acoustically fit for the effective use of powerful hearing aids, and ways of modifying hearing aids to enable very young children who are severely deaf to benefit from continuous auditory experience.

During the course of a brief final discussion, Prof. Hallowell Davies, of Washington University, St. Louis, said that in the Central Institute for the Deaf, with which he is associated, it has been found that children who are admitted to the nursery unit, at an early age, are much less liable to linguistic retardation than those who enter school later. No 'signs' have ever been used in the Institute.

As a personal comment, the present writer regrets that the first paper at the meeting tended to focus attention on the use of 'signs' as a means of communication with the deaf, and to divert it from consideration of the outstanding success with which secondary education for the deaf has been established at the Mary Hare Grammar School, which is a unique institution of exceptional interest to educators and psychologists. A dictionary of organized signs, prepared by the Abbé Sicard, who published in 1823, still exists ; its use was long attempted in France but was abandoned many years ago.

MEASUREMENT AND IMPORTANCE OF ELASTIC PROPERTIES OF METALS

A CONFERENCE was held at the National Physical Laboratory, Teddington, during March 20–21 on the "Measurement and Importance of the Elastic Properties of Metals", to discuss the measurements of elastic constants which have been going on in the Laboratory and elsewhere, and to consider how the information obtained from them could be used by metallurgists. It was attended by between eighty and ninety representatives from universities, industrial concerns and government departments. The first day was devoted mainly to describing experimental techniques and the results which have been obtained from them, while on the second day the speakers considered how elastic constant measurements could contribute to new knowledge of the physics of solid states.

The first paper was by Mr. A. F. C. Brown (National Physical Laboratory), on the "Static Measurement of Very Small Strains". He pointed out that in order to measure strain to an accuracy of ± 1 per cent it is often necessary to measure changes of length of less than 10^{-5} in. Even higher precision is needed if a study is being made of small variations in elastic constants, and great difficulty is experienced in transferring the strain to the extensometer without introducing significant errors. Generally, the most suitable methods are those in which the extension of a standard length of a specimen is made to rotate a mirror ; but direct microscopic examination of length changes, and interferometer techniques, have also been used. It is very important to ensure that the desired type of loading is achieved, and this has been the subject of considerable research in the National Physical Laboratory.

In a paper on "Medium and High Frequency Measurements of Elasticity", Mr. G. Bradfield (National Physical Laboratory) described the methods in use at Teddington for the dynamic measurement of elastic constants, pointing out that, except at very high frequencies, the moduli vary somewhat with rate of straining. This was illustrated by results with polycrystalline aluminium from 0·4 c./s. to 50 kc./s. over a temperature range of 30°–700° K.

Methods using pulse-travel times and frequencies of 1–20 Mc./s. are very useful for measuring elastic constants of single crystals, and accuracies of a fraction of 1 per cent have been obtained with crystals of a few millimetres in size. On fine-grain polycrystalline bars about 10 cm. long, accuracies of 0·03 per cent are possible. Generally, the quartz crystal transducers used are mounted on steel or fused quartz blocks, which are applied to the specimen under test. Although separate transducers for transmitting and receiving have been most widely used at the National Physical Laboratory, many measurements with a single probe on both solid and liquid specimens have been made at high temperatures, and an attempt is being made to reach 1,550° C. in this way.

Of many alternative resonance methods, those using magnetostrictive transducers (which can produce both rotational and irrotational vibrations) are preferred, and have been used from near absolute zero to 500° C. ; 1,000° C. is the probable limit with the present equipment. Inductor methods have been used for specimens weighing as little as $\frac{1}{4}$ gm. The best accuracy obtained by resonance techniques is a few parts in 10^4 in the elastic moduli.

For bars, the lateral inertia effect on velocity enables Poisson's ratio to be determined very accurately, and deviation from $(\frac{1}{2}E/G - 1)$ indicates anisotropy quantitatively, and thence the true constants for an isotropic material can be calculated, as described in the following paper.

