Institute of Acoustics

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Volume 19 No 4
July - August 1994

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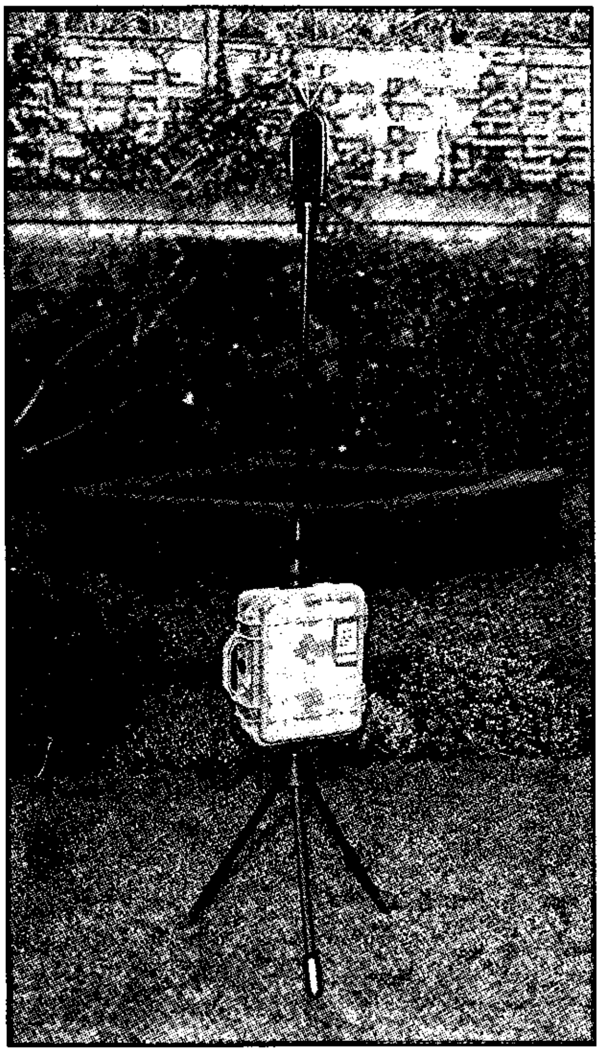

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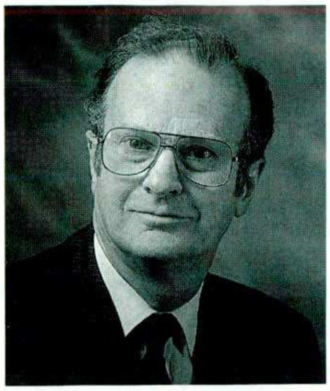

Dear Fellow Member

Publication of this issue of the Bulletin has been delayed to allow the preparation of the 1994/5 Register of Members which you will have received recently. I am sure that, like me, you will find the Register a useful publication which improves from year to year.

The early part of this year saw the registration of the European Acoustical Association as a European Economic Interest Grouping having a legal identity and the ability to make profits - or losses! The Institute, as a fully signed up member, shares in these profits, or makes up the losses. Inevitably there have been expenses in the start up period but it is in our interests to ensure that the Association soon moves into profit.

The most obvious sign of the EAA is the publication Acta Acustica. At present the flow of papers to the Editor is still less than had been hoped and I would urge members to offer material for publication in that journal. From 1995 onwards the IOA is no longer committed to taking a fixed number of copies but it is hoped that many members will subscribe in future years. The Institute has a number of copies of Acta Acustica which interested members can obtain to sample the wares. All orders for personal subscriptions at the reduced rate for members should be sent to the Institute office for passing to the publishers.

The other major activity of the EAA receives its initial publicity with this issue in the form of a preliminary announcement of the Forum Acusticum to be held in Antwerp in April 1996. This is expected to be a major multinational meeting but aimed particularly at researchers. Remember that Internoise '96, which is being organised by the Institute, will be held in Liverpool later that year so you should consider nearer the time keeping relevant material available with a view to offering it to that important event; look out for further details in the New Year.

For those of you who were not at Salford at the Spring Conference and so missed the fascinating lecture by Professor Ted Evans - a physiologist looking at the engineering of the ear, this issue contains a reprint of his paper which constituted the Rayleigh Medal for 1994. Read it, it's great stuff. I also commend to you the intriguing article by Whitlow Au and Paul Nachtigall on dolphin acoustics.

Mention of the Rayleigh Medal reminds me that we are seeking nominations on behalf of a non-UK acoustician for this Medal for 1995; details of this and other awards are in this issue.

Sincerely yours

Alex Burd

Alex Burd

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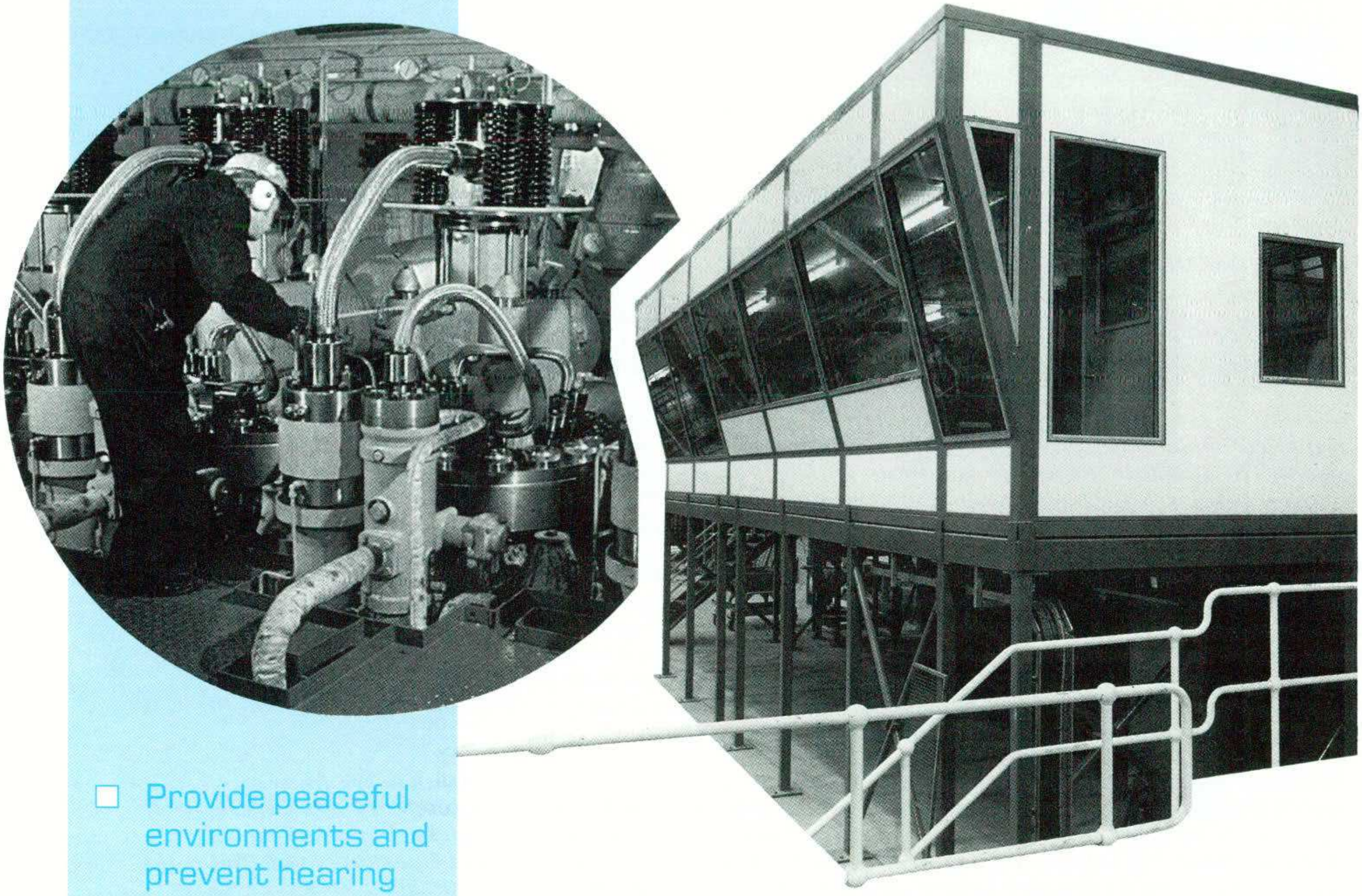

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AUDITORY FREQUENCY SELECTIVITY: A PHYSIOLOGIST LOOKS AT THE ENGINEERING OF THE EAR

E F Evans FIOA

Introduction

It has long been known, since the time of Ohm [1], that the ear is capable of a remarkably fine frequency analysis. That is to say, it can resolve a complex sound into its component frequencies, within certain limits.

However, it is only in the past 30 years that the mechanisms underlying this frequency selectivity have been identified with the auditory periphery, and only very recently has it been possible to make this identification in quantitative terms. The picture that emerges from this more recent work is of an ear, which far from being a passive microphone, achieves a remarkably fine frequency analysis as a result of a distributed active filtering mechanism.

This review aims to survey the underlying basis of our auditory frequency selectivity in normal hearing, its vulnerability, and the consequences for normal and impaired hearing, temporal coding and cochlear implants.

What Is Auditory Frequency Selectivity?

Auditory frequency selectivity, frequency resolution or frequency analysis is the ability of the ear to resolve a complex sound into its component frequencies. As far as complex sounds are concerned, the ear behaves as if it contained a bank of surprisingly narrowly tuned bandpass filters. Frequency selectivity is an expression of the width of the filters. Sounds falling within the bandwidths of the filters will sum and interact for threshold and beats respectively. Simultaneously present frequencies falling into separate filters will be heard apart. In order to distinguish the sounds of speech, for example, the ear has to be able to separate the constituent (formant) frequencies sufficiently to ascertain their relative separation and to track their transitions. Its ability to do this is limited by its frequency selectivity.

The classical measure of human auditory frequency selectivity was the 'critical band' [2,3], in width about 20% of the centre frequency of the band. This was obtained by measures that included the summation of loudness as a function of the widths of noise bands. More recent and precise measures involving the simultaneous masking of a tone by spectrally architectured noise maskers yield values of about 10% of the centre frequency of the band, for human hearing. The dotted line in Figure 10 shows a summary, for human hearing, of recent data obtained and collated by Moore and colleagues [4]. These bandwidths are approximately the half-power bandwidths of the ear's filters and are more precisely expressed as their equivalent rectangular bandwidths (ERBs), defined in more detail later.

The two main methods of psychophysically determining the shapes and bandwidths of the auditory filters using spectrally architectured noise masking are briefly as follows. The first, originally due to Patterson [5] and subsequently utilized by others (see summary in [6]) uses bandstop noise as the masker. A tone is typically centred in the stop band and the low and high frequency edges of the band are varied in frequency, while the greater or lesser effects of this are measured in terms of the masked threshold of the tone. Thus, when the notch widths are zero the masking is maximum and so is the masked threshold. As the notch width is progressively increased, the noise bands invade the auditory filter to a progressively smaller degree and this is reflected in less masking and a lower masked threshold. From the function describing the relationship between the masked threshold and the notch width, can be calculated the width of the auditory filter, typically fitting a Gaussian or rounded exponential filter shape to the data. An alternative method is to use comb-filtered or ripple or 'cosine' envelope noise as the masker [7,8] This has a cosinusoidal power spectrum, easily generated electronically [9]. The masked threshold of a tone, again at the centre frequency of the assumed auditory filter, is measured when the tone frequency coincides with successive valleys and peaks of the comb-filtered noise spectrum as the separation between the peaks (relative peak density) is progressively increased. From these measurements, the filter bandwidth can again be derived in terms of the best fitting Gaussian or rounded exponential filter models and in addition by a free-fitting model (utilizing a weighted Fourier transform of an oscillatory function defined by the masked threshold versus relative peak density data. For details, see [8]).

In each case, the assumptions are made that the model filters are linear; in most cases, that their shapes are symmetrical on a linear frequency scale. Surprisingly, these two assumptions turn out to be remarkably good (see later) in spite of the non-linear mechanisms underlying the processes.

Early Measurements of Physiological Auditory Frequency Selectivity

In 1973, Wilson and I [10] published measurements of the equivalent rectangular bandwidths of the tuning of cochlear nerve fibres recorded in the cat compared with

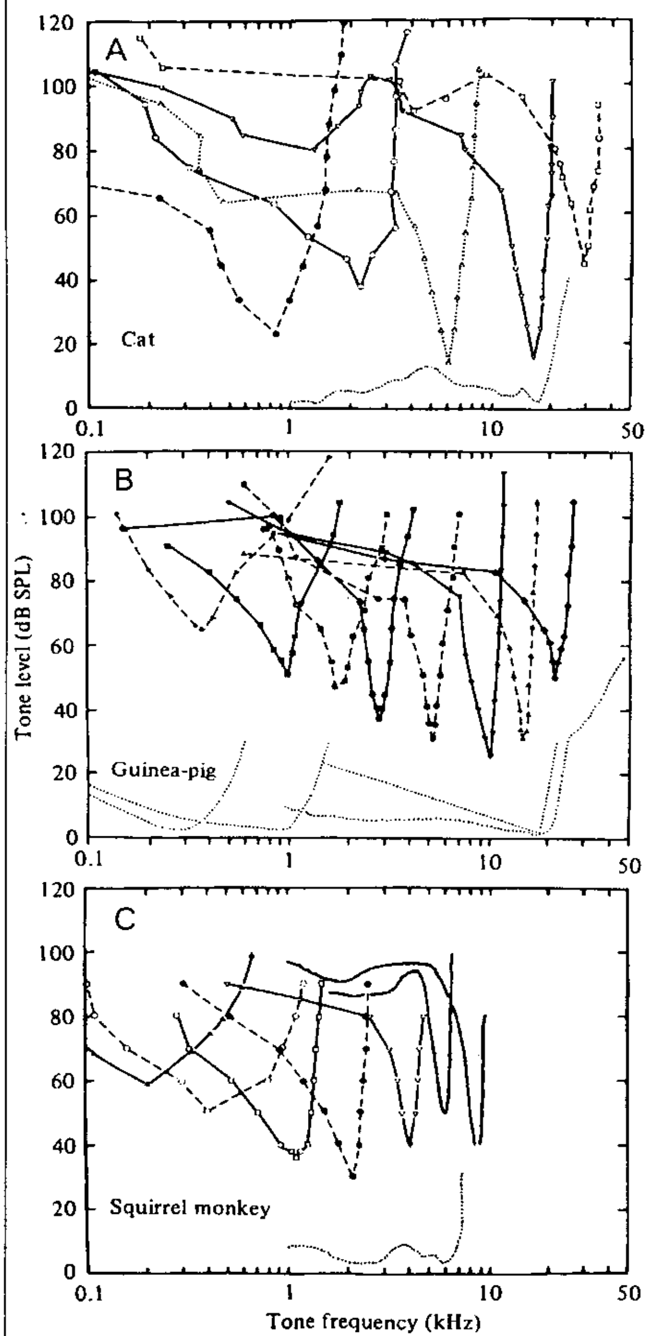

Fig. 1. Families of Frequency Threshold ('tuning') Curves (FTCs) for single cochlear nerve fibres in the cat, guinea pig and squirrel monkey. Each curve represents the tone level required to achieve a just threshold response from a single cochlear nerve fibre, the fibres chosen to cover a representative range of characteristic (most sensitive) frequencies. Below the neural curves are arbitrarily positioned analogous response curves of the passive vibration patterns of the basilar membrane (dotted lines). (From [25,80] after many sources cited therein).

the then most popular psychophysical measurements of frequency selectivity, the 'critical band'. The approximate similarity between these and other physiological and psychophysical measurements led us to propose the hypothesis that to a first approximation at least, the mechanisms underlying our auditory frequency selectivity were already determined at the level of the cochlea.

This was a departure from received wisdom. The classical measurements by von Bekesy [11,12] of the tuning of the basilar membrane (in many species) and by Tasaki [13] of cochlear nerve tuning (in the guinea pig) both suggested that the cochlea was a poorly tuned structure and therefore there was a need for subsequent filtering at higher levels of the auditory system to account for our auditory frequency selectivity.

Subsequent measurements of tuning in single cochlear nerve fibres in the cat by Katsuki [14] and by Kiang [15] (shown in Figure 1A) and their colleagues, indicated that the tuning at the cochlear nerve level was much sharper than Bekesy's and Tasaki's data had suggested. Moreover, there were doubts about the (post-mortem) conditions under which Bekesy had obtained his measurements and these were supported by somewhat sharper measurements of basilar membrane motion in the living guinea-pig obtained using the Mossbauer technique by Johnstone and collaborators [16]. However, the classical measurements of cochlear nerve tuning in the guinea-pig (by Tasaki [13]) were as broad as the mechanical tuning showed by Bekesy and Johnstone. This raised the question whether there were species differences in the sharp tuning of cat on the one hand and the poor tuning of the guinea-pig on the other. Therefore, having confirmed Kiang's finding of sharp tuning in individual cochlear nerve fibres of the cat cochlear nerve, I demonstrated that species differences were not involved by obtaining sharp tuning in the guinea-pig [17,18] (see Figure 1B). Using modern techniques, there is surprisingly good agreement across a wide variety of mammalian species in the shapes and the widths of the tuning curves obtained (Figure 1A,B,C).

Each tuning curve or frequency threshold curve (FTC) depicts the frequencies and their intensities evoking a just threshold response from the cochlear nerve fibre. The characteristic frequency (CF) is the frequency to which the nerve fibre responds best, ie the tip frequency of the tuning curve. It depends on the location of the cochlear fibre along the tonotopically organized cochlear partition – low CFs, from the cochlear apex, high CFs from the cochlear base. One has to imagine some 30,000 to 50,000 of these curves, overlapping and filling the frequency space in Figure 1. At CFs below about 2 kHz, the FTCs are roughly symmetrical with a segment having lower slope on the high frequency cut-off, whereas fibres with CFs above about 2 kHz are more asymmetrical with a much more pronounced low-slope segment on the low frequency cut-offs. These cochlear nerve filters are quite remarkable: they have half-power bandwidths in the one third to one sixth octave range and cut-off slopes of the order of 100 – 200 dB per octave for CFs above 2 kHz or so, approaching 1000 dB per octave on the high-frequency cut-offs.

The bandwidth of the FTCs can be expressed as the equivalent rectangular (effective) bandwidth (Figure 2) as the width of the rectangular filter having the same area as the FTC, integrating in the linear power/frequency domain. The assumption is that the rectangular filter will pass the same energy as the FTC from a wide band noise

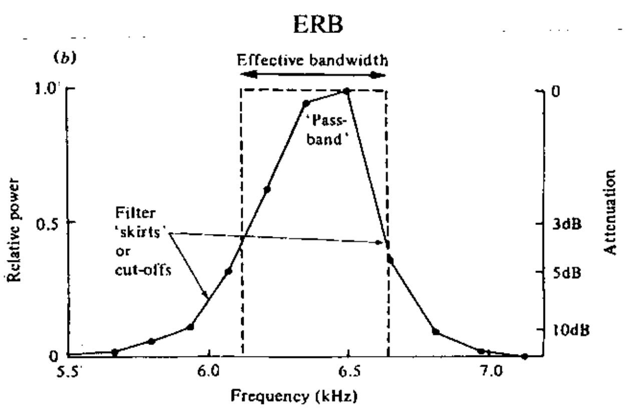

Fig. 2. Frequency Threshold Curve of single cochlear nerve fibre considered as a filter attenuation function with its equivalent rectangular (effective) band width (ERB). (From [81]).

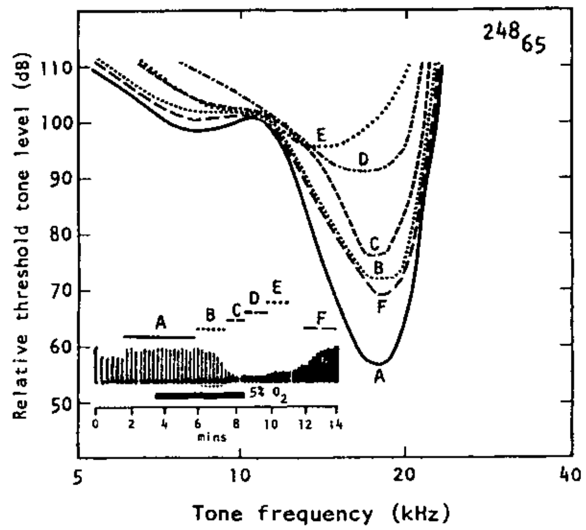

Fig. 3. The effect of hypoxia on the tuning of a single cochlear nerve fibre. Curve A: frequency threshold curve (FTC) of cat cochlear nerve fibre. Curves B, C, D, E and F: FTCs obtained during and following 4 minutes hypoxia produced by reducing the expired air oxygen concentration to 5%. Inset shows timing of collection of FTC data in relation to the period of hypoxia and the brief reversible reduction in amplitude of the gross cochlear action potential in response to a fixed amplitude click (from [20]).

signal, and this assumption is at least approximately justified as shown by Evans and Wilson, [19].

Figure 1A,B,C also show, in the dotted curves in the lower part of each section, basilar membrane tuning obtained in the cat, guinea-pig and squirrel monkey respectively, for comparison with the cochlear nerve tuning curves. It was clear that even in 1975 with the more modern Mössbauer and capacitive probe measurements there was still a large discrepancy between the basilar membrane and neural tuning.

In the 1972 experiments [17], I had also showed from the guinea-pig measurements that these sharp cochlear nerve tuning curves were only obtained when the cochlea was in pristine physiological condition In other words, the neural tuning curves were *physiologically vulnerable*. Reduction in the blood supply to the cochlea, or in its oxygenation, the effects of noise, certain drugs etc, would change the tuning curves from being normally low threshold and sharply tuned to high threshold and broadly tuned as shown in the interrupted curves of Figures 3 and 4. The tuning of individual cochlear nerve- fibres therefore could be deliberately manipulated by reduction in the oxygen supply to the ear ([20]: Figure 3) or by the use of agents like furosemide ([21]: Figure 4) known to produce hearing loss in man. Thus, the broad tuning in the classical Tasaki [13] measurements of cochlear nerve fibre tuning is likely to have been obtained from guinea pigs in poor physiological condition. We have developed a more appropriate anaesthetic technique for the guinea pig to minimize this problem [22,23].

By the mid 1970s, therefore, there was the following paradox: sharp tuning at the cochlear nerve level in the face of apparently broad tuning of the basilar membrane. We also had the demonstration referred to above that the cochlear nerve tuning was physiologically vulnerable, where changes in the physiological condition of the cochlea gave rise to cochlear nerve tuning which was as poor as the extant data for the basilar membrane tuning. These findings led us to propose the existence of an additional, biologically active (ie physiologically vulnerable) process sharpening up the relatively poorly tuned (passive) mechanics of the basilar membrane. We called it the cochlear 'second filter' as an expression of ignorance of the underlying mechanisms, but favoured at the time [17] a positive feedback process first proposed by Gold [24]; admittedly on spurious psychophysical evidence: (see [25]). At the same time, all the evidence relating to poor basilar membrane tuning pointed towards a *succession* of filtering processes: the first, basilar membrane filter, broadly tuned, followed by a much sharper second filter (see [10,26]). The nature of this 'second filter' hypothesis has been much misunderstood and it perhaps needs to be emphasized that in its original framing it was sufficiently wide to embrace any kind of mechanism which enhanced the (passive) tuning of the basilar membrane. Indeed, at the time, we explicitly questioned the validity of the extant mechanical data (eg [17,25]). Furthermore, our studies of the influence of kanamycin poisoning of the cochlea in the guinea pig [27,28] provided evidence that the sharp tuning of the cochlear nerve fibres depended upon the integrity of the *outer* hair cells, and this was confirmed elegantly in the cat by Liberman and Dodds [29]. This was a significant finding because it was well known from the work of Spoendlin [30] that the majority of cochlear nerve fibres arose exclusively from the *inner* hair cells.

The Cochlea as an Active Filter

Since the mid 1970s, several lines of evidence have modified the above picture and introduced us to a very exciting modern picture of cochlear filtering.

First, was the evidence in the late 1970s that the inner

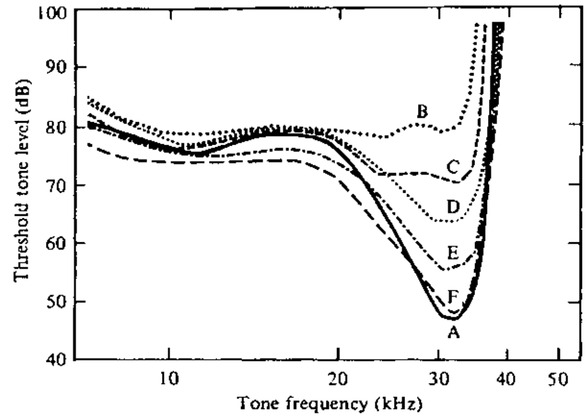

Fig. 4. Physiological vulnerability of tuning of single cochlear nerve fibre: action of the ototoxic diuretic furosemide injected into the cochlear blood circulation. Curve A: control frequency threshold curve (FTC) of cat cochlear nerve fibre. Curve B: FTC obtained during maximum effect of furosemide; C, D, E and F: during recovery. (From [21]).

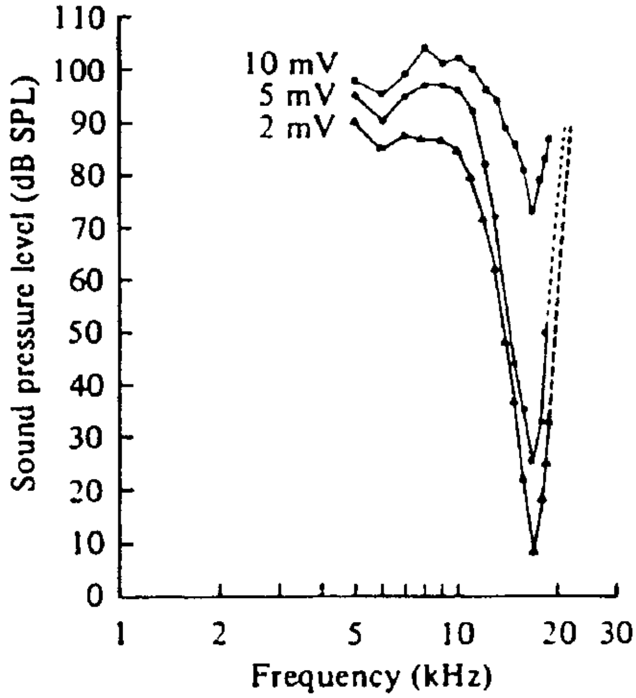

Fig. 5. 'Tuning curves' for the receptor potential recorded intracellularly in a guinea pig inner hair cell. Each curve represents the sound level required to maintain a constant receptor potential across frequency. (From [80] after [31]).

hair cells themselves were sharply tuned (Figure 5). Russell and Sellick [31] showed in the first successful recordings from the inner hair cells of guinea-pigs that the tuning of the hair cell (receptor) potentials were as sharp as those that had been recorded from the cochlear nerve fibres. Thus there was no need for hypotheses for the cochlear 'second filter' based on neural or electrical interactions *beyond* the hair cells.

Secondly, again at the end of the 1970s, was the discovery that the inner ear could *produce* sounds in response to sound inputs. Kemp [32] and Wilson [33] demonstrated the production of 'cochlear echoes' (better termed evoked otoacoustic emissions – OAEs) in response to clicks (see Figure 6) and tone bursts. This indicated that mechanical energy was being produced in response to sounds entering the ear. The amount of mechanical energy returned could be greater than that introduced. The emissions could be spontaneous and continuous (spontaneous otoacoustic emissions (SOAEs)). Wilson and I [34] were able to show in one particularly fortunate case (guinea-pig) that this SOAE was present in the cochlear microphonic (reflecting hair-cell potentials), and as such was not affected by section of the middle ear, but was physiologically vulnerable like the known cochlear

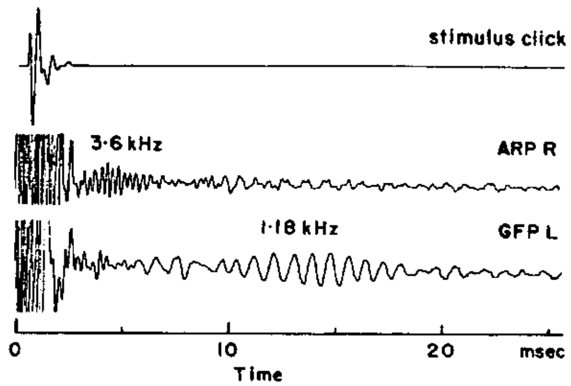

Fig. 6. Otoacoustic emissions from two human ears, evoked by clicks (upper trace). Averaged responses obtained from a low-noise microphone sealed into the ear canal. (From [33,82]).

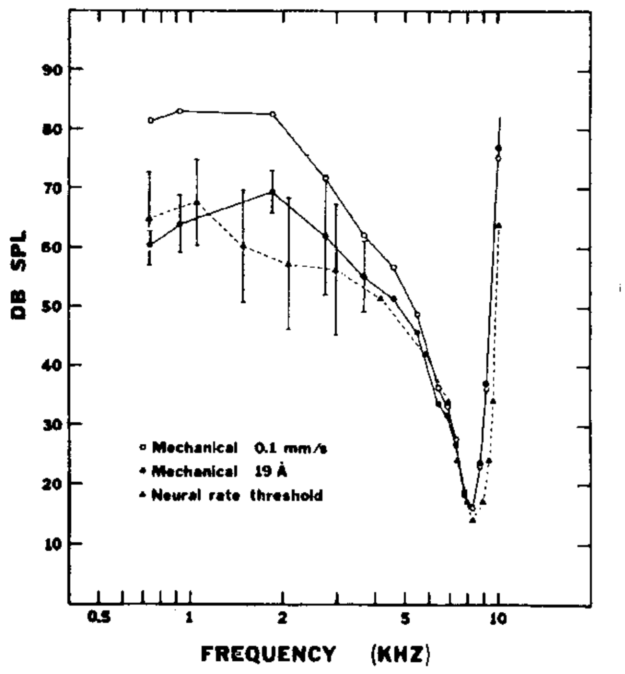

Fig. 7. 'Tuning curves' from basilar membrane of chinchilla cochlea (circles), compared with tuning of single cochlear nerve fibre (triangles). (From [82] after [39]).

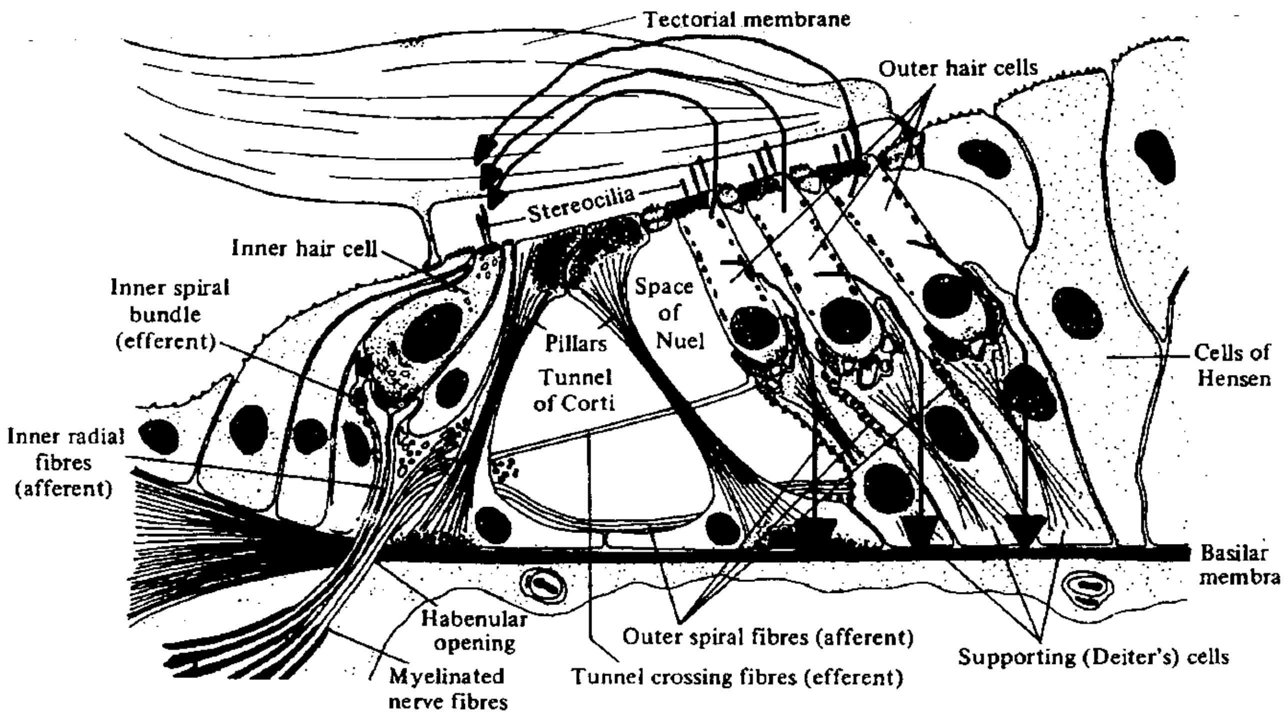

Fig. 8. Organ of Corti in the inner ear (cochlea), showing hypothetical feedback of mechanical energy from the motile outer hair cells to the sensory inner hair cells. (After [80]).

mechanisms. There is now no doubt that these emissions come from the inner ear.

