A Noise-attenuating Enclosure for Audiometer Earphones

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Noise-excluding earphones may be subdivided into circumaural earphones and noise-attenuating earphone enclosures. Two versions of 'Otocups', an example of the latter subdivision, were evaluated in a series of experiments and in comparison with a conventional type of earphone (Telephonics TDH-39 receiver in a MX-41/AR cushion). The experiments involved a comparison of auditory threshold, artificial-ear measurements, test-retest reliability, and pure-tone attenuation. The second version of 'Otocups' was considered sufficiently reliable for most purposes and to have practical applications in industrial and clinical audiometry when proper booths are not possible on account of cost, weight, or space factors.

In order that a pure tone of threshold intensity may not be masked by ambient noise, the sound pressure level of the pure tone must be at least 10 dB greater than that in the corresponding critical band of noise (French and Steinberg, 1947; Webster, 1954). This is an important factor when defining the maximum noise levels permissible in rooms to be used for audiometric purposes, but there are two other factors to be taken into account, namely auditory threshold and the attenuation provided by the audiometer headset.

The former depends on the type of audiometry (pure tone or speech), the mode of presentation (monaural or binaural, earphone or free-field), and the degree to which freedom from masking is required. About 5% of normal persons can hear pure tones 10 dB below the mean normal threshold, and hearing levels of - 10 dB (relative to International Standards Recommendation R389-1964 (International Organization for Standardization, 1964) or British Standard, B.S. 2497: 1954) are commonly the limit to which audiometers and acoustic environments are designed. For research purposes the requirement may be even more stringent, whilst other situations may occur when somewhat higher ambient noise levels and associated masking may be considered acceptable. There is no headset attenuation in free-field audiometry and values varying from single figures at low frequencies to over 30 dB at high frequencies are obtained in earphones mounted in MX-41/AR type cushions.

It is not always possible to provide an acoustic environment that meets with the criteria that can be defined from the above considerations. In such cases, any improvement in the attenuation properties provided by the headset will be of great benefit.

The opportunity to develop this arose with the design by Shaw and Thiessen (1954, 1958) of the circumaural ear defender which incorporated fluid-filled seals that allowed better contact with the head around the ear. At first the muffs were adapted to contain telephone receivers and form headsets with much increased noise-excluding qualities, but more recently they have been developed as the basis for audiometer headsets. As such, whether single-cavity or compound-cavity types (Shaw and Thiessen, 1962), they generally fall into two groups: (1) the true circumaural earphone in which there is a relatively large enclosed volume and the pinna fits inside the free space within the muff so allowing the fluid seal to take up its proper circumaural position; and (2) a fluid-seal muff that fits around a more or less standard type of earphone that is closely applied to the lateral surface of the pinna in the ordinary supra-aural way. The latter can best be described as a noise-attenuating earphone enclosure, because the MX-41/AR cushion prevents the pinna from lying free inside the cup of the enclosure and therefore the fluid seal cannot make a wholly circumaural contact. The two forms of headset are illustrated diagrammatically in Figure 1.

For audiometric screening of recruits to the Royal Navy and Royal Marines, the possibility of using noise-attenuating earphone enclosures has been considered in view of their advantage over audiometric booths in terms of cost, space, and floor-

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FIG. 1. Diagrammatic cross-sections of the two main types of earphone developed from circumaural ear defenders: (left) a true circumaural earphone and (right) a noise-attenuating earphone enclosure.

loading. Accordingly, under the auspices of the Medical Research Council's R.N. Personnel Research Committee, the author was requested to investigate the properties of Rudmose 'Otocups', an obvious choice in view of the selection of Rudmose ARJ.4 self-recording audiometers for the recruiting centres. After these investigations, two other types of noise-attenuating enclosures were examined, though in much less detail.

The results of these investigations and the conclusions drawn from them are the subject of this paper.

'Otocups' and the General Procedure

'Otocups' earphone enclosures have been developed through three models, namely, Marks I, II, and III. The Mark I was effectively the prototype and needs no description here.

The 'Otocups' available at the time of this investigation were the Mark II. These, similar to the earphone enclosure illustrated in Fig. 1b, consisted of a MX-41/AR cushion slightly cut away at the edges and flexibly mounted just within the aperture of the cavity of a fluid-seal ear muff. An unsatisfactory feature of the Mark II enclosure was that the cushion was mounted by means of a rubber strip glued to its surface. This gave a very poor fit onto the rim of a 9-A coupler, which is used for artificial-ear calibration of receivers in MX-41/AR cushions, and the cushion was not rigidly enough fixed to enable the proper force of application to be effective. At the same time, mounting of the cushion was insufficiently flexible for the pinna to be inserted

within the muff and so allow the fluid seals to take up their most efficient, circumaural position.

