Institute of Acoustics

acoustics BULLETIN

Volume 20 No 1
January - February 1995

acoustics BULLETIN

Volume 20 No 1
January - February 1995

Contributions and letters to:
The Editor, 11 Colwyn Close, Yateley, Camberley, Surrey GU17 7QH
Tel: 0252 871298

Books for review to:
A J Pretlove FIOA, Engineering Department, University of Reading, Whiteknights, Reading RG6 2AY

Information on new products to:
J W Sargent MIOA
Building Research Establishment
Garston, Watford WD2 7JR

Advertising:
Keith Rose FIOA
Brook Cottage, Royston Lane, Comberton, Cambs. CB3 7EE
Tel 01223 263800 Fax 01223 264827

Published and produced by:
The Institute of Acoustics, PO Box 320, St. Albans, Herts. AL1 1PZ
Tel 01727 848195 Fax 01727 850553

Production Editor:
R Lawrence FIOA
Oscar Faber Acoustics

Printed by:
Staples Press, Hatfield Road, St Albans

Single copy £8.00 Annual subscription (6 issues) £36.00

contents

The Institute of Acoustics was formed in 1974 through the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is the premier organisation in the United Kingdom concerned with acoustics. The present membership is in excess of two thousand and since 1977 it has been a fully professional Institute. The Institute has representation in many major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental, industrial and architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration. The Institute is a Registered Charity no. 267026.

Institute Council

Honorary Officers

President
A N Burd FIOA
(Sandy Brown Associates)

President Elect
B F Berry FIOA
(NPL)

Immediate Past President
Professor P D Wheeler FIOA
(University of Salford)

Hon Secretary
Dr D C Hothersall FIOA
(University of Bradford)

Hon Treasurer
G Kerry FIOA
(University of Salford)

Vice President
Dr R G Peters FIOA
(NESCOT)

Ordinary Members

S C Bennett FIOA
(International Mining Consultants)

K Broughton MIOA
(HSE)

J G Charles FIOA
(Bickerdike Allen Partners)

Dr R C Chivers FIOA
(University of Surrey)

Professor R J Craik FIOA
(Heriot Watt University)

Dr P F Dobbins MIOA
(BAeSEMA)

Dr L C Fothergill FIOA
(BRE)

Dr C A Hill FIOA
(Surrey County Council)

Professor P A Nelson MIOA
(ISVR)

A D Wallis MIOA
(Cirrus Research)

Secretary

C M Mackenzie

Institute Sponsor Members

Council of the Institute is pleased to acknowledge the valuable support of these organisations

Key Sponsors

Brüel & Kjær (UK) Ltd
Harrow, Middlesex

CEL Instruments Ltd
Hitchin, Herts

Cirrus Research plc
Hunmanby, N Yorks

Sponsoring Organisations

A Proctor Developments
Blairgowrie, Perthshire

Acoustic Air Technology
Weston Super Mare, Avon

Acoustic Consultancy Services
Glasgow

Sandy Brown Associates
London

Burgess – Manning
Ware, Herts

Cabot Safety
Stockport

Digisonix
London

Ecomax Acoustics
High Wycombe, Bucks

Ecophon Pilkington
Basingstoke, Hants

EMCO Acoustics
Hayes, Middlesex

Gracey & Associates
Chelveston, Northants

Hann Tucker Associates
Woking, Surrey

Industrial Acoustics
Company
Staines, Middx

Lafarge Plasterboard
Rainham, Essex

LMS UK
Somerset

Loughborough Sound
Images
Loughborough, Leics

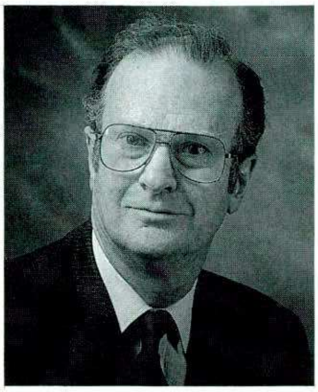
Mandoval Coatings Ltd
Nr Worksop, Notts

National Physical
Laboratory
Teddington, Middx

Oscar Faber Acoustics
St Albans, Herts

Salex Group
Colchester, Essex

Applications for Sponsor Membership of the Institute should be sent to the Institute office. Details of the benefits will be sent on request.



Dear Fellow Member

I write this on my return from the Opera and Concert Hall Acoustics conference at the Crest Hotel at Gatwick. It was truly a memorable event that I know was thoroughly enjoyed by the strongly international list of contributors and delegates. The next issue will carry a full account of the papers and the Saturday visit to Glyndebourne.

Reference has been made over recent months to the twenty-first anniversary of the formation of the Institute of Acoustics. 21 years old is probably a good time to look back over the period since inception and to note down some of the details for posterity - before the memories begin to fade. In fact, when the 21 years in question cover the later years of various individual lives, it may already prove to be too late!

Correspondence in the last few issues shows some of the uncertainties and, particularly, the interpretation of details and nomenclature in the history of the IOA and its antecedents. To be quite even handed about the current state of play, I am not convinced that any of the contributors agree completely with my own recollections!. Perhaps we should call a halt to the correspondence for the present and suggest that those who wish to contribute factual information or recollections should send them to the IOA office for collation.

As an interesting sideline I was fascinated to see among the R W B Stephens' archive presently being transferred from Dr Bob Chivers' garage to the Institute library the minutes of the first Acoustics Group meetings held during 1946. What other scraps of history, I wonder, will emerge from the depths of this formidable pile of papers?

Mention of the library leads me to one of the major changes now taking place in 5 Holywell Hill. The Institute recently took over two additional rooms in the building and the library has now been moved into more comfortable accommodation on the first floor. Indexing by our librarian is proceeding apace and already a useful reference library in acoustical literature is available to members. In due course a national archive of primarily acoustic material will be built up and the R W B Stephens collection represents the first substantial contribution. Members may wish to consider donating or bequeathing books and other material of particular interest to the Institute.

Having read about echolocation among the dolphins last August, I look forward to renewing my acquaintance with the world of bats in this issue. A comparison of the generation and processing of the echolocation signals on the two media and from the two species should prove instructive.