Their origin is now almost certainly to be from the outer hair cells because of the third discovery: that outer hair cells are motile when placed in an ac electrical field [35]. In other words, they undergo length changes on a cycle by cycle basis up to at least tens of kHz [36].

The last piece in the jig-saw has been the demonstration that the tuning of the basilar membrane measured under ideal physiological conditions can be as sharp as that of the cochlear nerve fibres or inner hair cells themselves (eg [37,38,39]), as indicated in Figure 7.

Thus, we now have a picture of tuning in the mammalian cochlea where the following sequence of events is hypothesized (Figures 8 and 9): sounds are transduced by the movements of the stereociliary hairs on the inner and outer hair cells to produce receptor potentials within the hair cells. In the case of the outer hair cells, these ac potentials are reflected in length changes, with the production of vibrations. If these find their way back (arrows in Figure 8) to the region of transduction of the inner hair cells, either via the overlying tectorial membrane and/or the basilar membrane and they are in phase with the incoming signal, then reinforcement of the micromechanics of the cochlear transduction could ensue. This would have the effect of enhancing the sensitivity and more importantly of the frequency selectivity (ie the filtering) of the cochlear partition as a result of the positive feedback of energy from the outer hair cells. While there are some difficulties in detail with the hypothesis, it does seem to do justice to most of the experimental data.

The 'second filter', therefore, in the mammalian cochlea is in parallel with the passive basilar membrane mechanics rather than being a serial 'add-on' as in the original second filter hypothesis. This is shown diagrammatically in Figure 9. By contrast, experiments on the reptilian cochlea (eg by Crawford and Fettiplace, [40]) suggest that the hair cells themselves have an intrinsic electromechanical filtering mechanism in addition to the relatively poor tuning of the basilar membrane. They therefore constitute a 'second filter' in the original serial sense (Figure 9).

Recent Comparisons of Physiological and Psychophysical Frequency Selectivity in the Same Species

Because the agreement between the human psychophysical and cat physiological tuning data [10] was approximate and because of the species difference inevitably involved, I have recently taken the opportunity to make direct comparisons of frequency selectivity in the same species, namely the guinea-pig (Figure 10). For the psychophysical measures, guinea-pigs are trained to respond to the presence of a tone by releasing a lever for a food reward. By means of an automated threshold tracking procedure of Pratt and Evans, [4]; (see also [42]) the masked thresholds of the guinea-pigs have been obtained with comb-filtered noise masking and with bandstop masking [43,42]. In Figure 10, the bracketed symbols indicate the mean and standard errors of estimations of equivalent rectangular bandwidth (ERB) using comb-filtered noise masking and the crosses ERBs

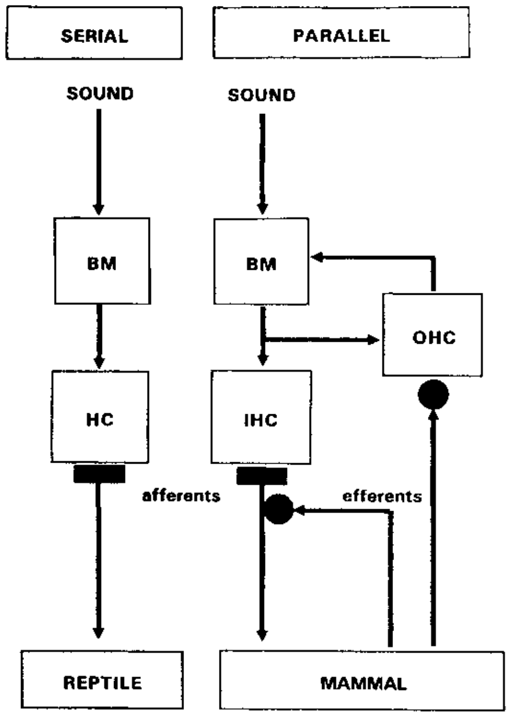

Fig. 9. Diagram of 'serial' and 'parallel' arrangement of the hypothetical second filter in reptilian and mammalian cochlea.

obtained using bandstop noise masking. The continuous line shows a regression through the comb-filtered noise masking data.

Entirely independently, recordings have been made from 385 cochlear nerve fibres from several guinea-pigs by Cooper and Evans, [44] from which 80 cochlear fibres have been selected from the animals under the best physiological condition (mean arterial blood pressure above 60 mm Hg; gross cochlear action potential threshold better than about 35 dB pe SPL to 33 μs clicks). The ERB was calculated for each tuning curve (as in Figure 2) and plotted against the characteristic frequency (CF) of each of the 80 fibres (open circles). The dashed line shows the regression through these data [45,42].

There is therefore excellent quantitative agreement between these behavioural and physiological measurements of frequency selectivity in the same species. For comparison, the human psychophysical ERBs obtained by a wide variety of methods [4] is shown as the dotted line. Human frequency selectivity is better than that of the guinea-pig at lower frequencies, up to about 6 kHz, but is less good at the higher frequencies for which the guinea-pig is better adapted.

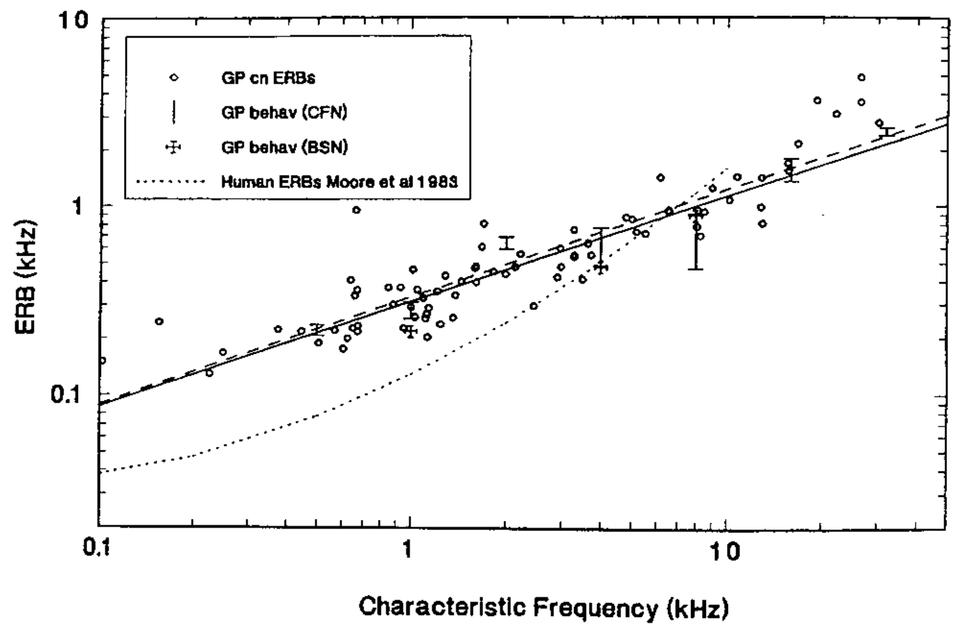

Fig. 10. Comparison of behavioural and physiological frequency selectivity in the guinea-pig. Open circles: equivalent rectangular bandwidths (ERBs) of guinea-pig cochlear nerve fibres recorded under optimal conditions ie with systemic arterial blood pressure 60mmhg and gross cochlear action potential threshold 35 dB pe SPL. Bracket symbols: behavioural equivalent rectangular bandwidths derived from comb-filtered noise masking +/-1 SE. Crosses: behavioural equivalent rectangular bandwidths derived from bandstop noise masking. The continuous line is the regression line through the mean equivalent rectangular bandwidths determined by comb-filtered noise masking. The dashed line is the regression line through the physiological data points. The dotted line represents human equivalent rectangular bandwidths from a variety of sources summarised in [4]. (From [45,42]).

Frequency Selectivity and Hearing Impairment

If our psychophysical auditory frequency selectivity is already determined by the filtering properties of the cochlea, and if cochlear filtering is physiologically vulnerable, then we would expect in cases of sensorineural hearing loss of cochlear origin, auditory frequency selectivity to be impaired [17,46]. That this is the case has been shown by many workers since about 1977 (ie by ourselves [8]). Figure 11 shows the ERBs of auditory filters obtained in patients with unilateral hearing impairment arising from noise induced hearing loss, vascular damage or Meniere's syndrome, plotted against the degree of hearing loss at the frequency of the measurement, for four frequencies. The open circles indicate the ERBs obtained in the patient's other (normal) ear by comparison. Generally speaking, there is a good correlation ($R = 0.6 - 0.72$) between the degree of hearing loss and the deterioration in frequency selectivity.

This relation between threshold and frequency selectivity is also found using another method of obtaining psychophysical information on auditory tuning, namely the psychoacoustic tuning curves (PTCs). Determining the frequencies and intensities required of a tone or noise band to mask a fixed frequency low level test tone yields a masking curve analogous to the physiological tuning curve (eg, [47]). In sensorineural hearing loss of cochlear origin, the bandwidths of these tuning curves increase and the slope of the low frequency cut-off deteriorates with increasing degree of hearing loss. This parallels the changes occurring in cochlear fibre tuning (Figures 3 and 4) under pathological conditions of the cochlea. It has been clear from a wide variety of sources, that the degree of hearing impairment suffered by a patient with sensorineural hearing loss of cochlear origin is much greater than would be predicted from the loss of sensitivity (ie the audiogram) alone. Deterioration of auditory frequency selectivity would mean that it will be more difficult to separate the frequency components of complex sounds, especially speech, (see Figure 12), that there will be upward spread of masking (ie from lower onto higher frequencies) and furthermore that these deficits will not be compensated by simple amplification as obtained with linear hearing aids. There is consequently a need (a) to determine the diagnostic utility of measurements of frequency selectivity; and (b) to compensate for deterioration in frequency selectivity as well (as defects of intensity coding) by the development of non-linear hearing aids, with for example emphasis of spectral contrasts in the speech signal in an attempt to compensate for decreased auditory frequency selectivity [48,49].

Dissociation Between Threshold and Frequency Selectivity

While there is a reasonable correlation between the degree of hearing loss (audiometric threshold) and deterioration in frequency selectivity (Figure 11), this expected relationship appears to break down under certain conditions. Thus, while it is possible in general to predict the concomitants of deteriorated frequency selectivity from threshold alone, it is not the case in all subjects. In particular, growing physiological, psychophysical and behavioural data suggest that under certain conditions a dissociation between bandwidth and threshold can occur. Given the model outlined above of the generation of sharp frequency selectivity in the cochlea by means of active (positive feedback) processes in the cochlea, this dissociation is unexpected: one would expect increase in tuning bandwidth to go hand in hand with elevation of threshold, ie loss of sensitivity.

The first evidence for this dissociation was obtained physiologically by Pratt and Comis [50], who showed changes in bandwidth of cochlear fibre tuning under chronic poisoning with a loop diuretic, without the expected changes in threshold.

The first psychophysical demonstration of this in our experience was a visit by one of our colleagues to a 'disco' from which he emerged with a 40 dB hearing loss in one ear that took about 3 days to recover to within normal limits. His frequency selectivity at 4 kHz was also severely impaired, but this, however, took much longer to recover to normal [51]. Thus, impaired frequency selectivity was a more sensitive indicator of (recovering) damage than threshold.

The next example came from a study of young adults complaining of difficulties in understanding speech in a 'cocktail party' situation but who had

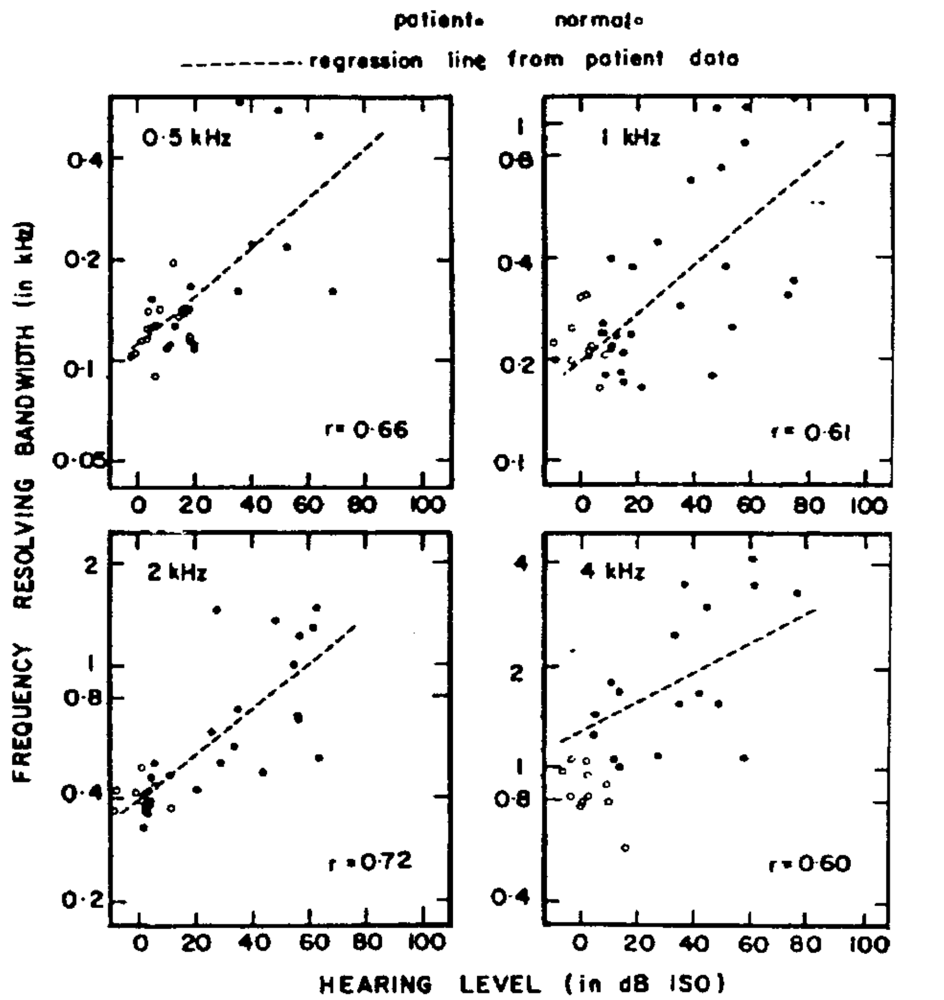

Fig. 11. Relationship between frequency selectivity and audiometric threshold in patients with unilateral hearing loss. Each plot respectively shows the ERBs of the psychoacoustic filters measured with comb-filtered noise masking (see text) plotted against the degree of hearing loss, for the frequencies: 0.5, 1, 2 and 4 kHz. Solid circles: data from damaged ears; open circles: from normal ears. (From [8]).

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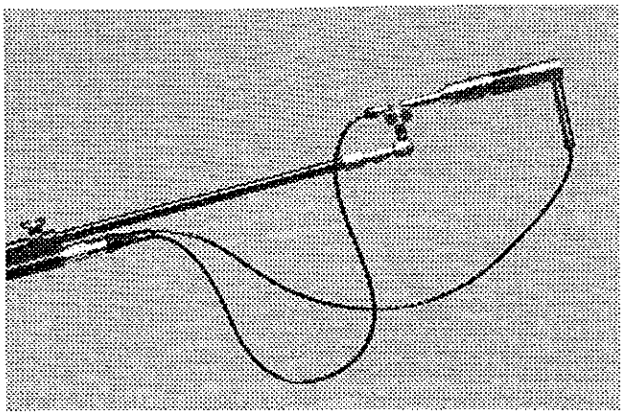

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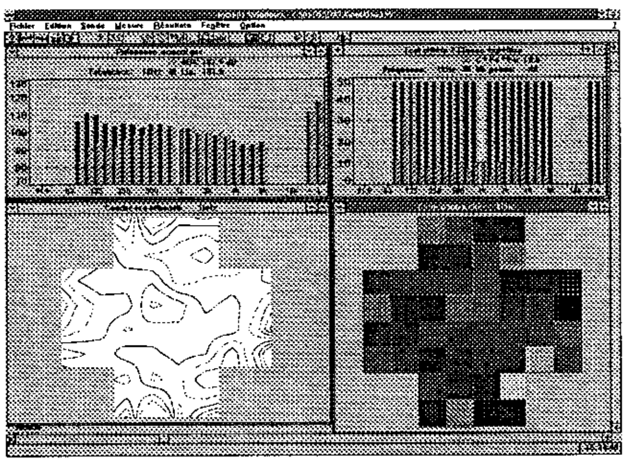

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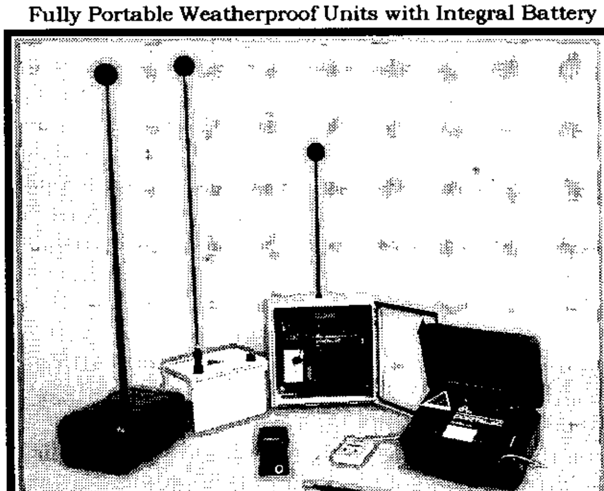

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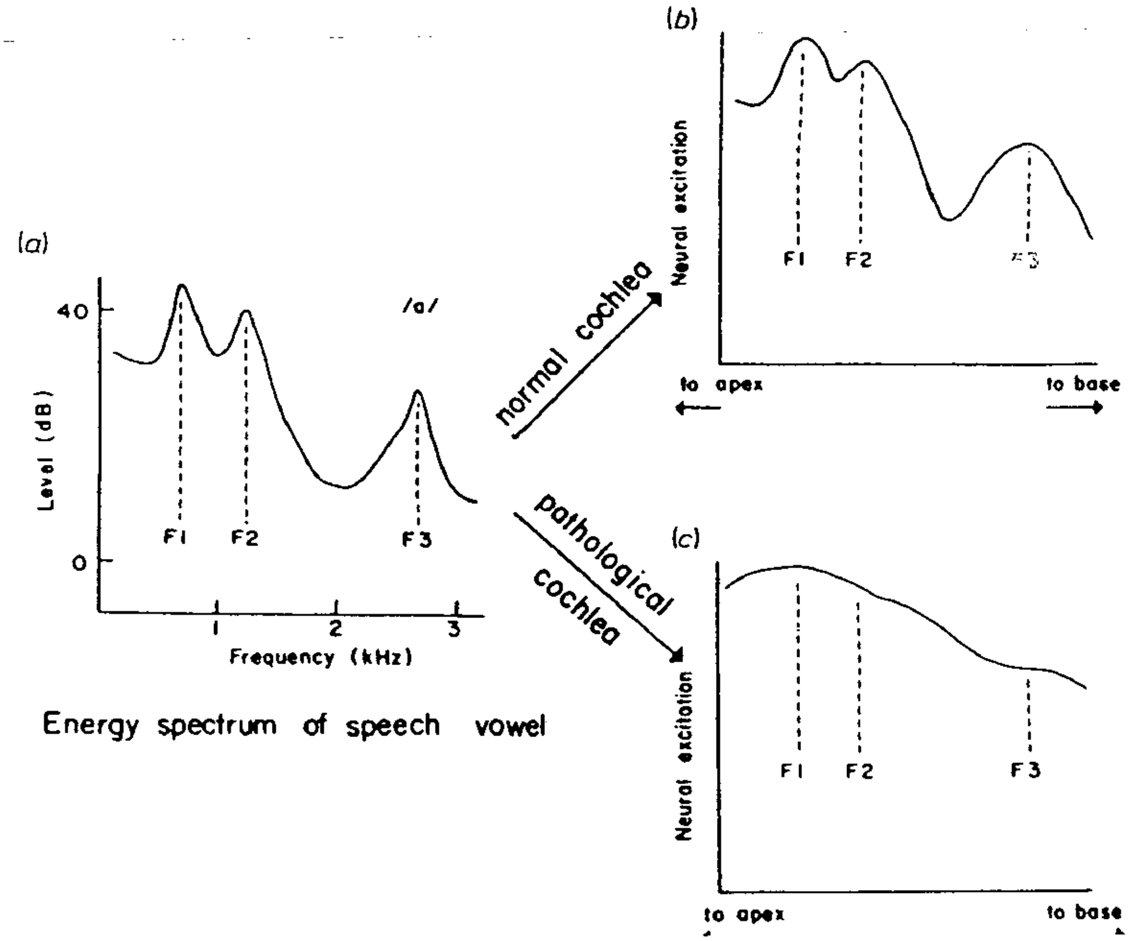

Fig. 12. Diagrammatic representation of 'place' coding of frequency of a speech vowel in normal and pathological cochleas. (a) energy spectrum of whispered vowel /a/; (b) hypothetical encoding in the normal cochlea, showing degree of excitation of cochlear nerve fibres along the tonotopic fibre array extending from apex (low CFs) to base of cochlea (high CFs); (c) as (b) but where the tuning of the cochlear nerve fibres is impaired by pathological conditions of the cochlea; hence 'blurring' of the representation of the speech energy. (From [49]).

otherwise normal audiometric findings. We found an abnormally high incidence of impaired frequency selectivity at 4 kHz but not at other frequencies in this group [52]. Again, the audiometric thresholds were within normal limits.

More recently, we have looked at a group of young listeners exposed to greater or lesser degrees of amplified ('pop') music [53]. Again, we found that the earliest sign of hearing impairment in the exposed groups was a deterioration of about 10–20% in the frequency selectivity, without significant changes in audiometric thresholds.

Finally, we have recently shown a dissociation between frequency selectivity and threshold in guinea-pigs treated with low doses of kanamycin. The threshold of hearing has unexpectedly shown a degree of recovery in many cases. However, in some, the frequency selectivity has not followed the recovery in threshold [54], in other words, dissociation is again evident.

Other animal studies have reported similar dissociation between frequency selectivity and threshold in noise-damaged cochleas (eg [55]).

All of these findings represent a challenge in two directions. Firstly, as noted above, is the challenge to our contemporary models of cochlear filtering in which the expectation is that sensitivity and frequency selectivity should go hand in hand. Second is the possibility that under certain conditions, measurements of frequency selectivity may be a more important and early warning indicator of impending or actual cochlear damage. There is a need for continued work at the behavioural, physiological and anatomical levels to unwravel these strands.

The Implications of Cochlear Frequency Selectivity for the Neural Coding of Complex Stimuli

So far, cochlear frequency selectivity has been considered in terms of the thresholds of cochlear nerve fibres. The implication is that the closer the signal to the centre frequency of the filter (CF) the greater the degree of excitation of the cochlear nerve fibre. This is subject to saturating non-linearities which limit the maximum discharge rate in the great majority of nerve fibres, but is

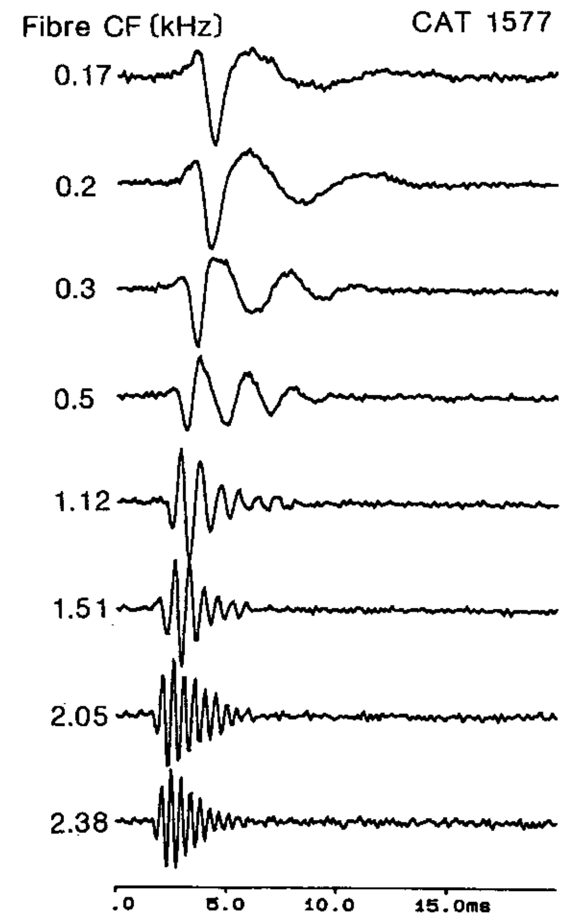

Fig. 13. Impulse reponses derived from reverse correlograms of 8 cochlear nerve fibres having the characteristic frequencies (CF) indicated. Cat. They represent the 'ringing' of the cochlear filter preceding each cochlear nerve fibre when excited by an impulsive stimulus. (From [67]).

true over a surprisingly wide dynamic range for a small minority [56,57,58,59]. Because the 30,000 or so of cochlear fibres in each ear are arrayed along the cochlea according to their characteristic frequency ('tonotopic organization'), from the lowest frequencies at the apex of the cochlea, to the highest at the base, this forms the basis of the 'place' coding of frequency in terms of the discharge rate of cochlear fibres.

Thus, as is shown diagrammatically in Figure 12, fine frequency analysis will allow a map of excitation versus place along the cochlear partition from apex (low frequencies) to base (high frequencies) to represent the power spectrum of the incoming complex sound – the vowel 'ah' in Figure 12. However, where the filter bandwidths have deteriorated, this mapping will become 'blurred' out, accounting for deterioration in speech intelligibility, uncompensated for by linear (hearing-aid) amplification.

It is not always recognised, however, the importance of cochlear filtering for determining the temporal response characteristics of cochlear nerve fibres ie the 'time' coding of complex stimuli [60].

The fine time structure of cochlear nerve fibre discharges in response to broadband noise stimuli can be used itself to extract information on the power and phase characteristics of the cochlear filter. This is easily done by the reverse correlation technique of De Boer [61] (see Evans [62,63,64]). This process of reverse correlation is comparable to cross-correlation between the spike discharge output of the cochlear nerve fibres and the broadband noise input to the ear, as has been shown by De Boer and Kuyper [65]. Figure 13 shows the impulse responses derived by the reverse correlation process in eight cochlear nerve fibres of differing CF indicating the different positions from which the nerve fibres originated along the tonotopically organised cochlear partition Each impulse response demonstrates a short delay (presumably that of the travelling wave along the basilar membrane), followed by a ringing response typical of multi-pole bandpass filters. This type of filter ensures an optimal compromise between frequency and temporal resolution [64].

In the cat at least, these impulse responses are remarkably unchanged with stimulus level [62]. In other words, the filtering characteristics remain remarkably stable over a very wide range of intensities. Typically the bandwidth of the cochlear filters in the cat changes only by about a factor of two over a dynamic range of about 90 dB with relatively little change in the first 40 dB or so. A small, but significant deterioration in frequency selectivity with level is also found in human psychophysical data (eg [66]). This surprising degree of linearity is remarkable in the face of the non-linear mechanisms which are found at every level in the cochlea from the basilar membrane active mechanics upwards.

A striking demonstration of this apparent linearity of cochlear filtering is shown in Figure 14. Here, the pure tone FTC (thick line) is compared with a number of measures of the cochlear filter extracted from the cochlear nerve fibre temporal discharge patterns. Cochlear nerve fibre discharges are 'phase locked' to frequencies up to about 5 kHz. The fine time structure of the cochlear fibre discharges can therefore be used to extract the cochlear filtering characteristics in terms of the weighting of different frequencies in the timing of the discharges. Figure 14 shows the plots of the tuning of three cochlear nerve fibres having relatively low, medium and high CFs at low (lower half of figure) and high (upper half) stimulus levels. The measures of tuning have been extracted from the weighting or degree of phase locking of the cochlear nerve fibre to individual component frequencies of a complex stimulus generated either by click trains (+ symbols), tone complexes (open circles) or broadband noise (reverse correlogram: thin line). Superimposed is the pure tone FTC (thick line). The filtering remains amazingly well preserved in the weighting of the time pattern over a surprisingly large dynamic range: as great as 90 dB in the cat [62,63,67]. (In the guinea-pig, however, there is evidence from our own and other studies that there are greater non-linearities with level [68,69], as appears also to be the case in the rat [70]).

When considering complex auditory stimuli, particularly harmonic complexes, it becomes clear that the

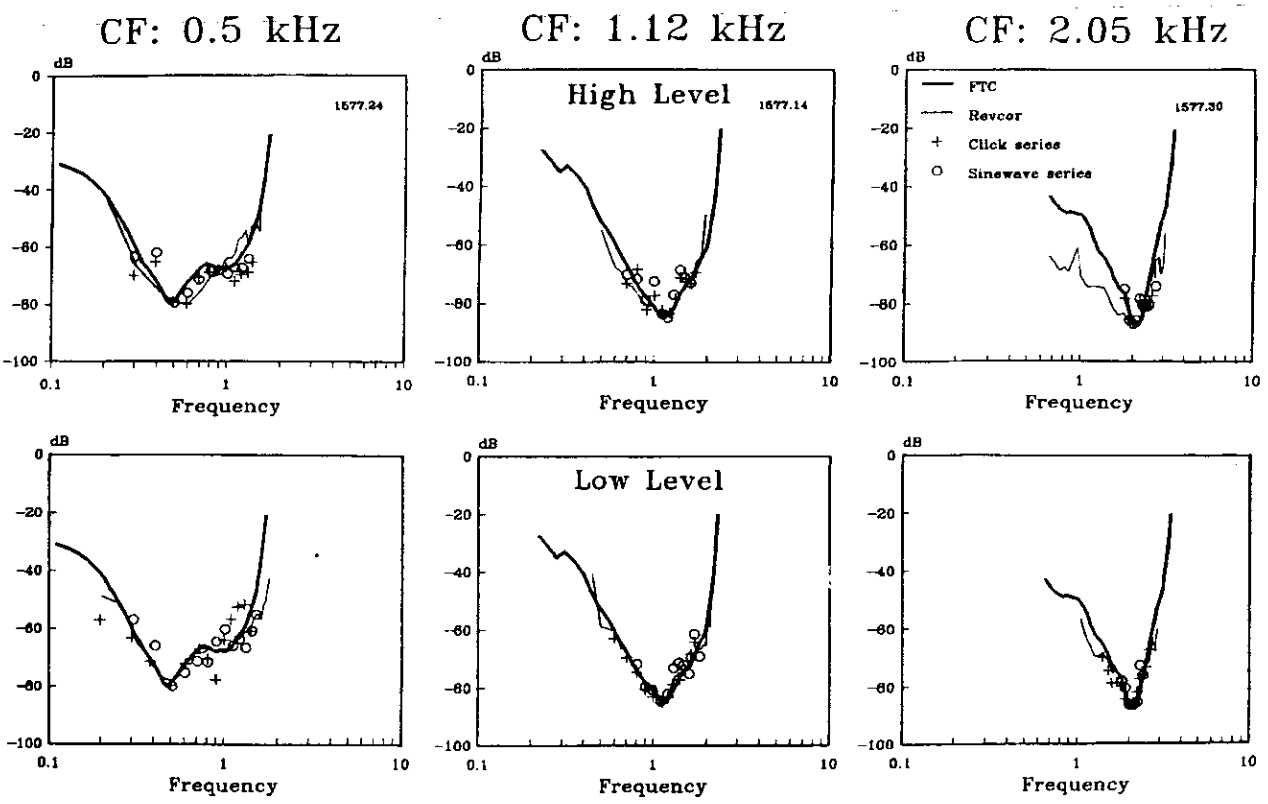

Fig. 14. Derivations of cochlear filtering through the discharge patterns of cat cochlear nerve fibres of low, middle and higher characteristic frequency near threshold (lower half) and at stimulus levels 50 dB or more above threshold (upper half). Thick lines: pure tone frequency threshold curves; thin lines: filter functions derived from reverse correlograms ('Revcor') with broad-band noise stimulation; crosses and circles: filter functions derived from weighting measures from temporal synchrony in response to click trains and sign-phase mixed tone complexes, respectively (from [67]).

degree to which the harmonics are admitted by the bandwidth of the cochlear nerve fibre filters determines the degree to which their temporal discharge patterns reflects the modulation ('beats') consequent on the interaction of the components [60,71]. Figure 15A shows stimuli (originally devised by Patterson [72]) but used by Wightman and Green [73] to test the importance of time cues in pitch perception. The two stimuli in row A are the waveforms generated by summing the 5th to the 10th harmonics of a 200 Hz fundamental mixed in cosine phase (left) and random phase (right). The cosine-phase waveform has a highly periodic amplitude profile, whereas the random-phase waveform has not. Wightman and Green argued that the cosine-mixed waveform could be expected to produce highly synchronised discharges in cochlear fibres by virtue of the amplitude periodicity; the other not so. And yet the pitches and pitch strengths evoked by the two stimuli are virtually identical. Wightman and Green therefore argued that time cues were not likely to be involved in the perception of the pitch. However, the argument entirely ignored the role of cochlear filtering. If the two waveforms are passed through a cochlear-like filter, one gets the waveforms shown in the row B of Figure 15. Not surprisingly, the temporal discharge patterns of cochlear nerve fibres evoked by the very different stimulus waveforms of the upper row are virtually identical. This is shown in C by the inter-spike interval histograms obtained from a single cochlear nerve fibre having a CF at the centre frequency of the harmonic complex under stimulation with the cosine- and random-phase mixed harmonics, respectively. This demonstrates how even temporal representations of aspects of complex sounds are determined by the peripheral filtering mechanisms, and are therefore importantly correlated with the *place* of origin along the cochlear partition. It also illustrates how it is that the ear is relatively 'phase-deaf' for harmonics that fall ouside the bandwidths of the auditory filters [60,74,75].