Soon after the investigations of the 'Otocups' Mark II were complete, the Mark III was introduced, and Rudmose kindly provided the necessary parts for modifications of the Mark II enclosures. This allowed the MX-41/AR cushion to be sited closer to the aperture in the fluid seal, and, in addition, a locking screw was provided to fix the cushion rigidly during its application to the 9-A coupler. The modified enclosures, now 'Otocups' Mark III, are shown in Figure 2.

FIG. 2. 'Otocups' (Mark III) earphone enclosures.

FIG. 3. A common form of audiometer earphone (Telephonics TDM-39 receiver in a MX-41/AR cushion).

The earphones most commonly used for audiometry in Great Britain are Telephonics TDH-39 receivers in MX-41/AR type cushions (Fig. 3). These are also the usual earphones provided with Rudmose ARJ-4 audiometers. By virtue of correction factors, such as those of Cox and Bilger (1960) or Whittle and Robinson (1961), and a variety of other data discussed recently by Rice and Coles (1966), these earphones are capable of reasonably accurate calibration to American, British, or International Standards of normal threshold of hearing. They were therefore used as the baseline to which the 'Otocups' were compared and for ease of description have been termed 'conventional earphones'.

When comparing 'Otocups' with conventional earphones, four types of investigation were performed. The methods and results of each experiment are detailed below.

Investigation of 'Otocups' Mark II

Experiment I

Comparison of auditory thresholds: 'Otocups' Mark II vs. conventional earphones The 12 subjects for this experiment were already experienced in listening tests and had hearing levels within 20 dB of the average normal threshold previously established for the audio-

FIG. 4. Comparison of 'Otocups' Mark II vs. conventional earphone by means of artificial ear and hearing threshold.

TABLE I
EFFECT OF 'OTOCUPS' MARK II ON AUDITORY THRESHOLD MEASUREMENT

	Frequency (c/s)							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Difference (dB) in mean threshold*	+7.5†	+3.0†	-1.4†	-1.8†	-2.4†	-1.3	-1.7	+3.3

*A positive sign indicates that the apparent hearing level with 'Otocups' was higher than with conventional earphones.

†Following analysis of variance, the differences up to and including those at 3,000 c/s were shown to differ significantly ($P = 0.01$) from zero.

meter concerned with a large number of subjects (Rice and Coles, 1966). They tracked the auditory threshold of the left ear at 500, 1,000, 2,000, 3,000, 4,000, 6,000, 250, 8,000 c/s, in that order, by means of a modified Rudmose ARJ-4 self-recording audiometer (Type ARJ-2S, serial number 1607). This procedure was performed four times in succession, alternating between 'Otocups' and conventional earphones, thus:—

Odd subject serial numbers (1) 'Otocups', (2) conventional, (3) 'Otocups', and (4) conventional;
Even number serial numbers (1) conventional, (2) 'Otocups', (3) conventional, and (4) 'Otocups'.

When calculating results, recording (3) was compared with the mean of recordings (2) and (4). Recording (1) was merely a practice session and its results were discarded. A closely matched pair of TDH-39 receivers was used for mounting in the left sides of both 'Otocups' and conventional earphones. Corrections were made to the mean thresholds to allow for slight differences in acoustic output between the receivers: by artificial-ear measurement in identical MX-41/AR cushions the differences ranged from +0.5 to -1.0 dB.

The result is given in Table I and illustrated in Figure 4.

Experiment II

Comparison of artificial-ear measurements: 'Otocups' Mark II vs. conventional earphones With the audiometer set to a nominal output of 60 dB hearing level, the acoustic output from the left 'Otocup' or left conventional earphone was measured by means of a Bruel and Kjaer Type 4152 artificial ear with 9-A coupler and Type 2112 audio-frequency spectrometer. The same TDH-39 receiver was used for both measurements.

The result is given in Table II and is also shown in Figure 4.

As only one set of measurements was made with each

earphone, significance tests were not applied. On the other hand, in two consecutive series of measurements of acoustic output over the above frequency range, with repositioning of the earphone on the same 9-A coupler between the two series, the difference in the readings was not in excess of about 1 dB, except at 6,000 c/s where the difference was up to 2 dB. This order of magnitude for placement errors has subsequently been confirmed in a more extensive series of measurements in connexion with other research. It is therefore considered that all the above are real differences due to substitution of an 'Otocup' Mark II for the conventional TDH-39: MX-41/AR earphone.