Mr. H. Pursey and Mr. T. H. Schofield (National Physical Laboratory, Physics Division and Metallurgy Division, respectively) presented a paper on "Elastic Constant Measurements on Some Alloys". Measurements of the elastic moduli of a series of α-solid solutions of copper with elements of the first long period show principally a fall in modulus as the percentage of stranger atoms increases, and for a given atomic percentage of solute the higher the number of valency electrons the greater the depression in elastic moduli. They pointed out, nevertheless, that plotting elastic moduli against electron concentration does not bring the four curves together, and it is clear that they cannot be brought together by plotting against any power of electron concentration. Zener's theory of the misfit effect between solute and solvent atoms was outlined, but this too fails to explain the results satisfactorily. A further anomaly exists at very low atomic percentages, where it is found that the effect of introducing small amounts of stranger atoms is, in fact, to raise the moduli above those obtained for the pure metal. This may be due to the tendency of the foreign atoms to provide 'anchor points' for dislocations, thereby strengthening the material.

The remainder of the paper was devoted to an explanation of the mathematical technique whereby the elastic constants of an isotropic material may be derived from measurements on an anisotropic specimen of the same composition, assuming the anisotropy to be due to preferential orientation of grains, and that the lattice has cubic symmetry. The corrections are functions of the single-crystal constants, and proportional to the fractional difference between $(\frac{1}{2}E/G - 1)$ and Poisson's ratio as determined from the lateral inertia effect on longitudinal vibrations.

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Since the functions vary slowly with the single-crystal constants, these need only be known to a relatively low degree of accuracy.

A discussion followed these papers, and in reply to a question by Dr. E. Billig, of Associated Electrical Industries, Ltd., Mr. Bradfield said that although propagation of waves up to 3,000 Mc./s. in solids has been reported, serious difficulty is likely to arise from scatter in polycrystalline materials. Replying to an inquiry, Mr. Bradfield said that the strains used in the resonance method were of the order of 5×10^{-7}.

The next paper was by Dr. E. G. Stanford (Aluminium Laboratories, Ltd.), and was entitled "The Variation of Young's Modulus of Aluminium Alloys with Temperature". He described measurements of the Young's modulus of aluminium by the resonance technique, using the fundamental mode of longitudinal vibration. The materials used were super-purity aluminium (99·992 per cent), commercially pure aluminium (99·5 per cent), an aluminium–manganese alloy (1¼ per cent manganese) and an alloy of the duralumin type. The specimens were subjected to heating and cooling processes, the rate of change of temperature being about 2° C. per minute, and measurements of Young's modulus were taken at intervals of 10° C. between room temperature and the melting points.

The results show a discontinuity in the Young's modulus/temperature curves at the recrystallization temperature, accompanied by an increase in internal friction. Precipitation from solid solution also causes a slight discontinuity for alloys which show age-hardening characteristics. The modulus of both the pure material and the alloys is generally decreased by cold work, and cannot always be made to recover by annealing. Recovery did not occur, for example, in the case of annealed super-purity material which had been strained 10 per cent in tension; however, when recovery does take place, it is greater in the case of the super-pure than in the commercially pure material. At 10 kc./s., relaxation occurs at a temperature of about 500° C. in the super-pure material, accompanied by an increase in internal friction. No such effects were observed at any temperature up to the melting point in the case of the impure materials. Dr. Stanford hoped that further work on the behaviour of alloys near their melting points would enable improvements to be made in casting techniques.

The final paper of the first day was by Prof. N. F. Mott (University of Bristol). He discussed the effect of temperature on the elastic modulus. The drop in the shear modulus is due partly to thermal expansion, there being no first-order change of entropy with shear, and hence no change of temperature on shearing. Some theoretical calculations have been made by Prof. Max Born's school for solid rare gases, but none for metals. He also discussed the effect of cold-work on the elastic modulus. He considered that a drop in the shear modulus of five to ten per cent is to be expected, and that this is due to the screw dislocations trapped in the lattice and not to the edge dislocations, the latter probably forming sessile (immobile) groups, for example, in deformation bands. The partial recovery of the elastic moduli after a low-temperature anneal, observed recently by A. D. N. Smith, should be due (like cross slip) to the mutual annihilation of screw dislocations, and a similar dependence on temperature is to be expected.