Postscript

One of the success stories in the application of fundamental physiological and psychophysical principles in the service of medicine is the cochlear implant. This is a device designed to by-pass a destroyed cochlea in order to stimulate electrically the surviving fibres of the cochlear nerve. The employment of multiple, *frequency selective*, channels of stimulation is critical to the success that these devices can have in imparting a limited amount of 'open set' speech discrimination to the profoundly hearing impaired (see [76,77,78,79] for reviews).

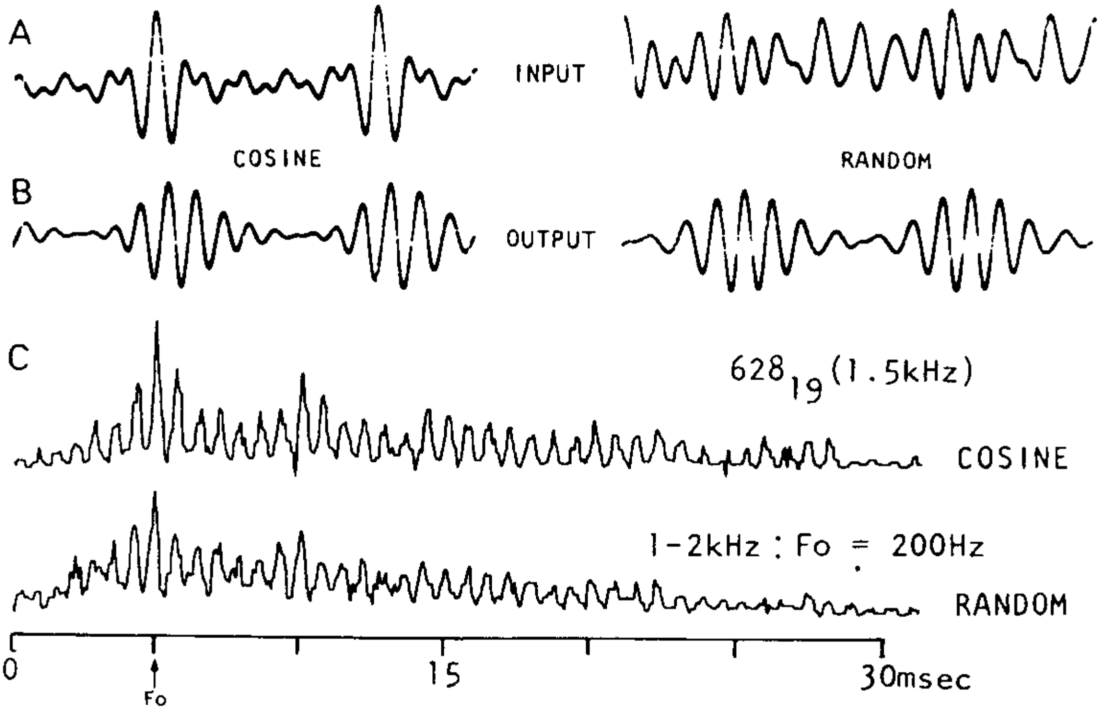

Fig. 15. Phase effects are minimised by cochlear filtering. The waveforms on line A represent the result of summing the 5th – 10th harmonics of a common fundamental in cosine left and random phase right respectively. Line B shows the effect of filtering the above signals by a band-pass filter with half power bandwidth approximately equal to neural bandwidths of appropriate frequency. Section C shows the inter-spike interval histograms of a single cochlear nerve fibre in response to the signals of line A, in which the harmonics are evenly distributed across the cochlear fibres filter function (CF: 1.5 kHz); fundamental frequency of complex: 200 Hz. (From [60,75]).

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DOLPHIN ACOUSTICS AND ECHOLOCATION

Whitlow W L Au and Paul E Nachtigall

Introduction

One of the most effective methods for an animal to probe an underwater environment for the purposes of navigation, obstacle and predator avoidance, and prey detection, is by the use of underwater sounds or acoustic signals. Dolphins emit sounds and analyze returning echoes to detect and recognize objects underwater, a process referred to as echolocation. Acoustic energy propagates in water more efficiently than almost any other form of energy, so the use of echolocation and passive acoustics (listening) by dolphins is ideal. Electromagnetic, thermal, light, and other forms of energy are severely attenuated in water. Often the natural habitat of shallow bays, inlets, coastal waters, swamps, marshlands, and rivers inhabited by various dolphin species are so murky or turbid that vision is severely limited. These animals must then rely almost exclusively on their auditory perception, including echolocation, for survival.

Dolphins echolocate by emitting high intensity broadband acoustic pulses in a directional beam and listening to echoes reflected from objects in their environment. By scanning their echolocation beam across objects and by analyzing the characteristics of the echoes, dolphins can obtain considerable information about their environment. The presence of, size, structure, material composition and shape of objects can be determined. The relative distance of objects can also be determined by estimating the time between the transmission of a pulse and the reception of echoes. The distance over which a dolphin's echolocation system can operate depends on the size of the objects and the ambient background noise of the environment. Distances of several hundred meters are well within the range of the animal's echolocation system. Most of the research results discussed here will pertain to the Atlantic bottlenose dolphin, *Tursiops truncatus*. Details of this general article are available from the book *The Sonar of Dolphins* by Au [1], and the interested reader can refer to the book for more specific details.

One unique feature of the research performed at our laboratory in Kaneohe Bay, Oahu, Hawaii is that acoustic and echolocation experiments are performed in a natural bay with animals housed in floating pens. The bottom of the bay consists of mud and silt, which absorbs acoustic energy and minimizes bottom reflections and reverberation. Therefore, the dolphins are exposed to a natural, open and spacious environment instead of a concrete or redwood tank. This environment allows us to investigate echolocation in a natural setting. The reverberant environment of tanks can also complicate the measurement and analysis of echolocation signals.

Acoustic Characteristics of the Echolocation System

Transmission System

The dolphin has a bistatic sonar system with the upper portion of its head used as the transmitter and the lower portion as the receiver. Although there has been a long-standing controversy on whether sounds are produced in the larynx or in the nasal system of odontocetes, almost all experimental data with *Tursiops* indicate that sounds are produced in the nasal system. Evidence from acoustic measurements (Diercks et al [2]), x-ray measurements (Dormer [3]), muscle activity and pressure measurements (Ridgway et al [4]), and ultrasonic Doppler motion detection measurements (Mackay & Liaw [5]) all implicated the nasal system in the vicinity of the nasal plugs in the generation of echolocation clicks. Proponents of the theory that the larynx is the site of sound production (Purves and Pilleri [6]) offer only anatomical arguments and results from laboratory simulation with expired animals, without any supportive experimental evidence from live sound-producing specimens. Figure 1 is a schematic of a bottlenose dolphin head depicting various structures associated with sound pro-

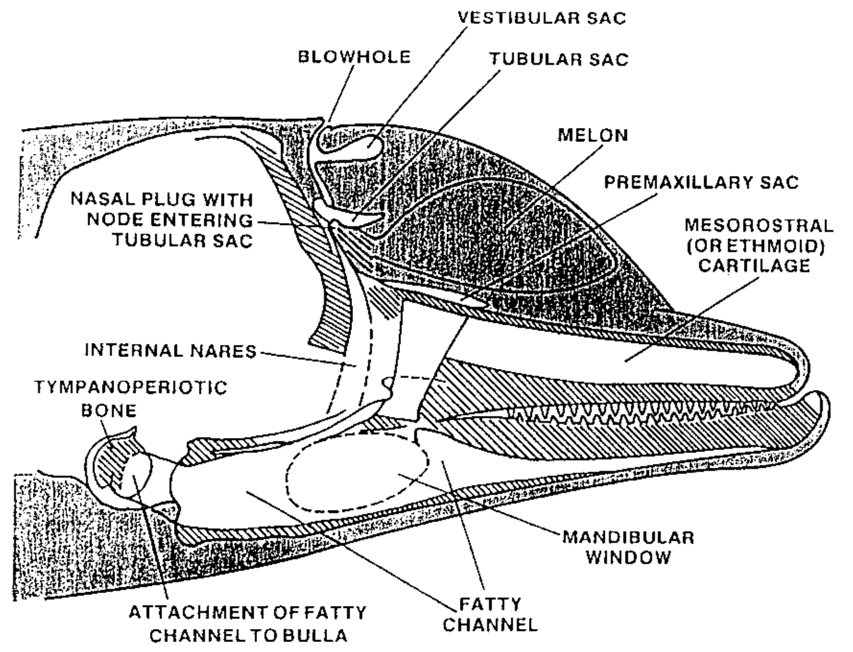

Fig. 1. Section of a dolphin's head showing various structures associated with sound reception and production (adapted from Norris [7]).

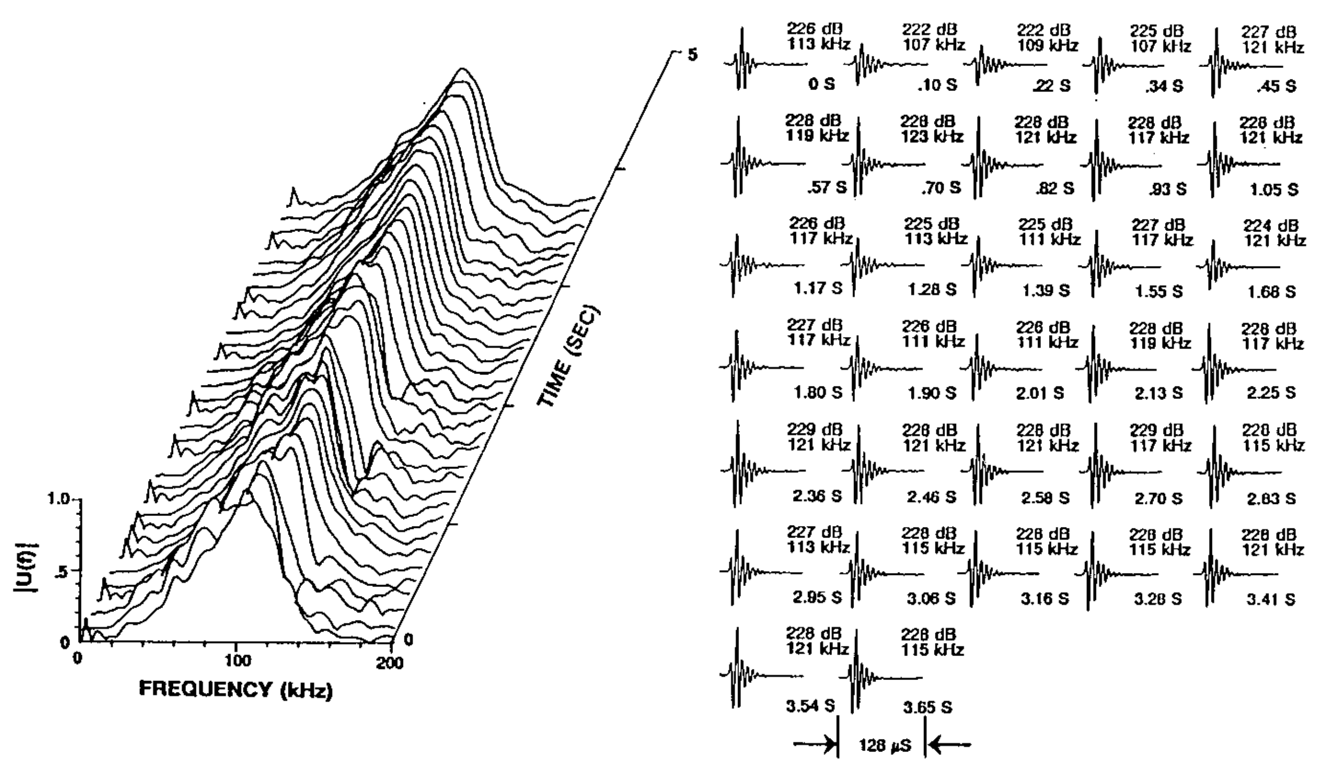

Fig. 2. Example of a bottlenose dolphin echolocation signals used in Kaneohe Bay, Oahu, Hawaii. On the left are the frequency spectra (relative amplitude versus frequency) as a function of time, and on the right are the signal waveforms (from Au [1]). The peak-to-peak amplitude in dB re 1 μPa and the peak frequency (frequency of peak energy) in kHz are given above each signal waveform, and the time of occurrence of the signals relative to the start of the click train is given below each click.

duction and reception.

The melon in front of the nasal plug may play a role in channelling sounds into the water. Norris & Harvey [8] found a low-velocity core extending from just below the anterior surface towards the right nasal plug, and a grated outer shell of high-velocity tissue. Such a velocity gradient could channel signals originating at the nasal plug region in both the vertical and horizontal planes. Cranford [9] has extensively examined dolphin heads using X-ray computer tomograph and magnetic resonance imaging and has found a very specific density structure in the melon with a low density core within the central portion of the melon, starting from where the melon connects against the nasal passage. The sound velocity and density structure within the melon may be important in channelling sounds from the nasal sac to the water by providing some focusing and impedance matching.

The ability of dolphins to perform difficult echolocation detection, recognition and discrimination tasks should depend heavily on the kinds of signals emitted. The signals must have sufficient information-carrying capacity so that important features of a target can be coded in the echoes. Extensive measurements of echolocation signals utilized by the bottlenose dolphin performing a variety of echolocation tasks have been made at our laboratory. Typical signals are short broadband transient-like clicks with durations between 50 and 70 μsec. An example of a typical echolocation click train emitted by a bottlenose dolphin performing a target detection task in Kaneohe Bay is shown in Figure 2. The frequency spectra, plotted as a function of time, are shown on the left and the individual click waveform is displayed on the right.

The peak-to-peak sound pressure level (SPL) is expressed in dB (decibels) referenced to a SPL of one micropascal (μPa) used in underwater acoustics. The signals in a typical click train tend to be highly repetitive. Their shape in the time domain resembles exponentially damped sine waves of 6 to 10 cycles. The frequency spectrum usually rises to a peak between 110 and 130 kHz, with secondary peaks between 60 and 80 kHz often present. These signals have considerably higher peak frequencies and amplitudes than previously measured peak frequencies between 30 and 60 kHz and amplitudes of 180 – 190 dB for dolphins in tanks. The dolphins' use of high frequencies and high amplitudes can be attributed to the high ambient noise environment of Kaneohe Bay. The Bay has a high ambient noise level caused by snapping shrimp and the noise energy extends beyond 100 kHz as can be seen in Figure 3.

Echolocation signals are projected from the dolphin's head in a directional beam. The transmission beam patterns in the vertical and horizontal planes for *Tursiops* are shown in Fig. 4 along with the reception beam which will be discussed later in this article. The inner beam in each plane is the broadband transmission beam obtained by measuring the peak-to-peak value of emitted clicks at different angles. The beam in the vertical plane indicates

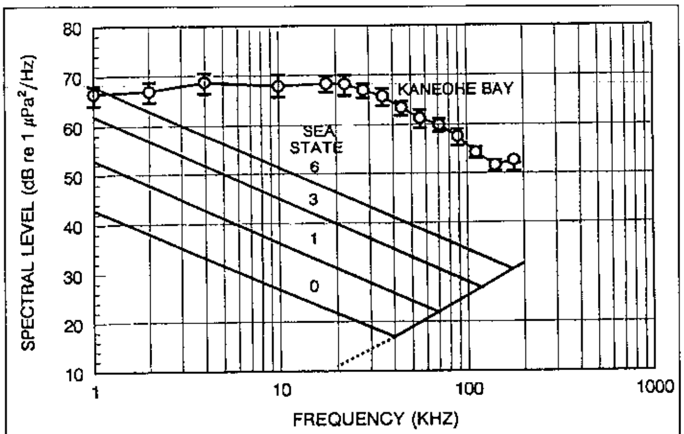

Fig. 3. Ambient noise environment of Kaneohe Bay measured in $^{1}/_{3}$ octave bands, along with the typical deep water sea state noise.

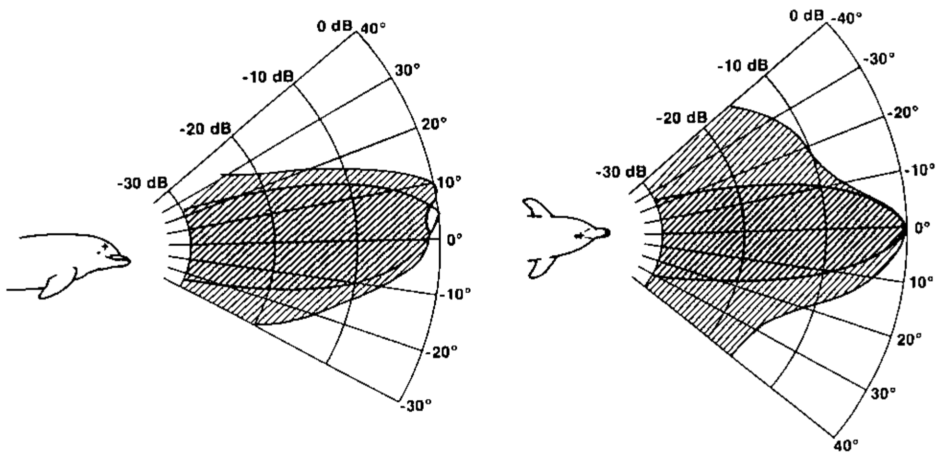

Fig. 4. Broadband transmission beam pattern (inner beam) of Tursiops, along with the reception beam pattern for a frequency of 120 kHz, in the (a) vertical plane and (b) horizontal plane (from Au [1]).

that echolocation signals are projected at an elevation angle of 5° above the animal's head in a narrow pattern and is aimed directly forward of the animal in the horizontal plane.

A narrow transmission beam allows a dolphin to scan across targets by moving its head from side to side as it echolocates. Such scanning can provide important information on the spatial characteristics of targets. A narrow beam also allows the dolphin to scan only a region of interest without receiving interfering echoes from objects in a different region. Finally, a narrow beam can be important in localizing, separating and tracking objects of interest.

Bottlenose dolphins typically echolocate in a pulse mode, sending out a signal and receiving the echo from the target before sending out another signal. Figure 5 shows the click interval as a function of target range for four different experiments with bottlenose dolphins. Also included in the figure is the two-way transit time required for an acoustic signal to travel from the dolphin to the target and back. The lag-time, which is defined as the time difference between the click interval and the two-way transit time, varied from 19 to 45 ms. This lag time indicates that the dolphin projects a signal, receives the target echo and waits from 19 to 45 ms before projecting the next pulse. The lag time may be indicative of the time required by the dolphin to process each echo. It is interesting to note that animals often 'lock-in' on the target range and will emit signals with the same click intervals on target-present and target-absent trials. They appear to attend to a relevant distance.

The amplitudes of dolphin echolocation signals are usually expressed in terms of peak-to-peak sound pressure levels (SPL) instead of root-mean-square (rms) pressure. The evaluation of a time integral would be required in order to calculate the rms SPL. The amplitudes can vary considerably within a click train, between click trains, and for different tasks (Au [10]). The peak-to-peak source level (SPL at a reference 1 metre from the animal) should depend on the signal-to-noise ratio of the received echoes that an animal requires or desires to have in order to perform a given task. The echo level (SPL of the echo) from a target can be expressed by the equation

$$EL = SL - \text{transmission loss} - \text{reflection loss} \qquad (1)$$

where EL is the echo level in dB and SL is the source level in dB. Equation 1 can be simplified to

$$EL = SL - \text{total loss} \qquad (2)$$

The peak-to-peak source level, as a function of the total loss for different bottlenose dolphins performing different tasks, is shown in Figure 6. The total loss in Figure 6 is equal to the sum of the propagation loss due to spherical spreading and absorption plus the reflection loss expressed as target strength (TS). Equation 2 indicates

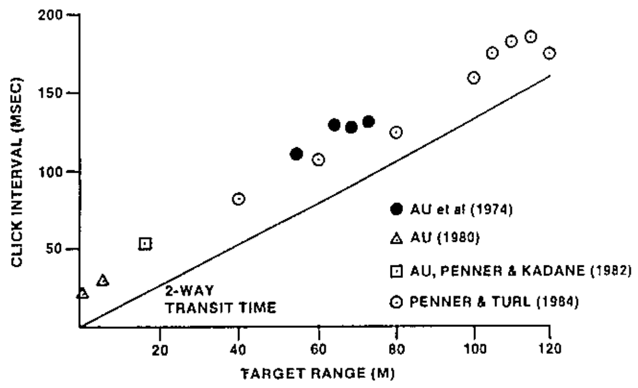

Fig. 5. Click interval as a function of target range for bottlenose dolphin. The value of the two-way transit time for any target range can be read off the click interval scale.

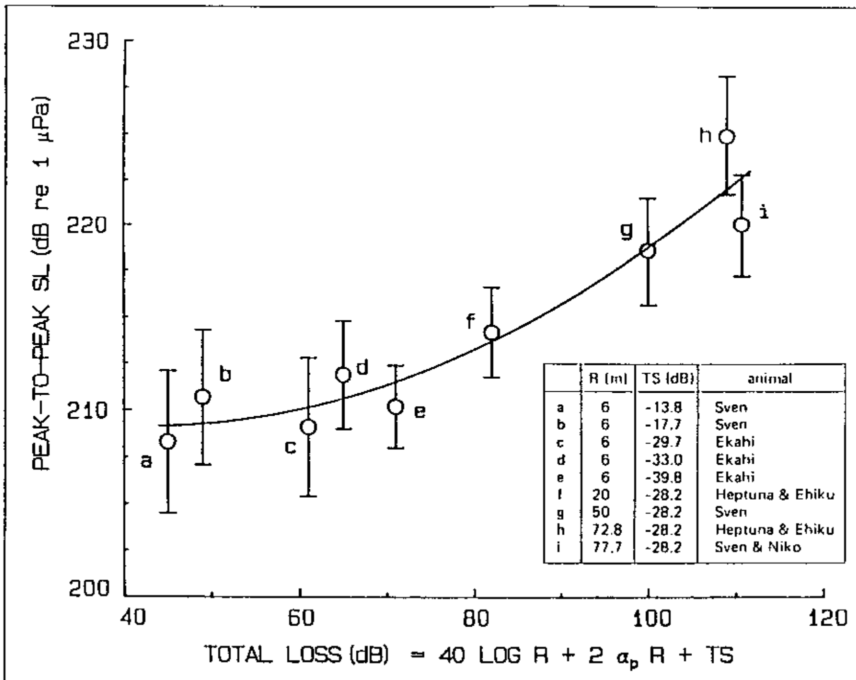

Fig. 6. Peak-to-peak source levels of the echolocation signals used by several bottlenose dolphins in Kaneohe Bay as a function of the total signal losses (from Au [10]).

that the echo level is inversely proportional to the total loss so that the greater the loss, the less energy in the echo. The data in Figure 6 indicate that the source levels increased as the total loss increased, suggesting that dolphins compensated for the amount of acoustic loss to the signal by varying their source level. The data also indicate that dolphins prefer to operate at a high signal-to-noise ratio, since the decrease in total losses from case (i) to case (a) exceeded 62 dB, yet the corresponding decrease in source level was only 12 dB.

From the data presented in Figure 6, the maximum average peak-to-peak source level in a trial was 227.5 dB for one of the trials in case (h). The largest single click measured was 230 dB, emitted by the dolphin named Heptuna in case (h). These source levels may seem inordinately high, since water cavitates at approximately 230 dB rms for a continuous signal. However, the levels for the dolphins are in peak-to-peak units and the durations of the signals are extremely short. The rms pressures for these signals are typically 15 dB lower than the peak-to-peak amplitudes. To get a better appreciation of the significance of these high amplitude clicks, it is useful to calculate the acoustic power in each click. Au [1] derived the following expression relating the acoustic power radiated into the water as a function of the peak-to-peak source level for the kinds of echolocation clicks typically used by *Tursiops* in Kaneohe Bay

$$10 \log P = SL_{pp} - 212.3 \text{ dB re 1 watt} \qquad (3)$$

where P is the acoustic power in watts. From Figure 6, case (h) had the highest averaged peak-to-peak source level of 224 dB, which translates to approximately 15 watts of acoustic power. An echolocation click with a peak-to-peak amplitude of 230 dB contains only 59 watts of acoustic power. These acoustic power levels are not very high when compared to some man-made sonars.

Limited observation of dolphins attacking fish prey coupled with the high peak-to-peak source levels as shown in Figure 6, have led Norris and Mohl [11] to hypothesize that dolphins may stun their prey by focusing high-intensity echolocation signals on their prey at short ranges. However, there has not been any experimental substantiation of the prey stunning hypothesis. We participated in a test in which simulated dolphin echolocation clicks with peak-to-peak sound pressure levels as high as 230 dB were projected at a repetition rate of 100 Hz on fishes contained in a plastic bag. The fishes showed no obvious signs of being affected by the clicks. Although the peak-to-peak source levels of a dolphin can be very high, the short duration of the clicks limit the amount of power that is radiated into the water. If prey stunning does take place with dolphins, it may occur with the use of longer duration whistle type signals, or with short duration high amplitude clicks emitted at a very high repetition rate, perhaps at around 1000 clicks per second

Bottlenose dolphins also emit a wide variety of other sounds not used for echolocation. Sound emissions can be classified into two broad categories of narrow-band frequency-varying continuous tonal sounds referred to as whistles and broadband echolocation clicks. Whistles appear to be used for intraspecific communication. These sounds are generally low frequency emissions between 5 and 30 kHz. They are also referred to as squeaks, squawks, and squeals, as well as whistles.

The Reception System

A dolphin's echolocation capabilities are also dependent on the characteristics of its auditory system as well as its neurological processing ability. One of the more popular theories of sound reception by dolphins was proposed by Norris [7], who postulated that the lower jaw acts as a receptor of sound. The sound enters through the thin oval (pan bone) area of the flared posterior end of the mandible (see Figure 1). Electrophysiological measurements of evoked potentials in the inferior colliculus by Bullock et al [12] and cochlea potentials by McCormick et al [13] indicated that maximum responses were obtained when a sound source was placed in the vicinity of the lower jaw and ears. According to McCormick et al, the upper jaw and most of the skull seem to be acoustically isolated from the ear, with the auditory meatus being vestigial.

In a pioneering study, Johnson [14] performed a carefully controlled psychophysical experiment to measure the auditory sensitivity of a bottlenose dolphin as a function of frequency. The dolphin's audiogram measured by Johnson is shown in Figure 7 along with a human audiogram. Johnson's results indicate that a bottlenose dolphin can hear over a wide frequency range between 75 Hz and

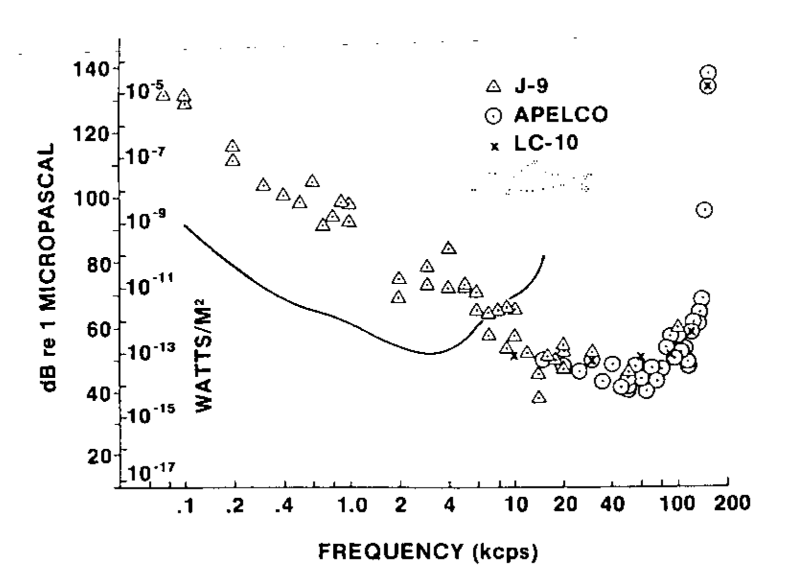

Fig. 7. Auditory sensitivity of a bottlenose dolphin and human subjects. The left ordinate of sound pressure level (SPL) in dB re 1 μPa is for the dolphin audiogram. The right ordinate of intensity in watts/m² is for both the dolphin audiogram and the human audiogram (adapted from Johnson [14]).

150 kHz, with maximum sensitivity (± 10 dB) between 10 kHz and 120 kHz. The dolphin and human audiograms are similar in shape, with the dolphin's shifted to higher frequencies by a factor of 10.

Johnson [15] extended his auditory sensitivity measurement to include the presence of broadband masking noise. He measured the dolphin's capability to detect pure-tone signals masked by broadband noise. From his masked threshold data, he determined the critical ratio of the bottlenose dolphin as a function of frequency. The notion of critical ratio comes from the hypothesis that a pure-tone signal is masked only by a narrow band of noise that is centered about the signal frequency. When the signal power is equal to the noise power in this band, the subject will not be able to detect the signal. Since noise is usually expressed as a power density (power per Hz), the width of this band can be estimated by taking the ratio of the signal power to noise density at the animal's hearing threshold in noise. The critical ratio as a function of frequency will then be related to the width of the internal auditory filter. Johnson's critical ratio results are shown in Figure 8 along with monaural and binaural human data. The bandwidth of the dolphin's internal auditory filter increases almost proportionately with frequency suggesting that the internal filter increases almost proportionately with frequency and that the dolphin's auditory system may be modelled as a bank of constant-Q filters. It is this filter bank property of the dolphin's auditory system which allows the animal to perform frequency analysis of received acoustic signals. The dolphin's critical ratio seems to be an extension of the human critical ratio to higher frequencies. The results of Figure 8 can also be used to indicate how much higher above the ambient noise a pure-tone signal needs to be in order for a dolphin to hear it. Another fundamental parameter of a sonar system is the spatial sensitivity pattern or the receiving beam pattern. It determines the amount of ambient noise and reverberation the sonar will receive, and may also affect the angular resolution of the sonar. The amount of ambient noise and reverberation a sonar receives is directly proportional to the width of the receiving beam. Au & Moore [16] measured the receiving beam pattern of a bottlenose dolphin in both the vertical and horizontal planes by determining the animal's masked threshold as the position of either the noise or signal sources varied in their angular position about the animal's head. The vertical and horizontal receive beam pattern at a frequency of 120 kHz is shown in Figure 4 along with the transmission beam pattern. The receiving beam is slightly wider than the transmission beam and is oriented in the same general direction as the transmission beam.

The ability to localize sound is also important for an echolocator in order to resolve echoes from closely spaced targets or from different portions of an extended target, and to determine the relative position of targets within the acoustic beam. Renaud & Popper [17] studied the sound localization capability of a bottlenose dolphin in the horizontal and vertical planes by measuring the minimum-audible angle (MAA). They measured MAA between 1° and 3° in both planes for pure-tone signals with frequencies between 20 and 90 kHz. At 6 and 100 kHz, the MAA increased to approximately 4°. Using simulated echo location clicks with a peak frequency of 64 kHz, MAAs of 0.7° to 0.8° were measured. The horizontal underwater pure-tone localization capability of

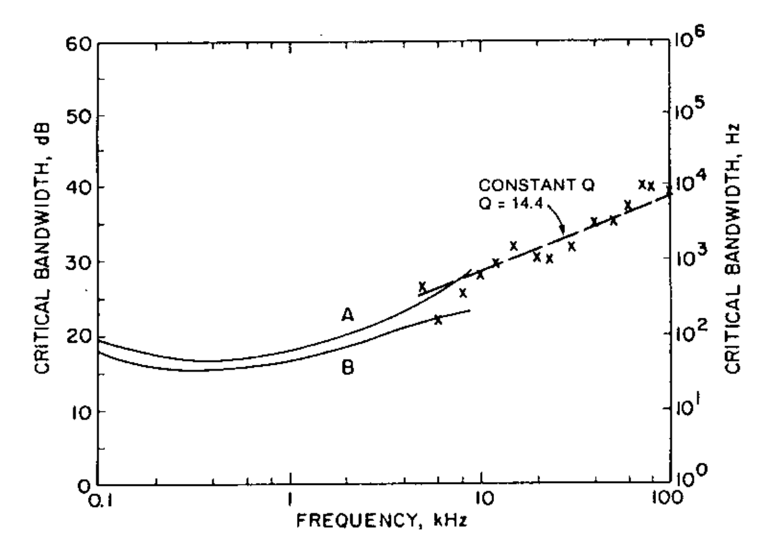

Fig. 8. Critical ratios for a bottlenose dolphin (X) and man (A for monaural and B for binaural) (adapted from Johnson [14]).

dolphins is about as good as the in-air capabilities of several mammals, including man. The dolphin's ability to localize the broad band click is considerably better than that of most mammals.

Echolocation Capabilities

Maximum Detection Range

The maximum detection range of two *Tursiops* was determined in Kaneohe Bay by Murchison [18] using a 2.54 cm diameter solid steel sphere and by Au and Synder [19] using a 7.62 cm diameter water-filled sphere. In both studies an overhead suspension system with a movable trolley and pulleys was used to vary target range between two poles spaced 200 m apart. The target was lowered into or raised out of the water by means of a nylon monofilament line that extended back to the experimenter's station. The results of both experiments are displayed in Figure 9 with correct detection and false alarm rates plotted as a function of the target range. The detection threshold ranges (range at 50% correct detection) for the 2.54 cm and 7.62 cm diameter spheres were 73 m and 113 m, respectively. The animal's results for the two different targets are relatively consistent if target differences are considered in the sonar equation.

