, and Bonderizing, are described.—J. H. W.

The Protection and Decoration of Aluminium and Its Alloys by Anodic Treatment. S. Wernick (*Indust. Chemist*, 1934, **10**, 179–183).—A review, covering methods of production of the film, theory of its formation, and method of detaching it.—E. S. H.

Is the Tinning of Copper Efficacious? Anon. (*Illust. Z. Blechindustrie*, 1934, **63**, 563–564).—From a report of the Preussische Landesanstalt für Wasser-, Boden- u. Lufthygiene. The practicability of tinning is influenced both by working conditions and by method. Galvanization, although so far of limited application, has given good results; wiping or dipping, unless lead is present, tends to give a brittle and porous coating, and on hygienic grounds the presence of lead is inadmissible for certain purposes, besides increasing the liability to corrosion. The progressive corrosion of tinned objects is described, with emphasis on the action of certain accelerating agents, the presence of which in water renders tinning ineffective.—P. M. C. R.

A New Zinc-Coating Process. J. L. Schueler (*Wire and Wire Products*, 1934, **9**, 139–141).—In the "Flame-Sealed" zinc-coating process, steel wire passes through an annealing furnace, is cooled, cleaned in hydrochloric acid and a fluxing solution, dried and passed through a bath of molten zinc. Thence it passes to a coating regulator, in which the amount of zinc to be carried by the wire is regulated mechanically. Finally, it passes through a flame-sealing unit where the coating is consolidated.—J. H. W.

†**The Present Position of Galvanizing Technique and Galvanizing as a Protection Against Rusting.** Hans M. Forstner (*Oberflächentechnik*, 1934, **11**, 51–53, 65–67, 75–79, 89–92).—Modern methods of coating ferrous metals with zinc are described and the properties of the coatings obtained by the various processes are critically discussed, with especial reference to their protective value against rusting.—A. R. P.

Behaviour of Sprayed Metal Coatings Towards Liquids and Gases. H. Reininger (*Metallwaren-Ind. u. Galvano-Tech.*, 1934, **32**, 235–236).—Vessels with sprayed protective coatings should not be used for boiling liquids, since liquid enters the pores and there vaporizes, with the production of a high pressure, which tears the coating away from the base metal. Sprayed zinc coatings, although porous, afford adequate protection for iron and steel articles against weathering, since the pores gradually become filled with zinc oxide and carbonate, which form an impervious cement binding the network of zinc together.—A. R. P.

Metallization by Projection. Anon. (*Galvano*, **1934**, (23), 28–29, (24), 27–28).—A review.—E. S. H.

New Process Employs Alternating Current to Rustproof Metal Parts [Granodizing]. Anon. (*Automotive Ind.*, 1934, **70**, 405).—The Granodizing protective process, primarily intended for steel sheet, can be modified to provide a resistant foundation for the reception of paint on zinc-base die-castings or cadmium plating. The chemically cleaned pieces are immersed in Granodine, a proprietary preparation, and exposed to a controlled a.c. for a period varying with the type of surface. A smooth, continuous, and insoluble deposit of tin–zinc phosphate is said to result.—P. M. C. R.

Difficulties in Painting Copper with Oil Colours. Fritz-Jürgen Peters (*Korrosion u. Metallschutz*, 1934, **10**, 91–93).—Oil colours dry very slowly and irregularly on copper, drying generally starting from more or less oxidized places and spreading outwards so that the dried paint film has a patchy appearance. Drying proceeds normally, however, on a uniformly oxidized copper surface, but this is difficult to obtain in practice, hence it is recommended to apply a lacquer film as a priming coat, since paint films dry normally on this.—A. R. P.

Protective Coatings for Metal Work. E. A. Hurst (*Indust. Finishing* (*U.S.A.*), 1934, **10**, (4), 16–22).—A review, confined to paint coatings.—E. S. H.

VI.—ELECTRODEPOSITION

(Continued from pp. 307–309.)

Cadmium Plating of Iron and Steel Parts. Werner Fröhlich (*Metallbörse*, 1933, **23**, 1537–1538).—Most of the faults found in cadmium-plated ferrous articles are attributable to incorrect preparation; practical hints are given for cleaning the articles and for operating various types of plating bath.
—A. R. P.

On Chromium Plating. Max Schlötter (*Oberflächentechnik*, 1934, **11**, 40–41).—The use of an intermediate nickel layer not less than 0·02 mm. thick is recommended in all cases where an outer chromium plate is to be applied, even when brass or copper is the base metal. The nickel should be deposited under such conditions that it is practically free from adsorbed hydrogen; it then acts as an adsorbent for the hydrogen generated during chromium plating, which otherwise would form a gas layer between the base metal and the chromium, and thereby impart a tendency to flake to the chromium plate.
—A. R. P.

Theory of Chromium Plating. Erich Müller (*Z. Elektrochem.*, 1934, **40**, 326–337).—E. Liebreich's theory of chromium plating (see *Met. Abs.*, this

volume, p. 184) is discussed and criticized and M.'s own theory is further elucidated. Cf. *J. Inst. Metals*, 1932, **50**, 370 *et ante*.—J. H. W.

The Reduction of Mist or Spray from Chromium Baths by Fixed Oils such as Fish Oil. C. M. Alter and F. C. Mathers (*Monthly Rev. Amer. Electroplaters' Soc.*, 1934, **20**, (9), 11–16).—Spray loss from chromium-plating baths can be reduced or almost entirely eliminated by covering the surface with a thin film of oil which forms a layer of foam; such oils are fish oil, whale oil, sperm oil, olive oil, castor oil, and lanoline. About one drop of oil per in.^{2} of surface is sufficient, but a few drops should be added occasionally to keep the foam layer intact. The oil does not affect the plating results in any way, and is not oxidized by the bath.—A. R. P.

***The Electrodeposition of Nickel from Solutions of More than p_H 7.0.** Marcel Ballay (*Compt. rend.*, 1934, **44**, 1494–1496).—Good deposits have been obtained by specially buffered solutions with p_H values between 3·5 and 10·0, with a current density up to 10 amp./dm.^{2}. The concentration of nickel in sulphate solutions is limited by the low solubility of the double nickel–ammonium sulphate. The addition of citric acid and its alkali salts prevents precipitation of nickel hydroxide. For concentrations of nickel of from 20·8 to 45 grm./litre, the minimum concentration of citrates must be such that the ratio of the atomic concentration of nickel to the molecular concentration of citrate is about 2. Glycollic and lactic acids and sodium lactate act in a similar manner. Malic and tartaric acids, glucose, maltose, and glycerine do not prevent precipitation of nickel hydroxide in the solutions studied. The following solution was particularly studied: nickel 20·8, NH_3 6·3, Cl 6·0, neutral crystalline sodium citrate 150 grm./litre at 40° C., with current density from 2 to 10 amp./dm.^{2} and p_H varying from 3·6 to 9·8. In the alkaline zone, the deposits are very fragile. With p_H = 5·0, 7·0, and 9·6, the respective cathodic efficiencies were 59·2, 90·0, and 94·2%, the anodic efficiency falling from 100% at p_H = 5·0–7·0 to 88% at 9·6. In the absence of citrate, a solution containing 20·8 grm./litre of nickel had a cathodic efficiency of about 82% at 50° C., and a current density of 1·1 amp./dm.^{2}. The nickel did not appear to be monovalent in this state as had been believed.—J. H. W.

Impurities of Nickel Solutions with Reference to Pitting of Electrodeposited Nickel. F. J. Liscomb (*Monthly Rev. Amer. Electroplaters' Soc.*, 1933, **20**, (4), 6–10; discussion, 10–15).—One of the chief causes of pitting in nickel plate is the presence in the solution of organic matter; this may be removed by the following treatment: the p_H is raised to 6·3 by addition of nickel carbonate, caustic soda, or ammonia, the bath is heated to 50°–65° C., and to every 100 gall. is added a solution of 12 oz. of ferrous sulphate crystals, followed by 33 oz. of 5% hydrogen peroxide, and, after standing over-night, the mud containing the organic matter and ferric hydroxide is filtered off. The p_H is then adjusted to 5·4–5·6 by addition of dilute H_2SO_4.—A. R. P.

On the Nickel Plating of Sheet Aluminium Articles. Robert J. Snelling (*Metallwaren-Ind. u. Galvano-Tech.*, 1934, **32**, 28–29).—The articles are polished and cleaned mechanically, then chemically cleaned by immersion for 1½ minutes at 95° C. in a solution containing borax 15, sodium carbonate 7·5, sodium hydroxide 2, ammonium chloride 2, and soap 4 grm./litre. After thorough washing, they are immersed in 1 : 4-hydrochloric acid containing cadmium chloride 18 and ammonium fluoride 4 grm./litre, again washed, and brass-plated in a cyanide solution. A final nickel coating of any desired thickness can then be applied in any of the usual high p_H nickel baths containing boric acid. Other preparatory methods are also described and briefly discussed.—A. R. P.

Nickel Plating Aluminium. M. Ballay (*Rev. Aluminium*, 1934, **11**, 2365–2370).—The history of the nickel plating of aluminium is briefly reviewed. Practical details for carrying out this process are given, and include degreasing,

compositions of baths for preparing the surface and for the nickel-plating operation itself and for chromium plating on the nickel plate. The properties of the nickel coat and methods of testing it are described, and notes and criticisms of methods employed in special cases are given.—J. H. W.