Experiment III

Repeatability of audiograms using 'Otocups' Mark II and conventional earphones The auditory thresholds of each ear of five experienced listeners were measured twice at the same eight frequencies on six nearly consecutive days. For one measurement each day the 'Otocups' were used, and for the other measurement conventional earphones were worn: the order of usage was alternated between days in order to minimize possible changes in performance due to practice or systematic changes in degree of mental concentration.

The variance of threshold determination is listed in Table III and illustrated in Figure 5.

Investigation of 'Otocups' Mark III

Knowledge of Mark III 'Otocups' coincided with the last stages of the investigations of the Mark II variety. Ideally, a single series of experiments, using both Mark II and Mark III 'Otocups' and the conventional earphones, would have been performed, but the additional precision gained might have been lost due to difficulties in maintaining the necessary mental concentration

TABLE II
EFFECT OF 'OTOCUPS' MARK II ON ARTIFICIAL-EAR MEASUREMENTS

	Frequency (c/s)							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Difference (dB) in artificial-ear measurements*	+10.4	+9.5	-4.1	-1.8	-1.4	-1.2	+6.3	+2.3

*A positive sign indicates that the acoustic output into the 9-A coupler was such as to cause higher hearing levels with 'Otocups' than with conventional earphones, *i.e.*, a lower acoustic output causes a higher apparent hearing level.

FIG. 5. Repeatability of threshold determinations with 'Otocups' Mark II and conventional earphones.

TABLE III
EFFECT OF 'OTOCUPS' MARK II ON REPEATABILITY OF THRESHOLD DETERMINATION

	Frequency (c/s)							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Variance (dB)²*								
With 'Otocups'	13.6	13.0	5.8	5.0	3.2	6.9	24.1	36.3
With conventional earphones	5.6	4.9	3.8	5.1	6.0	13.3	19.6	14.9

*Mean threshold values were determined for each ear of each subject at each frequency. The difference between these means and each measurement for the appropriate ear was used for analysis of variance. The variances for 'Otocups' Mark II and for conventional earphones were not significantly different at any of the frequencies.

TABLE IV
EFFECT OF 'OTOCUPS' MARK III ON AUDITORY THRESHOLD MEASUREMENT

	Frequency (c/s)							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Difference (dB) in mean threshold*	+4.0†	+1.1	+0.3	+0.9	+2.1	-0.3	+3.4	+3.4

*A positive sign indicates that the apparent hearing level with 'Otocups' was higher than with conventional earphones.

†Following analysis of variance this value was shown to differ significantly ($P = 0.05$) from zero.

during the long experimental sessions that would have been involved. To perform such experiments would also have meant abandoning previous results and adding 50% to the time requested of each subject for the additional Mark III 'Otocups' study. It was therefore decided to investigate the Mark III 'Otocups' as a separate series of experiments.

Experiment IV

Comparison of auditory thresholds: 'Otocups' Mark III vs. conventional earphones The method used was the same as that in experiment I except that not all the 12 subjects were the same as before.

The differences in mean thresholds are listed in Table IV and illustrated in Figure 6.

Experiment V

Comparison of artificial-ear measurements: 'Otocups' Mark III vs. conventional earphones The method used was the same as that in experiment II, except that two sets of observations were made and the results averaged.

The result is given in Table V and Figure 6.

On the basis of the arguments set out under experiment II, it is considered that none of the differences listed in Table V is significant.

Repeatability of audiograms using 'Otocups' Mark III and conventional earphones As the threshold repeatability with 'Otocups' Mark II (experiment III) was not significantly different from that with conventional earphones, and because the evidence from experiment IV

TABLE V
EFFECT OF 'OTOCUPS' MARK III ON ARTIFICIAL-EAR MEASUREMENT

	Frequency (c/s)							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Difference (dB) in artificial-ear measurements*	-0.1	+0.1	0	0	0	-0.1	+0.8	+0.4

*A positive sign indicates equivalence to an apparently greater hearing level to be expected with 'Otocups' than with conventional earphones.

FIG. 6. Comparison of 'Otocups' Mark III vs. conventional earphone by means of artificial ear and hearing threshold.

suggested that 'Otocups' Mark III approximated in performance more closely to conventional earphones than did the Mark II variety, it was not thought worth while to measure the repeatability of threshold determinations with 'Otocups' Mark III. Also, as the subjects used in experiment III were no longer available a further investigation with 'Otocups' Mark III could contribute no further statistical refinement to the analysis of experiment III.