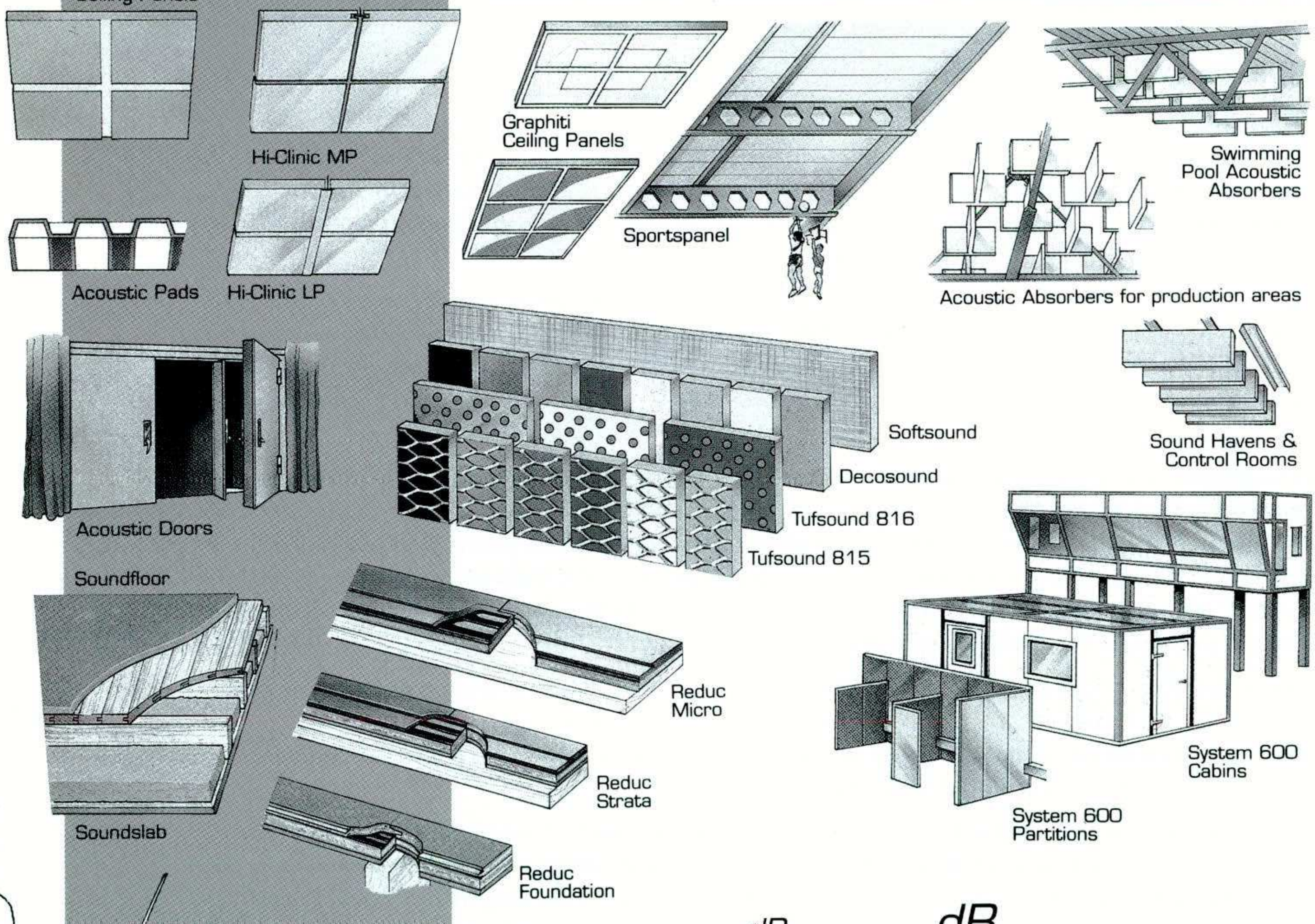
Sincerely yours

Alex Burd

Alex Burd

Architectural Acoustics
& NOISE CONTROL

A Symphony of Building products for calculated acoustics



dB dB

To avoid minor or major sound problems in your building,

treble the decibel absorption with Ecomax Acoustics products.

Our conductors will be pleased to provide a sound arrangement.

dB dB

For further information contact:

ECOMAX ACOUSTICS

Ecomax Acoustics Limited (Head Office)
Gomm Road, High Wycombe, Bucks HP13 7DJ
Fax: 01494 465274 Telephone: 01494 436345

ACOUSTICS AND ECHOLOCATION BY BATS

David Pye

Introduction

Bats are very varied animals and there is a remarkable diversity in the echolocation systems that they use to guide their nocturnal flight. There are nearly 1000 species currently divided into 19 families and they show a wide range of often specialised diets including fruit, nectar, insects, fish, small land vertebrates and the blood of larger ones. All this forms perhaps the most obvious reason for the diversity of bat echolocation: there are widely differing demands upon the systems and many alternative techniques are used in all aspects of their operation.

This is shown simply by the spectrum that is used. Even the insectivorous bats, which form the majority, tackle different kinds of insects in some strikingly contrasting ways, ranging from high speed chases at altitudes up to a thousand metres or more, to 'gleaning' for non-flying prey sitting on foliage and other solid surfaces. Now air attenuates high frequencies very severely as shown in Figure 1. So the fast flyers, needing to detect prey at some

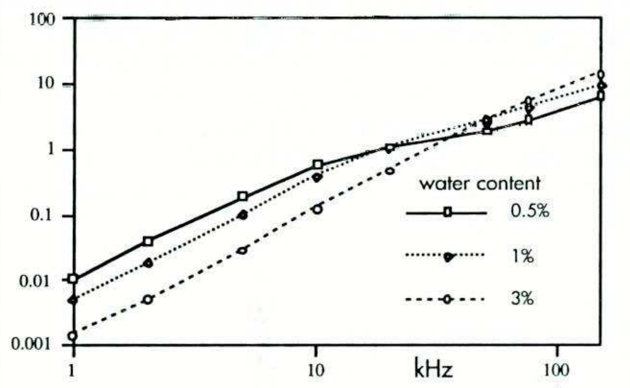


Fig. 1. Attenuation of ultrasound in air, shown as dB loss for echoes (round trip) per metre of target range, as a function of frequency. Mean slope is approximately proportional to frequency to the power 1.3. Additional losses of 12 dB per double distance are produced by the inverse fourth law for echoes.

distance, must use low frequencies, sometimes 10 kHz or less, and despite the long wavelengths they cannot have large ears because of aerodynamic drag. By contrast the gleaners fly slowly and hover when searching for prey atvery short range but against a complex reflective background. They can and do use high frequencies, commonly extending to over 150 kHz, with the consequent advantages of short wavelengths, while also having relatively enormous ears for both enhanced directionality and sensitivity.

The basic systems of bats, as defined by the nature of the signals used, fall into three broad categories: double impulses, broadband fm ranging and narrowband Doppler. These will be considered in turn.

Double Impulses

Most of the 175 or so species of Old World fruit bats, often called Megabats, do not use echolocation at all but rely on their superb night vision when flying. They are therefore obliged to roost in light places – on trees, cliffs or near the entrance of caves. There is one exception, however, in the small genus *Rousettus* whose members roost deep inside totally dark caves, presumably for the safety this provides. They find their way as they fly under these conditions by clicking their tongues sharply and repeatedly and responding to echoes. Each click, as heard by the human ear, is in fact a double impulse, as shown in Figure 2 and varies from a little under 20 ms to rather more than 30 ms in different species and regions.

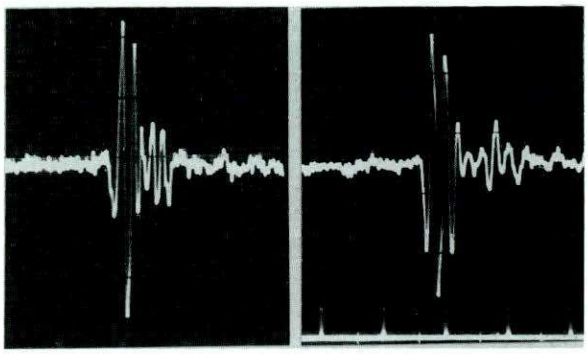


Fig. 2. Two impulses forming the click of a fruit bat Rousettus. The time marker shows intervals of 125 μs and the interval between the impulses has been reduced by 20 ms.