The sonar equation for a situation in which noise external to the sonar limits the detection range can be expressed as:

$$DT_E = (\text{echo energy flux density in dB}) - (\text{noise level in dB}) \quad (4)$$

where DT_E is the detection threshold. The echo energy flux density is equal to the source energy flux density (SE) of the projected signal minus the two-way transmission loss (TL) plus the reflective strength or target strength of the target (TS_E). The noise level is equal to the ambient noise spectrum density (NL) minus the directivity index (DI) of the receiving beam. Therefore, the generalized or transient form of the sonar equation can be expressed as (Au [1]):

$$DT_E = (SE - 2TL + TS_E) - (NL - DI) \quad (5)$$

The average source energy flux density used by the same dolphin whose data are shown in Figure 9, was approximately 167 dB re 1 μPa^2 s (Au [1]). Using a simulated dolphin echolocation signal, Au [1] measured the target strength of the 2.54 cm sphere to be −41.6 dB and −28.3 dB for the 7.62 cm sphere. The receiving directivity index for the reception beam shown in Fig 4 was calculated by Au and Moore [16] to be approximately 20.6 dB. Inserting the appropriate values for the transmission losses, target strength, the threshold were calculated to be 11.0 dB for the 2.54 cm sphere and 13.2 dB for the 7.62 cm sphere. This is good agreement considering the experiments were performed about two years apart.

The sonar equation can also be used to estimate the target detection range of a *Tursiops truncatus* for a different target and in a different noise environment. For example, a 30.5 cm target has a target strength that is approximately 12 dB greater than that of the 7.62 cm sphere. A dolphin in Kaneohe Bay should be able to detect the 30.5 cm sphere at a range of appoximately 170 m. If the dolphin was in a different body of water where the ambient noise is lower, the target detection ranges should be greater. Assume that a dolphin is in a body of water where the ambient noise is at the sea-state 6 level. At a frequency of 120 kHz, the sea-state 6 noise is about 17 dB lower than that of Kaneohe Bay. A dolphin in this body of water should be able to detect a 7.62 cm sphere at a range of approximately 197 m and a 30.5 cm sphere at a range of 270 m.

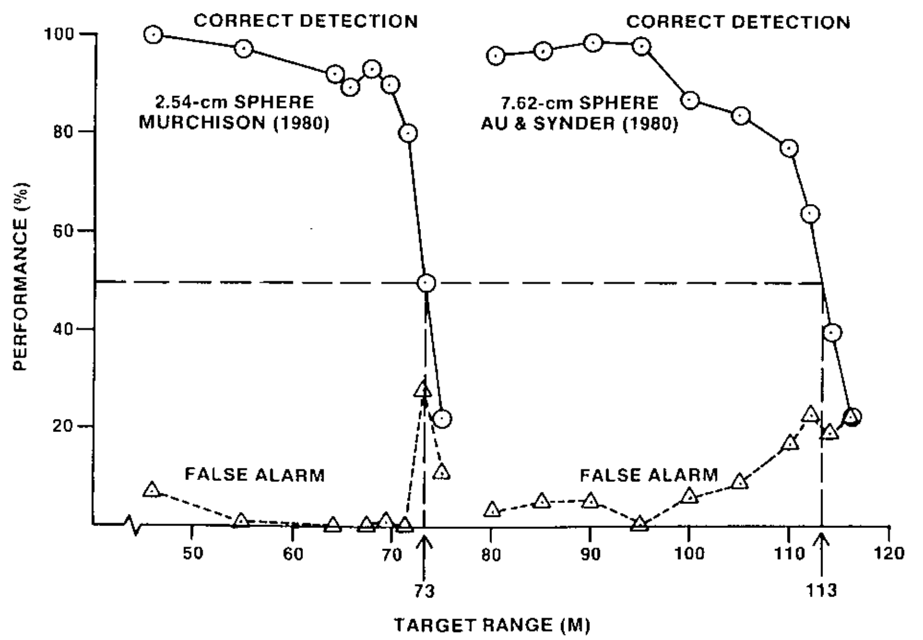

Fig. 9. Dolphin target detection performance as a function of range. The 2.54 cm sphere results are from Murchison [18] and the 7.62 cm sphere results are from Au & Snyder [19].

Detection in Reverberation

The target detection capability of any echolocation system, man-made or biological, is limited by both interfering noise and reverberation. Reverberation differs from noise in several aspects. It is caused by the echolocator itself, and is the total contribution of unwanted echoes scattered back from objects and inhomogeneities in the medium and on its boundaries. The spectral characteristics of reverberation are similar to those of the projected signal and its intensity is directly proportional to the intensity of the projected signal. Therefore, in a reverberation-limited situation, target detection cannot be improved by increasing the intensity of the projected signal. Target detection becomes dependent on the ability of the system to discriminate between the target of interest and false targets and clutter that contrib-

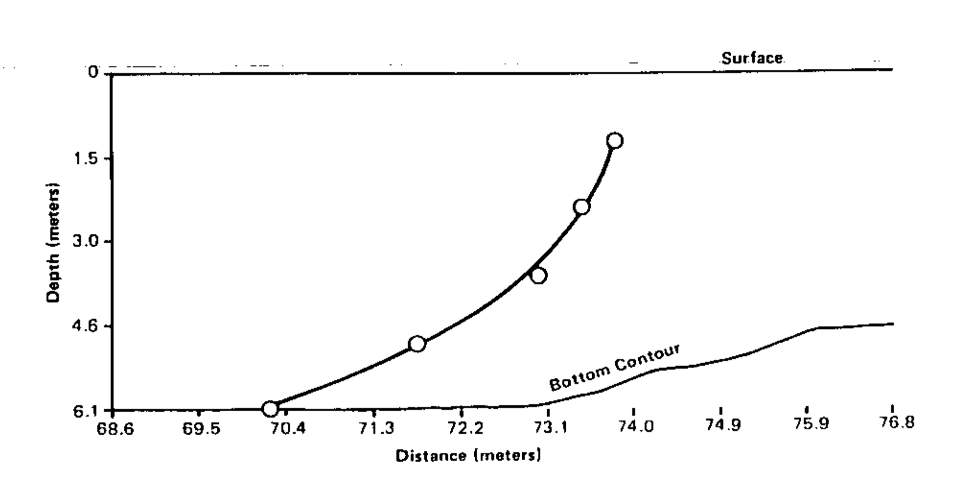

Fig. 10. 50% correct detection threshold ranges for two *Tursiops* as a function of the depth of the 6.35 cm spherical target (from Murchison [18]).

utes to the reverberation.

Murchison [18] studied the effects of bottom reverberation on the target detection capabilities of two *Tursiops* in Kaneohe Bay. A 6.35 cm diameter solid steel sphere was used at depths varying from 1.2 to 6.3 m. At a depth of 6.3 m, the target was on the bottom. The animals' 50% correct detection threshold ranges for the different target depths are plotted in Figure 10. As the target depth increased, the animals' detection ranges decreased, showing the effects of bottom reverberation. Au [20] used a monostatic echoranging system emitting simulated dolphin sonar signals to measure the scattering strength of the bottom where Murchison's experiment was conducted. The dolphin's detection threshold occurred at a echo-to-reverberation ratio of approximately 4 dB. The echoes in Figure 11 approximates the dolphin's situation at the threshold of detection. In shallow bays and inlets, dolphins must be able to detect targets in the presence of bottom reverberation.

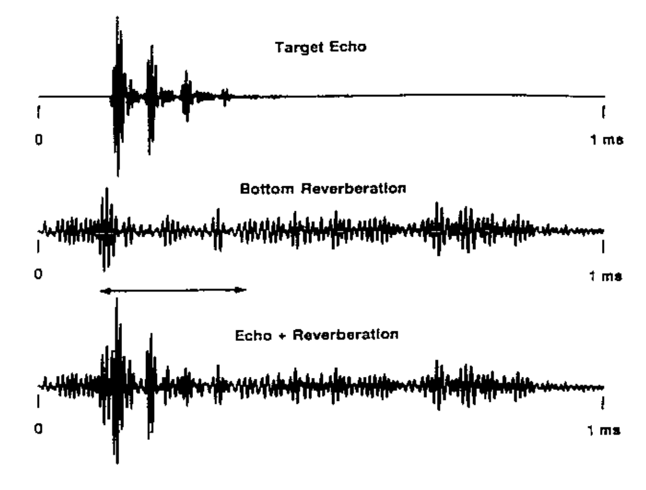

Fig. 11. Echoes from the 6.35 cm solid sphere used by Murchison [18] and the bottom reverberation measured by Au [20]. The relative amplitudes of the echoes were scaled for an echo-to-reverberation ratio of 4 dB.

Conclusion

Research clearly indicates that the dolphins possess keen echolocation capabilities and may be the 'premier' echolocators, even if man-made sonar is considered. Dolphins can successfully echolocate in environments that are difficult – if not impossible – for man-made sonar (eg noisy and shallow water or under-ice environments that are full of clutter). We have mainly considered the sonar detection capabilities of dolphins without discussing a fascinating area involving target discrimination, recognition and classification. The dolphin's ability to discriminate size, shape and material composition by echolocation is summarized by Nachtigall [21] and Au [1]. The dolphin's unique echolocation capabilities can be attributed to the properties of the signals used, its acoustic perception capabilities, and its capabilities to process acoustic information. The dolphin can transmit high intensity (up to 230 dB re 1 μPa), broadband (30 to 40 kHz bandwidth) signals over a large range of peak frequencies (30 to 120 kHz). The signals are transmitted in a directional beam that allows the animal to localize and scan across objects of interest. Dolphins can hear over a wide frequency range (0.1 to 150 kHz) and detect low intensity sounds (down to 40 dB re 1 μPa). They can discriminate fine angular differences (1 to 3°) in the direction of received sounds. Sounds are received in a directional beam and processed by an auditory filter system which may be modelled as a bank of constant-Q filters. A directional beam and a filter bank system are useful in limiting the amount of interfering noise and spurious signals received.

Dolphin echolocation and auditory research is in its infancy when compared to auditory research with humans and other animals, yet considerable progress has been made in understanding the echolocation process during the past 20 years. Auditory research with humans and other animals has been invaluable in defining parameters to measure, suggesting experimental procedures, and providing various theories of audition to consider. We look forward to a continuing discovery of the fascinating processes of echolocation in dolphins and other toothed-whales.

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Dr W W L Au and Dr P E Nactigall are with the Marine Mammal Research Program, Hawaii Institute of Marine Biology.

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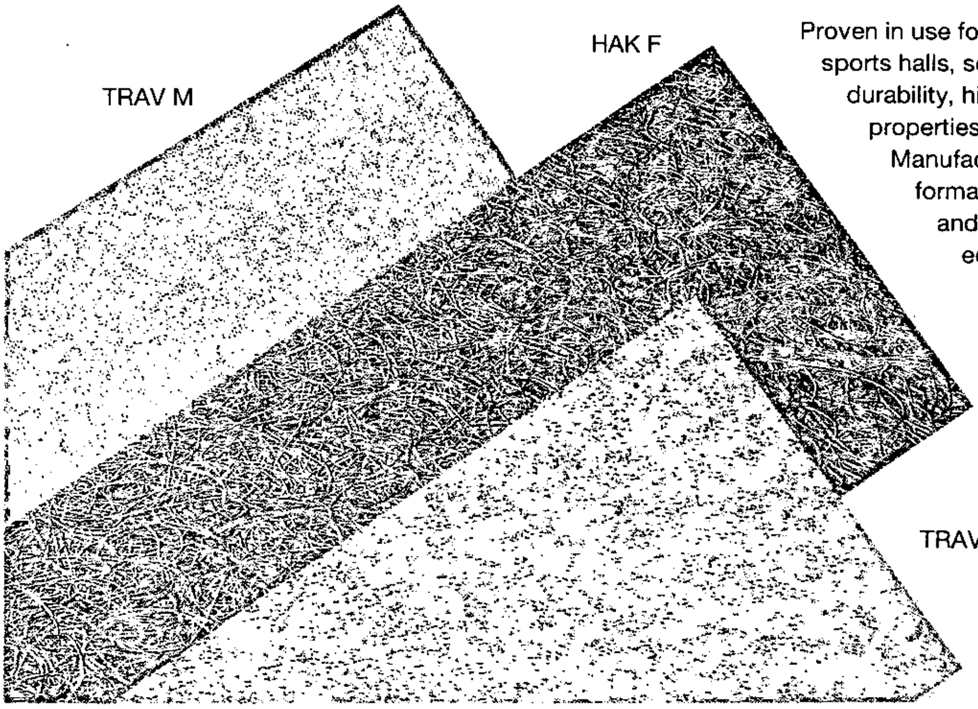

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THE EDINBURGH INTERNATIONAL CONFERENCE CENTRE

Kyri Kyriakides FIOA

Introduction

The Edinburgh International Conference Centre (EICC) is the first building in the UK which makes use of 'Turntable Divisible Auditoria' to convert a large auditorium into smaller auditoria. The sub-division takes place within moments by revolving two seating areas to create three separate self contained raked auditoria for 600 and 2 x 300 delegates.

The concept presents the acoustic consultant with interesting sound insulation and acoustic challenges, and provides the operators of such a venue with flexibility far beyond that which can be found in traditional fixed wall auditoria.

The Launch

Sandy Brown Associates have been involved in the acoustic design of major conference facilities for many years. The most recent is the £38m Edinburgh International Conference Centre which was launched on 28 March 1994 by the Rt Hon Ian Lang MP, Secretary of State for Scotland at an impressive ceremony attended by over 400 invited guests from the UK, Europe and North America. Among the guests were the Secretary of our Institute, Cathy Mackenzie and other IOA members from Sandy Brown Associates – David Binns, Kyri Kyriakides and Richard Muir.

Performing a number of traditional ceremonies, the Secretary of State for Scotland commemorated the 'Topping Out' of the building, which marked a significant stage in the 27-month building programme. The ceremony was performed exactly one year after construction work on site first began.

The EICC, which forms the cornerstone of a new financial and business district, The Exchange, will open in August 1995. So far the EICC has received bookings for 27 conferences. It has also been proposed as the venue for one of the future meetings of the International Congress on Acoustics.

Background

The conference and exhibition industry continues to expand world-wide as cities compete for delegates and the tourist trade that follows. The traditional illustrated address is often giving way to new concepts of 'meet and eat' and 'industrial theatre' for product launches.

The platform often becomes a stage with sophisticated lighting, stage machinery and projection systems. Simultaneous interpretation, voting and interactive delegate systems are all frequently needed.

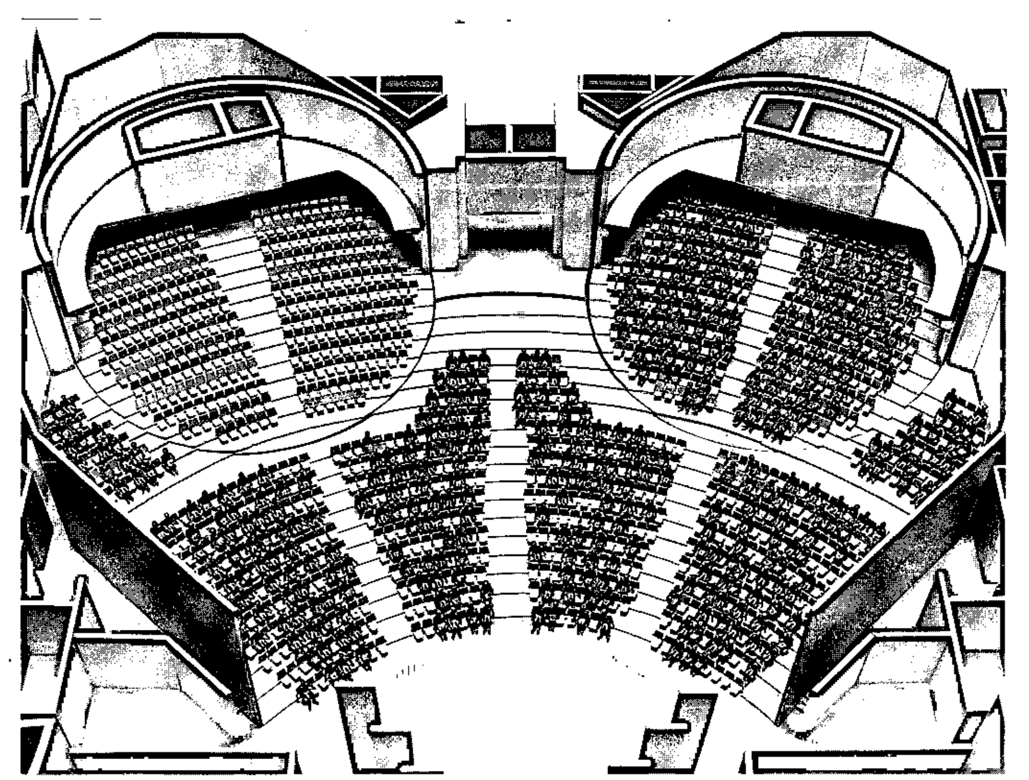

Fig. 1. Model of Edinburgh International Conference Centre showing the 1200 seat auditorium which includes the twin revolving seating areas.

The requirement for the City of Edinburgh to be able to successfully compete in the conference centre market in the face of increasing competition from both UK and overseas venues was recognised some years ago and a decision was taken to provide the city with a conference centre, the equal of any in the world.

Since that decision was taken a number of schemes have been put forward and assessed, culminating in the current scheme proposed by Terry Farrell & Company in February 1991. The objectives that had to be satisfied were to secure and develop Edinburgh's position in the

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Due to continued expansion a vacancy has arisen for an acoustics engineer at the Bristol office of Hoare Lea & Partners Acoustics. The position would ideally be filled by a graduate holding a relevant BSc and/or MSc degree qualification with a minimum of one year's practical experience in applied acoustics.

An attractive salary will be offered, commensurate with age, experience and qualifications. Excellent prospects exist for the career development of the successful applicant.

For further details please contact Dr Andrew Bullmore on 0454 201020 or write, enclosing your CV, to:

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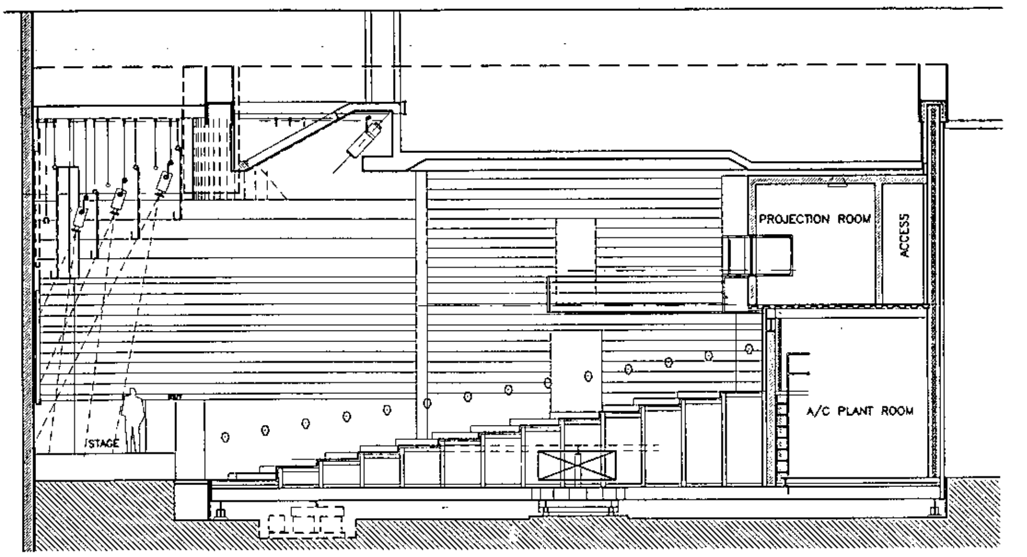

Fig. 2. Section through 300 seat revolve.

International and National Conference market, to promote Edinburgh and Scotland as a visitor venue and to enhance Scotland's image.

Prior to the competition which produced the current scheme, the City together with the Scottish Development Agency, undertook extensive research into the optimum size and other resources necessary to meet these requirements.

This research involved examination of the facilities offered by comparable venues within Europe and the functional requirements anticipated by major promoters and potential customers. The specific brief was consequently developed to meet the perceived market within the context of Edinburgh's position as a major European capital.

The Conference Centre

Following the selection of the urban design proposals, the design team was separately appointed to develop fully the original conceptual design for the EICC. This involved a detailed feasibility study which considered the technical, acoustic and engineering issues. It resulted in the development of initial concepts – with the full benefit of the market research – for the design of the Conference Auditorium, the related Seminar and Banqueting Suites, and the Foyer and Servicing Arrangements. The outcome was a complete and highly engineered solution to the brief.

The design also had to take into account, as far as was practical given site and budget considerations, recent changes in the conference market and in Edinburgh itself. For example, as well as the larger conferences with their associated exhibitions there is also a greater demand for more small meetings reflecting changes, especially in the world of medicine, science and technology. To take advantage of these opportunities it was essential to develop a design which maximised the flexibility of the main auditorium and the break-out spaces.

The EICC comprises four principal elements

(a) A main auditorium to seat 1200 delegates capable of sub-division into three separate auditoria with sufficient sound attenuation between them, and of providing technical facilities of the highest International standards.

(b) Breakout rooms providing seating for 600 people and capable of sub-division into a number of separate configurations.

(c) Committee rooms providing seating from 50 –150 delegates.

(d) An Exhibition Hall capable of supporting conference related events; this hall is also capable of adaptation to provide a major Banqueting Suite.

These facilities are linked by generous foyer, entrance and reception spaces. They have been designed so that the four principal facilities can be operated equally well together for a major international event, or entirely independently providing access, service and security for a wide variety of separate functions.

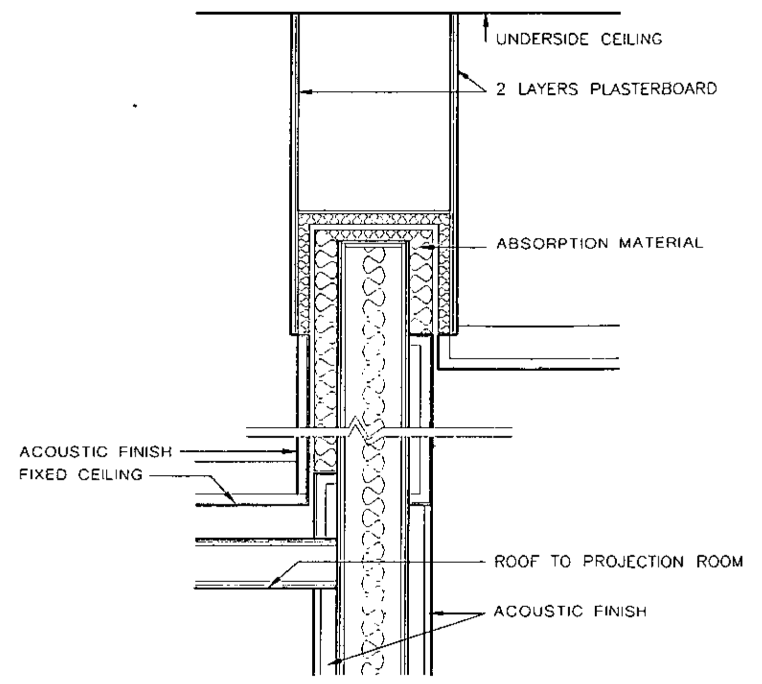

Fig. 3. Section through top of rotating wall

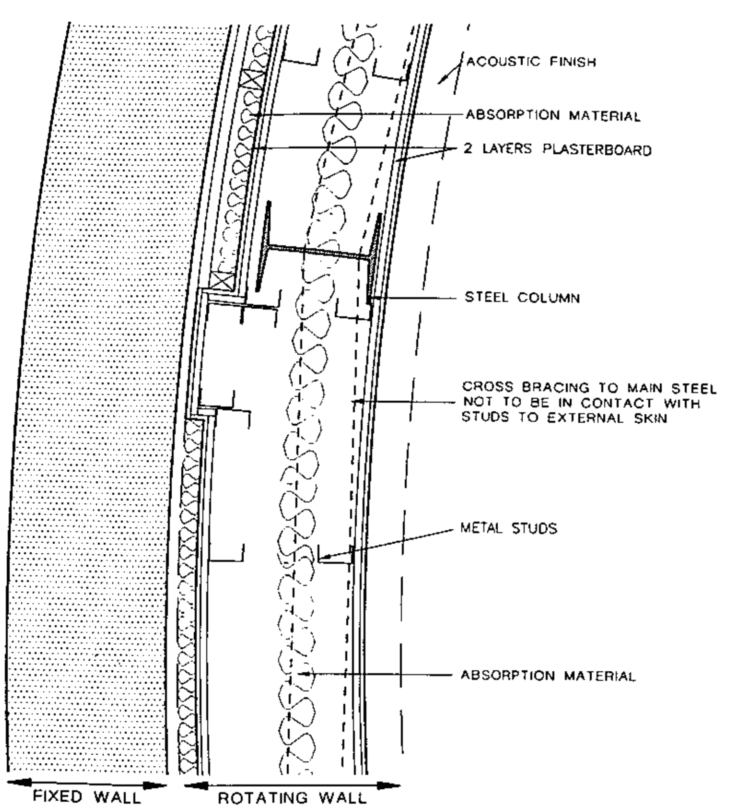

Fig. 4. Plan view.

Sound insulation

Turntable Divisible Auditoria

The relative expense in time and labour inherent in dividing an auditorium by movable partitions is well known. A solution that has been used in North America for some time, and more recently in Europe, is based on 'Turntable Divisible Auditoria' (TDA). In the EICC two such auditoria are used within a main auditorium which seats 1200 delegates, as shown in the photograph. The main auditorium can be converted in moments into three separate self-contained auditoria for 600 and 2 x 300 delegates, or into two auditoria, seating 900 and 300 delegates.

Each TDA consists of raked seating located on a revolving turntable, which has an integral back and side walls to provide sound attenuation. In the 'open' position the seats face towards the main stage. On rotating the turntable through 180 the seats face into a smaller hall. The back wall having turned with the seats becomes the sound barrier between the main auditorium and the one that has been formed by the rotation of the turntable.

TDA walls

The construction details of the rotating walls and the top of wall details are shown in the sketches. In arriving at proposals for wall constructions the effect of the gaps between the fixed and moving elements had to be taken into account. The walls themselves are expected to provide more than enough sound insulation between auditoria.

During the initial investigation phase, Sandy Brown Associates visited other TDA installations and carried out subjective and objective assessments of the sound insulation. The conclusion was that it was possible to improve on the sound insulation of the facilities visited and that simultaneous use of the adjoining spaces could be made as long as limitations were placed on extremes, eg the use of loud amplified 'pop' music in one auditorium would not permit satisfactory use of an adjacent auditorium requiring low background noise levels.

TDA ceilings

Two ways of constructing the ceiling over each TDA were considered.

(a) Attaching it to the back and side walls and cantilevering it over the open front part of the auditorium so that it turned with the turntable beneath.

(b) Keeping it fixed and supporting it from the overhead structure, the back wall rotating within deep slots in the ceiling itself.

The latter of the two was favoured by the design team for three main reasons. The weight of each revolve would be lower, the complications of having to deal with movable mechanical services would be avoided, and the cost of a fixed ceilings would be less.

Acoustics

The prime use of the auditoria is for conferences. The brief, therefore, was to design their acoustic so that speech intelligibility was good and background noise from the mechanical ventilation system, and from other external sources, was not intrusive.

Early discussions within the design team lead to decisions about ceiling profiles, auditoria volumes, and zones for acoustic finishes. The primary objective during these discussions was to put in place the fundamental parameters that would enable the performance criteria for the various spaces to be achieved.

The most unusual aspect was the specification of finishes. For all types of auditoria this needs to be judged correctly, but for those experienced in this area of acoustics it is not unduly difficult. In the case of revolving auditoria the task is more complicated. Acoustic finishes designed to optimise conditions within one auditorium will play a part in the acoustics of other merged auditoria. A major concern was to ensure that finishes would complement each other and thereby produce satisfactory results in individual auditoria and in combined auditoria.

Conclusions

The theoretical calculations and observations in other similar venues suggest that the sound insulation and acoustic parameters that have been specified will be achieved in the auditoria of the EICC. It is expected that the commissioning tests will confirm the predictions, but the ultimate test of success will come when the facilities are put into operation.

Kyri Kyriakides FIOA is with Sandy Brown Associates. Sandy Brown Associates are members of the Association of Noise Consultants.

ANNOUNCEMENT and CALL FOR PAPERS

1995 Spring Conference

ACOUSTICS '95

Environmental Noise and Vibration

(Organised by the Environmental Noise Group)

Britannia Adelphi Hotel, Liverpool
9-11 May 1995

The 1995 Spring Conference represents a departure from normal practice in that the conference focuses upon a specific cluster of topics around the environmental noise and vibration theme. It is also unusual in being organised by an Institute group.
Within this new format it is planned to cover a broad range of topics including:

Noise nuisance and the law, regulations and standardisation, transportation noise, planning (PPG), noise and sleep, neighbourhood noise, vibration, leisure noise, industrial noise, instrumentation, software, noise control, environmental health, education, measurement techniques, noise quality, European issues.

In addition it is hoped to include practical case study discussion sessions and workshops as well as the R W B Stephens and Rayleigh Medal Lectures. It is also planned to introduce a Manufacturers' Forum. The 1995 AGM and Annual Dinner will take place during the conference.

The Britannia Adelphi Hotel in Liverpool has been selected as the venue for Internoise '96 on account of a number of very special features which include an ability to cope with many parallel technical sessions and upwards of eight hundred delegates. It is also well provided with restaurants, swimming pool and leisure facilities. The size and complexity of the Internoise '96 event has played a part in the decision to hold the Institute's 1995 Spring Conference there.

The City of Liverpool and surrounding area of Merseyside has much to offer to complement the business side of the conference. A full social programme will be arranged that picks up on these special local attractions.

Offers of contributed papers should be sent with a 100-word abstract to the Institute office before 14 November 1994. Written papers will appear in Volume 17 of the Proceedings of the Institute of Acoustics (1995) which will be available to delegates upon arrival. Completed manuscripts, normally no more than 8 pages long and typed on the camera ready paper provided, must be with the Institute before 20 March 1995. Intending authors should indicate if it is their intention to have their paper refereed under the new procedure.

Those who are presently unlikely to submit a paper should make a note of this important event in their diary now. It is intended to offer advice later about CPD credits for attendance.

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CONFERENCE & MEETING UPDATE

For events that will have separate programmes published and distributed

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1994 Autumn Conference

Speech & Hearing

(organised by the Speech Group)

Windermere Hydro Hotel, 24–27 November 1994

1994 Tyndall Medal Lecture by Dr R K Moore FIOA
24 formal presentations and 55 poster presentations accepted
Special reduced conference fees for research students
Contact the Institute office

International Conference

Underwater Acoustic Scattering

(organised by the Underwater Acoustics Group)

Weymouth, 20–22 December 1994

Invited Speakers will present papers on the following topics: Paul Crowther, Marconi - *Sea Surface Scattering*; Darrell Jackson, APL - UW, Seattle, USA - *Scattering from the Sea-Bed*; Peter Thorne, POL - *Volume Scattering by Marine Suspensions*; Nicholas Pace, University of Bath - *Sediment Volume Scattering*. 24 contributed papers have also been accepted.
For further information please contact the Conference Organisers: G J Heald (Tel: 0305 863105) or S A S Jones (Tel: 0305 863461), Defence Research Agency, Southwell, Portland, Dorset DTS 2JS, UK, Fax: 0305 863446, or the Institute office.

1995 International Auditoria Conference

Opera and Concert Hall Acoustics

(Organised by the Building Acoustics Group)

Gatwick, UK, 10–12 February 1995

To date over twenty contributed papers have been accepted.

The opening in 1994 of the first new Opera House in the UK for 60 years (Glyndebourne) has stimulated interest in the acoustics of this special type of music auditorium. The meeting will include contributions from the acoustic consultants to Glyndebourne, and those responsible for three other UK music auditoria. A visit to the new auditorium is planned during the conference.

Programme Committee Chairman: Jeff G Charles FIOA, Bickerdike Allen Partners.
Further information as it becomes available from the Institute office.

PRELIMINARY ANNOUNCEMENT
and
CALL FOR PAPERS

Sonar Transducers '95

(Organised by the Underwater Acoustics Group)

3–5 April 1995
University of Birmingham, UK

There are still many interesting problems concerned with sonar transducers, but with modern methods of analysis the design procedures can be very much more detailed than in the past, and also progress is being made in developing new materials. It is now four years since the last Institute of Acoustics Underwater Acoustics Group Conference on this subject and it is time to have another one.

Here are some suggestions for topics:

- Applications of composite materials, active and passive
- Designs for extreme depths
- Finite Element and Boundary Element analysis
- Flextensional transducers
- Hydrophones
- New magetostrictive materials and applications
- Very wide bandwidth sources

It is hoped to arrange prestigious talks from the international community on several of these subjects.

Prospective authors are invited to submit a 200 word synopsis not later than 1 October 1994, and successful authors will be notified by the end of October. Arrangements will be made for papers to be refereed if authors would prefer.