On the Nickel Plating of Aluminium. W. Fröhlich (*Metallbörse*, 1934, **24**, 405–406, 439, 469–470).—Notes on the preparation of the metal and on the composition and operation of suitable nickel plating baths.—A. R. P.

Splitting of Nickel-Plated Brass Articles and Its Cause and Prevention. H. Reininger (*Metallwaren-Ind. u. Galvano-Tech.*, 1934, **32**, 143–144, 163–165, 211–213).—The splitting (season-cracking) of nickel-plated brass articles is attributed to the use of unsuitable brass and the presence of high internal stresses combined with the notch effect of riffles introduced by deep-drawing, of scratches produced in polishing, of non-metallic particles of abrasive forced into the metal, and of hydrogen absorption in plating. Intercrystalline corrosion produced by inclusion of electrolyte in unsound parts is also a fruitful cause of failure of the metal. To avoid these troubles the brass used should be practically pure α, it should be annealed dead soft prior to deep-drawing and spinning; if severely cold-worked during fabrication it should be given a relief-anneal, and all irregularities introduced during working should be thoroughly polished out before plating.—A. R. P.

Factors Contributing Toward Quality of Plated Zinc Die-Castings. Carl Hussner (*Monthly Rev. Amer. Electroplaters' Soc.*, 1933, **20**, (4), 15–20; discussion, 20–23).—Practical hints are given for preparing the castings for plating and for obtaining good nickel deposits. Copper or brass undercoats are deemed unnecessary.—A. R. P.

Action of Buffers on Electrolytic Metallic Deposits. J. Salauze (*Bull. Soc. franç. Elect.*, 1934, [v], **4**, 473–490; discussion, 491–492).—The action of a buffering agent may be purely mechanical, molecules of the material becoming adsorbed on the cathode. The composition of the liquid cathodic film may be modified either by a diminution of p_H value by reaction with the cathode, or by the formation of a protective viscous screen round it. Certain buffering agents may give rise to colloidal metal which becomes incorporated in the deposit and profoundly modifies its character. Others form substances which are mechanically included in the deposits and which may thus cause brittleness. Fuseya's observations on the discharge of complex ions at the cathode, with consequent refinement of the deposit, are summarized. The effect of ageing is considered, and lines for further investigation are suggested. A *bibliography* is given.—P. M. C. R.

Selenium Rectifiers for Plating Plant. Karl Maier (*Metallwaren-Ind. u. Galvano-Tech.*, 1934, **32**, 67–68).—The use and operation of the selenium rectifier is described with reference to wiring diagrams.—A. R. P.

Health Protection in Plating Plants. R. J. Piersol (*Metal Cleaning and Finishing*, 1934, **6**, 25–29; *C. Abs.*, 1934, **28**, 2625).—A detailed description of methods employed in plating plant to guard against health hazards.—S. G.

VII.—ELECTROMETALLURGY AND ELECTROCHEMISTRY
(Other than Electrodeposition and Electro-Refining.)

(Continued from pp. 309–310.)

Electro-Metallurgical Progress in 1933. S. Wernick (*Indust. Chemist*, 1934, **10**, 13–14).—A review, with special reference to deposition from molten electrolytes and aqueous solutions of organic and inorganic salts. Notes are given on the deposition of nickel, chromium, cadmium, platinum, palladium, and rhodium.—E. S. H.

***Development and Use of Anaconda Electro-Sheet Copper.** William M. Shakespeare (*Trans. Amer. Inst. Min. Met. Eng.*, 1933, **106**, 441–448).—Copper sheet weighing upwards of 1 oz. per ft.^{2} is produced in large quantities directly from anode copper at the Raritan Copper Works. In the first stage the cathode consists of a lead-covered copper drum rotating half-immersed in a solution of copper sulphate and sulphuric acid, a lead anode being spaced $\frac{1}{2}$ in. from the whole of the immersed surface of the drum so that the vigorous oxygen evolution keeps the electrolyte well agitated; the deposited sheet (0·00135 in. thick) is continuously removed from the topmost point of the drum and wound in rolls. The sheet on these rolls is then built up to any desired thickness by passing it continuously in a series of loops suspended between vertical copper electrodes spaced regularly through a long tank. Operating details of both sections of the plant are given, together with a brief account of the difficulties met with in developing the process. Sheet copper produced by the process is finding an extending use in making roofing shingles and flashings, for making automobile tops, for making plywood compositions, and even in bookbinding and the manufacture of fancy boxes.—A. R. P.

VIII.—REFINING

(Including Electro-Refining.)

(Continued from pp. 249 250.)

***Removal of Arsenic and Antimony from Copper by Furnace-Refining Methods.** W. J. Hillebrand, R. K. Poull, and H. C. Kenny (*Trans. Amer. Inst. Min. Met. Eng.*, 1933, **106**, 483–486).—Arsenic and antimony can be practically entirely removed from copper by blowing the molten metal with air until it contains about 1% of oxygen, then blowing powdered sodium carbonate through the metal to dissolve the oxidized antimony and arsenic compounds. In this way elimination of these impurities is rapid, and the slag can be removed before it has an opportunity to attack the lining of the furnace.—A. R. P.

Notes on the Purification of Electrolytes in Copper Refining. E. S. Bardwell and R. J. Lapee (*Trans. Amer. Inst. Min. Met. Eng.*, 1933, **106**, 417–426; discussion, 426).—For abstract of the paper see *Met. Abs.*, this volume, p. 190. In the discussion *O. Nielsen* recommends the use of a soft-iron pan over an open fire for evaporating acid sulphate electrolytes. No action on the pan occurs when the density of the solution exceeds 1·4 and evaporation can be continued to *d* 1·6; the liquor is removed from the pan, the suspended anhydrous sulphates are allowed to settle, and the strong acid liquor is returned to the pan and diluted down to *d* 1·4 by addition of fresh electrolyte.—A. R. P.

IX.—ANALYSIS

(Continued from pp. 310-311.)

The Development of Analytical Chemistry. P. F. Thompson (*Chem. Eng. Min. Rev.*, 1934, **26**, 213–217).—The history of chemical science and the testing of metals and modern chemical methods is briefly traced from the earliest times to the end of the last century.—J. H. W.

Metallurgical Spectrum Analysis. Welton J. Crook (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 708–732).—C. describes the construction and use of a 21-ft. focal length grating spectrograph as applied to metallurgical analysis. A new method of reading is described in which the spectrum film is placed in an enlarger and projected on to visual charts. The readings are made at a magnification such that 1A. = 5 mm. In this way the tedious method of using a micro-comparator is obviated.—S. G.

***A Contribution to Quantitative Optical Spectroanalysis.** W. Seith and E. Hofer (*Z. Elektrochem.*, 1934, **40**, 313–322).—Tables have been drawn up for the quantitative optical spectroanalysis, by the method of homologous conjugate lines due to Gerlach and Schweitzer, for the detection and estimation of Ni in Pb, Pb in Sn, Mg in Pb, and Ca in Pb. This method cannot be used for the detection of Cu in Pb, Pb in Cd, or Cd in Pb, and another method has been worked out for these cases, depending on the comparison of the darkening of certain lines of both the constituents of the alloys by means of a photometer. This method gives reproducible results.—J. H. W.

A New Analytical Method for the Metal Industry. Julius Grant (*Met. Ind. (Lond.)*, 1934, **44**, 459–460).—A discussion is given of nephelometry, the methods of measuring and comparing turbidity, including the use of photo-electric cells, and the applications of the method for the estimation of zinc, silver, calcium, mercury, aluminium, phosphorus, arsenic, lead, and magnesium.

—J. H. W.

***Analysis of Silver Baths: A Method of Determining the Potassium Formate Content of Old Silver Plating Baths.** Curt Lochmann (*Metallwaren-Ind. u. Galvano-Tech.*, 1934, **32**, 188).—Since potassium formate is formed by hydrolysis of cyanide in old silver plating baths and its presence necessitates the use of a smaller amount of free cyanide than usual, the following procedure for its determination has been worked out: the solution (10 c.c.) is acidified with H_2SO_4, the AgCN filtered off, and the filtrate neutralized with $NaHCO_3$, treated with a rapid current of CO_2 for 4 hrs. to expel HCN, again acidified with H_2SO_4 and distilled to expel HCOOH, which is collected in dilute NaOH solution. The resulting $NaCHO_2$ is oxidized to carbonate by warming with excess (T_1 c.c.) of 0·1*N*-permanganate, the solution is acidified with H_2SO_4 and warmed with 0·1*N*-oxalic acid (t c.c.) to destroy the MnO_2, &c., and the excess of oxalic acid (T'_2 c.c.) is determined by titration with permanganate; then $0{\cdot}34(T_1 + T_2 - t)$ = grm. of potassium formate per litre of bath.—A. R. P.

***On a New Colour Reaction for Cobalt.** Eduardo F. Brau (*Rev. Fac. Cienc. quim. La Plata*, 1933, **6**, 65–70; *Chem. Zentr.*, 1934, **105**, I, 2797).—In the presence of $CH_3{\cdot}COONa$ Co gives an intense orange-red to red colour with a mixture of dimethylglyoxime and one of the following: benzidine, tolidine, dianisidine, 2 : 7-diaminodibenzofurane, 2 : 7-diaminofluorene.—A. R. P.