The clicks contain appreciable energy, determined by resonance of the mouth cavity, up to at least 50 – 60 kHz but there is some doubt about how much of this spectrum is actually used. The audiogram of one species, *R.aegyptiacus*, has been measured both by behavioural methods and from cochlear microphonic responses [1] and shows a sharp peak at 10 – 11 kHz. This is supported by studies of acoustic overload, which produces extensive damage to the cochlear hair cells at 10 kHz and none at all at 20 kHz or above. The ability of these bats to detect wire obstacles across their flight path also suggests that rather long wavelengths are used. But another species, *R.amplexicaudatus*, which emits virtually identical clicks, has been shown to have mid-brain responses that peak broadly at about 50 kHz as in several other species of small fruit bats. Clearly further comparative studies are needed.

It may be significant that most of the echolocating swiftlets that also roost in deep caves (some making birds-nest soup nests) also emit paired impulses with a very similar spacing, although their spectrum does not extend above 9 – 15 kHz. Paired ultrasonic clicks are also often produced by dolphins. Indeed even humans can easily produce click pairs with a fixed interval of about 25 ms by clicking the tongue with a downward action from the palate to the floor of the mouth – making a 'clock' sound. The frequency here is quite low and there is clearly no function in echolocation!

It is also worth noting that a few other specialised fruit bats are known to roost in deep caves but without emitting obvious audible or ultrasonic sounds. Their sensory abilities are still unknown but it is conceivable that they clap their wings together in flight when necessary. Curiously these particular species lack the sharp claw on the index finger that is present in all other Megabats but which could cause damage if the wings touched together.

Fm Ranging

Microbats, comprising all the other 18 families, are known to emit vocal ultrasound, generated by the larynx and often filtered to some extent by vocal tract resonance, for their echolocation. The majority use quite short pulses, one to a few milliseconds in duration, during cruising flight and generally the frequency is swept steeply downwards as shown in Figure 3 (overleaf). Bats such as *Myotis*, that are generally considered to be advanced in evolution, emit a single component, the fundamental, that sweeps down by an octave or more (Figure 3a). In other cases the sweep is less deep but bandwidth is extended by the inclusion of harmonics (Figures 3b – 3f). Vocal tract filtering may select some harmonics and reject the fundamental (Figures 3e and 3f), giving quite complex waveforms with both amplitude and phase changes.

All such signals should be well suited to measuring the time of echo returns and thus target range, for which radar theory demands wide bandwidth. This has been confirmed by behavioural experiments pioneered and largely developed by Simmons [2]. Originally bats were trained to fly or walk towards the nearer of two identical targets spaced well apart laterally. Their accuracy was around 1 cm for 75% success, closely matching the predictions for an 'ideal receiver' based on autocorrelation of the pulses they used for the task. Bats with strong harmonics in their calls showed some ambiguity over certain range differences, again as predicted from their autocorrelation functions.

Subsequently bats were trained to discriminate between 'virtual' targets that could be manipulated electronically. Their calls were picked up by a nearby microphone and replayed from two loudspeakers, thus simulating two targets halfway between the bat and each speaker. Small delays in either of the speaker channels allowed the apparent position of the virtual target to be varied. By a development of this technique, Simmons then investigated responses to target 'jitter', where either of the targets was subjected to a small delay only for alternate pulses so that it appeared to jump to and fro in range. Amazingly, bats were able to choose the jittering target from the 'stationary' one even when the jitter was as small as 10 – 40 ns, corresponding to only 2 – 7 μm in range. These findings have generated heated debate [3,4] but the matter remains unresolved. It seems impossible that ear and brain could achieve such fine discrimination but careful scrutiny of the experimental technique has failed to show any stimulus artifact that could make the bats' task easier, and the use of different methods for generating the delays has produced essentially similar results.

The frequency sweep is usually curved (Figure 3) and the shape is approximately hyperbolic, for plots of waveperiod (1/f) are usually almost linear. Such hyperbolic fm or linear period modulation has been shown to be 'Doppler tolerant' since cross-correlation between pulse and echo is not degraded by target velocity (review in [5]). While the Doppler effect changes the echo frequency, it also changes its duration, so the sweep keeps the same slope and remains parallel to that of the original pulse. The only mismatch occurs at the ends of the signals where amplitudes, and thus energy, are small anyway. An example of such Doppler tolerance for all practical velocities is shown by the correlation traces of Figure 4.

When fm bats are closing in on prey or negotiating

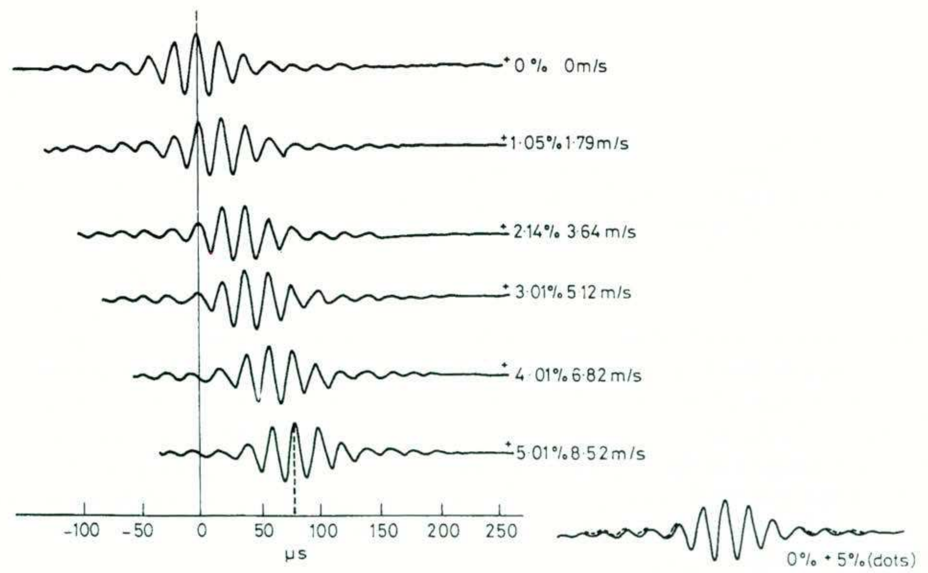


Fig. 4. Correlation traces of a 1.6 ms pure fundamental f.m. pulse from Myotis. Top is the autocorrelation, corresponding to the echo from a stationary point target; below are crosscorrelations simulating various degrees of Doppler shift. The inset superimposes the two extreme traces to show that no degradation is produced by a relative velocity of 8.5 m s^{-1}, about top speed for such a bat.