Complete manuscripts, which may be up to 10 pages long including diagrams, must be on the camera-ready paper to be supplied and in the hands of the Conference Secretary by 17 January 1995 in order to be included in the printed proceedings which will be available at the Conference.

The Conference will be held in the School of Electronic and Electrical Engineering, University of Birmingham and limited residential accommodation will be available in an adjacent Hall of Residence. Registration Forms and programme details will be circulated in December 1994.

All communications should be sent to the Conference Secretary:

Mr J R Dunn MIOA, School of Electronic and Electrical Engineering,
University of Birmingham, Edgbaston, Birmingham B15 2TT.
Tel: 021 414 4312 Fax: 021 414 4291
EMail: JDUNN@EE-ADMN.BHAM.AC.UK
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WORKSHOP NOTICE

Workshop on

Environmental Noise Assessment

University of the West of England, Bristol

20 September 1994

(Organised jointly by the Environmental Noise Group and the South-west Branch)

Following the formation of the new Environmental Noise Group, a series of half day regional workshops is being organised. The first of these will address the issue of Environmental Assessment of Noise.

Programme

12.00 Buffet Lunch
13.00 Introduction
13.10 The requirements of the Noise element of an Environmental Statement
Martin Slater, Institute of Environmental Assessment
13.40 Environmental Noise Assessment - current techniques available
K M Collins, Ashdown Environmental & S W Turner, TBV Science
14.10 Tea
14.30 Workshop Session
15.30 Feedback
16.00 Close

As can be seen, the workshop is concentrating upon the techniques that are currently available for meeting the environmental assessment requirements for the noise impact of a project. The techniques include measurement and prediction methodologies, guidelines and standards, and the level of detail required. Having set the scene with the two presentations, the workshop session will enable small groups to consider separately what is needed in order to improve the methods available for carrying out the noise element of an environmental assessment. The feedback session will allow the ideas to be shared.

It is likely that a similar workshop will be held in other regions and it is hoped that the next will be held in conjunction with the Scottish Branch.

I wish to attend the Workshop on **Environmental Noise Assessment.**

Name:
Organisation: Tel: Fax:
Address:

☐ I enclose a cheque ☐ please invoice me at the above address for the delegate's fee
(☐ Members £35.00 incl VAT ☐ Non-members £50.00 incl VAT)

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WORKSHOP NOTICE

Workshop on

Current Issues In Standardisation

Commonwealth Conference Centre, London

11 November 1994

(organiser Roger Higginson FIOA)

The next plenary meetings of International Electrotechnical Commission (IEC) Technical Committee 29, Electroacoustics, International Organization for Standardization (ISO) Technical Committee 43 Acoustics, and ISO Technical Committee 43 Sub-Committee 1. Noise, are taking place in London during the weeks of 14–18 and 21–25 November.

Many of the working groups of these three major committees will also meet during the same two weeks. It is more than twenty years since they all came to this country and a workshop is being arranged to provide an opportunity for leading speakers active in the various committees to describe some of the issues under discussion, and to debate these issues.

The major international standards giving performance requirements for sound level meters are being revised and new standards are under development for instance on aircraft noise, machinery noise measurement and declaration, sound intensity and methods of noise reduction.

Provisional Programme

10.30	Introduction
11.00	Standards in Electroacoustics
12.15	Standards for Audiometry
13.00	Lunch
14.00	Standards for Noise Measurement and Declaration
15.15	Workshop Session
16.00	Feedback
16.30	Close

The intention is to have speakers who will set the scene and introduce the technical issues, and then for a lively debate to take place in which everyone will be able to take part. Delegates to the plenary meetings will be present and will be keen to hear views which they can carry forward during the next two weeks. With European Directives coming to rely more and more on the use of standards for their implementation, standards are assuming an ever more important role in the legislative framework. All who are concerned with the serious business of acoustical measurements will want to attend this Workshop.

I wish to attend the Workshop on **Current Issues in Standardisation.**

Name:

Organisation: Tel: Fax:

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REQUESTS FOR CONTRIBUTIONS

Workshop Discussion

Applications of Active Noise Control

27 October 1994

Church House Conference Centre, Westminster

Developments in active noise control, which are rapidly leading to 'off-the-shelf' systems for some simple applications, makes this an appropriate time to consider what can and cannot be achieved by present commercial active control systems. The workshop will attempt to answer the questions:

What are the present applications?
What are the present limitations?
What do prospective users want active noise control to do for them?
What can we expect in the future?

The workshop will commence with a few short, broadly-based papers describing the background to active control and its applications.

Members wishing to contribute papers should respond by 9 September 1994 to the workshop organiser Dr Geoff Leventhall FIOA, Digisonix, South Bank Technopark, 90 London Road, London SE1 6LN Tel: 071 922 8884 Fax: 071 922 8887

Members who wish to keep informed about progress with the programme should fax to the Institute office.

Workshop Discussion

Miniature Microphones

9 November 1994, Salford

(Organised by the University of Salford in collaboration with the Engineering Division of the Institute)

It is intended to have verbal presentations in the morning and laboratory-based activities in the afternoon. Anyone interested in participating should contact the Institute office.

One Day Meeting

Sound Power Measurement

30 November 1994

Commonwealth Conference Centre, London

With the imminent arrival of new legislation in the form of the Machinery Directive, it is timely to hold a meeting on Sound Power Measurement and the implications of the new Regulations. This one day meeting will seek to address the most important issues and it is hoped that presentations covering the following areas will be included:

- Sound Power Measurement Techniques
- Sound Intensity Techniques for Sound Power Evaluation
- Standards
- Legislation
- A User's Perspective
- A Manufacturer's Perspective

The meeting will be of interest to all concerned with sound power measurement and the implications of the new Regulations, particularly Test Houses, Manufacturers and Suppliers.

Further details are available from the Institute or Alistair Mackinnon at NEL Tel: 03552 20222

INSTITUTE DIARY 1994/5

1994

20 SEP
Environmental Noise Group and South-west Branch: Environmental Noise Assessment Workshop
Bristol

21 SEP
London Branch mtg: Channel Tunnel Railway Routes
London

23 SEP
Internoise 96 Committee
St Albans

28 SEP
Eastern Branch mtg: Acoustic Design of Broadcasting Studios
Cambridge

28 SEP
CPD Working Party
St Albans

29 SEP
IOA Meetings Committee
St Albans

30 SEP
IOA Executive Committee
St Albans

6 OCT
IOA Medals & Awards, Membership, Publications, Council
St Albans

14 OCT
IOA CofC in Workplace Noise Assessment exam
Accredited Centres

19 OCT
London Branch mtg: Design Manual for Roads and Bridges
Croydon

26 OCT
Eastern Branch mtg: Sound Quality
Norwich

27 OCT
Active Noise Control Workshop
London

3 NOV
Reproduced Sound 10, 4 days
Windermere

4 NOV
IOA CofC in Env Noise M'ment exam
Accredited Centres

9 NOV
Miniature Microphone Workshop
University of Salford

10 NOV
IOA Education Committee
St Albans

10 NOV
South-west Branch meeting: Underwater Acoustics
Bristol

11 NOV
Workshop: Current Issues in Standardization
London

11 NOV
IOA CofC in W'place Noise Ass't Advisory Committee
St Albans

16 NOV
London Branch Annual Dinner

24 NOV
1994 Autumn Conference: Speech & Hearing, 4 days
Windermere

30 NOV
Workshop: Sound Power Measurement
London

1 DEC
IOA Meetings Committee
St Albans

2 DEC
IOA CofC in Environmental Noise Mm'nt Advisory Committee
St Albans

8 DEC
IOA Membership, Medals & Awards, Publications, Council
St Albans

14 DEC
London Branch mtg: Loudspeaker Design
London

20-22 DEC
Underwater Group Conference: Underwater Acoustic Scattering
Weymouth

1995

2 FEB
IOA Meetings Committee
St Albans

10 FEB
IOA CofC in Workplace Noise Assessment exam
Accredited Centres

10-12 FEB
1995 International Auditorium Conference: Opera & Concert Hall Acoustics (organised by the Building Acoustics Group)
Gatwick & Glyndebourne

16 FEB
IOA Education Committee
St Albans

2 MAR
IOA Medals & Awards, Membership, Publications, Council
St Albans

3 MAR
IOA CofC in Env Noise M'ment exam
Accredited Centres

10 MAR
IOA CofC in W'place Noise Ass't Advisory Committee
St Albans

15 MAR
London Branch mtg: Building Services Noise
London

31 MAR
IOA CofC in Environmental Noise Mm'nt Advisory Committee
St Albans

3-5 APR
Sonar Transducers '95: Underwater Acoustics Group Conference
Birmingham

26 APR
London Branch mtg: Acoustic Intensity
St Albans

27 APR
IOA Meetings Committee
St Albans

4 MAY
IOA Education Committee
St Albans

9-11 MAY
ACOUSTICS '95 1995 Spring Conference: Environmental Noise & Vibration
Liverpool

10 MAY
IOA 1995 AGM and Annual Dinner
Liverpool

19 MAY
IOA CofC in Workplace Noise Assessment exam
Accredited Centres

25 MAY
IOA Medals & Awards, Membership, Publications, Council
St Albans

9 JUN
IOA CofC in Env Noise M'ment exam
Accredited Centres

If any organisation is contacted by someone asking for details of employees, allegedly on behalf of the Institute, please contact the Institute office with the details

MEMBERSHIP

The following were elected at the Council Meeting held on 26 May 1994

Fellow
Berry, B F
Gresswell, D J
Thorne, P D
Turner, S W
Tyler, R G
Watkins, A J

Member
Anderson, C J
Baughan, C J
Cox, T J
Emmanuel, T A
Frommer, G H
Mallard, P
Patterson, D
Rayns, M C
Robbins, N A
Stanton, P
Thompson, A C
Vidler, M J
Ward, T
Wilkinson, R W
Yiu, K C

Associate Member
Anderson, N G
Blair, C
Bromilow, I D
Dean, A H
Dolling, R
Evans, J
Gandy, S J
Garlick, J W
Hookway, C J
Horne, T J
Kirkby, C A
Labarr, W J
Locke, A
Mitchell, C G
Mullan, A
Overton, R
Pantelides, A C
Purdie, J
Rowntree, R H
Shields, P J
Thorne, C J
Tomlinson, L
Wong, K F

Associate
Norrish, Z
Tang, K H
Bentley, C D

Student
Beard, J J
Cozens, J R
Hall, R
Maluski, S
Morgan, P A

Certificate of Competence in Workplace Noise Assessment

The following were successful in the 15th and 16th examinations

15th Examination
(February 1994)

Bristol
Allbrighton, D
Allez, B
Bragg, J R
Childs, G
Hemming, M
Hughes, L G
Kearn, R
Langford, G J
Northover, D R
Owen, B J

British Rail
Burdis, S J
Sowden, J A
Thompson, B

Colchester
Baldock, S T
Copland, R
Crooke, D J
Kitching, D P
McCrea, D
Memmott, A
Palmer, B
Staples, B A
Wigens, D G

Glasgow
Dick, M
Figures, M L
Gillies, I W
Leslie, D B
McCormick, J
McKeown, I
Morrison, W C

Staffordshire
Bartmanis, N
Davis R
Hendry, D C
Knowles, D
Wilmot, R

16th Examination
(May 1994)

Bristol
Buckner, S E
Greaves, G R
Skeen, M
Spodris, G
Wharton, R P

British Rail
Belshaw, E
Darby, G W
Futcher, S
Good, P R
Harrison, S G
Longley, M J
Maitland, T
Smith, P J

Colchester
Ashby, K
Bird, C P
Brown, P J
Davis, B
Littmoden, M
Mellor, S J
Stevens, L J

Derby
Garner, A
Myshrall, R
Timmins, A L
Weatherby, R K

Liverpool
Lyons, J A
Story, P E
Teare, S A
Wells, R

Salford
Chesworth, R
Critchlow, S
Darby, A M
Woolley, K

Sheffield
Bennett, D J
Cosgrove, G B
Sutton, C
Wilburn, A

South Bank
Beament, D
Henley-King, J S

Certificate of Competence in Environmental Noise Measurement

The following were successful in the 3rd and 4th examinations

3rd Examination
(March 1994)

Colchester
Bratton, J
Churcher, S W
Etheridge, N P
James, H R
Mathews, R I
Taylor-Grout, G
Williams, K

Derby
Bowran, C D
Horton, A
Langley, J S
Rogers, P W
Westerman, R

Liverpool
De Salis, M
German-Lloyd, E
Stanworth, I K

NESCOT
Adams, S
Ashton, S
Beed, R J
Easterbrook, R
Fowler, N J
Johnston, R
Plummer, M P
Streetly, R
Williams, J A
Woodward, K L

Sheffield
Etches, M A
Simpson, T G

South Bank
Bain, C D
Bruckshaw, A
Cleaver, P J
Fitter, K L
Hodgson, S
Kitto, R
Mackenzie, J
White, N J
Whiteley, W N

4th Examination
(June 1994)

Bristol
Bartlett, C A
Cosher, J E
Durell, P J
Portman, S M
Rees, M

Colchester
Ahmet, P
Blay, S R
Blott, P
Lambra, R
Robinson-Ferrars, I
Wastle, R
Wright, G C

Liverpool
Greenwood, D J
Lord, A C
Williamson, M A

NESCOT
Howard, N
Skinner, M J
Stannard, J L
Taylor, F E
Wilcock, S R
Wiles, P S

1994 Spring Conference
ACOUSTICS '94
Salford, April 1994

This was in many ways one of the most successful of the Institute's annual Spring Conferences. The simple statistics, which do not convey the entire picture, can be summarised as 169 delegates from a wide variety of professions attended and fifty-one papers were presented.

At a Civic Reception in the L S Lowry Gallery of the City Art Gallery, the conference delegates were welcomed by the Mayor of Salford, and provided with an opportunity to view the superb collection of Lowry and other art works.

Among the major highlights of this conference were the two invited lectures.

The 1994 Rayleigh Lecture was given by Professor Ted Evans of Keele University on his specialist subject, the physiology of the ear. It was expertly delivered and the content was of absorbing interest as can be judged on page 5 of this issue where the paper is reproduced in full.

Professor Jens Blauert of Ruhr–Universität Bochum, Germany, gave the 1994 R W B Stephens Lecture, 'Foundations and application opportunities of binaural technology'. This fascinating talk covered a wide range of topics in the field of binaural technology including the theory of binaural hearing and the applications to recording and reproduction and aural simulation and displays. Both these prestigious lectures stimulated interesting discussions and set a high standard for the rest of the conference.

The Annual General Meeting preceded the Annual Dinner and both occasions saw the transfer of presidential power from Peter Wheeler to Alex Burd in the time honoured manner. The Annual Dinner was held at Manchester United's hospitality suite and followed an absorbing tour of the ground. This was an opportunity for Peter Mapp to demonstrate what he called the world's largest hi-fi set featuring some thirty seven large Toa loudspeaker units mounted at roof level above the football stands, the main purpose of which is to expedite evacuation of the crowd on match days.

Another event which lightened the proceedings was a visit to Granada TV's studios, which included viewing the Coronation Street, Sherlock Holmes and Downing Street film sets. Our new president reluctantly agreed to be photographed in front of No 10 in the company of a police constable; however permission was not granted for publication in the Bulletin!

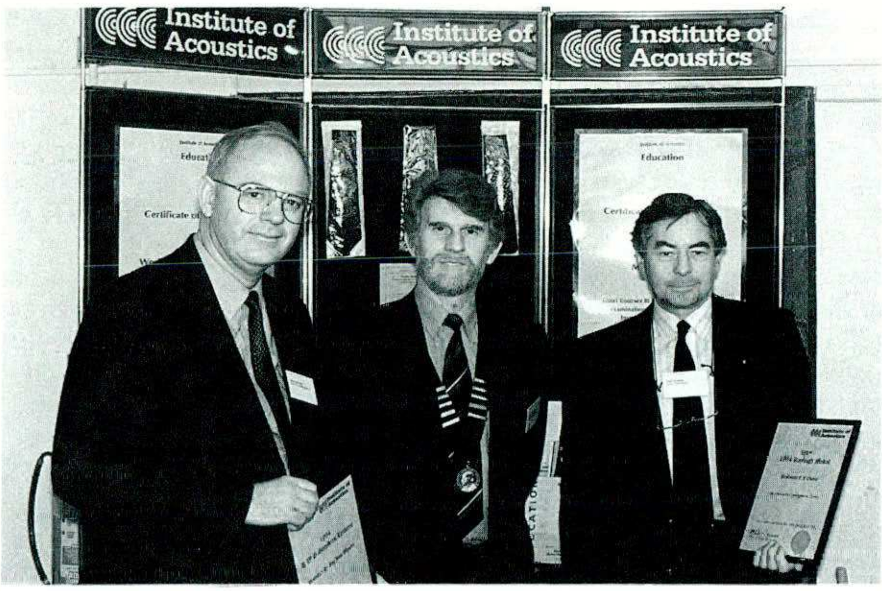
The organisation of the conference was in the capable and energetic hands of Salford University's Geoff Kerry and Peter Wheeler.

The conference commenced with parallel sessions on aircraft noise and occupational noise. Reports from all sessions follow.

Occupational noise

In a well supported session presentations covered a wide variety of workplace scenarios, from miners to musicians. P M Pitts opened the session with a paper describing the application of noise zones to the mining industry, followed by M R Forrest who reported the results of a study of hearing conservation in the Army, covering in particular the effects of combat in the Gulf war on hearing levels. In stark contrast, S W Kahn presented a study of noise dose measurements on musicians, making the point that for this occupation the sound (or the noise!) produced is the work itself rather than an unwanted by product of the work. The session continued with papers on motorcyclists' noise exposure by M C Lower et al, a look at the interaction of the Machinery Directive and the Noise at Work Directive by the HSE's K A Broughton, and a presentation by G Custard on a novel way of estimating noise induced hearing loss for workers with complex noise exposure histories. The morning concluded with a paper by F Irving on the extreme noise levels experienced by shot blasters, in which the author highlighted the unnecessary contribution of noise exposure produced by inappropriately designed communication headsets.

This theme of hearing protection and communications was picked up again in the afternoon session. D Smeatham reported the results of



Left to right Professor Jens Blauert (R W B Stephens Lecturer), Professor Peter Wheeler (IOA President) and Professor Ted Evans (1994 Rayleigh Medal Lecturer) a study of impulsive noise sources in the workplace and described the characteristics of potential laboratory test noise sources suitable for assessing the impulse performance of hearing protectors.

Liz Bruek reported a series of laboratory experiments identifying the amplification which some designs of amplitude sensitive earmuffs can give in steady state noise at moderate levels and Jacqui Lloyd described field measurements of passive and amplitude sensitive earmuffs for gun fire noise, comparing peak level attenuations in the field with REAT data. D Humpheson described the factors involved in the selection of amplitude sensitive hearing protectors, for small arms range use in the RAF.

The afternoon concluded with an open discussion led by R Weston and G Custard, on the use of miniature microphones in hearing protector and noise dose measurements. This session attracted the interest of the delegates from a variety of backgrounds and produced a lively exchange of views. The need for both field survey procedures and for precision laboratory techniques was recognised and it was generally agreed that a one day workshop should be planned to continue the discussion (Note: this workshop will be held at Salford in the Autumn, details are given elsewhere).

Environmental noise

This topic was treated in two parts. The first part opened with a set of three related presentations on the CA survey of aircraft noise and sleep disturbance around the four main UK airports.

J B Ollerhead from the CAA gave a general overview of the project emphasising that it was very much a team effort. He outlined the planning, the structure of the project team and their objectives and then gave a summary of key results.

K Hulme from Manchester Metropolitan University described how EEG, EOG and EMG recordings were obtained from a sample of 46 volunteer subjects. Changes in EEG due to aircraft noise events were mainly restricted to changes in depth of sleep or brief arousals which did not lead to awakening.

J Horne from the Sleep Research Laboratory at Loughborough University was responsible for an 'actimetry' study of 400 subjects living at one of eight sites with different levels of night flying. Each subject wore a device which detected and logged small body movements. The considerable problems in filtering and interpreting the actimetry recordings were clearly illustrated. Here again a surprisingly small proportion of aircraft noise events affected sleep, with domestic and idiosyncratic factors having much greater effect.

The prediction of aircraft noise contours normally involves expensive software packages to which operators of small general aviation airfields do not have ready access. M E House explained the steps in the simplified prediction method he has developed,

The final paper was given by J Tingay from Cirrus Research in which he described a new technique – sound gating – for automatic identifiation of aircraft noise events in airport monitoring systems.

The second session on this subject area illustrated the wide range of topics that can be included in the general heading of environmental noise.

G Vulkan, environmental consultant, opened the session with a paper which gave his view of the development of noise assessment, guidelines and planning since the early sixties, mainly relating to London but also referring to outstanding issues regarding noise standards such as those applying to major new railway routes.

D C Hothersall and J N B Harriott, University of Bradford, presented a paper which described the formulation of a method, based on the concept of the Fresnel Zone, to predict sound propagation over a multi-impedance plane. A paper by N J Edwards and Y W Lam described investigations into a simple method of including the effects of turbulence in the atmosphere into short to medium range sound propagation prediction schemes.

P A Morgan and D C Hothersall of University of Bradford and S N Chandler-Wilde of Brunel University, gave a paper describing a method of predicting the effects of parallel traffic noise barriers using a boundary element numerical model. K M Li and K Attenborough of The Open University followed with a description of an analytical approximation of sound propagation in a stratified medium. The session closed with a paper on the automatic monitoring of environmental noise by R B W Heng of Sheffield Hallam University and J McCabe of Doncaster Metropolitan Borough Council. This described the use by members of the public who have made complaints about noise nuisance, of sound recording equipment supplied by the Council to record the particular noise events.

Structure-Borne Sound

This short session covered the topic of structural-borne sound which forms an important part in the control of noise in building acoustics, isolation of machinery, vehicle noise and many other areas. It was therefore not surprising that the session attracted over 30 delegates.

Three papers were presented in the session. The first two were from the Acoustics Research Unit at the University of Liverpool. The first paper, by R A Fulford and B M Gibbs, considered the estimation of the structural-borne sound power transmitted through multiple contacts. It generated a question from the audience concerning the importance of bending moment estimation. A detailed answer to the question was provided fittingly in the second paper by A T Moorehouse who was working on a related project on the characterisation of the source power of structure-borne sound.

The final paper was presented by Professor R J M Craik of Heriot-Watt University who gave a very lively presentation on the modelling of noise transmission through elastic layers in buildings. The presentation was well timed to allow sufficient time for several questions to be raised and answered before the break for lunch.

Vibration

This session covered a range of topics concerned with the vibration of structures and acoustic interaction. There were two contributions from the Department of Aeronautical and Automotive Engineering and Transport Studies of the University of Technology at Loughborough. The first, presented by A J Smirlas, gave results of a theoretical study of the vibrational power transmission through a beam junction. The second paper, presented by Jane Horner, described experimental results for the transmission of longitudinal vibration through adhesive joints in rods.

L C Chow of British Aerospace Airbus Ltd presented a paper which outlined the ways in which the sonic fatigue certification requirements of the Joint Airworthiness Authorities were addressed for the A340, A330 and A321 aircraft. In a further paper he described random vibration fatigue tests on superplastic formed and diffusion bonded titanium alloy coupons. Tests on aircraft spoiler structures were also considered.

The results of experimental studies of wave motion in a mild steel, curved and stiffened beam were reported by S Walsh of ISVR. These were compared with a corresponding theoretical model. He concluded that for radial excitation the point response is dominated by the stiffening of the beam. For circumferential excitation the point response is dominated by the curvature of the beam. Also from ISVR, P Clarke, in his paper, considered theoretically the effects of discontinuities representative of vibration control devices mounted asymetrically on a beamlike structure, with particular reference to vibrational power transmission and wave conversion.

Building acoustics

This session showed a strong concentration on sound insulation/ impact isolation with two papers on floors, two on lightweight cladding and one on a new laboratory for measuring sound insulation.

C Walker (Lafarge Plasterboard) applied his long-standing knowledge of plasterboard to the development of a new testing laboratory for his present employers. The construction used multiple layers of plasterboard where mass could safely be dispensed with and as a result provided separate sets of rooms for walls and floors at a very competitive price. The test rooms now have NAMAS accreditation; several independent test laboratories may well notice a reduction in business as a result of the new in-house facilities.

Professor R K Mackenzie (with R Hall, both of Sheffield Hallam University) described the development of a shallow profile floor, only 20 mm thick for refurbishment work, using the specialised knowledge of polymer foams available in Hallam University. Combinations of open and closed cell foams allowed the construction of well supported floors giving a 19 dB impact isolation improvement for concrete floors and 10 dB for timber floors. Professor Craik with R S Smith and R Wilson, all of Heriot-Watt University, described the development of a statistical energy analysis model which predicts the performance of floors of timber joists, walking surface and ceiling by examining each of the transmission paths. Some modification of earlier theory was necessary but good agreement with measured results was then found. The model can be developed to include more complex forms of construction.

Dr Y W Lam (with R M Windle, both of Salford University) explored the effects of bending wave resonances, the spacing of the skins and the type of infill material of double skin cladding systems to explain the measured results and derive an optimum arrangement for the sound insulation of such materials. In a second paper, Dr Lam looked at single skin cladding and showed that a simple empirical, user-friendly method could predict modefrequencies and hence dips in the SRI curve. Correcting existing theory provided a realistic estimate of the sound insulation with surprising accuracy.

J N Pinder (ISVR Consulting Services) looked at the use of a microporous polyethylene lined enclosure for providing noise reduction on bottling conveyor lines. The material was shown to be effective as a lining spaced from the wall of an enclosure but its transmission loss was too low to allow it to be used without an enclosure. The protection for nearby workers was enhanced by some 4 dB relative to the unlined cover. Maintaining clean conditions during manufacture proved most irnportant.

P J Barnett (AMS Acoustics) described the acoustic environment on several underground platforms measured during his search for improved intelligibility from public address systems. Reverberation did not involve all the volume of the space and could be quite localised. Sound was attenuated during transmission along the length of the platforms and a reverberant level was not found. Intelligibility could be predicted using an empirical expression for attenuation.

Active control

The Active Control session at Acoustics '94 attracted a useful selection of papers covering both the practical control of sound and vibration and the theoretical development and analysis of active control strategies.

In the first paper, A K M Azad, of the University of Sheffield, discussed a conventional control application in robotics, illustrating how intelligent design of the control system can improve performance of a flexible manipulator. M E Johnson of ISVR then gave an interesting presentation describing an investigation into the active control of noise transmission into a cylindrical body, motivated by the damaging levels of noise entering the payload bay of a space vehicle at launch. Experimental results were shown which verified theoretical models of the noise reduction achieved by a very simple control system, suggesting that active techniques could be a practical solution to this interesting problem. C J Mazzola, of NAMLAK, USA, delivered a paper in which the principles established in his recent book on Acoustic Absorption were developed in the context of a vibrating mechanical system.

The local control of acoustic noise to produce a 'zone of quiet' was the subject of the next paper. J Garcia Bonito, of ISVR, reported some elegant simulation work which demonstrated that the zones of quiet produced by realistic sources were similar to those predicted from previous naive analyses using point sources. The paper also showed evidence that the presence of a diffracting object, such as a listener's head, near the control point does not degrade the cancelling performance. In the second contribution from the University of Sheffield's Automatic Control Department, M A Hossain presented the results of some simulations of a single channel active controller, which is optimised by manipulating two plant transfer functions, measured during an identification phase.

The final paper was delivered by S J Elliott of ISVR, who discussed the differences between active control systems using feedforward and feedback architectures. The presentation explained, in Dr Elliott's usual illuminating style, those aspects of the dynamics of the system under control and the statistics of the disturbance which would favour the application of either feedforward or feedback controllers.

Architectural acoustics

The two sessions on architectural acoustics produced ten varied papers six of which dealt specifically with concert halls and opera houses. D Sugden of Arup Acoustics dealt with the complexities and sometimes contradictions of hall design using the characteristics of several famous buildings as examples.

M J Howarth and Y W Lam of University of Salford described their work on the computer modelling of auditoria; A N Burd and L Haslam of Sandy Brown Associates considered the relationship between choir and orchestra in two new halls where they were acoustic consultants – St Davids Hall, Cardiff and the Glasgow Royal Concert Hall. The first session closed with a paper by S W Kahn and Bridget Shield of South Bank University which presented the results of a study which measured noise levels during performances at the Royal Opera House of ballet, opera and a vocal recital. The object was to determine the ambient noise minima during performance in relation to unoccupied noise.

The second session started with N V Jordan of Jordan Akustik describing the results of a competition for the design of a new concert hall for Copenhagan. D W Templeton of BDP Acoustics reviewed his company's experience in modelling auditoria acoustics using the ODEON computer modelling system, and R W B Heng of Sheffield Hallam University dealt with the measurements of the acoustics of a highly reverberent entertainment centre. S M Dance and B Shield followed with a paper on noise control modelling in non–diffuse enclosed spaces using the RAYCUB and CISM models. H A Akil, D J Oldham and B M G Cheetham of University of Liverpool followed earlier work on the scattering effects of fittings in industrial spaces by considering the corrections for excessive air absorption in the acoustic scale models used in this research. Finally Y W Lam of the University of Salford showed, by comparisons of seven physical scale model halls of different sizes and shapes, that the inclusion of diffuse reflection is important for a com-puter model to predict accurately the acoustics of concert halls.

Instrumentation and Quality

The drive to improve quality through accreditation has gathered pace over the past few years and although accepted by industry as a necessity the value of such exercises has not always been fully appreciated, especially after the increased burdens of time and cost are taken into account. Of particular importance to those involved in measurement is the quality of both results and the instrumentation used to obtain them. This special session was intended to bring together views on instrumentation and quality from manufacturer to end user.

The first paper was given by M S Shipton of the NAMAS executive. It concerned the problems experienced during the process of accreditation by NAMAS of laboratories to the standards of ISO Guide 25 and EN 45001. These are being discussed in NAMAS prior to the preparation of a guidance document for existing and applicant acoustic testing laboratories. In particular the paper outlined the thinking of the working group preparing a guidance document covering the problem of obtaining full verification in cases where embedded software or complex equipment is involved

Susan Dowson from the National Physical Laboratory then took the audience through the problems of calibration and verification of sound level meters and calibrators, dis-

At the Civic Reception hosted by the Mayor of Salford cussing current international standards, their shortcomings and the work of a British Standards Institution working group set up to write the standard on 'periodic verification of sound level meters'. The result of their work, BS 7580, which was published in 1992 was discussed and the speaker also took a look into the future of sound level meter testing.

R Tyler of CEL Instruments outlined, from a manufacturer's point of view, the problems experienced with the verification of sound level meters to meet the requirements of BS 7580:1992 and suggested how instrument design could minimise the time and expense of the tests. In particular he advocated the provision of additional facilities so that the control of functions and settings could be obtained from a PC which simultaneously set the input signal and monitored the output during the execution of a verification programme.

I J Campbell, now with Cirrus Research plc, discussed the current moves towards legal metrology, the need for trained 'competent' technicians and for the independent verification of both instrumentation and results. He pointed out that current quality schemes such as those encompassed by ISO 9000 (BS 5750) essentially benefitted the manufacturer more than the end user.

The final paper in the session was given by D Fleming who put the user's point of view. He argued that a competent consultant used many methods to ensure that the overall quality of his measurement work remained high and maintained that when detailed calibration and verification procedures were being incorporated in measurement standards or legislation a flexible approach should be allowed so that in practice the methods adopted can be tailored to the requirements of the job in hand to avoid unnecessary wastage of time and effort.

Open session

A feature of the open session was the wide ranging and interesting topics that were covered. There were a total of eight papers presented in this session including two student papers. The first paper by S J Clampton of Vickers Shipbuilding & Engineering Ltd described a study showing how the methods to calculate acoustic absorption values had been developed and he explained that having confidence in the predicted compartment levels for new classes of submarines, an accurate selection of acoustic treatments can be made.

T Ward from the Health and Safety Executive described his work on the measurement of sound power of woodworking machines using sound intensity techniques. The work examined three case studies and aimed at assessing the accuracy and ease of use of the sound intensity technique as compared with a sound pressure level method based on ISO/DIS 230/5. He concluded that although the major advantages of using sound intensity over conventional methods include taking measurements in 'hostile' environments and the detection of localised areas of high noise levels, the method can be time consuming and has the limitation of requiring specialist equipment.

G W Burrows of Ferranti Components examined the topic of acoustics in aircraft sensing systems. He explained the applicability of acoustic technology to influence fuzes for fully autonomous weapon systems where a wide variety of microphone arrangements and signal processing techniques allow acoustics to fulfil all the appropriate system functions.

The topic area then changed to personal sound. A Asbury, a 3rd year student from Salford, presented a joint paper on work at Philips Research Laboratory, Eindhoven on the problem of multiple sound sources with multiple listeners. He described the work on increasing the sound to noise ratio at the listening position by using loudspeaker arrays with various directivity patterns and he gave a convincing audio presentation to the audience.

The fifth paper, from J Shelton of Acsoft Ltd gave an informed historical overview of acoustical instrumentation and new trends in instrument architecture. He examined the simple requirements of an acoustical measurement system in terms of basic building blocks and moved through to integrating the whole instrument onto computing architecture or 'virtual instrument'.