Detection and Microdetermination of Silver, Mercury, and Iodides. I. M. Korenmann (*Mikrochemie*, 1934, **14**, 181–188).—The solution is titrated with 0·01*N*-KI containing a small amount of I_2 and starch until the blue colour disappears.—A. R. P.

***Method of Separating Antimony and Tin.** M. Raymond (*Compt. rend.*, 1934, **198**, 1609–1611).—Sn can be separated from Sb in alkaline solutions containing triethanolamine, $N(CH_2{\cdot}CH_2{\cdot}OH)_3$. The freshly precipitated hydroxides are readily soluble in the reagent, but become insoluble on keeping or heating. Solutions containing Sn^{IV} salts are easily decomposed by weak acids (CO_2, H_2S) or by alkali or NH_4 salts (chlorides, sulphates, or carbonates), whereas $Sb^{\cdots}$ or Sb^{V} solutions are much more stable; this behaviour enables a separation of the metals to be made provided that the $Sn(OH)_4$, which first separates as a colloid and thus adsorbs Sb, is reprecipitated. The HCl solution of the metals is oxidized with Br, and a large excess of NH_4HCO_3 solution added, followed by a small excess of 20% ethanolamine solution; the hydroxides first precipitated redissolve on warming, but later the $Sn(OH)_4$ separates and is flocculated after heating for 1 hour on the water-bath. The precipitate is washed with 10% $(NH_4)_2CO_3$ solution, redissolved in HCl, reprecipitated as before, and ignited to SnO_2. The filtrate is acidified with $CH_3{\cdot}CO_2H$, and treated with H_2S, the Sb_2S_3 being heated at 280° C. in CO_2 for weighing.—J. H. W.

***A Separation Reaction for Mercury.** M. Stschigol (*Z. anal. Chem.*, 1934, **96**, 328–330).—The solution is treated with an equal volume of 10% KI solution, a large excess of 30% NaOH solution is added, and the Hg precipitated by boiling with 1 c.c. of glycerol.—A. R. P.

***Estimation of Small Amounts of Bismuth, Antimony, Tin, and Molybdenum in Copper.** Bartholow Park (*Indust. and Eng. Chem.* (*Analyt. Edn.*), 1934, **6**, 189–190).—Bi, Sb, Sn, and Mo are quantitatively separated from Cu by boiling the neutral nitrate solution of the metal (100 grm. of Cu evaporated to dryness with 400 c.c. of HNO_3 and the solution of the residue neutralized with Na_2CO_3) with 10 c.c. of 20% KBr solution and 10 c.c. of 3% $KMnO_4$ solution until Br ceases to be evolved. The precipitate is collected, washed, and dissolved in HCl, the solution treated with H_2S, the sulphides dissolved in HNO_3 and HCl, and the solution evaporated to 5 c.c. and tested spectrographically against standards prepared similarly, using graphite electrodes with an arc discharge. —A. R. P.

***A New Volumetric Determination of Cobalt.** G. Spacu and M. Kuraš (*Bul. Soc. Ştiinţe Cluj*, 1934, **7**, 377–383; *Chem. Zentr.*, 1934, **105**, I, 2797).—The Co is precipitated with C_5H_5N and 0·1*N*-NH_4CNS as the complex $Co(C_5H_5N)_4(CNS)_2$ and the excess NH_4CNS is titrated with 0·1*N*-$AgNO_3$.—A. R. P.

***Rapid Determination of Copper in White Metals by Direct Precipitation in the Presence of Tin, Antimony, Lead, &c.** E. Azzarello and A. Accardo (*Ann. chim. applicata*, 1933, **23**, 483–490; *Chem. Zentr.*, 1934, 105, I, 2626).—The alloy is dissolved in *aqua regia*, the solution treated with tartaric acid and an excess of NaOH, boiled, cooled, and filtered, and an aliquot part of the filtrate is made just acid with HCl and treated with a 1% solution of salicylaldoxime to precipitate the Cu. The Cu compound is collected on a glass filter, washed, dried *in vacuo*, and weighed; it contains 18·95% Cu.—A. R. P.

***A New Colorimetric Method for the Determination of Lead.** S. Feinberg (*Z. anal. Chem.*, 1934, **96**, 415–518).—The Pb is precipitated as $PbMoO_4$ and the Mo determined colorimetrically with KCNS and $SnCl_2$ in the usual way.—A. R. P.

***On the Determination of Lead as Carbonate and Its Separation from Silver by Means of Carbonic Acid in Dilute Pyridine Solution.** A. Jílek and J. Kota (*Coll. Trav. Chim. Tchécoslov.*, 1933, **5**, 396–409).—The solution containing not more than 0·2 grm. of lead or silver is diluted to 80 c.c., and 5 c.c. of C_2H_5OH are added, followed by 10% C_5H_5N solution until neutral to methyl orange; after 5–20 minutes, when a slight turbidity develops, a further 15 c.c. of C_5H_5N (10%) are added, and the solution is treated with a stream of CO_2 for 45 minutes. The precipitate of $PbCO_3$ is collected in a Gooch crucible, washed with dilute C_2H_5OH containing C_5H_5N and saturated with CO_2, dried at 120° C., and weighed.—A. R. P.

***A Rapid Semi-Micro-Method for the Gravimetric Determination of Magnesium as $MgNH_4PO_4,6H_2O$ or as $MgNH_4AsO_4,6H_2O$.** L. W. Winkler (*Z. anal. Chem.*, 1934, **96**, 241–245).—The solution (20 c.c.) is treated with 0·5 grm. of NH_4Cl and heated just to boiling, 1 c.c. of 20% NH_4OH and 2 c.c. of 10% Na_2HPO_4 solution are added, and the mixture is stirred until the flocculent precipitate crystallizes (5 minutes). The precipitate is collected, washed with dilute NH_4OH, then with C_2H_5OH, dried *in vacuo*, and weighed as $NH_4PO_4,6H_2O$. The As compound can be produced similarly—A. R. P.

***A Gravimetric Method for the Determination of Magnesium as $MgNH_4AsO_4,6H_2O$.** J. Dick and A. Rudner (*Z. anal. Chem.*, 1934, **96**, 245–248).—The solution is treated with 3–5 grm. of NH_4Cl, 1 grm. of $(NH_4)_2HAsO_4$, and HCl until clear; 2·5% NH_4OH is then added drop by drop to the cold solution with stirring until just alkaline to phenolphthalein, followed by ⅓rd the total volume of strong NH_4OH. After 1–1½ hrs. the precipitate is collected on a porous filter, washed with 2·5% NH_4OH, then with 95% C_2H_5OH, dried *in vacuo*, and weighed as $MgNH_4AsO_4,6H_2O$.—A. R. P.

***Rapid Determination of Small Amounts of Magnesium in Presence of Phosphates.** F. Thompson (*Indust. Chemist*, 1934, **10**, 142).—The determination is based on the formation of a lake by Mg with turmeric in presence of NaOH, followed by colorimetric comparison with standards. Although the presence of phosphates affects the colour, interference due to this cause is eliminated by dissolving $Ca_3(PO_4)_2$ in the colour standard. The suspensions of lake may be made more stable by adding starch glycerite solution. A method for removing Fe is given.—E. S. H.

***A New Method for the Volumetric Determination of Mercury.** M. Stschigol (*Z. anal. Chem.*, 1934, **96**, 330–333).—The Hg is precipitated as described in *Z. anal. Chem.*, 1934, **96**, 328–330; *Met. Abs.*, this volume, p. 357, and the washed precipitate dissolved in HNO_3 and $KMnO_4$ to give $Hg(NO_3)_2$. The excess of $KMnO_4$ is just destroyed by cautious addition of $FeSO_4$, and the Hg titrated with 0·1*N*-NH_4CNS (1 c.c. = 0·01003 grm. of Hg).—A. R. P.

An Indirect Method for the Potentiometric Determination of Nickel. G. Spacu and P. Spacu (*Z. anal. Chem.*, 1934, **96**, 270–273).—The Ni is precipitated as $Ni(C_5H_5N)_4(CSN)_2$ and the excess of KCNS titrated potentiometrically with $AgNO_3$ after acidifying the filtrate with HNO_3.—A. R. P.

Detection and Estimation of Small Amounts of the Platinum Metals. H. Wölbling (*Ber. deut. chem. Ges.*, 1934, [B], **67**, 773–776).—Colour reactions are described for the recognition and estimation of the platinum metals in the presence of each other, in quantities of, if necessary, less than 1 mg., the methods including certain modifications of the thiourea and stannous chloride reactions. A scheme is given for the separation of the entire group, and a note is appended on the isolation of small amounts of these metals from dilute solution, and on the behaviour of the group on precipitation with ammonia.—P. M. C. R.

X.—LABORATORY APPARATUS, INSTRUMENTS, &c.

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

(Continued from pp. 311–312.)

On the Design and Construction of a Precision High-Power Metallographic Apparatus. Francis F. Lucas (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 1112–1134; discussion, 1134–1135).—A new metallographic apparatus of advanced design is described. It was planned to make this microscope as perfect mechanically as possible and to incorporate in its design the most efficient optical systems that could be devised. Its resolving power is of the highest order with visible light. Crisp, bright images are secured at magnifications of × 4000 and × 6000. The specimen may be illuminated with monochromatic light, a narrow band or a broad filtered band of light from any region of the visible spectrum—S. G.

A New Optical Dilatometer. F. Bollenrath (*Light Metals Research*, 1934, **2**, (48), 1–10).—Translated from *Z. Metallkunde*, 1934, **26**, 62–65. See *Met. Abs.*, this volume, p. 311.—J. C. C.