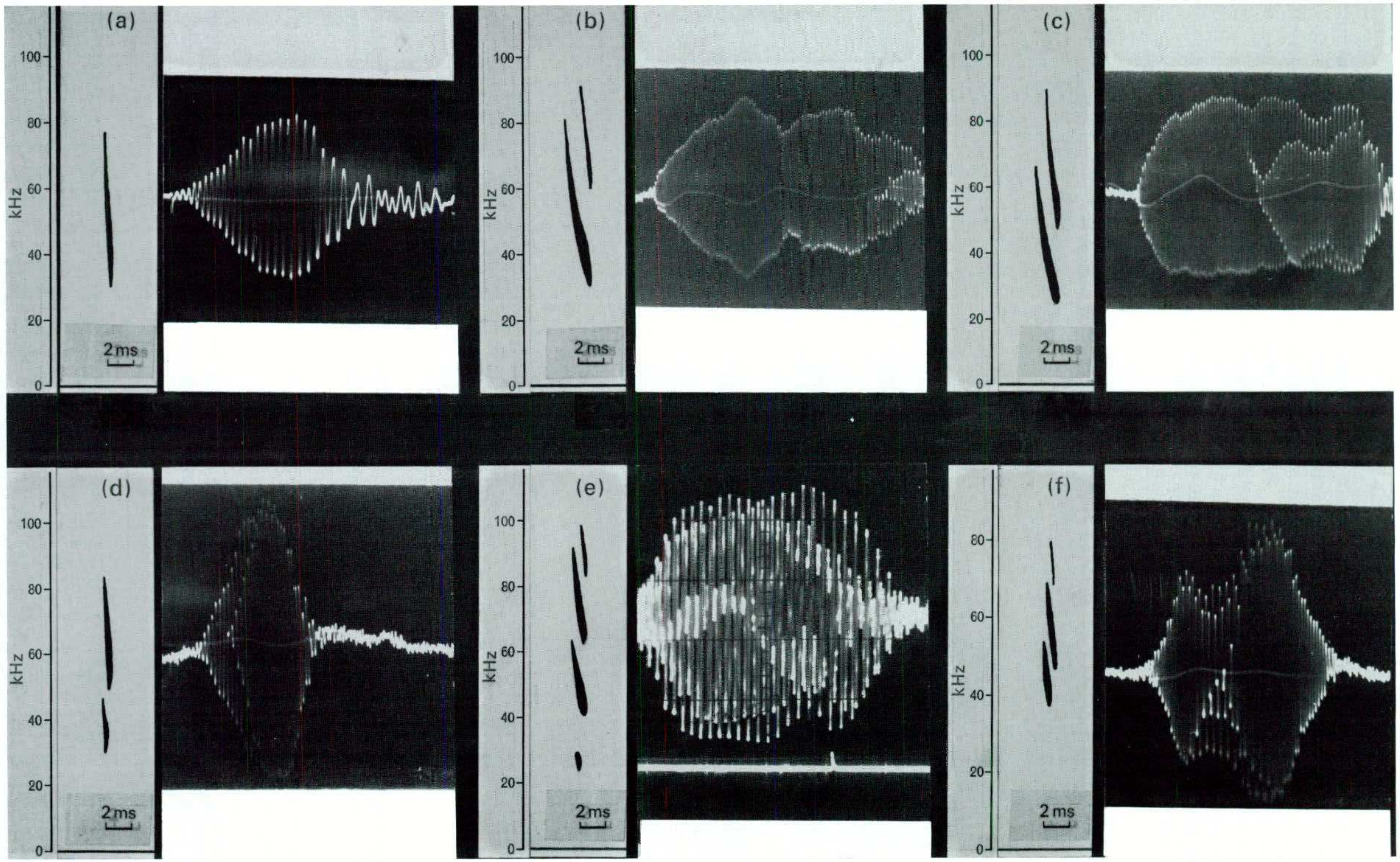
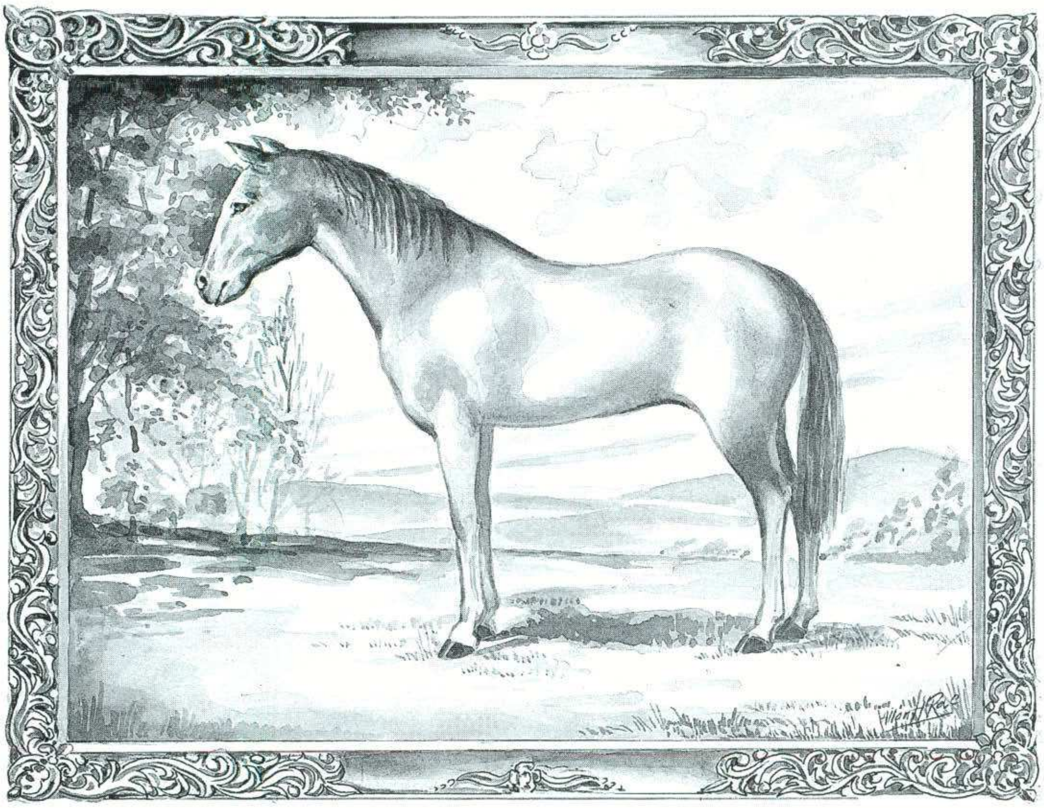


Fig. 3. Fm pulses produced by six different species of Microbats, showing increasing harmonic content and eventually suppression of the fundamental. Frequency plots are to the left of each waveform with all time bars 2 ms.
a. *Myotis nattereri*, b. *Myotis daubentoni*, c. *Nyctalus leisleri*, d. *Iecotus auritus*, e. *Cardioderma cor.*, f. *Desmodus rotundus*.



A RATHER NICE PICTURE OF A HORSE

obstacles their pulse repetition rate increases from 10 – 15 s^{-1} (synchronised with both breathing and wingbeat) of cruising flight to a brief burst at up to 150 – 200 s^{-1}. Pulse duration shortens to perhaps 0.25 ms and the frequency falls as the sweep is reduced. With a real-time detector, human ears cannot resolve such a sequence into separate pulses, leading to the name 'interception buzz' for the manoeuvre.

Narrowband Doppler

A minority of bats, all of them insectivorous by habit, emit much longer pulses of very narrow bandwidth as shown in Figure 5. The pulse duration may exceed 50 ms and the frequency is extremely constant except for a small downward sweep at the end, and sometimes an upward one at the start. Curiously, the single component is an almost pure second harmonic, with the fundamental and higher harmonics strongly suppressed by vocal tract resonances. During pursuit or avoidance manoeuvres some constant frequency (cf) element is retained so the pulses only shorten to about 10 ms, and rates can only rise to about 80 s^{-1}.