R D Wright of Alfred Peters plc changed the subject and dealt with the individual differences in response to noise and the identification of enhanced risk of hearing damage. Review research had uncovered identifying characteristics of those at risk which related to acoustic reflex and vasoconstriction reactions. These have been used in developing an instrument to carry out a screening procedure quickly and accurately.

M Greaves, a final year undergraduate automotive engineering student of Loughborough University, presented the results of an investigation into a small reverberant enclosure containing highly absorbent material. His study had identified an interesting double decay rate. Finally S Jain, a student from ISVR, Southampton described the Cranfield Trident Trial, a fascinating study into the use of voice recording systems in aircraft to locate and estimate the size of charges. The work arose from an investigation into whether the black box system in the Lockerbie bombing could be used to give information about the disaster.

All the participants are to be congratulated on their informative and high quality presentations.

Contributors: B F Berry, A N Burd, P Darlington, D C Hothersall, G Kerry, Y W Lam, N Porter, J W Tyler, P D Wheeler

Noise Control in Russia

• Collected Reviews on Principle Topics •

Price £30 from the Institute office

PREDICTION AND ASSESSMENT OF STRUCTURE BORNE NOISE FROM UNDERGROUND RAILWAYS

London, 10 January 1994

Introduction

A workshop format was chosen for this meeting in order to promote the exchange of ideas among members professionally involved in the subject without the constraints of contractual confidentiality or formal written papers.

The workshop was organised and chaired by Chris Manning of Arup Acoustics.

A series of short contributions were presented in the morning session by five invited speakers as a catalyst for the afternoon's debate. This format was clearly successful with a frank and lively exchange of ideas with contributions from more than half of the thirty-two attendees.

Contributions

Robert Peirce, Travers Morgan

Robert opened the debate on the question of assessment criteria for structure borne noise affecting residential properties. He queried the basis of the 40 dB(A) maximum noise level being promoted by many new underground railway projects.

He referred to work undertaken by London Transport but noted the small sample and that definitive conclusions could not be drawn. He felt that one problem was that the population used in such surveys was already exposed to structure borne noise from underground railways. He felt a different response might result from a population newly exposed to structure borne noise from a railway.

A group of London and Kent Authorities have proposed a criteria of 35 dB L_{Amax}. This is based on the US APTA guidelines which quote a range of 30–40 dB(A) depending on population density and area. The London and Kent Authorities' view is also that criteria being set now should be looking forward to appropriate standards for the twenty-first century.

Robert also referred to research carried out in Stockholm under test conditions where people were asked to adjust recorded train noise signatures until they were at an acceptable level. This gave an average level of approximately 30 dB(A) as acceptable.

On structure borne noise in commercial buildings he referred to the published work by Ridler. Here the view was that a frequency dependent increase over background (services) noise levels was a good approach.

Robert posed a number of questions relating to what constitutes an ideal standard and gave his views on the answers:

1: Should it be inaudible? – No, this was not practical.
2: Should it be the cheapest? – No.
3: Should it be at a reasonable level? – Depends on definition.
4: Should it be low enough to prevent significant disturbance? – Yes.
5: Should it prevent sleep disturbance? – Yes.

He concluded by offering an alternative criteria for discussion as follows: 'That the underground railway noise criterion should be the lowest of (a) the internal L_{A90} + 10 dB or (b) an absolute L_{Amax} of 35/40 dB.'

Tom Dawn, British Rail

Tom described the many factors controlling vibration generation and propagation as far as the tunnel wall. This vibration manifests itself as feelable vibration at low frequencies and noise at higher frequencies with a crossover around 30 Hz. He showed a slide of tunnel wall vibration spectra for tunnels at Stansted airport, London Heathrow Terminal 4 and Liverpool loop line. This indicated a broad peak centred on the 63 Hz band but with significant levels in the adjacent 31.5 Hz and 125 Hz bands.

He described the main factors affecting vibration generation as follows:

- Rail roughness: for a typical rapid transit speed of 64 km/h, railhead roughness wavelength bands in the range 140 mm to 560 mm give rise to the important frequency range noted above. Rail corrugation which is typically 50 mm and sleeper spacing of 650–700 mm are outside this range from 360 mm to 1410 mm. This now includes the normal rail support spacing and the effect of this needs to be considered.

There is a lack of measured roughness data in this wavelength range. Measurements taken for noise studies concentrate on wavelengths less than 178 mm while measurements for track quality which affect vehicle ride are generally at wavelengths greater than 1 m.

- Wheel roughness: the differences noted in the literature between disc braked and tread braked wheels, which are so important for noise, are at the shorter wavelengths and have not been shown to give different levels of structure borne vibration. Cases have been reported where lobes have been found around the circumference of the wheel. These can cause vibration in the re-radiated frequency range especially at higher train speeds.
- Vehicle design: force input is dependent on unsprung mass, suspension system (softer suspension less vibration) and axle load (an issue because the track is not uniformly stiff).
- Train speed: whilst there is a general recorded increase in vibration with increase in speed, it is not that simple due to coincidence of various resonant frequencies.
- Track design: ballasted track: wood or concrete sleepers in ~300 mm ballast: direct laid track (rail fastened to concrete slab, popular in tunnels where clearance is an issue): resilient track: between rail/sleeper, sleeper/support, base slab/tunnel invert.

For adjusting the track design

parameters a computer model is used which represents the track as a two dimensional, multiple layer, beam on a three dimensional half-space. This has been used to predict the improvement gained from the use of sleeper soffit pads in conventional concrete sleepered track, for example, in the tunnel under the Birmingham Convention Centre. A slide showed reasonable agreement between the predicted and measured result for this case.

There is currently interest in soft baseplate supports on concrete slab track and it is believed that even better agreement between the prediction and measurement would be achieved in this case because the resilient parameters are better defined. (Ballast parameters can vary considerably.)

Rupert Taylor, Rupert Taylor Ltd

Rupert described his numerical modelling approach to railway structure borne noise prediction.

He employs a basic set of equations (based on Cremer & Heckl) for beam and plate elements and the general field equation for solids. The equations are then solved by finite differencing.

He claimed that this method was valid for frequencies up to 250 Hz, the highest frequency of interest for structure borne noise.

Tunnels are modelled as a rolled up plate. The force input to the model is the rail roughness parameter described by Tom Dawn scaled to the frequency range of interest. It assumes the system behaves as a hertzian contact spring with the steel being compressed over a small contact area. He gave examples of the output of the model.

In considering propagation beyond the tunnel wall, he reported that the vibration levels were higher at the base of the tunnel wall compared to the sides and top.

Richard Greer, Ashdown Environmental Ltd

Richard started by noting that none of the popular descriptors – structure borne, ground borne or re-radiated noise were ideal. Firstly, the problem cannot be ascribed solely to the structure or the ground. Secondly, the noise is radiated for the first time

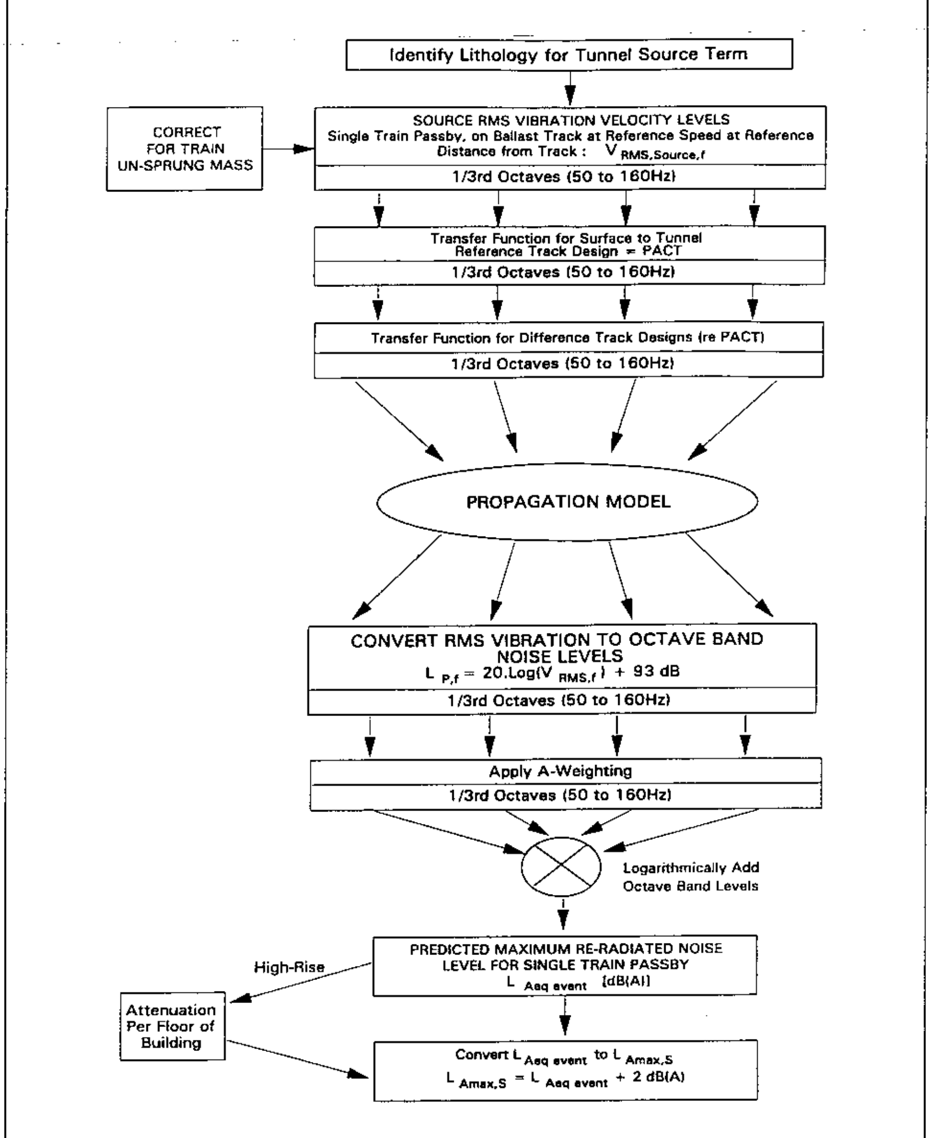


Fig. 1. Calculation of ground borne noise from tunnels

within the building and hence cannot be described as re-radiated.

He commented on the confusion with existing assessment criteria, noting that L_{Amax} could be 3 dB different if measured as fast or slow response. Furthermore, short period L_{eq} levels could be measured either over the pass-by period or over the event period (between 10 dB down points) which also led to different results. Therefore it was essential to have both numbers and indices clearly defined in any assessment criterion.

He presented a flow diagram, Figure 1, describing the ground borne noise calculation procedure that AEL had developed to assess the proposed high speed rail link between the Channel Tunnel and London and acknowledged the support of Union Railways Limited. The procedure was separated into three sections, the source, the propagation and the building response terms. For the high speed railway the source terms were based upon vibration velocity measurements measured at a reference distance from surface sections of ballasted track. The surface data were then converted to tunnel source terms using a transfer function derived from measurements at Stansted. These measurements additionally compared ballast and PAved Concrete Track (PACT) systems and showed that PACT resulted in more noise while the ballast track more vibration.

He also noted, like Rupert Taylor,

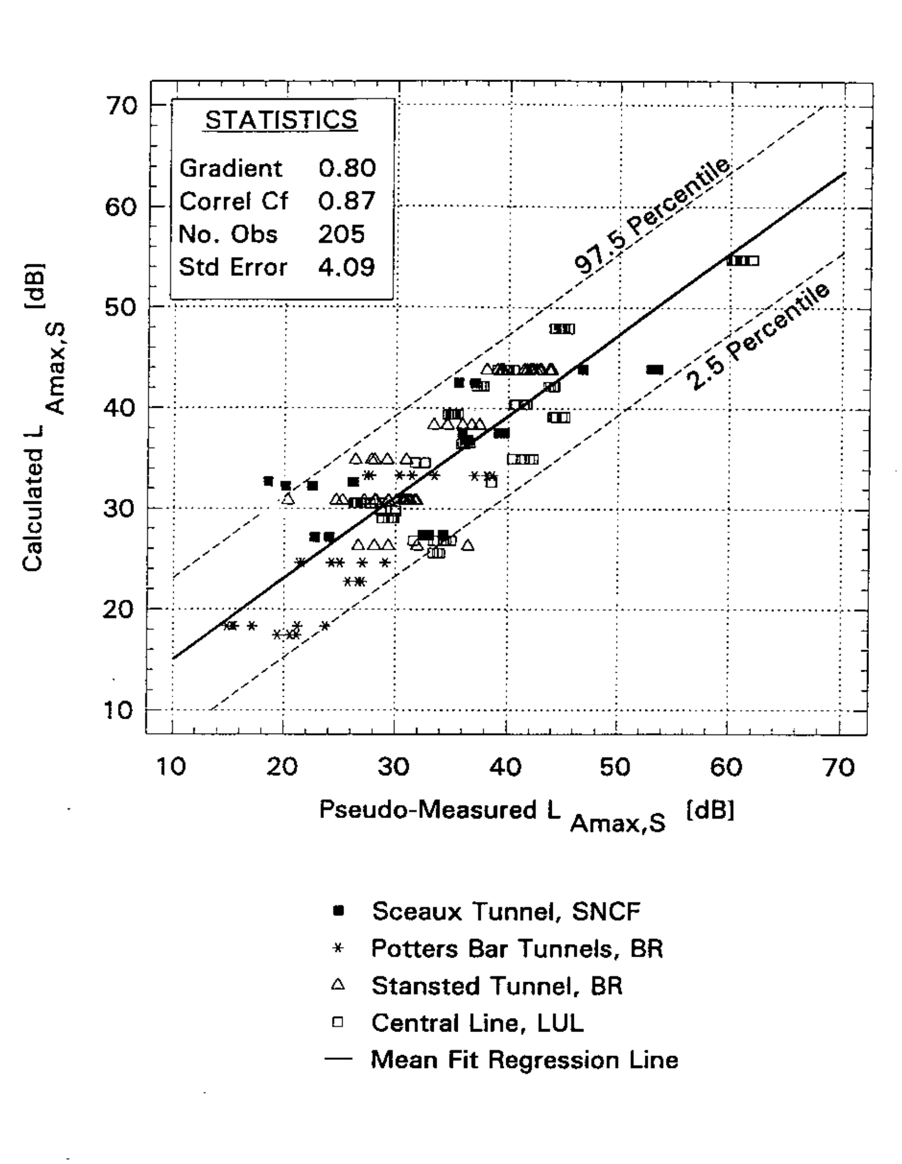


Fig. 2.Ground borne noise calculation procedure for tunnelled sections of railway

that the highest vibration possibly occurred at the bottom of the tunnel section. This, and other factors, meant that the highest vibration levels did not necessarily result immediately above the tunnel and he presented a propagation model based upon statistical analysis of measured data.

For the building response term he described a set of simultaneous noise and vibration measurements in fifteen buildings over the LUL Central Line. There was often a 3 to 6 dB(A) variation in noise levels within a room highlighting the need to also specify the measurement location within an assessment criterion. He presented a simple empirical model $L_{eq,f} = 20 \text{ Log } (V_{rms,\ pass\text{-}by,f}) + 93$ dB which could be applied to free field vertical vibration measurements outside a property, in $^1/_3$ octave bands of centre frequency f, to predict internal ground borne noise levels. The overall level was calculated by A-weighting and summing over the bands. The procedure was demonstrated to show very good agreement with measured levels.

The total ground borne noise model had been validated, Figure 2, by using measurements taken over the LUL Central Line and tunnels at Potters Bar (East Coast Main Line), Stansted and at Sceaux (TGV-A).

David Anderson, Arup Acoustics

David presented the results of a number of measurement studies with which Arup Acoustics had been involved.

For offices, he noted that Arup Acoustics use a criterion based on an excess over the background services noise rating criterion. For NR35 services level the acceptability criterion equates to 48/49 dB L_{Amax} (fast).

He described an empirical prediction method and tests on buildings to assess the various input parameters, with the following results:

- Measurements showed little reduction in vibration with transmission from ground to foundation piles.
- There were inconclusive results from a comparison of rafted and piled foundations.
- Predictions made using frequency dependent values of radiation efficiency did not correlate well with measurements.
- The use of maximum pass-by levels and fast response gave best subjective correlation on site.

He gave the following advice to those attempting to predict vibration propagation into buildings and resultant low frequency noise radiation (a) 'Coupling loss' factors from the literature should be used with caution; (b) At low frequencies (below audio range) vibration levels increase with storey height up to about 6 storeys; (c) Audio frequency vibration falls off at a rate of around 1dB per floor; (d) it is not necessary to use frequency dependent radiation efficiencies in prediction, σ_{rad} = 1 is adequate.

Discussion

The whole afternoon was spent in lively discussion guided by the sequence of the morning's contributions. Many questions were posed with no consensus answers. A brief summary of some of the key points is given below.

Criteria and Standards

The discussion covered units, measurement periods, times and locations.

John Walker, ISVR, reported that subjective tests gave best correlation with dB(B), PNC and loudness, whilst dB(A) showed poor correlation. Bridget Shield, South Bank University, reported that work on Docklands Light Railway gave best correlation with L_{max} linear. David Hunter, Hann Tucker Associates, felt that as both airborne and structure borne noise sounded similar inside a building it was best for practioners to stick to dB(A) until something else was proven.

Prediction

Victor Krylov, Nottingham Trent University, reported on his recent work on mathematical modelling of railway vibration. He concluded that longitudinal waves were negligible compared to shear waves for shallow tunnels and that there was little difference between spectrum shape for surface and underground trains.

In response to a question from David Malam, WS Atkins, he confirmed that his model has not yet been experimentally validated. Rupert Taylor had found to the contrary that longitudinal waves were dominant and not negligible.

In response to a question from Hugh Hunt, Cambridge University, Rupert Taylor confirmed that damping was also important, most models used viscous damping but in practice hysteretic damping was also important. Mike Westcott, Union Railways (Environmental) queried the validity of circular plate theory for concrete elemental tunnel linings which are not bolted together.

Colin McCulloch, Dynamic Engineering reported that he used a finite element prediction model. This requires high computational power but he believes it to be valid up to 125 Hz.

Vibration Control

Nick Marks, London Borough of Hackney, queried the lifespan of resilient mountings.

Mike Westcott reported that some natural rubber bearings had been taken out from the Barbican floating track slab after twenty years and tests confirmed no significant deterioration in performance. It was generally noted that baseplate systems required no more maintenance than conventional ballasted track.

David Fleming, Fleming and Barron, asked whether axle loads were important. Tom Dawn said this was not significant for track in good condition but did have an effect where track support varied. He also reported that freight trains had load-sensitive dampers which could lock up at low force levels, thus becoming effectively unsprung with increased vibration levels.

Victor Krylov said that at high axle loads there could be loss of contact between wheel and track with increased high frequency vibration generation. For underground trains axle loads were less than this critical load. David Malam reported 10 dB measured reduction from the use of sleeper soffit pads. Bridget Shield reported that rail grinding at Glasgow gave no significant benefit, but 8 dB reduction was achieved by installing pads.

Structural Response

Richard Greer asked whether sheathed piles were beneficial. David Anderson said they had been used at Birmingham International Convention Centre to protect against Rayleigh waves but actual benefit is difficult to quantify. In response to a question from David Fleming, David Anderson confirmed that vibration amplification at resonant floor modes in buildings did reduce after fit out when live loads were added.

Conclusions

The controversies that still abound over criteria, methods of assessment, measurement and prediction were clearly highlighted by the exchange of views from a well informed audience at this workshop. There is a clear message to the academic world that further research is needed in most of these areas. There is also a clear need for consistent guidance from central government or standards organisations. In the meantime, the issues have to be faced by consultants, engineers and planners who were all well represented at the workshop. Similar lively debates are therefore expected for some time to come.

C Manning

NOISE NUISANCE AND THE LAW

London, 19 May 94

Members of the London Branch and the newly formed Environmental Noise Group were happy to welcome delegates from all over the country to a one-day meeting at Church House Conference Centre, Westminster. The meeting was organised by Stephen Turner and Paul Freeborn of TBV Science.

There were over one hundred delegates with demand oustripping supply. The general discussion as delegates gathered was about the interest that had been generated by this one day meeting. It was felt that although so closely linked, *Noise* and *The Law* had not for some time, if at all, appeared together in a title.

The meeting, which was chaired by John Simson, opened with a scene-setting paper from a lawyer, Philip Barnes of Stephenson Harwood, describing the background to the current law. Apart from amusing our Scottish colleagues by suggesting that Section 58 was no more, he gave a meticulous talk (a written version of which has been published in the Bulletin). Of course, the opportunity of having a captive lawyer providing advice without the fee clock running proved irresistible and Philip fielded many questions.

The meeting did not overlook the 'no man's land' of codes of practice which straddle, some would say uneasily, the law and technology, and this subject was addressed by Nick Antonio of the Building Research Establishment. David Horrocks then gave a thought provoking paper looking at the interaction between planning powers and nuisance law.

Colin Cobbing of TBV Science (now with the London Borough of Hillingdon) concluded the morning session with an interestingly researched paper on the thorny question of when does nuisance arise from construction site noise.

Having commenced the day with

a lawyer, it was appropriate that the afternoon session opened with a Barrister, Rosalind Malcolm, who presented a paper which had been jointly prepared with her University of Surrey colleague, Bob Chivers. It covered the practical aspects of prosecuting for noise nuisance and generated wide ranging questioning.

John Hinton of Birmingham City Council followed, describing in his usual entertaining way the idiosyncracies of some of the population of that City and how the unattended tape recording method his team employ is developing. He reported on a means by which residents could remotely start a tape recorder when a domestic noise situation arises. Just in case a complainant should wish to claim incorrectly that a recording had been made at night, an automatic date and time coding facility has been incorporated. A version of a recording unit now commercially available was to be seen at the exhibition which accompanied the meeting.

The day finished with not just a talk, but more of a performance from Ricky Burnett of Glasgow City Council. The heart of his paper, was the serious and possibly far reaching development in Scotland of the apparent need now for objective evidence to confirm nuisance. *(An item on the case in question has already been published in Acoustics Bulletin).*

By including perspectives from practitioners occupying both sides of the legal divide without ignoring the slightly different approaches embodied in English and Scottish Law, the meeting delegates enjoyed an informative and interesting exchange of ideas and experience.

The London Branch and the Environmental Noise Group committees would like to thank all the speakers for their contributions and the delegates for their energetic participation in the discussion.

In view of the interest in this subject area, the Institute's Meetings Committee is considering the possibility of holding repeat events in other parts of the country.

S Turner & J Simson

BRANCH MEETINGS

Eastern Branch

Over 25 members attended an evening meeting at Colchester Institute on 25 May 1994 and heard a talk by John Hustwick of Sound Research Laboratories about their low frequency (taken as below 261 Hz) noise survey carried out for the DoE.

The meeting heard that SRL had over 300 noise events reported to them by respondents who were mostly over 50 years old. Forty per cent of the events extended over a period of 5 years. The usual description of the noise was that similar to a diesel engine.

The report was reported to be currently under preparation and John was only able to give outline conclusions:

- The source of any particular problem is unlikely to be British Gas!
- Investigations established that in one or two cases the mains hum from electrical transformers was the source.
- It was important to respond sympathetically to sufferers and a protocol was established, which it is hoped will be made available for use by EHOs and others confronted by complaints.

T Metcalfe

London Branch

On 27 April, a meeting was held, for the first time, at Institute HQ, Agriculture House in St Albans. A near-capacity audience of 28 turned out for a presentation by John Sargent of the Building Research Establishment, on BRE's Noise Incidence Survey of England and Wales. The reason for conducting this survey was to provide information about the noise climate in England and Wales against which the effectiveness of national or future European noise legislation could be measured and to indicate priorities for noise control initiatives. John described the sampling techniques and measurement parameters used and reported the findings, comparing them with the results of an earlier survey by Transport and Road Research Laboratory in 1972, since which time there appears to have been little change in overall levels of road traffic noise. He found that 56% of the population have daytime levels which exceed World Health Organisation recommendations and observed also that life in the countryside is not as quiet as many might imagine.

Despite a rail strike, the London Evening Meeting on 22 June, hosted by North East Surrey College of Technology (NESCOT) in Epsom, was well-attended. An audience of 27 braved the traffic to hear Keith Attenborough of the Open University speak on the subject of Outdoor Sound Propagation. They were treated to an interesting talk and lively discussion on what has been a controversial and difficult topic for many years. Recent research reported at conferences held in the United States together with results from the ESDU/Rolls Royce tests at Hucknall demonstrated quite clearly the importance of ground effects, the nature of the terrain, vegetation and microclimate. Comparisons with the work of Parkin and Scholes during the mid-sixties was of particular interest to the 'oldies' present. Keith's work gives a good insight into the mechanisms which are at play and the effects of long distance propagation on the spectral characteristics of noise. Whilst it was generally accepted that new proposals by ISO represent a significant advance, the apparent discrepancies between experimental and field data must still be a cause for concern.

The 94/95 programme will see a new venue in Croydon added, courtesy of TBV Science. The committee members hope that this will give the opportunity for more members to become involved with the activities of the Branch. On 21 September at TBV Science, Great Guildford House, Great Guildford Street SE1, Mark Southwood of Union Railways will give a talk on the environmental impact of the Channel

Tunnel railway routes. The meeting will commence at 6.15 pm.

J Miller

North-west Branch

An evening meeting was held on 14 July at the premises of Messrs Vibronoise at Cheadle Hulme.

A small but intensely involved audience rejected the alternative attractions of a sweltering summer evening to hear a presentation by Ian Melling of that company on general issues surrounding the use of BS 6472 'Guide to Evaluation of Human Exposure to Vibration in Buildings 1 Hz to 80 Hz'.

The talk was enriched by many specific examples from Vibronoise's case book. During the discussion it became evident that there would be value in wider dissemination of practical experience in this developing field. The meeting agreed that the possibility of holding a workshop style meeting at national level was worth exploring.

The company provided welcome refreshments.

K Irish

Scottish Branch

A combined AGM and branch meeting was held on 14 June 1994 at Wimpey Asphalt's Hillwood Quarry at Ratho near Edinburgh.

Members were welcomed by quarry manager Robert McNaughton who spoke about how the company deals with noise and vibration problems associated with quarrying operations both with regard to health and safety of operatives and nuisance at the site perimeter and beyond. This was followed by a tour of the quarry to see site operations.

The AGM followed and Patrick Corbishley and Andy Watson were re-elected for another term, joining Ricky Burnett, Bill Frame, Bernadette McKell, Ron McLaughlin and John Nicol. Patrick Corbishley will be chairman for this term and Andy Watson and Ron McLaughlin will continue as hon. treasurer and hon. secretary respectively.

The first event will be an afternoon visit to Messrs Jetstream at Prestwick, probably in September.

R McLaughlin

South-west Branch

The South-west Branch continued its revival with a technical meeting at Messrs Nuaire, Caerphilly.

This commenced with a tour of the fan production area and the research and development department where the computer aided design facilities generated great interest.

Considerable time was then spent in the extensive fan testing laboratories which included a large reverberant chamber with a closed circuit duct system for full performance evaluation of a range of fan sizes. Proposals for acoustic induct testing were also discussed.

After a buffet, courtesy of Nuaire, there was a formal presentation by Tony Breen of the company on the current test methods.

This was followed by a broad ranging discussion on the complexities of the British Standards Committees led by Neil Jones of Nuaire.

N J Pittams ❖

University of Southampton

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19 - 23 September	23rd Advanced Course in Noise and Vibration
7 - 11 November	3rd International Course on Noise and Vibration from Rail Transport Systems
13 -15 December	Mechanical Vibration Measurement Techniques

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THE INSTITUTE'S EDUCATIONAL ACTIVITIES

Roy Lawrence FIOA

Introduction

Institute Council delegates to the Education Committee the task of advising it on all matters concerned with education in acoustics. In practice this means running the Institute's three national certification courses. The most important of these, and the longest established, is the Diploma in Acoustics and Noise Control. Most typically this involves a course of part-time study of one day per week lasting a year and candidates would probably have previously qualified to professional level in a field that has some relationship to acoustics.

The Certificate of Competence in Work Place Noise Assessment is for individuals with a responsibility for, or at least an interest in, assessing the risk to employees of occupational hearing loss. Courses of instruction last a total of five days.

The recently introduced Certificate of Competence in Environmental Noise Measurement is designed for anyone who may be required to make meaningful measurements of environmental noise without necessarily having an involvement in the subject of sufficient depth to justify taking the Diploma. The pattern follows closely that of the first certificate in that courses last for five days and there is an examination and practical test at the end.

Diploma in Acoustics and Noise Control

This was established in 1977 and the first examination was taken in June 1978. A major stimulus in the development of the course was the newly, or soon to be, enacted UK environmental noise legislation, and a realisation that a form of post-experience training was a fundamental necessity for those charged with enforcing the legislation.

To the late Dr R W B Stephens fell the major task of giving the Diploma its initial shape, a shape that has in its essence withstood the test of time. Alex Burd, currently Institute President, and Professors Frank Fahy and Peter Lord were also instrumental in establishing the general pattern of the qualification that has stood more or less unchanged to the present.

The award of this diploma satisfies the academic requirements for immediate election to the non-corporate grade of Associate Member and, after a qualifying period of acceptable experience, to the corporate grade of Member.

The status of the course rests heavily on two major features. The first embraces the dual concept of Accredited Centres and Institute Approved Tutors. Centres are accredited initially on the basis of adequate physical and staff resources comprising tutors with practitioner or research experience. Centres apply for re-accreditation on a five-yearly basis, the procedure for which may or may not involve an inspection visit.

The second aspect upon which the Institute places considerable store for quality control is the fact that the written examinations are set by the Institute and all candidates take the same papers irrespective of their mode of preparation.

The regulation of the course is the responsibility of the Education Committee which works through a Diploma Examination Board. This is chaired by the Chief Examiner, currently Dr John Bowsher FIOA, assisted by the Deputy Chief Examiner who is presently Jeff Charles FIOA of Bickerdike Allen Partners. The other examiners also sit on this Board.

The award of the Diploma currently requires that the candidate has

(i) undertaken a course of instruction that is acceptable for the purpose
(ii) achieved a satisfactory result in one three-hour paper on the General Principles of Acoustics and in two one-and-a-half hour papers on specialist topics
(iii) satisfactorily completed a project investigation
(iv) completed required course work which includes laboratory exercises

The individual elements may be satisfied at different sittings except that the award of a Pass grade in the General Principles of Acoustics paper requires that element (iv) has been satisfied in the same year or previously.

The specialist topics presently available are
Architectural and Building Acoustics
Law and Administration
Measurement
Noise Control Engineering
Sound Reproduction
Transportation Noise
Vibration Control

The project requirement has always been considered a central element of the whole exercise. In its ideal form it offers candidates an opportunity to benefit from the professional guidance of their tutor as they carry out a planned investigation into a topic that interests them. The intention has always been that the transfer of experience has been the paramount ingredient rather than, for example, the value of the results obtained through the exercise. Candidates are required to report their work in a properly structured manner following the usual conventions. It has long been evident that the form of personal development that is available in a well managed project exercise is something from which a large percentage of candidates could benefit.

In terms of the conduct of the course over the years it is encouraging that numerical support for the course has remained high as shown in Table 1. I think it is fair to say that the Diploma has gained over the years a reputation

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as a well-designed course enabling students to acquire a broad knowledge of the fundamentals of acoustics and noise control. Certainly there have been no reports reaching the Institute office that the Diploma is considered a qualification that is easy to acquire. The strongest element of demand for places on courses comes from the Local Authority Environmental Health domain and there is evidence that students are willing to travel considerable distances to avail themselves of the training on offer.

It would be ureal, however, to deny that there is concern about the future. Some of the teaching staff who were in at the foundation of the course and have been central to its stable development subsequently have retired and not been replaced as part of a pattern of cost-reduction methods in higher education establishments generally. The insistence that the course should only be taught by those who have well established practical experience leads inevitably to problems over continuing course provision. Some historically strong courses such as the one at Liverpool John Moores University, the former Liverpool Polytechnic, with a catchment area from Cumbria down to North Wales and Anglesey, have closed.

It has been clear for some time that the Institute has to take action on its own account if the role of the Diploma in bringing new blood into the field is to be preserved. It is helpful in this regard that for some time the Education Committee has involved itself in distance learning methods to broaden the availability of the course. Initially Dr Michael Latham, when he was on the staff at Cornwall College, arranged such a programme based on written material, audio tapes and tutorials. This was targeted on the south-west of England and proved successful in bringing the course to many who would not have been in a postion to travel to the College. Yet, mindful of the problems that would arise if alternative forms of study could undermine the viability of the taught courses, the Education Committee set down firm geographical limits to the Cornwall scheme.

1978	31
1979	35
1980	102
1981	77
1982	79
1983	110
1984	100
1985	103
1986	116
1987	93
1988	85
1989	127
1990	96
1991	144
1992	110
1993	133
Total	1541

Table 1. Number of Diplomas awarded each year

The Institute has also allowed students to undertake a programme based on the methodology, and some of the material, of the tutored video instruction package developed at Heriot-Watt University for their MSc programme. Costs to students were necessarily on the high side and support for this approach was restricted to a few students who had specific difficulties in attending a Centre on a weekly basis.

The increase in the areas of the country now being left without provision has led the Education Committee to extend these ideas by establishing a new tutored distance learning arrangement. This is based on written material with exercises produced by a team led by Dr John Goodchild MIOA who is at Liverpool University and distributed from the Institute office. Dr Goodchild also organises the two two-day laboratory schools which each student attends at the University of Liverpool. The question of protecting the viability of existing courses remains a particularly live issue and is addressed by requiring prospective students to show clear reason, such as distance or conditions of employment, why attendance on regular course is not a practical possibility.