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

(Continued from pp. 312–313.)

Non-Destructive Tests. E. C. Rollason (*Metallurgia*, 1934, **10**, 9–12).—Non-destructive methods of testing, valuable as investigatory tests for improvements in the design or method of manufacture of an article, or for testing the quality or soundness of an article without damage, are discussed. Such tests include magnetic tests either by means of oscillographic records or by the magnetic dust methods; electromagnetic tests; acoustic tests; the use of the X-rays either by the Debye–Scherrer method or by radiography; and the

γ-ray method of examination. Each of the test methods referred to is described in brief detail and is illustrated diagrammatically.—J. W. D.

Methods of Testing in the Supervision of the Manufacture and Properties of Die-Castings. R. Schulze (*T.Z. prakt. Metallbearbeitung*, 1933, **43**, 322–324).—A summary of desirable properties of alloys to be used for die-casting, of works' tests, of laboratory inspection, and of the making of physico-mechanical examinations. To these are added microscopical investigation and trials of corrosion-resisting properties. The summary is useful and concise.

—W. A. C. N.

†**Testing of Stamping Materials.** H. D. Brasch (*T.Z. prakt. Metallbearbeitung*, 1933, **43**, 317–321).—A review of the methods which are available for the testing of sheet metals that are to be used for stamping or deep-drawing. The processes are compared with regard to their utility.—W. A. C. N.

†**Present Knowledge of Testing by Machining.** Anon. (*T.Z. prakt. Metallbearbeitung*, 1933, **43**, 303–305).—A review of the development of testing materials and tools by critical examination of machining processes employed on those materials. Such methods embrace the measurement of the increase in temperature due to the dissipation of heat during working and the determination of the lives of standard tools used in machining alloys under standard conditions. A relationship has been determined between the rate of cutting and the Brinell hardness.—W. A. C. N.

†**Reliable Work's Methods for Testing and Comparing the Cutting Durability of Tools and the Machining Properties of Engineering Materials.** H. Schallbroch (*T.Z. prakt. Metallbearbeitung*, 1933, **43**, 305–311).—A preliminary discussion of the serviceability of machine tools and the resistance of engineering alloys to their action. These two factors are not necessarily dependent one on the other. In all machining processes the four fundamental factors are (1) the cutting time for a tool with normal life should be as long as possible; (2) the form of the alloy and the surface should be as favourable as possible; (3) the power required to induce cutting and the energy absorbed should be as small as possible; (4) the development of stress should be a minimum. The development of testing methods, bearing these factors in mind, is reviewed, and instruments designed to carry out these tests are illustrated and described.

—W. A. C. N.

†**Testing of Hot-Worked Engineering Materials.** M. Moser (*T.Z. prakt. Metallbearbeitung*, 1933, **43**, 312–316).—Test results on materials formed hot, and not the result of machining, are affected considerably by the method of working and the orientation of the test-piece. The underlying reasons for this are the irregular solidification causing differences in chemical composition, and the creation of non-uniform stresses within the body. An attempt is made to reconcile the results obtained.—W. A. C. N.

***Studies on a Modification of the Rohn Test for Investigating Creep of Metals.** C. R. Austin and J. R. Gier (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 293–307; discussion, 308–314; also abstract *Found. Trade J.*, 1934, **50**, 213).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 519. The discussion, in which *G. M. Eaton*, *H. W. Gillett*, *H. J. Gough*, *E. E. Thum*, and C. R. A., took part deals with the interpretation of the results obtained by the Rohn test and with the effect of possible changes which occur in the structure of the metal during the test on the results. E. E. T. summarizes the remarks by pointing out that the test is merely a rapid indicator of the metal's probable behaviour under temperature and load, and does not provide a numerical relation between temperature, volume, and stress; nevertheless reliable information can be obtained as to the comparative behaviour of various metals under load at high temperatures in a relatively short time, and it must be remembered that structural changes occur in practice when a metal is kept under stress at high temperatures for prolonged periods.—A. R. P.

High-Temperature and Creep Testing of Metals. (I.) I. Musatti and A. Reggiori. (II.) H. Dustin. (III.) F. Körber (*Congrès du Chauffage Industriel* (Preprint), *Group* 1, *Sect.* 3, **1933**, 8 pp., 10 pp., 16 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 17).—M. and R. deal with equipment for high temperature and creep testing, D. with the high temperature testing of steels as carried out by him at Brussels, while K. deals generally with creep testing and properties of steel.
—S. G.

Thermal Auto-Stabilization : Applications of the Study of High-Temperature Steels. G. Ranque and P. Henry (*Congrès du Chauffage Industriel* (Preprint), *Group* 1, *Sect.* 3, **1933**, 16 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 16).—"Thermal auto-stabilization" is the name applied by the authors to Rohn's method of creep testing. Stress is laid on the importance of maintaining constancy of length of test-piece. Automatic apparatus for applying this method to steels at high temperature is described and discussed.—S. G.

***Some Factors Affecting Strain Measurements in Tests of Metals.** R. L. Templin (*Amer. Soc. Test. Mat. Preprint*, **1934**, June, 1–13).—This paper is based on results of a large number of tests carried out for the purpose of affording a comparison of deformations on various elements of both tension and compression specimens of various forms in both the elastic and plastic ranges. The testing procedure has been laid out for the purpose of determining the effects of eccentric and oblique loadings on the specimens; the effects of different types of testing machine jaws on the deformations obtained, and the effects of different types of plugs in the case of the hollow round tension specimens. The results obtained indicate definitely the need for uniform and axial loading of specimens, especially when determining the elastic modulus. Under such conditions of testing, it appears relatively unimportant whether strains are measured on one or more elements of the specimen. Under conditions of non-uniform or non-axial loading, it would appear necessary to determine strains simultaneously on opposite elements of a specimen in order to obtain satisfactory values for modulus of elasticity. The test conditions for obtaining satisfactory yield-strength values are much less exacting than those for obtaining satisfactory modulus values.—S. G.

***An "Overnight" Test for Determining Endurance Limit.** H. F. Moore and H. B. Wishart (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 334–340; discussion, 341–347).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 517. The discussion, in which *J. B. Kommers, R. E. Peterson, R. L. Templin, T. McL. Jasper, A. V. de Forest, E. H. Dix, Jr., H. J. Gough, E. E. Thum*, and H. F. M. took part, ranges round the reliability of short-time fatigue tests, the general concensus of opinion being that the number of cycles recommended is insufficient with many materials to develop a crack of such size and shape as to overcome the hardening effect of the cyclic stresses. H. F. M. stated that no evidence had been found to indicate that any general structural change occurs during the test, but the crack spreads at an accelerated rate as the test proceeds. E. E. T. suggested that the surface hardness should be explored at the reduced section in slightly over-sized specimens, which are then machined to the exact dimensions to remove the metal disturbed by the hardness tests; this would overcome objections that the hardness is determined at points other than those subjected to the fatigue test.—A. R. P.

***Fatigue Tests on Galvanized Wire under Pulsating Tensile Stress.** S. M. Shelton and W. H. Swanger (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 348–360; discussion, 361–363).—The limiting range of pulsating tensile stress, *i.e.* the "tensile fatigue limit" of commercially galvanized wire 0·192 in. in diameter has been determined at mean stresses of 50,000–150,000 lb./in.^{2}, the results for each mean stress are plotted on *S–N* diagrams, and the limiting ranges for the various mean stresses are plotted on a single diagram for each type of wire (cold-drawn and heat-treated). In all cases the tensile fatigue limit is practically

independent of the mean stress within the above range; it is determined by the magnitude of the range of stress rather than by the value of the maximum stress. No experiments have been made to determine the effect of galvanizing on the endurance properties. The discussion, in which *R. L. Templin*, *H. J. Gough*, and *H. F. Moore* took part, is entirely concerned with the behaviour of ferrous metals in endurance tests.—A. R. P.

***A High-Speed Fatigue-Testing Machine and Some Tests of Speed Effect on Endurance Limit.** G. N. Krouse (*Amer. Soc. Test. Mat. Preprint*, **1934**, June, 1–5).—K. presents a shorter and less expensive method of determining the endurance limits of materials by the use of a high-speed fatigue-testing machine driven by an air turbine, operating over a range of speeds from 5000 to 30,000 r.p.m. Two inexpensive specimens are described with the critical section approaching the ideal and worst surface conditions. The results of tests on 4 steels, 2 cast irons, brass, and Duralumin, covering a wide range of endurance limits and speeds are presented. Check tests made on the slower-speed rotating-beam machine show that the speed effect may be estimated with a fair degree of accuracy and is of small import when compared with the effect of surface finish.—S. G.

Autographic Stress–Strain Curves of Deep-Drawing Sheets. Reid L. Kenyon and Robert S. Burns (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 577–601; discussion, 601–612).—A description is given of the design and manipulation of an autographic apparatus for drawing stress–strain curves for sheet tensile specimens. A special curve-measuring ruler and its use are also described. Tensile stress–strain curves obtained with the new autographic attachment are shown, some of which give an experimental confirmation of the theory that the sharp yield-point in mild steel is related to stretcher-straining. A method is developed for computing the depth of the stretcher-strains from the amount of elongation through the yield-point. Curves are given for sheet material that has received various percentages of cold-rolling. True stress curves have been constructed from autographic stress–strain curves of sheet samples and these are discussed briefly. The stress–strain curve is shown to furnish considerable information concerning the behaviour of deep-drawing sheet material in addition to that obtained from the ordinary tensile test. The yield-point elongation and the uniform elongation are specific examples of significant values that can be determined only from accurate autographic stress–strain curves. —S. G.