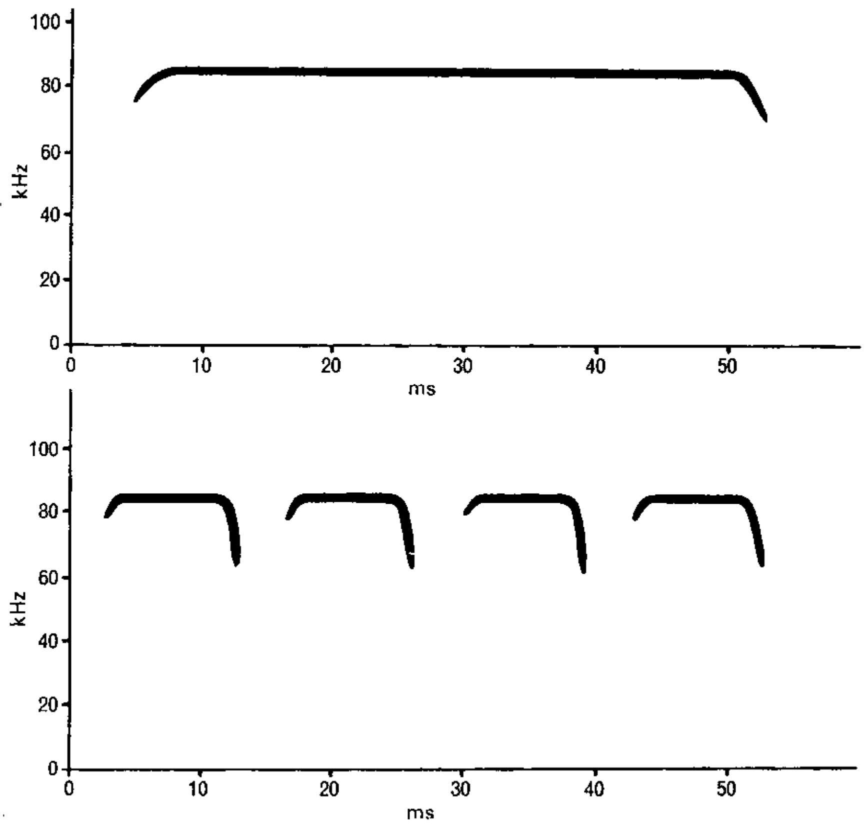


Fig. 5. Pulses emitted by a horseshoe bat, *Rhinolophus ferrumequinum*, showing the long duration and mainly constant frequency. Top is a pulse from cruising flight and below is a short train when examining a target. Only the second harmonic is shown as the suppressed fundamental is too weak to register.

Such constant frequency pulses must be hopeless for range measurement but should be excellent for detecting the relative velocity (the first derivative of range) of targets from Doppler shifts, which demands a high time-frequency product. Most of these bats hunt in dense woods, often hanging from a vantage point until suitable prey flies by, where Doppler operation would greatly improve clutter rejection.

This has been confirmed by the ingenious work of Schnitzler [6] who demonstrated the phenomenon of Doppler compensation behaviour in cf horseshoe bats. When there is an upward Doppler shift due to decreasing range, the bats reduce their emitted frequency so that the echoes are maintained at the original frequency. This happens whether the motion is produced by the target or by the bats' own flight (or both); it also occurs regardless of wind-speed and even in an oxygen-helium atmosphere where Doppler shifts are reduced. The reason is that a preponderance of the cochlear membrane and of auditory brain centres in these bats is devoted to one narrow part of the spectrum (the acoustic 'fovea') and the bat must ensure that echoes of interest fall in this region.

Virtual echo experiments, with induced frequency changes instead of variable delays, have shown that these bats are able to detect Doppler shifts to the limits imposed by their signals: about 0.1 ms^{-1} for 20 ms pulses at 85 kHz, representing a Doppler shift of 50 Hz or 0.06%.

Doppler compensation has now been found in cf bats of three different families. Other bats emit narrowband pulses but without a precisely constant frequency, generally as very shallow sweeps, say 1 – 2 kHz or so over a duration of 10 – 25 ms. It would be interesting to know whether these bats also detect Doppler shifts. In most such cases the behaviour is flexible, with narrowband pulses being used only in cruising flight clear of obstacles, and there is a change to deep fm sweeps when close to the ground or during manoeuvres (Figure 6). Only fm is used indoors so all observations must be made in the field and this makes experimentation difficult.

Directionality

There are two contrasting ways by which bats control their emitted beamwidth. In most cases the pulses are shouted through the mouth which is formed into a simple horn as in Figure 7a. The dimensions are small but in relation to wavelength can produce a – 3 dB beamwidth of about a radian (reviewed in [7]). Of course deep fm sweeps are more directional at the start where frequencies are higher and wavelengths are shorter.

In the other method, used by a large minority of spe-

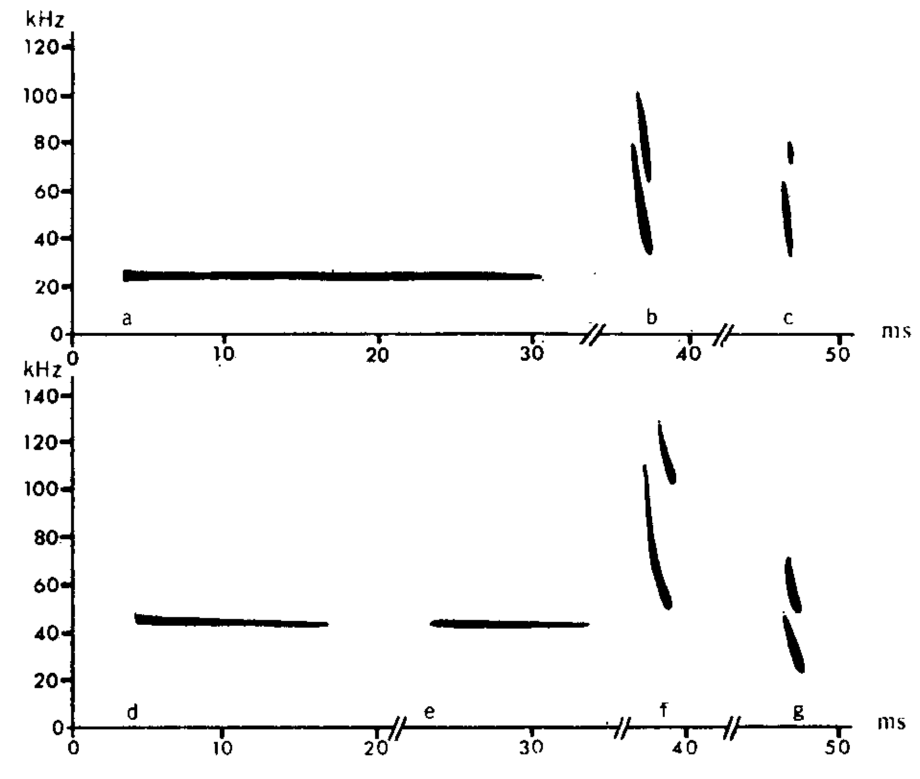


Fig. 6. Pulses emitted by two common British bats, the noctule (Nyctalus noctula – top) and the pipistrelle (Pipistrellus pipistrellus – below). When cruising in the open, both emit quite long narrowband pulses (a, d, e) but on detecting a target they change to short fm pulses (b, f) and during interception produce a rapid buzz of even shorter pulses (c, g).

cies, the sounds emerge from the nostrils instead and the mouth is kept shut except when eating. In all these cases, the nostrils are surrounded by curious structures of naked skin called noseleaves, shown in Figures 7b and 7c. These are often so strange that they are probably responsible for the bats' quite undeserved (!) reputation for ugliness. They are actually beam-forming arrangements and interference between the two sources determines the basic beam pattern.

