Letters to the Editor

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Scales of Loudness

IN the course of an extensive investigation into the measurement of noise, it became clear that the accepted standards of sensitivity of the human ear both on a basis of absolute pressure and subjective loudness needed revision. Previous work on this subject has been largely directed towards telephone conditions of listening, whereas in the more usual case of listening under 'free space' conditions, other factors such as the collecting power of the outer ear, and diffraction of the sound waves by the listener's head are involved. In order to obtain representative data, measurements have been made on 48 people of the just inaudible sound pressures at typical frequencies. All the subjects were of normal hearing and the pressures were those measured by a microphone of accurately determined field calibration in the absence of the subject. The figures given in Table I are the modes of the results and, therefore, refer to the most probable values. The subjects were chosen to represent both sexes and ages from fifteen to sixty-five years.

TABLE I

Frequency	100	200	400	800	1,600	3,200	6,400
Pressure R.M.S. Dynes/ Sq. cm.	0·0036	0·0018	0·00040	0·00023	0·00020	0·00020	0·00097

The unsatisfactory nature of the loudness scale based on the law of the logarithmic sensitivity of the ear, and conveniently embodied in the decibel scale, became obvious during experience with the method of assessing noise in terms of the intensity of an 800 cycle note which appears equally loud. By expressing the results in decibels above the threshold of audibility at 800 cycles, the figures should, by the above law, be proportional to loudness. Experience gained on the measurement of a great variety of noises shows this is not so; for example, the relation between two noises assessed in this way at 90 and 45 db. is judged by the average person to be that one is much more than "twice as loud" as the other. Since this aural comparison of loudness is so common and is, indeed, the final criterion of any scale of loudness, measurements were made on 30 people to determine what meaning, if any, could be attached to the estimate "twice as loud". The results were surprising in that, in spite of misgivings on the part of the subjects, the results were quite concordant. This result was in agreement with that obtained over a more restricted range by Ham and Parkinson[2] who also gave a reference to a paper by Richardson and Ross[3]. After preliminary measurements, the normal range of intensities at 800 cycles was covered in steps of 2 : 1, starting from 100 db., which was called 100 on the loudness scale. What is perhaps more surprising is that the curve obtained with 4 : 1 steps agreed very well with that derived from the 2 : 1 steps. Table II gives the final average figures for the relation between decibels above the threshold at 800 cycles and loudness deduced from these 2 : 1 and 4 : 1 estimates.

TABLE II

Db. above Threshold at 800 cycles	0	49	58·5	68·5	80	87·5	94·5	100	104·5	108	110
Loudness	0	5	10	20	40	60	80	100	120	140	160

An alternative loudness scale constructed as suggested by Kingsbury[3] by integrating the minimum detectable intensity changes, redetermined at 800 cycles for free space conditions, while being better than the simple decibel scale, was much less in accordance with mental estimates than the above.

To make the loudness scale apply to other frequencies the equal loudness contours determined by Kingsbury were redetermined for free space conditions, and his figures, obtained with a telephone, found to be applicable. His results were extended to 6,400 cycles and up to 100 db.

Several years' experience with the 800 cycle comparison tone method of assessing noise intensities has shown that it is most reliable, particularly for fairly steady noises, assessments by different individuals being usually to within $\pm$ 2 db. A suitable 800 cycle valve oscillator, direct reading attenuator, and single headphone have been developed in easily portable form, and this apparatus has been used to measure a great variety of noises both in the laboratory and in particular places such as streets, buildings, etc. The attenuator reads directly in decibels but the above table enables the corresponding loudness figures to be determined.

An account of the development of this apparatus and the determination of the above tables from the physical, psychological and practical points of view will be published in the near future.

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[1] *J. Ac. Soc. Am.*, April, 1932.
[2] *J. Gen. Psychol.*, April, 1930.
[3] *Phys. Rev.*, **29**, 588; 1927.

Diffraction of Electrons in Amorphous and in Crystalline Antimony

A THIN layer of antimony was deposited on a film of cellulose nitrate by evaporating in high vacuum. The specimen was then examined by electron diffraction in transmission. It was mounted in such a way that it could be rotated about an axis lying in the plane of the film and perpendicular to the electron beam. The following results were obtained and could be repeated at will:

When the metallic deposit is not too thick (showing weak or medium absorption of light) the diffraction pattern (Fig. 1, *a*) shows that the structure is amorphous. Numerous tests with other metals and blank films exclude the possibility that the pattern observed may be due to a cause other than the deposit of antimony.

If the deposit is very thin, the amorphous state remains absolutely unchanged for an indefinite time (at least for six months); electronic bombardment seems to have no influence. In the case of medium thickness, crystalline spots appear after some time