Characteristics of the Huggenberger Tensometer. R. W. Vose (*Amer. Soc. Test. Mat. Preprint*, **1934**, June, 1–12).—V. describes the behaviour of the Huggenberger Tensometer as determined by the use of a specially designed interferometer calibrator. It is first shown that under any fixed condition of use the readings of the instrument are proportional to the motion involved, and second that this factor of proportionality varies markedly with different conditions of use. The conditions covered include variations in mounting pressure, material of the specimen, balance and position of the instrument, seating on the specimen, and friction within the instrument. An attempt is made to analyze the causes of these effects and to suggest means for their remedy. From figures obtained in calibration, the accuracy of the instrument is calculated and the deviations to be expected in routine use are indicated.—S. G.

The Torsion Impact Test. G. V. Luerssen and O. V. Greene (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 315–327; discussion, 328–333).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 652. The use of the test in determining the effect of heat-treatment on steel is discussed by *Howard Scott*, *H. S. Rawdon*, *Haakon Styri*, *A. L. Davis*, *A. V. de Forest*, *Archibald Hurtgren*, and the authors. —A. R. P.

Mechanical Hardness Influenced by Magnetism and Measured by Magneto-strictive Effects. S. R. Williams (*Trans. Amer. Soc. Steel Treat.*, 1933, **21**, 741–768).—The paper deals with the problem of mechanical hardness and the

methods employed to measure it. At present there is no uniformity in the measurements of hardness. Hardness is one thing for one manufacturing plant and something else for another. In studying the changes in length of ferromagnetic rods, when magnetized longitudinally, it was found that variations in mechanical hardness varied this magnetostrictive effect in a very interesting way. This longitudinal change of length in a magnetic field was, in fact, found to have possibilities as a means for measuring hardness. An extensive study has been made of this relation between magnetostriction and mechanical hardness. During the study it was discovered that a magnetization process itself produces changes in hardness. The first effect is to reduce the hardness.—S. G.

Factors in the Presentation and Comparison of Particle Size Data. E. J. Dunn, Jr., and John Shaw (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 692–703).—Discusses certain important factors affecting the presentation and comparison of particle size data. Some problems of measurement are briefly discussed. Various graphical forms of presenting data are listed and summarized. Four accurately sized products giving diversified ranges of size are used in certain illustrative graphs. The present status and use of representative functions of particle size data are described. The need for standardization of methods of particle size analysis and presentation of data is emphasized.—S. G.

RADIOLOGY.

Radiographic Examination of Fillet Welds. W. Grimm and F. Wulff (*Autogene Metallbearbeitung*, 1934, **27**, 101–104).—The effect of unequal cross-sections of parent metal is removed by using wedges of the same material, suitably placed. Special cassettes of convex shape are recommended, and methods of application for various types of weld are illustrated.—H. W. G. H.

Some Limitations of X-Ray Inspection of Welds. A. S. Douglass (*J. Amer. Weld. Soc.*, 1934, **13**, (2), 15–16; discussion 16).—By tack-welding machined blocks of weld metal in a joint, a condition of imperfect fusion was simulated. Radiographs failed to show the presence of any flaw, and it was concluded that lack of fusion in a welded joint can escape detection in an X-ray examination. In the discussion *Gilbert E. Doan* and *J. E. Waugh* point out that, in practice, lack of fusion is always accompanied by porosity and slag inclusions which are clearly shown on a radiograph. *Bela Ronay* refers to the danger of unfused areas in planes almost parallel to the beam of X-rays.—H. W. G. H.

The Use of X-Rays for Engineering Test Purposes by the German State Railways. Anon. (*Welding Ind.*, 1933, **1**, 337–339; 1934, **2**, 21–23, 115–117).—Systematic inspection of welded, forged, and cast parts is said to have improved the quality of product and effected economies in manufacture. The methods used for examining fire-boxes are described. Gas cylinders, also, are tested at regular intervals to prevent possible failures from hidden defects or damage in service. A completely equipped X-ray van, with dark-room and power generator, is used for outdoor inspection of welded steel structures and reinforced concrete work. Special precautions have to be taken against vibration, which causes blurring of the skiagraph, and special film holders are used to keep the film close to the part under examination. Specimen radiographs of a welded plate girder are shown.—H. W. G. H.

Relative Merits of Film and Paper for Industrial X-Ray Work. Ancel St. John and H. R. Isenburger (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 761–769).—See *J. Inst. Metals*, 1933, **53**, 655.—S. G.

Sensitivity of the Gamma-Ray Method of Radiography. John T. Norton and Alfred Ziegler (*Trans. Amer. Soc. Metals*, 1934, **22**, 271–279; discussion, 279–288).—See *J. Inst. Metals*, 1933, **53**, 656.—S. G.

XII.—TEMPERATURE MEASUREMENT AND CONTROL

(Continued from pp. 313–314.)

A New Thermocouple for the Determination of Temperatures up to at Least 1800° C. G. R. Fitterer (*Trans. Amer. Inst. Min. Met. Eng.*, 1933, **105**, Iron Steel Div., 290–297; discussion, 297–301).—For abstract of the paper see *J. Inst. Metals*, 1933, **53**, 265. The discussion is concerned solely with the utility of the graphite–carborundum couple in measuring the temperature of molten slag and metal in the steelworks.—A. R. P.

The Technique of Sputtering Sensitive Thermocouples. Louis Harris and Ellis A. Johnson (*Rev. Sci. Instruments*, 1934, [New], **5**, 153–158).—The technique of producing sensitive thermocouples by cathodic sputtering of bismuth, antimony, and tellurium on thin cellulose is described.—J. S. G. T.

XIII.—FOUNDRY PRACTICE AND APPLIANCES

(Continued from pp. 314–315.)

Some Aspects of Non-Ferrous Founding. A. Logan (*Found. Trade J.*, 1934, **50**, 321–322).—Discussion of a paper read before the Lancashire Branch of the Institute of British Foundrymen, and L.'s reply. See *Met. Abs.*, this volume, p. 257.—J. H. W.

The Use of Sodium Carbonate in Foundry Practice. N. L. Evans (*Met. Ind.* (*Lond.*), 1934, **44**, 514; and *Found. Trade J.*, 1934, **50**, 303; discussion 303 and 310).—Abstract of a paper read before the Sheffield Branch of the Institute of British Foundrymen. Describes the use of an improved form of sodium carbonate, known as "Granular Ash," for use in ferrous and non-ferrous founding.—J. H. W.

Magnesium–Chromium as a Deoxidizer of Copper. Charles Vickers (*Metallurgia*, 1934, **10**, 43).—The utilization of a combination of chromium–copper and magnesium–copper as a deoxidizer for copper, gun-metal, red and yellow brass, and other common copper alloys is discussed Various experiments are described, which indicate that chromium–magnesium in suitable proportions added to the molten bath in such a way that it is immediately immersed in the bath has an excellent effect on copper and its alloys. In the case of copper it has a distinct influence in improving electrical conductivity, when compared with deoxidizing agents such as silico–calcium copper, calcium carbide and calcium borax, and calcium boride, and in the case of the copper alloys it acts as a decided strengthener.—J. W. D.

Fluxes and Slags in Brass Foundry Melting Practice. T. Tyrie (*Met. Ind.* (*Lond.*), 1934, **44**, 461–464, 487–496, 540–541).—Abstract of a paper read before the Scottish Section of the Institute of Metals. A description is given of the more commonly occurring impurities in non-ferrous metals, of their influence on the physical properties of the metals, and of their removal by the use of fluxes and slags, and some test figures obtained from metal so treated are given. —J. H. W.

Studies in Cast Bronzes. Francis B. Rowe (*Found. Trade J.*, 1934, **50**, 363–364, 366).—Abstract of a paper read before the Institute of British Foundrymen. The variation of the density with the casting temperature between 1250° and 1000° C., of bronzes containing 5–15% of copper, with or without phosphorus, has been investigated. The results of physical tests on bars cut from test rings cast with the bars are recorded.—J. H. W.

Casting a Pressure Chamber in Special Bronze. Friedrich Wilhelm (*Z. ges. Giesserei-Praxis: Das Metall*, 1934, **55**, 141–142).—Details of moulding and casting a pressure chamber in bronze are given.—J. H. W.

Bells—Their History and Manufacture. E. Denison Taylor (*Edgar Allen News*, 1934, **12**, 423–425, 434–436).—The history of bells is considered with reference to their development in design, size, and methods of sounding, special attention being given to certain well-known bells. The founding of bells is also considered with reference to the moulding of the cope and core, the metal used, and the time of cooling. It is also stated that where steel has been used for bells, it has been replaced by bronze in almost every case.

—J. W. D.

Problems on the Casting of Brass Bars. Werner Fröhlich (*Z. ges. Giesserei-Praxis: Das Metall*, 1934, **55**, 162–164).—Details on the casting of brass bars are given. Water-cooled iron moulds are recommended for rapid cooling and a compact structure. Structural defects are caused by replenishing an already filled mould during solidification of the metal. Cold air must not be admitted in pouring from the ladle, and casting should be done at 950°–1110° C. The composition of the flux to be used is discussed.—J. H. W.