In cf horseshoe bats (Figure 7b) the spacing between nostrils is always half a wavelength, suggesting a single lobe with – 3 dB width of about a radian [8,9]. But actual measurement (reviewed in [7–9]) showed that beamwidth is exactly half this value and has vertical constraints as well. This is probably due to diffraction from the various structures on the noseleaves themselves and I am currently investigating that hypothesis. In the case of multiharmonic fm bats (eg Figure 7c), noseleaves produce different patterns for each component and they all change as frequency falls [10]. Thus spaced microphones can detect quite different waveforms for the same pulse, as in Figure 8.

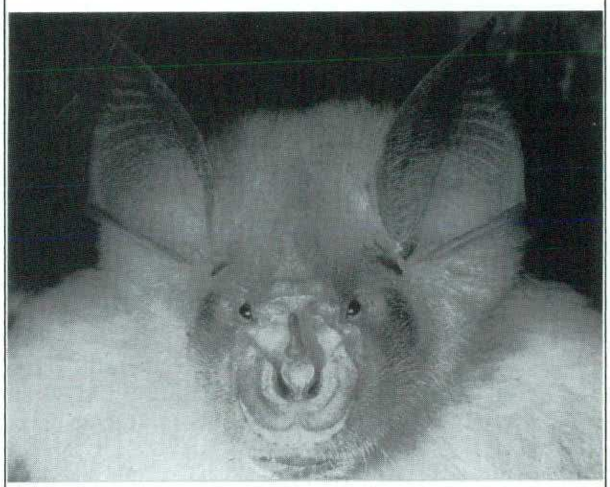
Directionality of hearing depends partly, as in ourselves, on interaction between the two ears. But it is also aided by the large size of the external ears in relation to the wavelength (reviews in [7] & [11]). In some cases this ratio can be very large although it varies widely as stated earlier. Big ears provide high 'antenna gain' as well as directionality but the most sensitive direction may vary with frequency. This is now known to depend, at least partly, on the tragus, a small spike in front of the ear canal that is small in man but may be very well developed indeed in some bats (a medium-sized one is seen in Figure 7a). In experimental tests, fm bats have been able to locate targets to about 2° [2].

In most bats the ears are largely immobile and only show a small degree of voluntary flexing. Those with the largest ears may indeed be severely disorientated by apparently quite minor distortion of their ear membranes. But by contrast the horseshoe bats and their cf relatives have extremely mobile ears that turn independently the whole time, as if scanning their surroundings. Furthermore, they also swing over wide arcs in a coordinated way, one forwards and the other backwards, for every pulse that is emitted. Even at 80 pulses per second the ears flap at 40 Hz and emit an audible hum as they do so. It may be that this is not simply synchronised scanning but that it also has implications for Doppler detection, increasing the shift for one ear and reducing it for the other, or allowing stationary targets to be examined.

Insect Countermeasures

There is one big drawback to locating prey by means of echolocation – the prey may listen in and take evasive action. It seems that when bats began to hunt by sound, probably about 50 – 60 million years ago, many groups of insects, which were already well established, responded by developing ultrasonic hearing. The anatomy of insects is generally very stereotyped, but their ears evolved in strangely different parts of the body and from a variety of mechanosensory precursors, presumably as independent responses to the new danger. The singing insects, such as crickets, bushcrickets and grasshoppers that communicate with each other by sound, often use high frequencies because of their small size, and it would be easy for them to hear bats. But more and more insects are now found to have ears that serve no known social function and appear to act solely as bat detectors [12], especially as most examples fly mainly at night. Different families of moths have ultrasonic ears on their faces, or on the side of the thorax or on the abdomen; some lacewings have them in the middle of the forewings and there are praying mantises with an unpaired 'cyclopian' ear ventrally between their legs.

All these have been shown to respond to the sounds of an approaching bat by dropping or power diving to



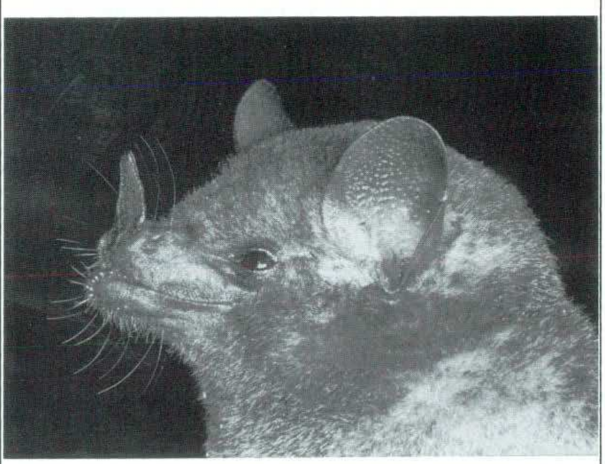


Fig 7. The faces of three contrasting bats: from the top the insectivorous fm mouse-eared bat, *Myotis myotis;* the insectivorous cf Doppler horseshoe bat, *Rhinolophus landeri;* the nectar drinking multiharmonic fm bat, *Lonchophylla robusta.*

the ground or else by flying a rapid and tortuous path that makes them difficult to catch. The response has an unpredictability that must itself be advantageous. Power diving gets the subject away from the bat's flight path quickest but is potentially disastrous if open water lies below. About an hour after dark there often appear bats, such as *Myotis daubentoni*, that specialise in flying very low over rivers or lakes and grabbing insects that are struggling in the water surface; many of these were probably trying to escape from other bats earlier in the evening. It seems likely that this situation in turn led to some bats learning to catch fish with their feet – a habit that has developed several times independently in different parts of the world.

Many tiger moths, of the Family Arctiidae, not only hear bats coming but, if evasion seems to be failing, answer back with a burst of loud wideband ultrasound. The sounds are generated by buckling a plate on the thorax which has a number of corrugations to increase the number of clicks for each operation. The moth only brings this into play if the bat's sounds become very rapid – an interception 'buzz' manoeuvre indicating the game is up. Evidence and opinions differ about whether the function is simply to startle the bat at the critical moment, to mask echoes from the moth's body or to give audible warning that the moth is distasteful. Many of these species have glands that secrete a noxious froth, and those that do not may be simulating those that do – a common anti-predator ploy. Of course all these effects may help each other and the main thing for the moth is that it works.

Counter-countermeasures

All this puts further pressure on the bats to increase their diversity. The 'best' echolocation system is not the most sensitive or the most accurate but the one that leads most directly to full stomachs even if it uses 'non-optimum' methods. Several counter-countermeasures are now being recognised in different bats. Some, such as the cf hipposiderids, use very high frequencies which, despite drawbacks on maximum range, can be above the moths' hearing range; others, such as the European free-tailed bat, appear to be driven down to very low frequencies to get below the moths' range, despite the limitations imposed by longer wavelengths [13].