Experiment VI

Attenuation characteristics of 'Otocups' Mark III and conventional earphones Binaural free-field thresholds of 12 subjects were determined by a self-recording technique under three experimental conditions, namely, with open ears, wearing 'Otocups', and wearing earphones. (In the latter two conditions the headsets were, of course,

entirely inert.) The order of experimental conditions was randomized to counterbalance possible effects due to practice or changes in concentration. At the end of the first condition, the first three frequencies (500, 1,000, 2,000 c/s) were retested: the values taken as threshold were the retest ones.

The mean and standard deviation of the attenuation values obtained are listed in Table VI. The differences in attenuation between the two types of headset are also included in the Table and are illustrated in Figure 7.

Discussion

Concerning Problems of Calibration and Reliability It is clear from the results of experiments I and II that 'Otocups' Mark II and III have acoustic properties that differ considerably from

TABLE VI
ATTENUATION CHARACTERISTICS OF 'OTOCUPS' MARK III AND OF MX-41/AR CUSHIONS WITH TDH-39 RECEIVERS
(CONVENTIONAL EARPHONES)

	Frequency (c/s)							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Mean attenuation (dB)								
By 'Otocups'	14	15	26	31	33	34	35	31
Standard deviation*	4.8	7.5				9.0		
By conventional earphones	5	7	13	25	27	26	24	21
Standard deviation*	4.5	9.2				12.7		

*The variances group reasonably, taking 250 c/s separately, into 500 to 4,000 c/s as one group and 6,000 to 8,000 c/s as the other. Comparison of the variances for the 'Otocups' and conventional earphones only just fails to show significance at $P = 0.05$.

FIG. 7. Increase in pure-tone attenuation attained by use of 'Otocups' Mark III.

those of conventional earphones. If the curves for both auditory threshold differences and artificial-ear differences shown in Fig. 4 had been identical within the limits of statistical significance (not calculated in this respect), the artificial-ear calibration of 'Otocups' Mark II could have been carried out as for conventional earphones.

Even where the artificial-ear and threshold data differed considerably (as at 250, 500, and 6,000 c/s in Fig. 4) calibration could theoretically be achieved by means of calibration correction factors. However, this would probably be rather unreliable because at 250 and 500 c/s the lack of agreement was almost certainly due to acoustic leakage, the artificial ear making a poor fit to the cushion within the 'Otocups' Mark II and the apparent acoustic output being very variable from one placement to another. At 6,000 c/s the discrepancy was considerably greater than would be expected from the already known (Rudmose, 1964) unsatisfactory performance of a TDH-39 earphone on a 9-A coupler at this frequency: it is likely that the variability in

enclosed volume and irregularity in its contours, due to the misfit between the coupler and the cushion in the Mark II 'Otocups', were the added factors accounting for the size of the discrepancy observed.

As the 'Otocups' Mark II could not be considered a true circumaural earphone with its full noise-excluding advantage, the logical step in its further development (to Mark III) was to make it as similar to the well-proven MX-41/AR cushion in its acoustic output and calibration characteristics as possible. Its designer did this by mounting the MX-41/AR cushion in such a way that its smooth surface was no longer interrupted by its means of attachment and it made proper contact with the pinna of the wearer and the rim of a 9-A coupler, and, by making provision for fixation of the cushion rigidly within the cup, the correct force of application became effective during artificial-ear calibration.

Evaluation of the 'Otocups' Mark III showed that the artificial-ear performance was essentially the same as with a standard MX-41/AR cushion (Fig. 5). In auditory threshold there was no signi-

ficant difference in performance, except marginally at 250 c/s. This latter was presumably due to acoustic leakage and it is tempting to guess that by fixing the cushion during threshold determinations, as in artificial-ear measurements, the error at 250 c/s would be eliminated also.

Since the experiments described, the author has conducted artificial-ear measurements on two other manufactures of noise-attenuating earphone enclosures. These were interesting in that the enclosed cushions were sufficiently near the opening in the fluid seals and stiffly mounted for a good seal on a 9-A coupler to be obtained and the artificial-ear differences between them and conventional earphones to be negligible. In spite of the agreement in artificial-ear performance, there were indications from reports on comparative threshold determinations (Wheeler, 1965; Royal National Institute for the Deaf, 1965) that on real ears they did not give the same results as conventional earphones. This was probably¹ the result of less close supra-aural application of the enclosed earphone cushions and a consequent increase in the enclosed volume as compared with conventional earphones or 'Otocups' Mark III. The discrepancies reported illustrate the necessity for carrying out both threshold measurement and artificial-ear evaluations of new forms of audiometer earphone.