Preparation and Casting of Aluminium–Brasses. E. T. Richards (*Metallbörse*, 1934, **24**, 408, 438–439, 470).—The advantages of addition of aluminium to brass are detailed, the precautions to be observed in obtaining sound castings pointed out, and the causes of unsound castings discussed.—A. R. P.

The Casting of Albanoid. Anon. (*Met. Ind. (Lond.)*, 1934, **44**, 444, 449; *Found. Trade J.*, 1934, **50**, 262).—Albanoid, a nickel–brass containing approximately 20% of nickel, and melting at 1095° C., should be poured at 1250°–1400° C. after fairly rapid melting under a flux. Although the alloy contains a slight excess of manganese, it should be deoxidized with magnesium. The pouring, moulds, chill-casting, use of scrap, and the causes of various types of unsoundness are discussed.—J. H. W.

The Manufacture of Bearings. Anon. (*Automobile Eng.*, 1934, **24**, 169–173).—The manufacture of anti-friction metals and finished bearings by highly specialized production methods is described. Two principal alloys containing more than 87% tin and no lead are dealt with, and the melting and mixing of these alloys, the foundry for casting the bearing shells, the press shop for the production of shells in steel and non-ferrous metals, the white-metalling, as well as the machining are described in detail, special reference being made to melting equipment, presses, and methods of running both in hand die-casting machines, and centrifugal casting machines.

—J. W. D.

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

(Continued from p. 315.)

The Remelting of Aluminium in Reverberatory Furnaces. E. T. Richards (*Chem.-Zeit.*, 1934, **58**, 135–136).—Reverberatory furnaces with a deep hearth are suitable for remelting aluminium scrap provided that precautions are taken to avoid absorption of oxygen, nitrogen, and hydrocarbon gases; fireclay or bauxite bricks and oil- or gas-firing are recommended. The temperature in the furnace should not exceed 750° C., and a reducing atmosphere free from suspended carbon particles or smoke should be maintained. The choice of suitable fluxes is discussed.—A. R. P.

The Production of New Ingot Aluminium from Scrap. H. Reininger (*Giesserei*, 1934, **21**, 115–119).—A review of modern practice in the recovery of a good grade of aluminium from scrap.—A. R. P.

Reclamation of Copper Wire. Anon. (*Bull. Nat. Elect. Light Assoc.*, 1933, **20**, 66–69).—Inspection and reclamation are centralized. A table is given showing some 38 classes into which scrap wire is divided, according to its condition and potential use. Wire of similar class is spliced in order to give

longer lengths. Occasionally the joints are soldered, or, more often, electrically brazed.—W. A. C. N.

On the Use of Copper-, Bronze-, and Brass-Scrap in the Foundry. E. R. Thews (*Z. ges. Giesserei-Praxis : Das Metall*, 1934, **55**, 245–247).—The method of sorting copper and copper-alloy scrap, the composition and nature of the scrap likely to be met with, and the methods of using it in foundry work are described.—J. H. W.

XV.—FURNACES AND FUELS

(Continued from pp. 316–317.)

Application of Reversed Combustion to Industrial Furnaces. —— Richard (*Congrès du Chauffage Industriel* (Preprint), *Group* 4, *Sect.* 1, **1933**, 9 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 14).—Reversed combustion consists, *e.g.*, in the combustion of air in gas, instead of the more usual direct combustion of gas in air. Gas furnaces based on this principle are described. The apparatus is somewhat complicated. Its application appears unlikely except in special cases, *e.g.*, where treatment in absence of air is necessary. Its application to special aluminium alloys, complex brasses, bronze, &c., is suggested.—S. G.

Heating of Rotatory Melting Furnaces and Their Application. —— Boutigny (*Congrès du Chauffage Industriel* (Preprint), *Group* 4, *Sect.* 1, **1933**, 14 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 13).—Includes short notes on the application of these furnaces, using oil fuel, to the melting of bronzes, refining of copper, melting of nickel and copper–nickel alloys and of aluminium.—S. G.

Heat-Treatment Furnaces. A. G. Robiette (*Heat-Treat. and Forging*, 1934, **20**, 147–148).—The use of artificial atmospheres, of producer gas, liquid ammonia, cracked gas, and steam in heat-treating furnaces is described.
—J. H. W.

Metals in Furnace Construction. —— Bassal (*Congrès du Chauffage Industriel* (Preprint), *Group* 4, *Sect.* 1, **1933**, 21 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 13).—A general survey of knowledge, mainly ferrous. Deals with metal as the outer frame of the furnace; metal in contact with fire, including sections on strength at high temperatures and resistance to oxidation; and metal as a heating agent (electric resistance alloys).—S. G.

The Application of Electric Energy in New Types of Metal Melting Furnaces. A. Karsten (*Metallbörse*, 1933, **23**, 1601–1602, 1633–1634).—Several types of small induction furnaces (high- and low-frequency) are described and illustrated.
—A. R. P.

Coreless Induction Furnaces. W. Reche (*Wiss. Veröff. Siemens-Konzern*, 1933, **12**, 1–33; *Sci. Abs.*, 1933, [B], **36**, 506).—A continuation of previous work. A method of calculating the heat liberated in coreless induction furnaces from the equation of the magnetic field is given. The solution also provides a description of the distribution of the eddy currents, a result which is checked experimentally. A method is now available for taking all the factors into account in designing the dimensions of the coils and selecting the frequency for operation.—S. G.

Heat-Losses in Electric Furnaces. V. Paschkis (*Elekt. u. Masch.*, 1933, **51**, 368–370; *Sci. Abs.*, 1933, [B], **36**, 506).—P. estimates theoretically the steady heat losses during continuous working of a rectangular resistance furnace with single or multiple walls. It is known that a multiple-layer furnace wall, of which the various wall thicknesses are interdependent because of temperature-drop considerations, passes a minimum steady heat loss for some particular wall thickness. The thickness for minimum loss depends on the furnace size.
—S. G.

Resistance Furnaces in Great Britain. A. G. Lobley (*World Power*, 1933, **20**, 86–89; *Sci. Abs.*, 1933, [B], **36**, 628).—Summary of a paper read before the

(1933) World Power Conference. Recent progress in design of low temperature furnaces tends to the use of more efficient air circulation, thus making for small temperature gradients and more uniform heating. Both centrifugal- and propeller-type fans are employed, and the air flow may be turbulent; the circulation should provide for closely packed charges. Fans also improve the efficiency of recuperative processes. Other improvements are in improved methods of handling the material, *e.g.*, a patented recuperative revolving-drum furnace with internal helix for annealing small parts, working an 8-hr. day with 65 kw.h. per ton (size not stated). Continuous furnaces show much higher load factors and give greater uniformity of product than those of the batch type. Resistance furnaces are in increasing use for the melting of non-ferrous metals and alloys.—S. G.

XVI.—REFRACTORIES AND FURNACE MATERIALS

(Continued from pp. 318–320.)

Refractories and Super-Refractories. (I.) D. Petit. (II.)——Maire (*Congrès du Chauffage Industriel* (Preprint), *Group* 4, *Sect.* 1, **1933**, 6 pp. and 4 pp.; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 18).—P. deals with recent progress in the production of industrial refractories, M. with carbon silicide and fused alumina and their applications.—S. G.

Tercod—A New Refractory. G. S. Diamond (*Ceramic Age*, 1934, **22**, 133–134).—Tercod consists of a mixture of silicon carbide, with or without graphite, a carbon bond, and a protective borosilicate glaze to prevent oxidation. The properties have been determined, and show that the thermal expansion coeff. of Tercod is less than half that of any other known refractory. Tercod is resistant to non-ferrous metals, although slightly attacked by lead at high temperatures.—E. S. H.

Improved Chrome Cement. Anon. (*Eng. and Min. J.*, 1934, **135**, 237).—A note on a cement consisting of chrome ore with a high chromic oxide and low silica content. Graded grain-size, smoothness and plasticity, are the special claims.—R. Gr.

The Baking of Refractories and Their Constancy to Dimensions. —— Vey (*Rev. Mat. constr. trav. publ.*, 1934, (**295**), 76B–77B).—Suitable, standardized, uniform and adequate heating eliminates many sources of weakness in the finished refractory product. V. considers that the modern continuously running regenerative furnace is the most economical in operation, and that, contrary to some opinions, alumina and silico-alumina bricks may be correctly treated in furnaces of this type. The special characteristics of furnace and materials are summarized, and the question of replacement is briefly considered.—P. M. C. R.

XVII.—HEAT-TREATMENT

(Continued from p. 320.)

†**Heat-Treatment of Metallurgical Products.** A. Portevin (*Aciers spéciaux*, 1934, **9**, (101), 2–23).—This dissertation is concluded under the following headings: heat-treatment of light aluminium alloys (those containing either or both Mg_2Si and $CuAl_2$) and their equilibrium diagrams; the mechanism of quenching and heat-treating these alloys, and its conception as a thermal cycle; the study of annealing and general considerations of heat-treatment; analogies and differences between the tempering of steels and that of light alloys; structural and precipitation hardening; hot-resistance and hot-hardening alloys; general considerations for the quenching of solid alloys; different types of quenching; analogy with the phenomena at solidification.—J. H. W.