Some bats use pulses of such low intensity that they have been dubbed 'whispering bats'. Many of these are fruit or nectar feeders and others are insect gleaners, but there also seems to be an advantage against flying insects. The prey is alerted by one-way propagation with an inverse square law, but the returning echo has an inverse fourth-power law; so reducing the emitted intensity favours the bat by reducing its maximum range of detection less than that of its prey. Of course the bat must be very agile if detection is only achieved at close range so this strategem cannot be used by fast flying species.

Finally, the long pulses and low repetition rates of cf bats may have an inherent advantage unrelated to Doppler. The insect ears are sensitive detectors but they are generally very simple analysers. To provide effective warning they need indicate only pulse repetition rate and

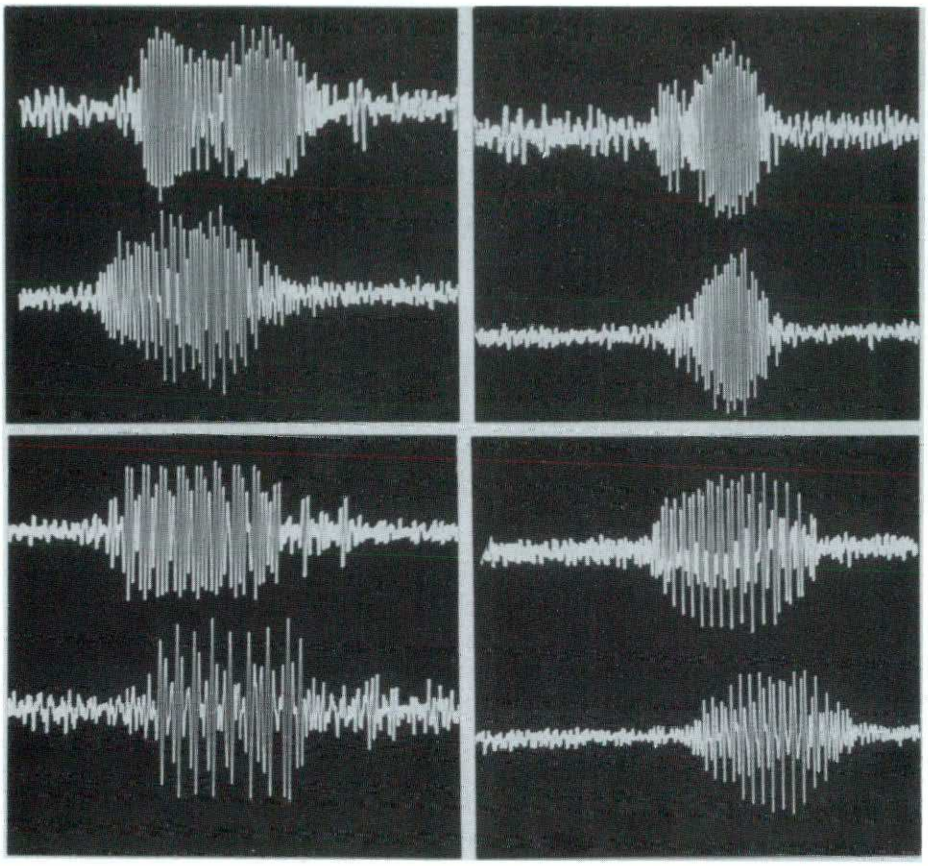


Fig. 8. Four multiharmonic fm pulses from various bats with noseleaves, each recorded by two microphones spaced about 60°apart. Such waveforms are seldom similar but differences disappear when the microphones are placed side by side.

the approximate intensity. But long pulse bats never produce the very high 'buzz' repetition rates that usually warn of the final attack. Many insects will respond only as if the bat is cruising by and has not spotted them, even if it is actually closing in and calling with a duty cycle of over 80%.

Conclusions

Many features of this account may seem familiar from human affairs. In order to achieve the highly technical feat of echolocation and optimise performance, animals as much as engineers have to follow the physical rules and adopt the appropriate design options where alternatives exist. Even the interactions between predator and prey are closely paralleled by the history of electronic warfare. The only real difference is that in nature it has all come about through competitive selection over long periods of time rather than by dedicated intellectual effort. But similar constraints and pressures must in the end result in similar solutions.

References

[1] J D PYE & A PYE, Echolocation sounds and hearing in the fruit bat, *Rousettus*, In S D G Stephens and S Prasansuk (Eds), Advances in Audiology 5: Measurement in Hearing and Balance, 1–12, Karger, Basel, (1988).

[2] J A SIMMONS & A D GRINNELL, The performance of echolocation: acoustic images perceived by echolocating bats, In P E Nachtigall and P W B Moore (Eds), Animal Sonar: Processes and Performance, (pp 353–385), Plenum Press, New York & London, (1988).

[3] G D POLLAK, Some comments on the proposed perception of phase and nanosecond time disparities by echolocating bats, Journal of Comparative Physiology A, 172, 523–531, (1993).

[4] J A SIMMONS, Evidence for perception of fine echo delay and phase by the fm bat, *Eptesicus fuscus*, Journal of Comparative Physiology A, 172, 533–547, (1993).

[5] J D PYE, Sonar signals as clues to system performance, Acustica, 61, 166–175, (1986).

[6] H-U SCHNITZLER & O W HENSON, Performance of airborne animal sonar systems: I Microchiroptera, in R-G Busnel & J F Fish (Eds), Animal Sonar Systems, 109–181, Plenum Press, New York & London, (1980).

[7] J D PYE, Echolocation signals and echoes in air, in R-G Busnel & J F Fish (Eds), Animal Sonar Systems, 309–353, Plenum Press, New York & London, (1980).

[81 J D PYE, Noseleaves and bat pulses, in P E Nachtigall & P W B Moore (Eds), Animal Sonar: Processes and Performance, 791–796, Plenum Press, New York & London, (1988).

[9] J D PYE, Is fidelity futile? The true signal is illusory, especially with ultrasound, Bioacoustics, 4, 271–286, (1993).

[10] D J HARTLEY & R A SUTHERS, Directional emission and time precision as a function of target angle in the echolocating bat *Carollia perspicillata*, in P E Nachtigall & P W B Moore (Eds), Animal Sonar: Processes and Performance, 275–279, Plenum Press, New York & London, (1988).

[11] A GUPPY & R B COLES, Acoustical aspects of hearing and echolocation in bats, in P E Nachtigall & P W B Moore (Eds), Animal Sonar: Processes and Performance, 289–294, Plenum Press, New York & London, (1988).

[12] A SURLYKKE, Interaction between echolocating bats and their prey, in P E Nachtigall & P W B.Moore (Eds), Animal Sonar: Processes and Performance, 551–566, Plenum Press, New York & London, (1988).

[13] J RYDELL & R ARLETTAZ, Low frequency echolocation enables the bat *Tadarida teniotis* to feed on tympanate insects, Proceedings of the Royal Society B, 257, 175–178, (1994).