Although the variances of repeated threshold determinations using 'Otocups' Mark II and conventional earphones were not significantly different, the evidence does suggest that a slight advantage may lie with the latter at the upper and lower ends of the usual range of audiometric frequencies, *i.e.*, at much the same frequencies as those at which the acoustic properties of 'Otocups' Mark II appear to be somewhat unsatisfactory. For reasons already stated, it was not thought worth while to repeat the test-retest reliability evaluation with 'Otocups' Mark III, but the comparisons of the Mark II and III varieties in respect of threshold determinations and artificial-ear measurements make it appear likely that the test-retest reliability of the Mark III might be almost identical with that of the conventional earphones.

Compared with conventional earphones, there is some evidence that circumaural ones have potentially greater test-retest reliability (Atherley, Lord, and Walker, 1965) and reduced between-subject real-ear sensitivity variance (Forshaw, 1966) at the

higher test frequencies, *e.g.*, at 6 kc/s. In intra-subject sensitivity variance, they appear to have some advantages at frequencies below 700 c/s also (Shaw, 1966). On the other hand, the data of Charan, Cox, and Niemoeller (1965) indicate that at frequencies above 2,000 c/s flat-plate couplers for artificial-ear calibration of circumaural earphones are still wanting in reliability. Further, comparison of the sensitivity variances reported by Forshaw for circumaural earphones and by Burkhard and Corliss (1954) for supra-aural earphones indicates an advantage for the latter in the more important middle frequency range, say 400 to 2,000 c/s. These differences are probably related to a large number of factors, among them the relation between wavelength and the length of the ear canal and earphone-cushion combination, but the reader must be referred to the paper by Shaw and Thiessen (1962) for a detailed account of the acoustics of circumaural earphones. Finally, wide discrepancies (20 dB) have occurred in measurements of apparent acoustic output for mean threshold excitation voltages across the terminals of the same type of circumaural earphone when placed on artificial ears with flat-plate couplers (Stein and Zerlin, 1963; Tillman and Gish, 1964). The more recent data of Shaw (1966), however, have shown good agreement between sensitivity measurements (Shaw and Thiessen, 1962) and the subjective threshold measurements of Tillman and Gish (1964) in respect of the differences between Sharpe HA-10 circumaural earphones on flat-plate couplers and Telephonics TDH-39: MX-41/AR earphones on 9-A couplers.

If and when the problem of artificial-ear calibration of true circumaural earphones is satisfactorily solved (and such a solution does not appear to be in sight: A.S.A. Committee on Couplers, 1966), the choice will remain whether it is worth while to sacrifice perhaps some precision in calibration for a general increase in attenuation of ambient noise. In the meantime, the use of noise-attenuating earphone enclosures, such as 'Otocups' Mark III, in place of conventional earphones appears to result in a minimal change in accuracy of both artificial-ear calibration and threshold determination. It appears also that the use of 'Otocups' would have little or no effect on reliability in temporary threshold shift experimentation.

Concerning Attenuation Characteristics The results of the attenuation measurements on conventional earphones are a little lower than those obtained in other laboratories (see Table VII).

The difference between laboratories may be due to a number of factors such as statistical chance, different methods, difference in cushion material

¹Further experience with the ME.70 headset has confirmed that the receivers are not sufficiently fixed within the enclosures, with the result that their position can become altered between tests with considerable effect on the apparent auditory thresholds measured.

TABLE VII
COMPARISON OF ATTENUATION DATA FOR MX-41/AR CUSHIONS

	Attenuation (dB) at the Following Frequencies (c/s):							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
Shaw (1945)	8	8	16	29	—	36	—	32
Harvard University (1946)	3	9	15	24	—	37	—	—
Wheeler-Bennett and Wheeler (1962)	4	11	21	29	36	33	30	21
Mean of above data	5	9	18	27	36	35	30	27
Present data	5	7	13	25	27	26	24	21

TABLE VIII
COMPARISON OF ATTENUATION DATA FOR NOISE-EXCLUDING EARMUFF AND EARPHONES

	Attenuation (dB) at the Following Frequencies (c/s):							
	250	500	1,000	2,000	3,000	4,000	6,000	8,000
'Eargards'	23	35	39	40	47	44	40	34
'Eargards' + telephone receivers	25	33	37	36	43	39	35	30
'Otocups' Mark III	14	15	26	31	33	34	35	31