***On the Age-Hardening of the Cast Alloy of Aluminium with 9% $MgZn_2$ and Its Mechanical and Corrosion Properties.** Heinz Günther Wiechell (*Forschungsarb. Metallkunde u. Röntgenmetallographie*, 1933, (**14**), 45 pp.; *Chem. Zentr.*, 1934, **105**, I, 2483).—The capacity of castings of the aluminium alloy with 9% $MgZn_2$ for age-hardening is not inferior to that of the rolled alloy; degassing before casting does not improve the tensile strength. The strength at high temperatures compared with that of the 8% copper–aluminium alloy and that of K.S.-Seewasser is extraordinarily high, and the resistance to corrosion by sea-water is as good as that of the K.S.-Seewasser alloy. Addition of small quantities of titanium has a deleterious effect on all the properties.—A. R. P.

XVIII.—WORKING

(Continued from pp. 320–322.)

Lead Cable Sheath Extrusion. Waldo L. Sherman (*Wire and Wire Products*, 1934, **9**, 103–113).—As a result of a series of studies of the defects which sometimes occur in extruded lead cable sheath, it was found that: (1) the size of the lead crystals does not have any apparent effect on the strength of the lead sheath, (2) when excessive inclusions are not present, the sheath will probably fail at its thinnest part, (3) weaknesses are not ordinarily due to the die-block weld, (4) when the inclusions are few, satisfactory sheathing is produced with regular lead encasing die-blocks, (5) attention must be given to (*a*) inclusions, (*b*) wall uniformity, (*c*) extrusion speed, (*d*) wall thickness, and (*e*) shrinkage. These conclusions are illustrated by a large number of photomicrographs.
—J. H. W.

Chromium-Coated Cutting Tools. Otto Scholl (*Werkstatt u. Betrieb*, 1934, **67**, 192).—A note on the advantages of chromium-plating as a protective medium, a repairing medium, and an auxiliary to the lubrication and cooling of cutting tools.—P. M. C. R.

XIX.—CLEANING AND FINISHING

(Continued from pp. 322–323.)

Abrasives in Metal Polishes. Cyril S. Kimball (*Chem. Industries*, 1934, **34**, 209–214).—Commercial metal polishes may be divided into four classes: (i) neutral naphtha base, (ii) naphtha base–ammonia, (iii) water base–pine oil, and (iv) water base–ammonia, silica sand of different types and grades being used in all cases as the abrasive. The characteristics of these types are discussed with reference to several examples.—A. R. P.

New Lacquers for Enamelled Wire. H. Courtney Bryson (*Indust. Chemist*, 1934, **10**, 145–146).—The processes involved in the drawing and lacquering of copper wire for electrical purposes are described. Brief notes are given on methods of testing the finished wire.—E. S. H.

XX.—JOINING

(Continued from pp. 323–325.)

Hammering Copper Welds. P. Tree (*Machinist* (*Eur. Edn.*), 1934, **78**, 173E).—A short note describing how copper welds should be hammered. Start hammering at the end of the weld, using light blows at first and have the work at red heat. Avoid annealing if possible, but if not, heat to 750° F. (400° C.) for 30 minutes and cool slowly.—J. H. W.

On the Repair of Bronze Bells. R. Meslier (*Rev. Soudure autogène*, 1934, **26**, 12–13).—Practical hints are given for welding cracked bells. "Bronze

welding " is recommended, mainly because it removes the necessity for pre-heating the whole bell.—H. W. G. H.

" Bronze-Welding." Anon. (*Soudeur-Coupeur*, 1934, **13**, (2), 1–25).—A series of short articles on the technique and applications of bronze-welding to various materials, including brasses, bronzes, galvanized iron, and ferrous metals. The joining of different materials, such as iron to copper, is also described.—H. W. G. H.

Rebuilding with Monel Metal. Anon. (*Oxy-Acetylene Tips*, 1934, **13**, 62–63).—The exposed ends of nitrided steel valve stems were being rapidly corroded by acid spray. The worn stems were built up with Monel metal by the oxy-acetylene process, using a reducing flame.—H. W. G. H.

Contraction Stresses in Welds. Hans Schmuckler (*Welding Ind.*, 1934, **2**, 74–78).—The causes of distortion due to welding are explained and some methods for avoiding or reducing it are described. The results of some recent researches, to estimate contraction and contraction stresses after welding, are reviewed, and it is pointed out that these differ surprisingly from theoretical estimates.—H. W. G. H.

Our Present Knowledge of the Tension Conditions within Welding Ribbons. D. Rosenthal (*Bull. Tech. Suisse Romande*, 1934, **60**, 87–89, 113–117).—Read at the Welding Congress, Lausanne, 1932. A study of the stresses in certain types of welded joint under specified conditions reveals certain inconsistencies with existing theory. A *bibliography* is given.—P. M. C. R.

Combined Stresses in Fillet Welds. Cyril D. Jensen (*J. Amer. Weld. Soc.*, 1934, **13**, (2), 17–21).—Three methods of stress analysis, for fillet welds placed at right angles to the load, are examined in the light of tests made to determine the strength of welds loaded by two forces at right angles. It is concluded that further investigation of stresses in fillet welds is required.—H. W. G. H.

***Stresses in Transverse Fillet Welds by Photoelastic Methods.** Arshag G. Solakian (*J. Amer. Weld. Soc.*, 1934, **13**, (2), 22–29).—Stress distributions in Bakelite models representing fillet welds were analyzed by photoelastic methods. A complete stress analysis was made for a 45° C. transverse fillet-welded lap joint and maximum shear stress distributions were determined for many other types of transverse fillets. The weld " leg " parallel to the load was found to be the critical section for elastic stresses, the shear stress being very high along this section, with pronounced stress concentrations at the root and the neck. Along the other " leg," normal to the load, the stress was pure tension. Stress concentration was reduced by increasing the length of the shear " leg " and by replacing the sharp re-entrant angle with a smooth curve. Oversized fillets were found to be of no advantage, but undersized fillets and undercutting at the neck were objectionable.—H. W. G. H.

Fatigue of Metals [Welds]. G. E. Thornton (*J. Amer. Weld. Soc.*, 1934, **13**, (3), 20–25).—The application of fatigue testing to welded joints is reviewed. It is suggested that the primary causes of low fatigue strength in welds are flaws, adjacent areas of large and small crystals, and differences in hardness between weld and parent metal. Rotating beam machines, various types of test-piece, and typical results, are described.—H. W. G. H.

Bending Tests of Welds. H. N. Boetcher (*J. Amer. Weld. Soc.*, 1934, **13**, (2), 31–32).—The many limitations of the usual forms of bending test are said to be overcome by changing the plane of bending, the specimens being sawn off, unmachined, and bent sideways so as to deform the entire cross-section of the weld uniformly.—H. W. G. H.

The Development of Welding Technique. D. Richardson (*Welding Ind.*, 1934, **2**, 41–42, and 47).—The importance of controlled technique in blowpipe welding is emphasized. The history, development, and scope of the method known as " backward " or " rightward " welding are discussed.—H. W. G. H.

The Development of Resistance Welding Electrical Power Control Devices. Rufus L. Briggs (*J. Amer. Weld. Soc.*, 1934, **13**, (3), 8–11).—An historical survey of the control of welding current for resistance welding machines is followed by a brief account of modern equipment used in conjunction with timing devices. Some typical controls are shortly described.—H. W. G. H.

Mixtures of Acetylene and Oil-Gas. Anon. (*Rev. Soudure autogène*, 1934, **26**, 10).—The addition of oil-gas lowers the temperature of the oxy-acetylene flame and produces no better results than would be obtained with additions of air or nitrogen.—H. W. G. H.

The New Welding Machine [of] S. A. Frap. R. Meslier (*Rev. Soudure autogène*, 1934, **26**, 6–9).—Describes an automatic oxy-acetylene welding machine in which the fillet rod is fed with a gyratory motion and an auxiliary air–acetylene flame is played on to the molten bath to keep it in a reducing atmosphere.—H. W. G. H.

XXI.—INDUSTRIAL USES AND APPLICATIONS

(Continued from pp. 325–329.)

Aluminium Drums for Chemicals. H. V. Churchill (*Chem. Industries*, 1934, **34**, 215–216).—The construction of aluminium drums for shipping concentrated nitric acid, acetic acid, and 30% hydrogen peroxide is briefly described. —A. R. P.

Installation of Aluminium Alloys in Vessels of the United States Navy. —— (*Bureau of Construction and Repair, U.S. Navy Dept. Pamphlet*, **1933**, April, 12 pp.; *Bull. B.N.F.M.R.A.*, 1934, (**61**), 4).—This pamphlet has been issued in order to disseminate the present knowledge of the application of aluminium alloys to shipbuilding, particularly methods to be followed and precautions to be taken to secure satisfactory installations. Various sections deal with contact with other materials, working fits, forming of various alloys, welding, riveting, machining, heat-treatment, and preservation.—S. G.

The Application of Aluminium in Heavy Vehicle Construction. Roland Sterner-Rainer (*Automobiltech. Z.*, 1934, **37**, 220–223).—The increasing use of aluminium and its alloys is reviewed historically. Tables show the composition of (1) common alloys for casting; (2) high-strength cast or forged alloys, with description of treatment: (3) non-corroding alloys; (4) piston alloys of important copper content; (5) piston alloys of important silicon content. A list of vehicle parts where light alloys are or can be employed is illustrated photographically and with diagrams of chassis and engine.—P. M. C. R.