The morning session of the second day opened with a paper entitled "Theory of the Elastic Constants of Metallic Crystals" by Prof. H. Jones (Imperial College of Science and Technology, London), who explained that on modern electron theory the cohesive energy of metals may be regarded as arising from: (*a*) the exchange interaction between the ionic shells, (*b*) the energy of the lowest state of the conduction electrons (spherical approximation), (*c*) a correction to (*b*), the electrostatic potential term, and (*d*) the Fermi energy of all the conduction electrons. Since in different metals these terms have differing relative importance and variation with strain, it is now becoming possible, by comparing theory and experiment, to understand the dominant effects in the elastic constants of a particular metal or alloy. For example, where the ion radius is considerably less than the atomic radius, as in sodium, the term (*a*) will be small and the electrostatic contributions predominate. These are very anisotropic and hence in accord with the observed elastic constants of sodium.

The effect of strain on the Fermi energy can be illustrated by considering shearing distortion of the first Brillouin zone in the face-centred cubic case. If there is only one electron per atom, the Fermi surface is well within the zone and is little altered by shear; but if there are 1·5 electrons per atom, the surface touches the zone, and shear causes a tendency of electrons to leave the zone. The larger the surface of contact the greater is the change in energy and hence the greater contribution to the elastic constants. Some results on β-brass in general accord with these ideas were then described. Prof. Jones pointed out that the treatment is most satisfactory for atoms where there are clearly marked closed shells and few valency electrons, such as copper, silver, gold, sodium, magnesium; in conclusion, he emphasized the need for experimental observations from single crystals.

In the subsequent discussion, Prof. Mott asked if there is any connexion between elastic constants and the diamagnetic effects at low temperature in aluminium and bismuth associated with small groups of electrons overlapping the zones. Prof. Jones replied that in any metal the Fermi surface is very complicated, and the diamagnetic effects are considered to arise from small parts of the surface of very high curvature, whereas the elastic constants are associated with large overlapping. In answer to a question by Prof. J. D. Bernal, Prof. Jones agreed that he would expect interesting differences between the hexagonal metals of long and short axial ratio, for example, magnesium and zinc, and would value some experimental observations. In particular, the measurements should be made at different temperatures in order to give an idea of the absolute zero values. This is important, since it enables some elimination of the influence of temperature and internal strain on the elastic constants, for internal strain has an effect decreasing with temperature. Dr. R. Street (University of Nottingham) mentioned that there is a considerable change in Young's modulus in passing through the Curie temperature, and in reply Prof. Jones said that he felt the present treatment could give no satisfactory explanation of this effect.

Dr. W. A. Wooster (University of Cambridge) spoke on "Diffuse X-ray Reflexions from Crystals in Relation to Elasticity and Structure". Dr. Wooster outlined the fundamental principle that perturbations in the atomic lattice produce additional diffuse reflexions between the normal spots on a Laue pattern. Alternatively, with monochromatic radiation the diffuse reflexions are observed when the

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crystal is rotated a small angle from the correct Bragg setting, that is to say, there is a spread of the reciprocal lattice points. By studying the diffuse reflexions near a particular point, attention is fixed on the thermal elastic waves of particular wave-length and wave-normal. From measurements of intensity the velocity of the waves can be derived and hence the elastic constants.

There are two main experimental methods: recording the reflexions on a photographic plate and using a microphotometer, or direct measurement of the intensities with a Geiger–Müller counter spectrometer. The former is less accurate, about $\pm$ 5 per cent, but has the advantage of showing the pattern of the reflexions. The Geiger–Müller method requires more elaborate equipment, namely, a highly stabilized X-ray source or a monitoring system, but can give an accuracy of about $\pm$ 3 per cent. Absolute measurements of the intensity of the X-ray beam, necessary if absolute values of the elastic constants are required, are less accurate (probably $\pm$ 10 per cent) owing to the difficulty of comparing the diffuse reflexions with a direct beam some 10^6 times stronger. The essential difference between this and all previous methods of measuring elastic constants is that the crystal is subjected to no external mechanical stress whatsoever. The constants, moreover, refer to very high frequencies, that is, wave-lengths in the region 0–200 A. There are few results yet obtained on metallic substances, the most important being those of Ohlmer on aluminium, who found marked dispersion for wave-lengths below about 10 A.