'Eargards' earmuffs (Denis-Ferranti Meters Ltd.) as used in the Royal Navy and Royal Air Force: attenuation measured by Wheeler-Bennett and Wheeler (1962). 'Eargards' with telephone receiver inserts: attenuation measured by McKay and Wheeler (1960).

and headband tension, and slight degrees of masking by ambient noise of the open-ear thresholds of subjects with very acute hearing. The latter two factors would be expected to have most effect at low frequencies, which is not apparent in comparison of the results of Table VII: on the other hand, there were only 12 subjects in the present investigation and this is thought to be the principal factor causing the low attenuation values of the present data.

Because of the low attenuation values, more attention should be paid to the differences in attenuation between 'Otocups' and conventional earphones: these are included in Table VI and are illustrated in Figure 7.

To put the present results still further into perspective, it is informative to compare the 'Otocups' attenuation data with those of a Shaw and Thiessen type of earmuff, and the same muff with telephone receiver inserts (Table VIII).

It is interesting to note in Table VIII how inclusion of a telephone inside a muff, even deep within it, results in a diminution of attenuation (by about 3 dB). With 'Otocups', the relatively small enclosed volume and the partly supra-aural fit of the fluid seals are probably the major factors accounting for the considerable further reduction in attenuation.

Conclusions

In assessing the practical applicability of a noise-attenuating earphone enclosure or circumaural earphone, the first consideration must be whether it is capable of artificial-ear calibration and whether the results of auditory threshold determinations can be related to recognized standards of normality with the same degree of reliability as with conventional earphones. 'Otocups' Mark III, but not Mark II, appear to meet these requirements for most audiometric purposes, except perhaps at low frequencies (250 c/s and below).

The other consideration concerns the circumstances in which the increased attenuation may be beneficial. The saving in cost, weight, and space over an acoustic booth is obvious, but the attenuation gained is very much less. An important factor here is the degree to which the audiometric procedure needs to reveal the true threshold of persons with normal hearing, the more important requirement usually being that elevated thresholds should be accurately measured; it may be asked, therefore, how much masking of normal threshold may be tolerated? It is suggested that, both for clinical audiometry and for monitoring audiometry as part of an industrial hearing conservation programme, it

may not be considered necessary to be able to measure hearing levels more acute than, say, the International Standard zero; and in some special circumstances it may even be possible to accept a further 10 dB of masking.

Criteria for maximum ambient noise levels in audiometric booths vary widely in stringency from that of Taylor, Burns, and Mair (1964), who were concerned with hearing levels up to -10 dB re I.S.O. zero, to that of Glorig and Harris (1957), based on calculations by Webster (1954) and Cox (1955), whose concern was with hearing levels equal to American Standard (1951) zero. The difference between these criteria in effect amounts to a measure of the amount of masking that can be considered acceptable. But when 'Otocups' or similar devices are used in place of conventional earphones about 10 dB greater ambient noise level can be present for the same amount of masking: further, it can be seen from the statistical analysis of Table VI that 'Otocups' have a further slight advantage in consistency of attenuation.

Apart from the direct peripheral masking effects considered above, any ambient noise that is perceived by the subject undergoing audiometry has a disturbing effect on his concentration and resultant apparent auditory threshold, an effect included under the term 'central masking'. Therefore as much outside sound should be kept out of the listener's ear as possible even though it may be at too low a frequency or intermittent to cause direct masking. Noise-attenuating earphones are an obvious advantage in this connexion also.

It is felt that 'Otocups' Mark III, or other similar earphone enclosures if proved satisfactory, may be a great benefit in the following situations:

- (1) for industrial audiometry in the absence of a room specifically designed for such tests
- (2) for clinical audiometry when carried out in the consulting room or other relatively quiet room
- (3) for research when the ambient noise level is already low but not quite low enough
- (4) for temporary threshold shift experimentation in the field to provide improved acoustic conditions when a proper booth is not available.

It should be emphasized again, though, that noise-attenuating earphones are not an automatic alternative to a properly constructed audiometric booth: where finance, space, and floor-loading considerations allow, the booth is invariably indicated.

If and when the calibration problems of true circumaural earphones are overcome, their use will entail two additional advantages; their noise-attenuating properties will be about 10 dB greater and they will be more comfortable to wear, particu-

larly for children and for periods greater than 15 minutes, than conventional earphones either by themselves or mounted in noise-attenuating enclosures.

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