The Use of Duralumin in Commercial Vehicle Body Construction. E. L. Oglethorpe (*J. Inst. British Carriage Manuf.*, **1934**, April; and (abbreviated) *Aluminium Broadcast*, 1934, **4**, (28), 1–10).—Read before the Institute of Consulting Motor Engineers. Methods of using Duralumin in the construction of various classes of vehicle bodies are discussed, the advantages of the material for this purpose outlined, and examples given of the savings which follow the resulting reduction in dead weight.—J. C. C.

Making an Old Bridge Lighter. R. G. Skerrett (*Compressed Air Mag.*, 1934, **39**, 4401–4405).—Cf. *Met. Abs.*, this volume, p. 326. An illustrated account of the replacement with light alloy members of the steel floor system of the Smithfield Street Bridge, Pittsburgh, U.S.A. The fabrication and working of the new members are described, and mechanical properties and applications are tabulated for the 4 alloys used (4 SH, 53 ST, 27 ST, 17 ST). The method of riveting is described, and dimensions, weights, and costs are given. —P. M. C. R.

Thermal Insulation with Aluminium Foil. J. F. O. Stratton (*Power Plant Eng.*, 1934, **38**, 241–242).—S. traces the development by Schmidt and Dykerhoff of Peclet's principle of foil insulation. Alternative methods of spacing are

considered, and tables show the relative thermal conductivity of aluminium foil as compared with 8 common heat-insulators, the surface temperatures of aluminium foil insulation of different numbers of layers on steam pipes, and the influence of the number of air-spaces on conductance values.—P. M. C. R.

Heat Transmission Through Aluminium Paper. A. F. Dufton (*J. Inst. Heating Ventilating Eng.*, 1933, **1**, 334–336; *Bull. B.N.F.M.R.A.*, 1933, (**60**), 4).—The results of experiments carried out at the National Physical Laboratory using aluminium paper (stout paper or similar material covered on both sides with aluminium foil) are described. They indicate that a closed air-space, not less than $\frac{3}{4}$ in. wide and bounded on one or both sides by a plane bright metallic surface, affords insulation equivalent to $\frac{1}{2}$ in. of cork.—S. G.

Minimum Specification for Fixing Cold-Water Services. —— (*Inst. Plumbers Minimum Specification* No. **2**, 1933, 9 pp.; *Bull. B.N.F.M.R.A.*, 1934, (**63**), 20).—The aim of this and other specifications of the Institute of Plumbers is to lay down a minimum of sound practice, and to reconcile local variations in various parts of the country. The present specifications deal with weight, strength, and thickness of pipe (lead, B.N.F. ternary alloy, copper, brass); fixing of pipes; storage cisterns; and precautions against frost.—S. G.

Advances in the Use of Elektron and Hydronalium in Heavy Vehicle Construction. —— Keinert (*Automobiltech. Z.*, 1934, **37**, 250–256).—Elektron finds increasing application for motor crank-cases, wheels, gear-cases, frames, and smaller die-cast parts. An outstanding advantage is the suitability of the material for autogenous welding. Important modifications in wheel and crank-case design have been necessitated by the use of light alloys: these improvements are shown diagrammatically. Elektron can, by careful construction and by insulation from wood and from other metals, be kept relatively free from corrosion, but Hydronalium is employed by preference where corrosive attack is expected.—P. M. C. R.

On the Use of Tantalum in the Chemical Industry. Ralph W. Harbison (*Metallbörse*, 1934, **24**, 533–534).—The preparation and properties, especially the resistance to attack by chemicals, of tantalum are described.—A. R. P.

XXII.—MISCELLANEOUS

(Continued from p. 329.)

Information and Research Bureaux for the Metal Industries in France. J. Cournot (*Bull. Soc. Belge Ing. et Indust.*, **1933**, (8), 737–786; *Bull. B.N.F.M.R.A.*, 1934, (**62**), 21).—An account of various French organizations which act as research and/or information centres for various metal and allied industries, including those dealing with welding, aluminium, nickel, cadmium, steel, molybdenum, founding, and beryllium.—S. G.

Metallurgical Research Work in Slavonic Countries. Anon. (*Univ. Birmingham Russian Dept. Pamphlets*, **1933**; *Bull. B.N.F.M.R.A.*, 1933, (**59**), 19).—These pamphlets give lists of researches, in all branches of science, in progress in Poland and Czechoslovakia in 1931–1932. There are no details. In Poland, W. Broniewski is working on the structure of alloys, the effect of cold-work on mechanical properties, and the relation of composition to magnetic properties; and E. Geisler on metal cutting. In Czechoslovakia, F. Hasa is investigating the mechanical properties of copper at high temperatures and the resistance and arc welding of copper.—S. G.

The Importance of Metallurgy to the Engineer. C. H. Bulleid (*Proc. Inst. Mech. Eng.*, 1932, **123**, 767–772).—An abridged version of a lecture delivered before the East Midlands Branch of the Institution of Mechanical Engineers. A number of examples are described of cases in which a knowledge of metallurgy

would have enabled the engineer to diagnose the cause of failures of metal parts, and to suggest suitable materials.—W. H.-R.

Copper Industry Approves Code and Selects Code Authority. Anon. (*Eng. and Min. J.*, 1934, **135**, 220–226).—Outlines the articles which include under Article II definitions of the words and phrases used in the metallurgical world. Copper, primary copper, secondary copper, by-product copper, custom copper, fire-refined copper, &c., are amongst those defined.—R. Gr.

On the Copper Age in Ancient China.—III. Tsurumatsu Dōno (*Bull. Chem. Soc. Japan*, 1934, **9**, 120–124).—[In English.] Analysis of an ancient spear-head showed it to contain copper 84·78, lead 6·02, and tin 0·24% (balance mainly iron). Two ancient halberds contained copper 88·14, lead 6·64, and copper 85·86, lead 13·05% respectively, with only a trace of tin. A halberd of apparently later date contained copper 84·92, tin 13·74%. These results support the previous argument in favour of the existence of a copper age and a transitional period in China prior to the bronze age.—E. S. H.

The Origin of Bronze. Cecil H. Desch (*Newcomen Soc. Advance Copy*, **1934**, 8 pp.).—The weight of evidence seems to be in favour of the theory that the Egyptians, Sumerians, and other early workers in bronze and copper obtained their metal by smelting copper carbonate ores either alone or with tinstone from alluvial or vein deposits. The sources from which the ores were obtained have not, however, yet been definitely identified except in a few cases.—A. R. P.

Planning for the Collection of Standardization Data. J. R. Townsend (*Proc. Amer. Soc. Test. Mat.*, 1933, **33**, (II), 770–785).—Written from the point of view of the work of the A.S.T.M., this paper deals with a method of planning for the collection of standardization data. Two engineering investigations leading to standardization by the A.S.T.M. are discussed as illustrations of how this method of planning works out in practice. The method of planning discussed is recommended for use and is explained in its broader aspects as well as in the details of its application to the 2 specific problems.—S. G.

Industrial Research: A Business Man's View. (Sir) Kenneth Lee (*Roy. Institution Reprint*, **1933**, Dec. 15, 16 pp.; *Bull. B.N.F.M.R.A.*, 1934, (**62**), 21).—The author is Chairman of the Industrial Grants Committee of the Department of Scientific and Industrial Research. He illustrates the application of research methods to an industrial problem by an interesting account of an investigation, carried out by his own company, on the reduction of creasing in cotton fabrics. He urges the provision of more funds for research. —S. G.

Application of Statistical Methods to Production and Research in Industry. R. H. Pickard (*Roy. Statistical Soc. Preprint*, **1933**, 4 pp.; *Bull. B.N.F.M.R.A.*, 1934, (**61**), 22).—Deals with the application of statistical methods to specification and sampling, to control of quality, to planning of laboratory or industrial investigations (in order to balance or average out uncontrolled variations), and to problems of management and production.—S. G.

Research in Relation to Industry. A. P. M. Fleming (*Inst. Indust. Administration Papers*, **1932–1933**, 24–31; *Bull. B.N.F.M.R.A.*, 1934, (**62**,) 21).—One function of research in relation to industry is to improve the efficiency of industrial operations, with special reference to tools, measurements, conversion processes, materials, labour, and design. The other is to create new knowledge and new industries, and this involves bridging the gap between discovery and application. Various aspects of these matters are discussed.—S. G.

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[Contains the following papers, which are with one exception reprinted from various sources: Paul Röntgen u. Rudolf Buchkremer: "Der Einfluss von metallischen Verunreinigungen auf die technische Zink-elektrolyse" (see *J. Inst. Metals*, 1933, **53**, 450); Paul Röntgen u. Heinz Borchers: "Herstellung und Elektrolyse von Schwefelaluminium" (see *Met. Abs.*, this volume, p. 23); Paul Röntgen u. Heinz Borchers: "Gewinnung von Reinaluminium"; Heinz Borchers: "Resistenzgrenze–Goldscheidung" (see *J. Inst. Metals*, 1933, **53**, 139); Walter Roth: "Betrachtungen über das Erstarren von Metallblöcken" (see *J. Inst. Metals*, 1933, **53**, 657); Paul Röntgen u. Hermann Braun: "Über die Löslichkeit von Gasen in Metallen. Das Verhalten von Wasserstoff und Stickstoff gegen Aluminium" (see *J. Inst. Metals*, 1932, **50**, 721); Paul Röntgen u. Fritz Möller: "Untersuchungen über den Wasserstoffgehalt in Zink

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