Programmes commence in the April or October of each year in preparation for the same examinations sat by all students fourteen or nine months later respectively. Tutoring sessions, which normally involves the students meeting with an Approved Tutor are scheduled to last for three hours on a two-weekly basis.

Tuition costs for this mode per student are rather high at the present figure of £1200 payable over two years, but this figure reflects the substantial costs of the tutorial element. In reality this figure compares well with the expense to an organisation of releasing an employee for up to one day per week for an academic year. Students, or their employers, have also to meet the travelling and examination costs.

Whether this initiative will really compensate for the closure of courses is a question that must await the passage of time. The Education Committee is tasked to keep a close watch on developments.

Continuing with the theme of trends for the future, the Education Committee is concerned that changes coming about in employment contract conditions may be causing some teaching staff at the Centres to encounter difficulties in maintaining the degree of contact with individual students necessary for successful project work. A case of ever increasing strength appears to be emerging for exploring other formats, less expensive in staff time, through which the educational aims ascribed to the project may be realised.

Certificate of Competence in Work Place Noise Assessment

Whilst the establishment of the diploma could be said to have been a response to such environmental noise legislation as the 1974 Control of Pollution Act, this certificate emerged in 1989 to meet the training requirements, as perceived by the Institute, of the Noise at Work Regulations 1989.

The documentation circulating prior to the publication of the Regulations made reference in general terms to assessments of the risk of occupational hearing loss being undertaken by a competent person. This terminology caused the Education Committee to be concerned over the possibility of a variety of agencies, perhaps educational or commercial, setting up individual training courses – with or without certification – to create persons who could claim to be competent. The spectre of a variety of such training programmes coming into being and the possible

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chaos that could result if the validity of these processes were tested in court, caused the Committee to decide that it would be helpful to establish a Institute certificate programme. In taking this step it was considered that the Institute would be utilising the experienced educational and administative framework it already had in place. It was also held that the Institute's position as the leading body concerned with acoustics in the UK would assist the certificate in gaining solid recognition and wide acceptance from those in the health and safety domain who could reasonably be unfamiliar with the acoustics and noise control world.

Council backed this approach and the Education Committee worked, and continues to work, through an Advisory Committee which benefits from the experience of members from a wide variety of backgrounds. Under the chairmanship of Dr Bob Peters of NESCOT a format emerged that produced a programme that was both practical and of sufficient rigour to match the seriousness of the overall task, that of protecting employees' hearing.

The format involves the attendance of candidates for a five day course at an Accredited Centre where at least eighty per cent of the tuition is undertaken by Approved Tutors, following the ideas developed for regulating the Diploma. It was appreciated that the likely candidates for this training would be staff with some resposibility for health and safety, which could mean anyone from Managing Director, through Training and Safety Officers to workshop chargehands.

The general thrust of the programme is to provide candidates with a good degree of competence at undertaking a limited range of tasks. It is also designed to make it clear to the course participants where the boundaries to their acquired competence lie, and, by extension, when and how to call for professional help. This last comment is clearly very much concerned with the degree of familiarity expected with the techniques of noise control engineering.

A Certificate is awarded as an acknowledgement that a candidate has achieved the aims of the programme; in practice this means satisfying the following requirements
(i) Attendance on a course designed for the purpose
(ii) Passing a two and a half hour written examination set nationally by the Institute
(iii) Passing a practical test
The written test is designed to ascertain that the candidate has a good grasp of relatively straight-forward material and for this reason a high mark is sought. This is in contrast to the classical University degree examination where candidates attempt five questions from eight and pass with good answers to about two; but then this certificate is not exploring the candidate's potential for development over passing years. The practical test is usually in the form of a workplace simulation exercise and candidates have to report their findings in the correct manner.

To allow for an expected variability in demand for the programme, and for the various Centres' capacity to run a course from time to time, it was decided to offer the examination on three occasions per year, namely in February, May and October. Members of the Advisory Committee under the chairmanship of the Chief Examiner, who is currently David Bull FIOA of Colchester, examine the scripts and practical test reports to determine the pass list. To date the examination has been set on fifteen occasions and a total of 909 certificates have been awarded.

Folklore provides many horror stories of assessments that have been judged incompetent; indeed some could be considered grossly incompetent. It is only reasonable to assume that the Health and Safety Executive would wish to take steps to attract national publicity over legal action being taken against a company that has had an incompetent assessment carried out, *pour encourage les autres?* This thought, coupled with the fact that workers' hearing is being dealt with, keeps the Education Committee mindful of its particular responsibilites in this respect.

With regard to the initial question of removing the possibility of chaos as a plethora of certification processes descended upon the market, it does seem as though the Institute's action might well have been a timely one; there is not much sign at the moment of problems in that direction.

The reaction of a number of Institute members to the establishment of this certificate did lead to potential problems initially. It is wholly understandable that some members, perhaps with many years' experience in the consulting field, should have strong thoughts about the Institute providing tangible recognition of achievement to those wholly outside the field after a five day course. The Education Committee took the view, and was supported in this by Council, that it would be totally wrong and unhelpful to give each corporate member, for example, a similar certificate purely on the basis of membership grade. The solution to this potentially divisive issue, and one which if not perfect appears to work as well as can be expected, was to offer the opportunity to corporate members to attest to their own knowledge and experience in this field, this attestation to be supported by another corporate member (the reservations over the seriousnessness of the issues as set out above apply equally or perhaps more so here).

Certificate of Competence in Environmental Noise Measurement

For some time prior to the establishment of this second certificate in 1993, the Education Committee had been aware that some employees have an occasional involvement in environmental noise issues but not to an extent that would justify them taking the Institute's Diploma. Such persons would frequently need the ability to choose the correct instrument and use it in a proper way so as to make meaningful environmental noise measurements.

The fact that the first certificate proved to have a workable format encouraged the Education Committee to establish a similar certificate for this purpose. The design of the programme was the output of a working party chaired by Dr John Goodchild and it too was based on a nationally set written paper and a practical exercise.

The examination has been set on four occasions since

June 1993 and a total of 112 certificates have been awarded. The initial versions of the taught syllabus proved rather too demanding for a five day course and modifications have been made. Encouragingly, there is evidence that some certificate holders find their appetites whetted sufficiently to register for the Diploma.

Other Activities of the Education Committee

The Committee is not solely concerned with the conduct of the Diploma and the two certificates, although clearly these do occupy a lot of attention. The working party set up recently by Council to explore the issues surrounding Continuing Professional Development reports initially to the Education Committee and it is intended that details of the progress of the deliberations will be reported to the membership in future issues of the Bulletin.

The Committee is also giving consideration to the possibility of setting up similar certificate courses on aspects of building services noise. This is prompted by the knowledge that there are many who work in the air movement industry who, although their total commitment to acoustics as a whole is manifestly small, do have the task of presenting or appreciating a limited range of noise data; experience shows that the proportion of such people who are comfortable in that role is rather small.

Additional evidence of the Committee's wish to carry its influence beyond the immediate confines of the membership is to be found in the Training Course for Sound System Engineers which may become a feature of the annual Reproduced Sound conferences. The first course was held in 1993 with 27 delegates attending and it is planned to restage it with some modifications this year.

Perhaps the most contentious issue, and one that has been inconclusively debated in past years is that of some form of Institute recognition of well-established acoustic consultants. The 1994 Institute Register again shows evidence of quite a number of members moving into the consultancy sphere. One can argue that having some accreditation process to aim for could lead to a significant raising of standards; alternatively consultants of considerable experience might see benefit in having that experience assessed and, if appropriate, recognised.

No one pretends that every proposal put forward is without controversy; at one time there was a suggestion of looking at the possibility that arrangements could be made for our members to take the Institute of Noise Control Engineering professional qualifying examination. It would have to be remembered of corse that our members act in a consultative capacity in fields other than noise and vibrtation. Information is being collected on how other countries approach the issue.

Dr R Lawrence FIOA is Chairman of the Institute's Education Committee.

Accredited Centres, June 1994

Amber Acoustics, (C)
Contact Mrs G Williams, PO Box 305, Derby DE1 9ZZ: Tel 0332 799875

Caledonian University (C)
Contact Mr L Mair MIOA, Cowcaddens Road, Glasgow, G4 0BA: Tel 041 331 3000

Colchester Institute(C) (D) (E)
Contact Mr D Bull FIOA, School of Engineering Technology, Sheepen Road, Colchester, Essex CO3 3LL: Tel 0206 718632

Heriot Watt University (D)
Contact Dr D Mackenzie MIOA, Dept of Building Engineering & Surveying, Riccarton, Edinburgh EH14 4AS: Tel 031 449 5111

Loughborough University (C)
Contact Dr D Wenham, Centre for Extension Studies, Ashby Road, Loughborough LE11 3TU: Tel 0509 222159

North East Surrey College of Technology (NESCOT) (C) (D) (E)
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Robert Gordon University, Aberdeen (C)
Contact Miss C M Walker, School of Applied Sciences, St Andrews Street, Aberdeen AB1 1HC: Tel 0224 262000

Salford University (C)
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(C) = Certificate of Competence in Workplace Noise Assessment: (D) = Diploma: (E) = Certificate of Competence in Environmental Noise Measurement

MEDALS AND AWARDS

The Institute of Acoustics annually honours people whose contributions to acoustics have been particularly noteworthy. Nominations are sought for the 1995 Rayleigh Medal (this has to be a non-UK acoustician) and the Simon Alport Prize. Suggestions are also invited for Honorary Fellowships. Members should write in confidence to the President via the Institute office. Details of the Awards are given below.

Rayleigh Medal
John William Strutt, Third Baron Rayleigh (1842-1919) is remembered as a most versatile physicist, both as an experimentalist and as a theoretician.
A graduate, fellow and finally Chancellor of Cambridge University, he was early elected to Fellowship of the Royal Society of which he was President from 1905 to 1908. He received the Nobel Prize for physics in 1904.
Rayleigh's work covered practically every branch of physics and he was the co-discoverer of the rare gas argon. In acoustics, he published over 100 articles and his book The Theory of Sound remains a land mark in the development of the subject.
The Rayleigh Medal, of gold-plated silver and bearing the portrait of Lord Rayleigh, is awarded without regard to age to persons of undoubted renown for outstanding contributions to acoustics.
The award is normally made to a United Kingdom acoustician in even numbered years.
The Institute is pleased to have honoured these acousticians with the Rayleigh Medal:
P H Parkin UK 1975
L M Brekhovskikh USSR 1977
E G S Paige UK 1978
E A G Shaw Canada 1979
P E Doak UK 1980
K U Ingard USA/Sweden 1981
G B Warburton UK 1982
E J Skudrzyk USA/Austria 1983
J E Ffowcs-Williams UK 1984
P J Westervelt USA 1985
E J Richards UK 1986
M R Schroeder Germany 1987
D G Crighton UK 1988
H E von Gierke USA 1989
F J Fahy UK 1990
M Heckl Germany 1991
Sir James Lighthill UK 1992
M Bruneau France 1993
E F Evans UK 1994

Tyndall Medal
John Tyndall (1820-1893) was active in acoustics before Rayleigh, and indeed Rayleigh actually succeeded Tyndall as Professor of Natural Philosophy at the Royal Institute.
Born in County Carlow, Ireland, he studied chemistry, physics and mathematics at Marburg University (under Bunsen) and was elected a Fellow of the Royal Society in 1852. Later he investigated the acoustic properties of the atmosphere and his volume of lectures On Sound has been reprinted many times.
Tyndall was a distinguished experimental physicist but is remembered primarily as one of the world's most brilliant scientific lecturers.
The Medal named after him, a silver-gilt medal, is awarded to a citizen of the UK, preferably under the age of 40, for achievement and services in the field of acoustics.
The following is the list of recipients:
M E Delany 1975
H G Leventhall 1978
R K Mackenzie 1980
F J Fahy 1982
R G White 1984
J G Charles 1986
M F E Barron 1988
N G Pace 1990
S J Elliott and P A Nelson1992
R K Moore 1994

A B Wood Medal
Albert Beaumont Wood was born in Yorkshire in 1890 and graduated from Manchester University in 1912.
In 1915 he became one of the first two research scientists to work for the Admiralty on anti-submarine problems and he later designed the first directional hydrophone for use in submarine detection.
He was well known for his many contributions to the science of underwater acoustics and for the help he gave to his younger colleagues.
The A B Wood Medal and Prize, instituted after his death and as a result of the generosity of his friends on both sides of the Atlantic, is aimed at younger researchers whose work is associated with the sea.
The silver medal, parchment scroll and cash prize were awarded from 1970, prior to the formation of the Institute of Acoustics, by the Institute of Physics. The award is made alternately to acousticians domiciled in the UK and in the USA/Canada.
Recipients of the A B Wood Medal are as follows:
P A Crowther UK 1976
P R Stepanishen USA 1977
A D Hawkins UK 1978
P H Rogers USA 1979
I Roebuck UK 1980
R C Spindel USA 1981
M J Buckingham UK 1982
P N Mikhalevsky USA 1983
M J Earwicker UK 1984
T K Stanton USA 1985
P D Thorne UK 1986
D Chapman Canada 1987
V F Humphrey UK 1988
M G Brown USA 1989
A P Dowling UK 1990
M B Porter USA 1991
C H Harrison UK 1992
M D Collins USA 1993

The Simon Alport Prize
This prize is awarded from time by the Institute to young acousticians for notable work in the field of computation applied to acoustics.
It was established, and donated, by Cirrus Research plc, for whom Simon Alport worked and who died at a tragically young age.
The prize of £250 is awarded to the person who, in the opinion of the judges, has published the best recent paper describing work that involves the application of computers to any branch of acoustics.

Honorary Fellowships
Honorary Fellowships are awarded to distinguished persons intimately connected with acoustics, or a science allied thereto, whom the Institute wishes to honour for exceptionally important services in connection therewith, and any distinguished person whom the Institute may desire to honour for service to the Institute or whose association therewith is of benefit to the Institute, shall be eligible to become Honorary Fellow of the Institute.
The total number of Honorary Fellows shall not exceed 2 per cent of the number of persons elected as Corporate Members of the Institute. Honorary Fellows are:
Sir J Lighthill UK 1978
W A Allen UK 1978
E J Richards UK 1978
C A Taylor UK 1985
Sir A B Pippard UK 1985
P V Bruel Denmark 1986
C M McKinney USA 1986
M E Delany UK 1989
P Lord UK 1992
B L Clarkson UK 1993
D W Robinson UK 1993
A Dove UK 1994
G H Vulkan UK 1994

VOL 11, SECTION 3, PART 7 OF THE DESIGN MANUAL FOR ROADS AND BRIDGES: AN EVALUATION

R G Owen MIOA

Introduction

As we are all too well aware the most ubiquitous noise source in the general environment is road traffic, indeed according to numerous social surveys road traffic noise appears to be the main source of noise disturbance. It is not surprising, therefore, that people's response to road traffic noise has been the subject of considerable research and investigation.

Much of this work was undertaken in the late sixties and early seventies and was primarily directed towards determining noise standards for planning and legislative purposes [1], confirming the suitability of the L_{A10} parameter as a traffic noise index [2], and the development of reliable traffic noise predictive procedures [3]. This is exemplified by the adoption of $L_{A10,18hr}$ for assessing eligibility under the Noise Insulation Regulations (NIR) [4] and the publication in 1975 of the Department of Transport's Technical Memorandum Calculation of Road Traffic Noise (CRTN) [5].

Since publication CRTN procedures have been extensively used not only in conjunction with the NIR, but also for more general applications such as land use planning [6] and environmental appraisal of road schemes. With regard to the latter, the previous DoT guidance on environmental assessment of road schemes was contained in the Manual of Environmental Appraisal (MEA) [7]. The manual, first published in 1983, predates EC Directive 337/85 [8] and has recently been superseded, to conform fully to the Directive and UK enacting legislative requirements [9], by Volume 11 of the Design Manual for Roads and Bridges (DMRB) [10]. The DMRB includes some major additions to the noise assessment method, and this paper briefly outlines the more significant changes and discusses some potential problems in its application.

Design Manual for Roads and Bridges 1993 (DMRB)

The DMRB provides detailed guidance on environmental assessment of trunk roads and motorways under twelve topics and follows a key stage procedure 1–3, of increasingly detailed assessments corresponding to pre-programmed planning requirements. The environmental assessment and planning stages are, therefore, iterative processes enabling appropriate decision making at each developmental stage of the scheme.

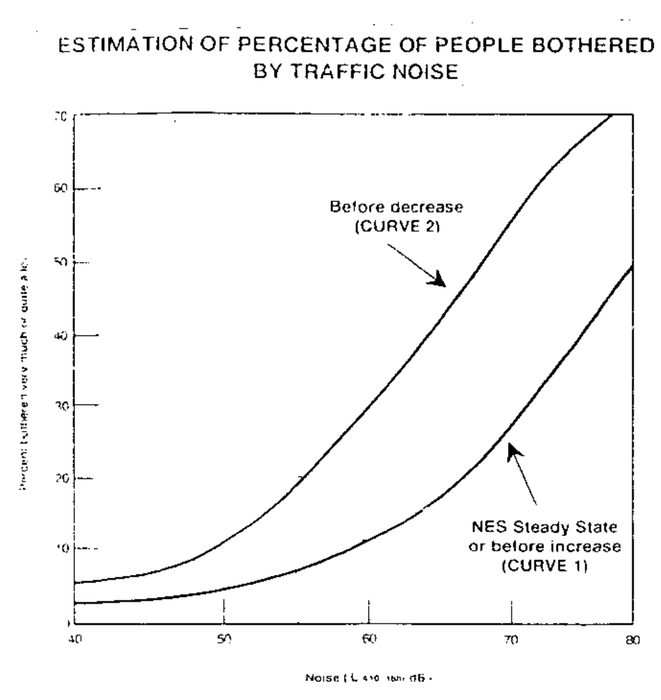
Section 3 Part 7 of the DMRB describes the methodology for evaluating the significant traffic noise and vibration impacts and contains several important changes and additions to those of the MEA. Some of the changes simply broaden the scope of the assessment and relate to the presentational format of data. However, a number of subtle revisions have been made which arguably change the nature of the assessment and which collectively may have far reaching consequences for future road scheme assessments.

In common with the MEA, the DMRB assessment procedures evaluate the noise and vibration impacts, in terms of the effects on people and, principally, occupiers of residential property. The assessment procedure involves classifying locations where existing traffic flow changes by ± 25%, (equivalent to a change in noise level of about ±1 dB(A), all else remaining equal), as a result of the proposed road scheme, according to their measured or predicted ambient noise level in 10 dB(A) categories ie <50 dB(A), 50–60 dB(A), 60–70 dB(A) and >70 dB(A).

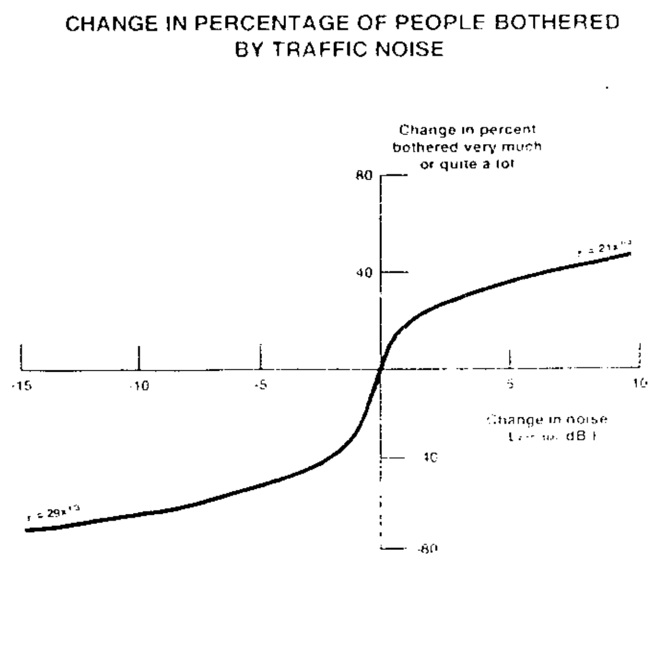
CRTN prediction procedures assuming worst case traffic flow conditions in the first 15 years after the scheme opens are used to determine post-scheme noise levels and the resulting noise changes expected at individual buildings are then quantified in bands ie 1–<3 dB(A), 3–5 dB (A), 5–10 dB(A), 10–15 dB(A) and >15 dB(A). Finally, the assessment requires that the number of properties subject to each designated noise change band be identified and assigned to each ambient noise category. Such a system facilitates the presentation of data in a tabular form thus allowing comparisons between various route options and future road network scenarios. These tabular presentations, termed Environmental Impact Tables (EITs), are an essential tool in road scheme assessment and are regarded as a vital component of the Environmental Statement (ES).

This emphasis on the provision of factual data was a feature of the MEA but it gave little guidance on how noise changes could be interpreted in terms of the human response. DMRB seeks to rectify this deficiency by correlating noise changes with a change in the 'percentage of people bothered by traffic noise', using 'steady state' and 'abrupt change' $L_{A10,18hr}$ noise models. The former was derived from the National Environmental Survey [11] and the latter from more recent research, by Baughan and Huddart, [12] which investigated responses to noise changes at fourteen sites in England, nine of which were subject to traffic decreases and five to traffic increases.

The methodology requires that long and short-term noise 'nuisance' effects be quantified utilising both models. 'Nuisance' in this context is assumed to be equivalent to the concept of bother or annoyance. Practically, the assessment method involves the use of DMRB Figure 2 to establish 'bother levels' prior to an increase (curve 1) and decrease (curve 2), and DMRB Figure 3 to establish short-



DMRB, Figure 2



DMRB, Figure 3

term bother levels as a result of an immediate change in the noise level. Long-term noise changes, in the design year, 15 years after opening, are derived from curve 1. The adoption of the abrupt change model, is an important departure and acknowledges the step-change nature of the noise impact arising from new road schemes. However, whilst accepting the need for an evaluation method, which recognises both noise changes and absolute level, the implication is that a 1 dB(A) abrupt rise in the $L_{A10,18hr}$ noise level, gives rise to a 20% change in the number of people deemed to be bothered by traffic noise regardless of ambient level. This is equivalent in steady-state terms to the percentage bother attributed to people subject to a noise level of 68 dB $L_{A10,18hr}$ ie the level which qualifies for eligibility under the NIR. This apparent anomaly is difficult to reconcile and will undoubtedly be viewed with a degree of scepticism by road scheme objectors, statutory consultees and Public Inquiry Inspectors. However, the main criticism of the use of the abrupt change noise model is that the model was derived from sites where existing traffic noise levels ranged from 65 to 78 dB and which were only subject to a 10 dB(A) change. This situation is hardly comparable with the nature of noise changes in rural settings subject to new roads where ambient levels from undefined sources could be as low as 35–40 dB(A), and where the intrusion of traffic noise would not only represent substantial increase in the $L_{A10,18hr}$ noise level but a change in the noise character of the existing environment. Furthermore, as Baughan and Huddart point out, the lack of data from noise increase sites where the maximum increase was 5 dB, means that the equation for abrupt noise increase should be treated with some caution.

Further modifications from the MEA are the procedures to categorise ambient noise environments into those dominated by traffic, those subject to undefined sources and those where noise from non-traffic noise is dominant. Where there is clearly no discernible traffic noise, DMRB suggests the possible use of L_{A90} as an ambient noise descriptor. However, the application of such a procedure will inevitably lead to higher estimates of 'nuisance' and hence the disbenefits of a road scheme and may weight the comparison against areas where traffic relief occurs. While such an approach has distinct advantages in evaluating the likely impact in rural localities characterised by non-traffic or distant traffic sources, it should be remembered that such noise climates are not exclusively rural and similar situations exist within residential areas ie the interior of housing estates, distant and screened from main roads, and only subject to sporadic traffic movements which may disproportionately affect the $L_{A10,18hr}$ level.

In addition to the changes in the methodology, the scope of the assessment has been increased. Archaeological and built-heritage sites, eg historic buildings may need to be assessed in addition to schools, hospitals and amenity areas, including footpaths etc. In rural areas many of these locations will be subject to a discernible (ie ± 1 dB) change even if located outside the road scheme corridor ie at a distance greater than 300 metres and hence beyond the validated range of the CRTN procedures. It is rather disappointing that the only advice provided is reference to the same TRL paper as occurred in the MEA, which itself gives only limited assistance. Intuitively, in such areas, the effective impact of a major road would probably be to change the L_{A90} level, although the effect on a day to day basis would depend on the local climatic conditions. Given the extent of road building over the past twenty years, it is unfortunate that the experience that must have been gained in that time has not been translated into more helpful advice in the Design Manual.

A further addition to the manual is the guidance on sleep disturbance. Unfortunately the advice is not particularly helpful and draws on aircraft noise studies. The Manual states that properties subject to future levels of 68 dB(A) where the weekday flows between 2200 and 0600 are 10% of the total should be identified. No instructions are given on the interpretation of these figures.

Unlike its predecessor the DMRB proposes an assessment of the vibration impact. The assessment procedure described relies solely on the evaluation of airborne induced vibration using the $L_{A10,18hr}$ index as an indicator of vibration 'nuisance'. The convenience of such an assessment is obvious. However, given the almost identical correlation between vibration and traffic noise nuisance, there must be doubts whether such an assessment is necessary unless the effects are cumulative.

Disruption due to construction is considered in Section 4 Para 3 of the design manual. Noise and vibration effects are specifically noted; however, no specific assessment procedures are given. The omission of guidance is somewhat disappointing since, in certain circumstances there are provisions for the sound insulation treatment of eligible buildings against construction noise in the Noise Insulation Regulations (NIR), and standard methods exist for the prediction of construction noise [13]. Furthermore, the assessment of vibration using the $L_{A10,18hr}$ model is not readily applicable to construction noise sources, and no guidance is given on the assessment of ground-borne vibration which could be problematic to property occupiers in close proximity to the scheme during the construction phase.

Mitigation of noise is dealt with in Section 2 Part 3 of the manual. Only general guidance is given, which is disappointing since there are a number of possible options to reduce the noise impact ranging from initial vertical and horizontal alignment of the road to the selection of quieter porous asphalt road surfacing, the choice of various types of noise fences and bunds and the relative merits of these when compared with contoured landscaping.

Conclusion

In retrospect it appears that the MEA, being based on a steady state noise change model and the $L_{A10,18hr}$ dose relationship was probably too simplistic and mainly applicable to urban areas. The DMRB is a far more substantial document and far more ambitious in the scope of the noise assessment. Relating the noise change to the prevailing ambient level is a welcome advance, as is the inclusion of a form of, albeit limited, vibration assessment. In terms of sleep disturbance and the impact of major roads on rural areas, though, the advice is very limited leaving much scope for interpretation regarding the significance of these impacts. It is also a pity that this document hasn't helped to bridge the gap between the draft PPG which proposes the $L_{Aeq,16}$ as the parameter for assessing the effect of road traffic noise on new housing and the $L_{A10,18hr}$ used to predict the level of road traffic noise.

Arguably, though, the greatest challenge for the practioners presenting the results of a DMRB assessment to the public is the paradox that now appears. In the past, it has generally been accepted that changes of up to 3 dB(A) can be described as 'not significant' or 'barely perceptible' and this interpretation is widely known and expected beyond the environmental noise profession. Now the DMRB is stating that a change of 1 dB is significant, in terms of the corresponding change in traffic flow, and that an increase of 1 dB would be expected to cause a 20% increase in nuisance, which many would interpret as significant.

Acknowledgement

The author wishes to thank his colleagues, Stephen Turner and Stephen Fisher, for their comments and assistance in preparing this article.

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Hansard

24 May 1994
Noise Regulations
Mr Soley: To ask the Secretary of State for Transport when he will publish the draft noise regulations for new railway lines.
Mr Freeman: Comments on the draft already issued for public consultation are currently being considered. Our aim is to present draft regulations to Parliament during the summer.

25 May 1994
Clay Target Shooting
Mr Chris Smith: To ask the Secretary of State for the Environment when he will publish the results of research by the Building Research Establishment on public response to noise from clay target shooting: what further research is planned on the subject: and whether he will now approve the draft code of practice on clay target shooting under the Control of Pollution Act 1974.
Mr Atkins: Preliminary studies on response to clay target shooting noise were carried out by the Building Research Establishment, but, having regard to competing research priorities and the likely outputs from the project, it has not been pursued.
I do, however, recognise that there is some concern about this issue. In July 1993 the Institution of Environmental Health Officers, the Clay Pigeon Shooting Association and the British Shooting Sports Council were asked to produce an agreed code of practice on this activity. It was made clear that if an agreed code could not be produced then the decision not to introduce further restrictions over clay target shooting under the general development order would be reconsidered. I understand that the organisations involved hope to reach agreement on such a code in the near future. It will be for these organisations to decide whether the code is subsequenty submitted for approval by the Secretary of State under section 71 of the Control of Pollution Act 1974.
Extracts provided by Rupert Taylor FIOA

Book Reviews

Underwater Electroacoustic Transducers
D Stansfield
Bath University Press and Institute of Acoustics, 1990.
ISBN 0 86197 082 9 and 1 873082 09 6
413 pp. Price £35

This is an excellent book. The author, Dennis Stansfield, has given us the benefit of his extensive experience as a transducer designer at the Admiralty Underwater Weapons Establishment at Portland, UK. Because of the interdisciplinary nature of transducer design, involving expertise in electrical, mechanical, and acoustical engineering, skilled practitioners of this craft are a rare breed, and those that write intelligently about it are rarer still. Those of us who have tried to practise and teach underwater acoustic transducer design principles owe a debt of gratitude to Dr Stansfield. Like a well-designed transducer, the book is optimised to fill a particular requirement, namely, the need for an authoritative, yet practical text on transducer design.

The book's main focus is on the piezoelectric ceramic tonpilz transducer, commonly used as a projector element in sonar arrays, as an illustration of design principles. The transducer is considered as part of a larger system whose performance is to be optimised. Thus the requirements placed on the projector driving-point impedance by the power amplifier are considered at length in a chapter entitled 'Bandwidth'. Here, the importance of the transducer coupling factor is made apparent when electrical filter theory is used to keep the transducer impedance variation within reason over the largest possible bandwidth so that maximum output power can be obtained from the amplifier-tuning network-projector system.

The theoretical treatment is based on the use of equivalent circuits especially the familiar Van Dyke equivalent circuit. In describing mechanical systems, the author prefers the mechanical impedance analogy to the mobility analogy, and so there is none of the confusion that has occurred in other textbooks where both approaches are presented. Similarly, the electrical behaviour is treated almost entirely from the admittance (rather than impedance) standpoint, again avoiding unnecessary duplication and gyrations in the mind of the reader. The admittance description is appropriate for the piezoelectric transducers to which most of the text is devoted. Magnetic transducers are only discussed briefly.

Practical considerations in designing, fabricating, and testing transducers are discussed throughout the book, but two chapters, *Practical Transducer Design*, and *Testing*, are devoted exclusively to helpful suggestions that are based on the author's experience. He advocates buying the piezoceramic material early so that it can be allowed to age while design and construction of the rest of the transducer proceed. He describes various practical pressure-release arrangements. In discussing seals, he points out that the allowable leak rates are comparable to those of a good vacuum system, so that similar quality control during fabrication is required.

The 'Hydrophones' chapter covers tonpilz, cylindrical, spherical, acceleration cancelling, and dipole configurations. Hydrophone and preamplifier noise sources are discussed and practical means for reducing them are suggested. Contrary to common practice, the pressure sensitivity, rather than the free field sensitivity, is used extensively in this test, perhaps to avoid the necessity of introducing the diffraction factor.

An extensive glossary of symbols is provided as an appendix. This is necessary because the author often does not use standard notation. For example, the single subscript, c, is sometimes used to refer to piezoceramic material properties. One cannot always tell from the context whether the constant in question is for open- or short-circuit conditions or whether a thickness or 33 (ie, extensional) drive situation obtains (Unfortunately the author usually refers to the latter as a 'thickness mode').

Aside from typographical errors, which are not terribly numerous, the book contains a few outright errors, most of which will be caught by the attentive reader and are therefore probably harmless. For example, the stress amplification factor for a sphere of radius, b, and wall thickness, t, is b/2t, not 2b/t, and the ratio of the sound speed of water to that of air is approximately 5, not 3. And there are a few occasions on which obscurity is introduced into the text, as happens in Sec 5-4, where undefined filter coefficients are used. Fortunately, they are intermediate quantities whose physical meaning is not essential to understanding the end result.

On the whole, however, one gets the impression that Dr Stansfield is an excellent teacher who knows his subject thoroughly and presents it in a carefully constructed manner that students will surely appreciate. The book is suitable for practising engineers, graduate students, and advanced undergraduates.

Mark B Moffett, Reproduced from JASA, 1787, 91(3), March 1992

Artificial Neural Networks for Speech & Vision
Edited by Richard J Mammone,
ISBN 0 412 54850 X
price £35.95
Chapman & Hall London, 1994

This book is one of very many current publications dealing with the highly popular field of artificial neural networks (ANNs). This particular work brings together recent significant research publications in one volume, each particular piece of work being dealt with in a separate chapter. The book is further organised into three parts – firstly that of general ANN theory, followed by two sections on the application of ANNs – the first one dealing with speech and language understanding, and the second with computer vision. It is clearly apparent that the book is intended as a reference for other researchers and academics in these two fields. The problem faced by any editor of such a collection is how to select from the huge diversity of published research that is available, such is the current interest in this area. Given this problem, the book provides a well filtered volume containing some of the most promising developments in ANN research and its application to speech and vision processing.