Dr. R. S. Leigh (Imperial College of Science and Technology, London) spoke on "Relations between Elastic Constants and Phase Boundaries in Alloys". Dr. Leigh explained that the free energy, F, of an alloy can be expressed as $F = E_0 + (E_v - TS_v) - TS_m$, where E_0 is the electronic energy at absolute zero; $(E_v - TS_v)$ is the lattice vibration term, E_v being the internal energy and S_v the entropy; and S_m is the mixing entropy in the case of a disordered solid solution. The equilibrium state of the alloy at a given temperature is, of course, that state which has the lowest free energy. An example of a theory based on the effect of lattice vibrations is that of Zener explaining the V-shaped phase boundaries of disordered body-centred cubic β-phases. This requires that the β-phase should have a lower Debye temperature than neighbouring phases. Zener has suggested that this is due to repulsive ion–ion interaction which in turn leads to a low value of $\frac{1}{2}(C_{11}-C_{12})$, a low cut-off frequency in the Debye treatment and hence a low characteristic temperature.

Considering the aluminium–zinc system, the solubility gap implies that here the mixture of the α- and α-face-centred cubic structures has a lower free energy than an equivalent homogeneous phase. Thus the free-energy curve must be such as to have a common tangent at two points. The theory put forward to explain this is based on the idea of shearing the Brillouin zone, the overlapping electrons giving a negative contribution to the shear constant. The calculation leads to phase boundaries of the gap at 275° C. of 20 and 70 atomic per cent in comparison with observed values of 16 and 59 per cent. In conclusion, Dr. Leigh stressed the value of elastic constant measurements on single crystals, in particular in this field on solid solutions of aluminium with zinc, silver, lithium and magnesium.

The afternoon opened with a paper by Prof. C. S. Barrett (University of Birmingham), in which he discussed the after-effects in metals following plastic deformation and showed that they depend on the time occupied by the stress-cycle. He explained the after-effects in terms of anchoring and release of dislocations in the material. In discussion, it was pointed out that recent work at Bristol, in which care was taken to ensure that a homogeneous stress system was obtained, confirmed Prof. Barrett's views.

In the final paper, Mr. H. L. Cox (National Physical Laboratory) referred to the general issue of stability. He stated that failure by structural instability within the elastic range is always a possibility, and that it is quite easy to devise laboratory models which would collapse in this way under any prescribed form of loading; until the nature of the true forces of cohesion within a solid material is better understood, the possibility that the strength of the material is limited by elastic instability should not be overlooked.

After a short discussion, Dr. N. P. Allen, in closing the conference, expressed the hope that the National Physical Laboratory would have similar opportunities in the future for bringing the results of specialized research into closer relation with technological interests.

STANDARDS OF LIFE IN LESS-DEVELOPED AREAS

TWENTY years or so ago, the number of surveys of living conditions carried out each year in the 'less-developed' as well as in the 'more-developed' countries began to increase rapidly, reaching its peak just before the Second World War. This was, of course, due in the first instance to efforts on the part of administrative agencies to collect information on the basis of which action could be taken to combat the consequences of the economic depression—or sometimes, perhaps, to justify a reluctance to discharge responsibilities of this kind. A large amount of information has thus been made available as a by-product of government activity, rather than as a result of scientific research properly so called. The reports in which this information is presented have been collected by the United Nations Department of Social Affairs*, and an opportunity has now arisen to see what they amount to, and to evaluate their reliability.

The task is an important one, partly because of the urgent need for dealing with the problems of poverty and squalor in the less-developed countries, and partly because it is high time that administrative agencies so plan their work as to make available as much raw material as possible for scientific research. The range of social problems in the international field is so vast that it is unlikely that *ad hoc* researches can be undertaken to throw light on them. The proper planning of national and local surveys to secure comparability of the results is therefore an obvious necessity.

The first report which the Department of Social Affairs has published in the series dealing with inquiries into household standards of living in less-developed areas surveys the organization and geographic and demographic range of field-investiga-

* United Nations. Enquiries into Household Standards of Living in Less-Developed Areas: a Survey of the Organization and Geographic and Demographic Range of Field Investigations of the Income, Expenditure and Food Consumption of Selected Households in Africa, Asia, the Caribbean, Latin America and the Pacific. Pp. viii+191. (New York: United Nations; London: H.M. Stationery Office, 1951.) 2 dollars; 15s.

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