The content of the book expects that the reader has a prior basic knowledge not only of the applications that are dealt with, but also with the theory behind neural networks themselves. Therefore this book should not be viewed as an introduction for beginners, who may find it rather difficult to digest. Indeed the whole subject of ANN theory can be viewed as a very interesting history lesson as well as a current, highly demanding technical subject. It is interesting to note therefore that, in his preface, the editor declares that 'the book is intended for people who are interested in gaining a working knowledge of the care and feeding of modern neural networks'. The reviewers agree with this statement in that perhaps ANNs now have aged and matured into respectability but will continue to require care and attention for their successful application.

N Chen & S Lawson

Introduction to Elastic Wave Propagation by
A Bedford and D S Drumheller
ISBN 0 47193884 X
Price £34.95
Wiley, 1993

After presenting an extensive review of basic linear elasticity theory, this book deals with the propagation of waves through isotropic elastic materials. The mathematical methods required for solving steady-state and transient wave problems are developed and their use illustrated in numerous examples set as exercises with worked solutions. This format is a particularly useful feature of the book. In the final part wave propagation under non-linear conditions, as in shock waves and loading and release waves, is discussed.

Overall the book provides useful condensed accounts of several mathematical techniques (such as the method of characteristics, Laplace and Fourier transforms and methods with functions of a complex variable). Although any reader first encountering these techniques would want to consult one of the many available fuller treatments, it is of considerable value to see how the methods are brought to bear on this class of physical problem. Reference is made in the introduction to the wide range of possible applications in the fields of engineering, geology, materials research and medicine, but this is not taken up in the main text. This would seem to reduce the target readership of the book to those who already have a pressing need to resolve specific problems in this area.

M J Sangster

BRE Information Paper 6/95

Most environmental noise enters a building through windows which are not adequately sealed according to BRE Information Paper 6/95, 'The sound insulation provided by windows', which considers ways in which people in buildings can be better protected from external noise.

BRE studies have found that the sound insulation provided by similar types of windows varies considerably and the Paper describes experiments on a number of window elements, including the sealing of openable panes, the types of frame material, the size of the window panes, and their spacing in multiple systems. It identifies the main factors that affect sound insulation and lists the potential insulation values for various types of window.

The Paper's main conclusions and recommendations include: the sound insulation of windows is very dependent on the quality of the sealing; the material from the frame is made is not significant, providing that sealing is adequate; multiple panes improve insulation; several small frames perform slightly better than a single pane of similar area; and the use of an absorbent liner is beneficial at higher frequencies.

Copies of IP6/94 are available from the BRE Bookshop, Building Research Establishment, Garston, Watford WD2 7JR, Tel 0923 664444: Fax 0923 664400, price £3.50 (plus 35p p&p).

J Sargent ❖

Contributions

Engineering Council

A message from Sir John Fairclough, FEng headed 'Unification of the Engineering Profession - Stage II' dated April 1994.

'I am pleased to report that we have made significant progress in the three months since my last update on Stage II of the unification study.

The Stage II Policy Group has reached broad agreement on an outline structure for the New Relationship between a New Engineering Council and the engineering Institutions. This will take the form of a single corporate entity (the New Engineering Council) and Boards for Engineers' Registration and the Engineering Profession.

Under the outline structure, The New Engineering Council would be responsible for leading, initiating when necessary, and agreeing overall policy for the engineering profession... It would operate principally through two Boards to which clear delegated powers would be given.

The Board for Engineering Regulation (BER) would set, review and monitor education and training standards for formation and continuing professional development and maintain a register of appropriately qualified engineers and technicians.

The Board for the Engineering Profession (BEP) would initiate and facilitate activities to provide a focus for engineering affairs on matters that have an inter-institution dimension. It would be empowered to respond to those issues on which the profession needs to have 'a single voice' or a co-ordinated approach and would establish a process that draws on the skills and knowledge from the member institutions, arrange appropriate consultation, and establish appropriate action.

The Chairmen of the Boards would be accountable to the New Engineering Council... I believe that we now have a basic framework on which we can build the New Relationship. The devil, as always, is in the detail, and it is the detail with which the New Relationship Working Group is now getting to grips...

The Statutory Powers Working Group is also making good progress. A series of meetings with outside bodies, including the Health and Safety Executive and employers' organisations, is being arranged to gauge their reaction to the Group's initial thoughts on the need or otherwise for new legislation to regulate the profession... I believe that we must listen carefully to the views of others before we make that decision.

The Policy Group remains committed to maintaining a tight timescale with the aim of publishing proposals for the New Relationship by the Autumn.'

Clay Pigeon Shooting

Perth and Kinross District Council Notes of Guidance and Code of Practice

Having experienced problems with noise from clay pigeon shooting sites within its area, and in view of unsatisfactory existing guidance and standards to control noise from this activity, Perth and Kinross District Council, Environmental Health Department and Planning Department elected in 1991 to prepare a Code of Practice and Notes of Guidance to control clay pigeon shooting developments in its area, particularly in relation to noise emissions.

The CoP contains the following information:

- details of legal controls in relation to Planning and Environmental Health
- guidance to persons wishing to make applications for planning permission to establish clay pigeon shooting sites
- factors to be taken into account when considering whether there is a potential for noise disturbance from a clay pigeon shooting site
- practical noise control measures which can be taken
- a method for measuring and assessing a guideline noise rating for clay pigeon shooting noise
- other considerations such as health and safety and pollution of land and water.

Probably the most debatable item within this document is the guideline noise rating, which suggests a general maximum noise level for clay pigeon shooting of 55 dB(A) (impulse), from arithmetically averaging 25 gunshot reports at noise sensitive premises. However it must be stressed that this rating value is very much a guideline figure, and can be revised according to individual circumstances. It is interesting to note that a Scottish Office Reporter recently recommended this particular rating level as a satisfactory standard for a planning condition on a clay pigeon shooting site as part of her decision over a planning appeal.

Further information or copies of this document are available from Keith McNamara, Senior Environmental Health Officer, Perth and Kinross District Council, 2 High Street, Perth PH1 5PH (Tel: 0738 39911). The Notes of Guidance and Code of Practice are available at a cost of £6.00, including post and packing.

Sunday Trading: Controlling Early Sunday Morning Deliveries

The Government brought forward an amendment at Report Stage, having listened to the arguments put forward at Committee Stage by Joan Ruddock, M.P. for Deptford. The amendment was based on advice from a number of AMA authorities.

The new clause will allow local authorities to adopt a schedule in their area controlling early morning deliveries. The schedule requires that there should be no loading or unloading of goods from a vehicle before 9.00 am on Sundays, unless the local authority has given consent.

Authorities were clear that they would like a specific power between exhortation and general statutory powers. The new clause and schedule bridge that gap.

Most large stores will be unaffected because they do not run adjacent to residential areas. It will add a significant preventative power to those other powers which can be used to control noise pollution.

Sir John Fairclough, Keith McNamara, J Clegg ❖

New Products

DIFA

Dynamic Signal Analyzers

For high speed dynamic signal acquisition and analysis on up to 32 channels, the Dynamic Signal Analyzers of the Difa DSA 200 series offer complete, cost effective solutions. With their built-in high-speed computer, the Dynamic Signal Analysers are complete and economic multi-channel FFT workstations.

The DSA 200 Series supports signal conditioning for accelerometers and microphones. Each channel includes analog and digital filtering, 16-bit data acquisition and user programmable signal generation. High speed digital signal processors provide real-time capabilities.

The DSA 200 models are complete systems for experimental structural analysis. The multi-channel systems reduce testing time to a minimum by measuring large numbers of FRF functions simultaneously. Modal analysis is handled conveniently by built-in third party Modal software packages.

Sound and acoustic engineers can easily measure the acoustic intensity vector. With a dynamic range in excess of 90 dB, these analyzers have the capability to handle the most sensitive measurements. Further dedicated acoustic functions include narrow-band spectral analysis and $^1/_3$ octave analysis, including A, B, and C weighting. Post-processing functions like articulation index and loudness support psycho-acoustic research.

For more information contact the Sales Support Department of Difa Measuring Systems BV in Breda, The Netherlands. Tel: +31(76) 710 144 or Fax: +31 (76) 711 953.

LARSON DAVIS LTD

A New Range of Sound Level Meters

Larson Davis announce a new range of sound level meters suitable for a multitude of applications. The instruments are all pocket sized and meet IEC 651 and IEC 804 either type 1 or type 2 depending on choice and have a dynamic range of 110 dB without range switching.

The two 700 series instruments are both configured to be used as personal noise dosemeters with 1 metre of microphone cable enabling the user to protect the instrument body by placing it in a sturdy leather case whilst the microphone is placed at the ear. The meter will then gather data providing user defined time histories of L_{eq} and L_{peak} values as well as Dose and Projected dose in units of Percentage daily dose and Pa^2Hr to both 90 dB(A) and 85 dB(A) criteria with one measurement. All collected data can be downloaded to a standard, commercially available printer or computer using one of the two computer programs.

For environmental noise monitoring applications, both the 700 series and the two type 1 instruments (800 series) are stated to provide superb measurement capabilities and when used with the optional weatherproof case and outdoor microphone, should give the user an ideal system for long term measurements. Additional data collected by the new instruments contains Interval values including L_{eq}, L_{max}, L_{min}, L_{peak} (weighted and unweighted), SEL, L_N's, Interval duration, and the Interval start time and date. The Models 720 and 820 also provide exceedance data including a time history of that data, and can be programmed to 'wake up' and begin operation at preset times.

For more information contact Alan Boyer on 0642 491565.

HARTNELL & ROSE LTD

SOUNDBREAKER

Hartnell & Rose Ltd have given details of a new acoustic barrier for ceiling voids, SOUNDBREAKER. Some currently available barriers require framing or other support, especially the plasterboard type. SOUNDBREAKER is designed to provide high acoustic insulation and to cut and seal easily around services penetrations.

Further information from E J Williams, Hartnell & Rose Ltd, 4 Lever House, Lever Street, Bolton BL3 6NY. Tel: 0204 380074 Fax: 0204 380957.

B&K played a part in the acoustic design of the new Aston Martin Lagonda DB7

News Items

Brüel & Kjær and Aston Martin Lagonda

Production of the Aston Martin DB7 began in April this year after two years of intensive design and development. Brüel and Kjær report that their Type 2145 Portable Real Time Analyser was used in achieving the interior noise targets and in preparing the vehicle for noise certification. The Aston Martin test and development manager said 'We decided to build our own noise evaluation capability rather than rely on test houses as we wanted to develop new expertise within the company. The 2145 makes all the facilities we need very easily accessible – for road noise testing it is simply a matter of plugging the equipment into the car's cigar lighter socket, fixing a tacho to the engine and you are ready to test'. B&K say that by providing both digital filter analysis and FFT analysis in a single portable instrument the 2145 offers all the acoustic measurement capability essential for a wide range of applications in component and vehicle acoustic engineering. The analyser is also suited, say B&K, to routine noise and vibration testing and trouble shooting of any rotating equipment.

Acoustic Research Laboratories Pty Ltd

Australian instrument manufacturer, Acoustic Research Laboratories, are currently seeking a suitably qualified representative to handle their range of noise and vibration loggers in the UK and Europe; see the advert in this issue for brief product information. Interested parties should respond by fax to Mr Ken Williams on IDD + 612 4840884.

Noise Control at BP Test Facility

IAC (Industrial Acoustics Company) have designed, manufactured and installed a variety of noise control measures in the Engine and Vehicle Test Facility, part of BP Oil's Technology Centre at Sunbury, Middlesex. The centre has eighteen separate engine test cells all capable of running engines at full power with consequent noise emission problems. The walls and ceilings of the test cells are lined with 100 mm thick galvanised steel modular acoustic panels from IAC's Noise-Foil range. High performance IAC double leaf Noise-Lock doors provide access for engines and test equipment. Two test cells have a cold start capability to – 20° C; IAC modified the design of its doors to incorporate special heat treated acoustic seals and furniture to combat freezing.

For more information contact Simon White, Director of Marketing, Industrial Acoustics Company, Walton House, Central Trading Estate, Staines, Middlesex TW18 4XB Tel: 0784 456251 Fax: 0784 463303.

New Oscar Duct Attenuator

Oscar Engineering Limited report the publication and availability of their new 4-page Duct Attenuator Technical Bulletin.

This bulletin contains complete acoustic and aerodynamic performance characteristics and a fully detailed construction specification for the broad range of duct attenuators produced by Oscar Engineering for building services applications. The Bulletin, number 2.005.01, is available from: Oscar Engineering Ltd, Four Brands Hatch Park, Fawkham, Kent, DA3 8PH Tel: 0474 873122.

Society of Environmental Engineers (SEE)

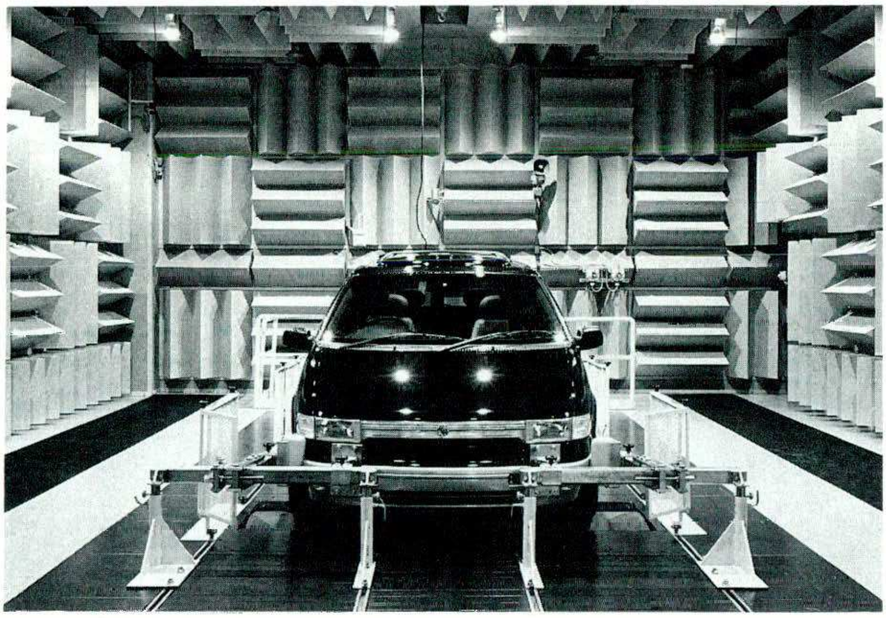
The SEE has announced a competition for the best journal article written by an SEE member under 25 years of age on any subject of direct relevance to the Society.

Interested persons should apply for an entry form to the Society of Environmental Engineers, Owles Hall, Owles Lane, Buntingford, Herts, SG9 9PL, Tel: 0763 271209, Fax: 0763 273255.

Closing date for entries is 30 September 1994. New members joining before the closing date will be eligible to compete.

Industrial Acoustics Company (IAC)

Industrial Acoustics Company, based at Staines, has completed what it believes to be the largest contract for ventilation duct silencers ever to be placed in the UK. It has manufactured and installed almost 1700 silencers – at an average rate of 70 per week – for the new Glaxo Medicines Research Centre currently nearing completion at Stevenage Herts. Over 40% were manufactured from stainless steel, as opposed to standard galvanised steel and because some were required for a sterile environment, IAC supplied a special version of its 'Cleanflow' silencer design. Half the silencers were required to meet unusually high levels of attenuation in the low frequencies, in particular the 63 and 125 octave bands. This was satisfied by supplying a special type of silencer – the 'LF Quiet Duct'– which makes use of impedance matching technology to increase low frquency noise control.



Anechoic test room built using the new Metadyne wedge

AC has also launched a new type of anechoic wedge, IAC Metadyne, which is claimed to have several major practical advantages over fibreglass or foam wedges. The new wedge is constructed from a shell of perforated steel containing a lightweight, but highly acoustically absorbant mineral fibre filling.

The company has published an 18 page guide to the design and construction of anechoic and semi-anechoic rooms which contains technical data and test results for the new Metadyne wedge.

For more information on the above products contact Simon White or Bryan Jaffrey of Industrial Acoustics Company (UK), Tel: 0784 456251, Fax: 0784.463303.

Larson Davis Ltd

As announced in the May/June issue Larson Davis Inc is the new owner of Industrial and Marine Acoustics Ltd, the Scarborough based UK agents of the Larsen Davis range of noise and vibration monitoring instrumentation.

The company has now provided more information about the change for the information of existing and potential customers. As part of a long term expansion project, Larson Davis Ltd will operate from its Redcar office.

The long established Scarborough office will continue to run as the Service and Calibration Centre and will be developed to accommodate the needs of all Larson Davis European agents.

This centre will be managed by David Marsh. The sales and marketing operation will continue to be managed from the Redcar office by Alan Boyer.

'This move' says Alan Boyer, 'enables us to develop our operation in the UK and increase the level of service and calibration support to our European agents and their customers'.

For more information please contact Alan Boyer at Sales and Marketing, Redcar Station Business Centre, Station Road, Redcar, Cleveland, TS10 2RD Tel: 0642 491565 Fax: 0642 490809

Ecophon Pilkington

Superior aesthetics, acoustic control and total moisture resistance were crucial factors, says Ecophon, in the decision by the Architects of South Glamorgan County Council's Property Services Department to specify Ecophon Pilkington ceilings for the £2.3 million Maindy Swimming Pool opened in Cardiff last year.

The pool area has an unusual and very attractive ceiling with Ecophon S-Line curved panels being used to form five coffers across the width of the pool.

Ecophon claim that one of the major benefits of all their products is their ability to combine effective acoustic control with total moisture resistance.

Manufactured from resin bonded glass wool the sound absorbing ceiling and wall panels help to eliminate the reflected sound which creates the characteristic echo of older swimming pool areas, increasing speech intelligibility and with it, the safety of bathers who are better able to hear warnings as well as to make themselves heard if in trouble.

For further information contact Geoff Billett at Ecophon Pilkington Ltd, Old Brick Kiln, Ramsdell, Basingstoke, Hants RG26 5PP Tel: 0256 850989 Fax: 0256 851550.

Ecophon Pilkington are Sponsor Members of the Institute.

The future management of DTI Laboratories

On 14 April 1994, Mr Michael Heseltine, the President of the Board of Trade announced his intentions to Parliament on the future of the DTI Laboratories following an extensive review by KPMG Peat Marwick on the prospects for privatisation or other ownership arrangements. The review included the National Physical Laboratory (NPL), the National Engineering Laboratory (NEL), and the Laboratory of the Government Chemist (LGC).

The intention is for NPL to remain in public ownership but with its management contracted out to the private sector during 1995. For each laboratory, Mr Heseltine commented that in the light of reductions in prospective workload, the laboratories feel the need to reduce and restructure their operations. On NPL, Mr Heseltine said 'Commercial progress under the management contractors will be carefully reviewed, and might in due course result in NPL becoming ready to move into private sector ownership'.

Mr Heseltine is also considering separately the future of the National Measurement Accreditation Service, which is part of NPL, and which the consultants felt should be viable on its own and could more appropriately operate independently of NPL.

For NEL, the recommendation which the President has accepted is that a trade purchaser should be found during the summer of 1995.

Heraklith UK Ltd

A new product catalogue is now available from Heraklith UK outlining their range of thermal insulation and noise control boards and panels. Heraklith UK is the new, wholly owned subsidiary of Heraklith of Austria.

No CFC's or HCFC's are used in the manufacturing processes of the artificial insulants and the natural wood fibre insulation products originate from managed woodlands.

The product range includes Heraklith's unique magnesite bound robust wood wool boards and panels for general construction and noise control applications, Heralan mineral wool boards for thermal and sound insulation and various laminated insulation boards for internal and external masonry wall insulation and the thermal insulation of metal clad industrial buildings.

Heraklith laminated boards have been developed to combine magnesite bound wood wool's unique surface attributes of good adhesion or sound absorption with the high thermal insulation properties of polystyrene, polyurethane and mineral fibre cores. Very high insulation values are now possible.

For further information contact James Muir at Broadway House, 21 Broadway, Maidenhead, Berkshire SL6 1JK Tel: 0628 784330 Fax: 0628 74788

The Editor
Acoustics Bulletin

Sir,
I am concerned that scientific units used in the ultrasonics industry are often misunderstood. Discussions at the recent 2nd Int. Underwater Acoustics Conference in Copenhagen have reinforced my view that there is a need for better standards. Roy Preston (NPL) has suggested that I air these misgivings in a letter to the Institute.

1. The difficulties with decibels

As a professional acoustician (MIOA) I use the decibel daily. Nevertheless, I believe that its merits for quick mental arithmetic are often outweighed by the dangers of misunderstandings. By the nature of this logarithmic scale, any errors then tend to be big ones.

This problem was epitomised in the plenary talk on July 6th by Walter Munk (University of California). He described the difficulties currently encountered by the ATOC research (Acoustic Thermometry of Ocean Climate). The quoted source levels of 195 dB have been misunderstood by the press to indicate a power of 250 Megawatt rather than the 250 watt reality. In hindsight, if the power had been quoted in watts, this serious problem may not have occurred. As it is, a large proportion of the public now believe that thousands of whales may be killed or deafened, whereas the use of 250 watts (peak) is very common (eg battery operated Sonardyne transponders). Military transducers emit kilowatts. There is a danger that this work, with its major contribution to our understanding of world ecology may be banned!

The difficulty lies in the need for a carefully defined reference unit, a need often not understood. A decibel can refer to ANY physical unit, and I frequently have to try to decode published information to try to ascertain not only the size of the reference level, but also the physical nature of the unit (eg pressure, power, intensity, source level). I believe that if the standards were set using linear units, this problem would be much reduced.

As pointed out in Copenhagen, the logarithmic decibel units originated in pre-calculator days. With a calculator and scientific units, multiplications and divisions are easy. It is then more important to keep the concepts simple and avoid logarithms if they are not necessary.

2. Pressure, source level, power and intensity

All of the above parameters can be measured with a hydrophone. When the hydrophone is small compared with a wavelength, it measures the acoustic pressure at a point. Several different reference units of pressure have been used (eg microPascal, microBar, dyne/cm ^{2}, 20 microPascal) [1].

I would prefer to use the SI unit, the Pascal, as a reference pressure for values quoted in decibels. I also feel that a linear value should be quoted where clarity is important. This would then encourage the distinction between rms pressure P and peak pressure to be made clear. The bel convention is the logarithm of the mean square pressure, with decibels one tenth of a bel, to give a pressure level

$$PL = 20 \log P = 10 \log p^2$$

The linear presentation can be either rms pressure, suitable for power or decibel calculation, or the peak pressure, suitable for stress calculations etc.

In a free field (no reverberation) a point source can be simply characterised by a source level SL. This depends on the measured pressure P and the range R

$$SL = 20 \log P + 20 \log R$$
$$= 10 \log (P^*R)^2$$

Decibel source levels as quoted are often ambiguous. A good sonar specification may quote 'dB referred to 1 microPascal at 1 metre'. Since this is so cumbersome, various abbreviations are used, such as the careless use of 'dB re 1 µPa', in which the range is assumed. Unfortunately, not all users assume the same range. This unit could be either a pressure level or a source level.

In contrast a linear SI unit could be Pa.m (Pascal.metres). This is unambiguous and succinct. Furthermore, the '195 dB' referred to above for the ATOC source now becomes 5623 Pa.m, an easily handled number! There remains a difficulty over the name of this value if 'level' is to be reserved for decibel units. I have failed so far to find a standard term, and have used 'source potency' to refer to this parameter, since 'source strength' has a different meaning.

3. Power

Source levels are related to power if the source is omnidirectional. The conversion is 170.8 dB re $(\mu Pa.m)^2/W$, the source level referred to 1 microPascal at 1 metre, generated by 1 watt, radiated omnidirectionally in seawater.

The linear equivalent is 120500 $(Pa.m)^2/W$. This value corresponds to seawater of density 1030 kg/m ^{3}, and speed of sound 1470 m/s, typical of cool medium depth water. It is directly generated by multiplying density by speed of sound to give specific acoustic impedance, and dividing by 4π.

The ATOC source is thus $5623^2/120500 = 262$ W. It is possible to refer to this as a power level of 24.2 dB re 1 W, but care must be taken to use the 10 log convention appropriate to a power value. I believe that the linear calculations are less prone to error.

4. Intensity and reverberation

The intensity, or power transmitted per unit area, is closely linked to pressure but is not normally quoted in dB. It is used for predictions of cavitation and other 'stress' related properties, such as tissue damage. For a known specific acoustic impedance, it is determined by P^2 when there is no reverberation.

With reverberation, an omnidirectional hydrophone will measure the total acoustic field, which can be considered as the sum of a direct field and a reverberant field. This is useful in an enclosed tank or chamber, but the units need careful consideration.

In many cases the reverberant field is effectively uniform over most of the chamber. In this case the measured pressure can be used to calculate the acoustic power being generated (and lost through the walls). This technique has proved valuable for the characterisation of underwater noise sources [2]. The separation of direct field from reverberant field can be achieved by a plot of P^2 against $1/R^2$, to give a straight line, where the gradient determines the noise power. The use of linear units is then essential.

5. Spectra, especially noise spectra
Frequency spectra give, in my experience, the most uncertainty. All of the units described above will usually vary with frequency, and it is often necessary to measure these spectra. Any measurements other than those in a narrow band (eg single frequency waves) must be quoted with a bandwidth, if the results are to be meaningful. This is often not done!

In linear terms the results can be divided by bandwidth B to give a spectrum value, provided the sources are uncorrelated so that energies can be added.

Thus, for example, a noise source spectrum can be quoted in $(Pa.m)^2/Hz$, if the actual measurement is corrected by dividing the square of the 'source potency' in Pa.m by the bandwidth of the measurement equipment.

This contrasts with frequent difficulties encountered when studying results on noise measurements. 'Spectrum level dB re 1μPa' may or may not refer to a 1Hz band, and may or may not refer to a source level at 1 metre.

Summary
Despite some serious if not exhaustive attempts to find an authoritative standard for ultrasonic measurements, I have failed to find all I need, and feel there is considerable scope for improvements.

The decibel terminology, whilst very valuable in many areas, also causes considerable confusion, in and out of the engineering discipline. I believe there are many areas where it is better to quote linear units. This is often more concise, and conveys a better understanding of the nature of the parameter being measured.

My prime motivation is to try to improve the understanding of these issues by other scientists, engineers and the intelligent lay-person.

References
[1] Principles of Underwater Sound, Urick R J, McGraw-Hill, 3rd Ed (1983).
[2] Controlling Noise to Improve Underwater Positioning, Hazelwood R A, IEE Colloquium Digest 1993/232 Dec 93.

Yours sincerely
Dr R A Hazelwood MIOA

The Editor
Acoustics Bulletin

Sir,
A meeting has recently been held of the British Standards Institute committee (RHE/6/1) concerned with the revision of the two parts of BS 4856 'Methods for testing and rating fan coil units, unit heaters and unit coolers' related to acoustic testing ie Part 4: 1978 'Acoustic performance; without additional ducting' and Part 5: 1979 'Acoustic performance; with ducting'.

It will be appreciated that these standards were developed before the introduction of the ISO 3740 / BS 4196 series of standards and therefore revision is long overdue. At the moment the committee is proposing combining these two parts of BS 4856 into one part which would be on the lines of ISO 5135 'Acoustics – Determination of sound power levels of noise from air terminal devices, air terminal units, dampers and valves by measurement in a reverberation room' (equivalent to BS 4773: Part 2: 1989) which is itself currently being revised.

If the standard is revised in this manner only sound power levels will be covered but some manufacturers of these devices habitually quote sound output only as sound pressure level at some specified position. This may be seen expressed as a dB(A) value, a full spectrum or a derivative such as an NR or NC value; some consultants actually prefer their data in this form. But such is the wider state of education on noise matters, that we are still not too surprised when manufacturers' data fails to specify the distance or the conditions of a sound pressure level measurement.

The committee is quite prepared to elaborate the standard (or to create a separate standard) that will cover the measurement and/or calculation of sound pressure levels, etc (possibly incorporating some of the ideas from the HEVAC document 'Real Room Acoustic Test Procedure') but only if it can be reasonably certain of sufficient interest from manufacturers, consultants, etc.

Considerable effort has already been made to ascertain this interest but at the moment the resounding response of real interest amounts to a total of precisely one manufacturer (who is on the committee) so as a last resort this letter is being sent to the Institute Bulletin with a request for anyone who has used these parts of BS 4856 to let the committee secretary know their feelings on these matters. The committee secretary is: Mr V G Edwards, Project Manager RHE/6, British Standards Institution, 2 Park Street, London W1A 2BS.

If no comments have been received by 30 September 1994 the committee will most likely assume that there is no requirement for anything other than sound power levels.

Your sincerely,
L F Moore FIOA

Environmental Assessment and Planning:
Consultation Draft Guide on the Preparation of Environmental Statements

The Institute has been asked to comment on the above document and the Environmental Noise Group Committee will draw up a response. Any member wishing to comment should do so in writing to the Institute office.

Members who would like a copy of the document should send a request with a cheque for £7.00 to cover photocopying charges to the Institute office.

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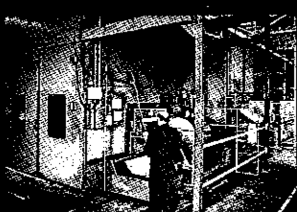

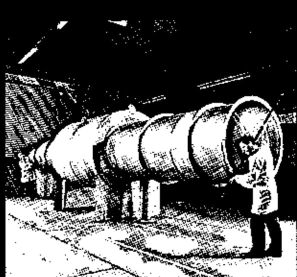

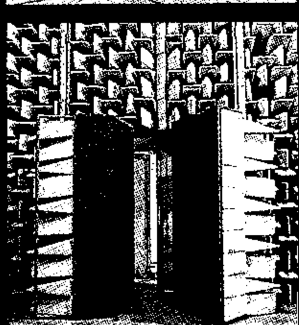

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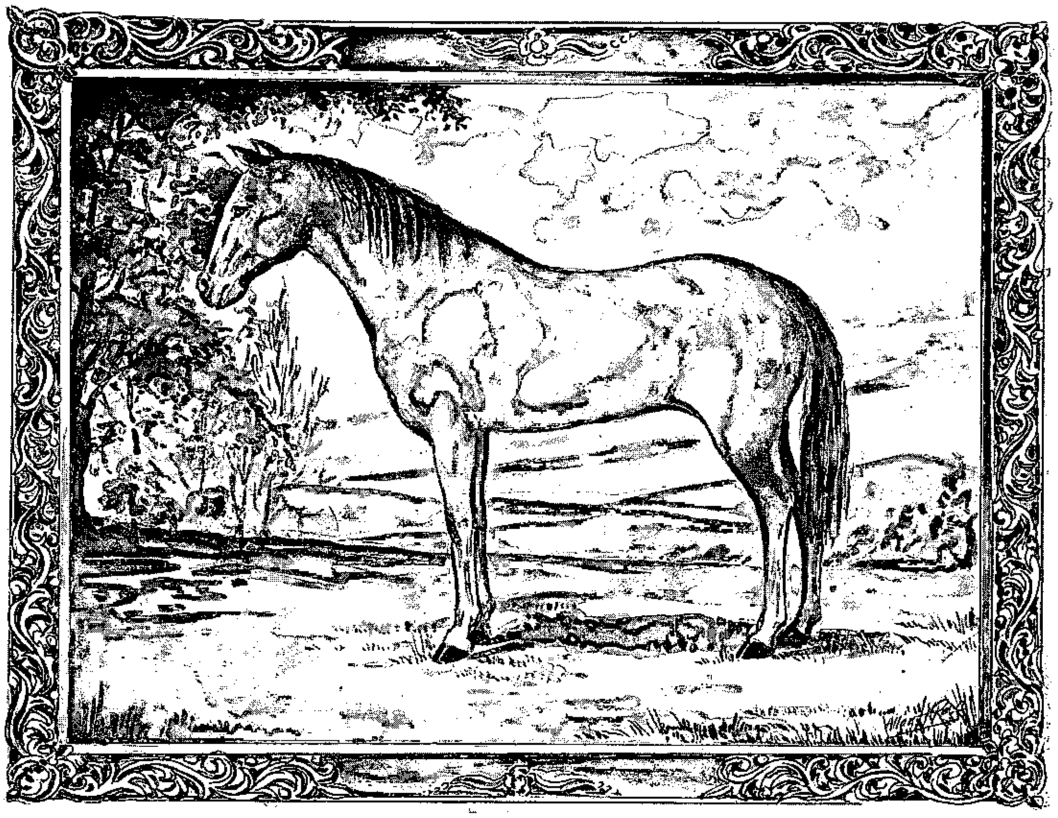
I am told by our sales force that some readers of this journal tell them that they have never heard of Larson*Davis noise and vibration instrumentation and they have asked me to look into the problem. I am a little puzzled as to what to do next as we take a full page of space in every IOA Bulletin and have done for some time now. We also exhibit at the major IOA seminars and conferences and advertise in many other journals and magazines.
So, just in case we need to change our approach to advertising I have decided to display a rather nice picture of a horse so that the next time you require noise and vibration instrumentation you'll remember the horse and hopefully Larson*Davis.



A RATHER NICE PICTURE OF A HORSE

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