David Pye is Emeritus Professor of Zoology at Queen Mary and Westfield College, University of London. ❖

POWER ULTRASOUND

John P Perkins

Introduction

The majority of chemists who have an interest in sonochemistry will naturally have acquired some familiarity with the types of ultrasonic equipment used for their work. However, with the increased usage of ultrasound in chemistry, as evidenced by the large number of sonochemical papers currently being published in the literature, more chemists are seeking information on the choice of equipment available and those already in the field may well be looking for more refined instrumentation. As part of any refinement one would expect a move towards some means of monitoring acoustic performance.

The purpose of this chapter is to explore some of the principles behind the generation of power ultrasound. In doing so it is hoped that a practising chemist may gain not only a better knowledge of these fundamentals but also an appreciation of some of the parameters which ought to be monitored when applying acoustic energy in fundamental sonochemical studies.

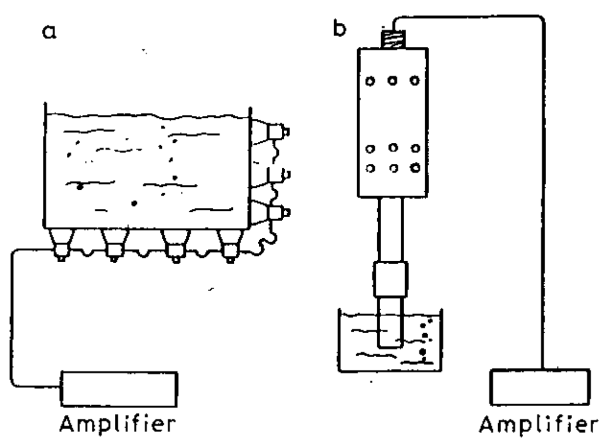


Fig. 1. Basic systems operating at 20 – 80 kHz (a) low intensity system 1 – 2 W cm^{-2}, (b) high intensity system, >100 W cm^{-2}.

There are two basic methods of applying acoustic power to liquid loads (Figure 1). One is a low intensity system, essentially an ultrasonic cleaning bath in which a liquid filled tank has multiple transducers bonded around the base and walls. The other is a single transducer which couples energy into a chemical reaction by means of a horn or velocity transformer. The latter will be referred to as a probe system. Each transducer arrangement is powered by a generator or power amplifier.

One of the basic parameters in ultrasonic engineering is power density which can be defined as the electrical power into the transducer divided by the horn radiating surface area. The low intensity (bath) system uses a power density at the transducer face of the order 1 – 2 W cm^{-2} for a modern piezoelectric transducer. It is normal, therefore, to employ a number of transducers to put high powers into liquids contained in such tanks. For the probe system we can achieve a much greater maximum power density at the radiating face of the horn. This can be of the order of several hundred W cm^{-2}. In both of these cases the working frequencies are of the order 20 – 40 kHz. Both types of systems have merit but for research purposes the probe system seems to offer the following advantages:

(1) it is possible to achieve much greater vibrational amplitudes;
(2) as a result of this, much greater energy densities can be achieved; and
(3) there is a greater degree of control on the energy density within a test sample.

Probe System

Construction of the Transducer

Transducers used in modern power ultrasonic systems are almost without exception based upon the prestressed piezoelectric design. In this construction, a number of piezoelectric elements – normally two or four – are bolted between a pair of metal end masses. The piezo elements would be a prepolarized lead titanate zirconate composition which exhibit high activity coupled with both low loss and aging characteristics. They are ideally suited to form the basis of an efficient and rugged transducer.

If we consider a length of polarized piezoelectric rod and drive this with an alternating voltage, at a frequency corresponding to its resonant length, then this dimension will change in sympathy with the applied voltage. Such a rod would have a length of the order 70 mm at a frequency of 20 kHz. Its power handling capacity would be low since these ceramics have poor thermal capacity and low tensile strength. To overcome these inherent weaknesses, a number of thin elements are clamped between two acoustically low loss metal end masses; either titanium or aluminium would be used. The assembly would be designed so that the overall length was one half-wave at the required frequency of operation.

Figure 2 illustrates a typical transducer construction. Two piezo elements are positioned near to the point of maximum stress in a half-wave resonant assembly. Because the elements are prepolarized they can be so arranged that they are mechanically aiding but electrically opposing. This feature enables both end masses to be at an earth potential. The assembly is clamped together by means of a high tensile bolt which ensures the ceramics are in compression at maximum transducer displacement.

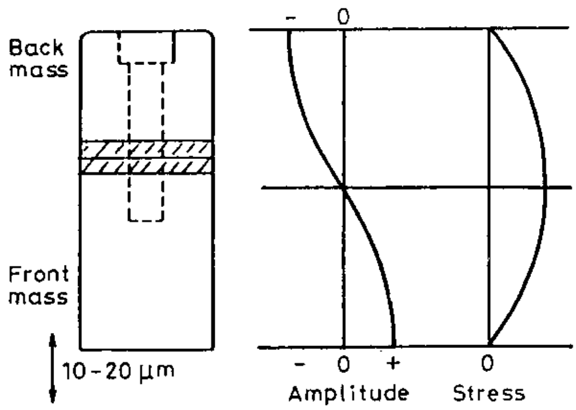


Fig. 2. Sandwich transducer operating at 1 – 200 kHz.

Transducers constructed in this way can have potential efficiencies of 98% and will handle power transfers of the order 500 – 1000 W when employed in a mode of continuous operation. Maximum peak to peak displacements at the transducer radiating face would be of the order 15 – 20 μm when operating at a frequency of 20 kHz.

For a detailed analysis of the prestressed piezoelectric transducer, the reader is directed to [1] and [2].

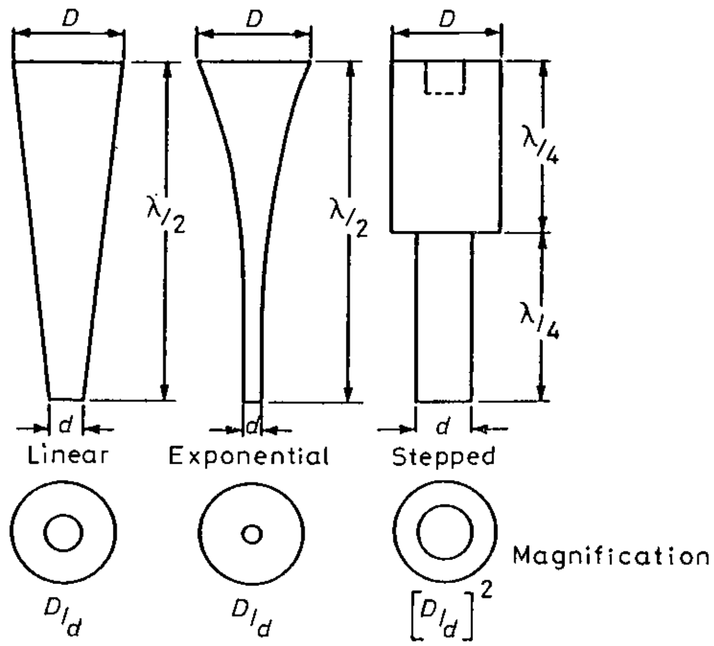


Fig. 3. Horn designs. (a) Linear taper. Simple to make but its potential magnification is limited to a factor of approximately four-fold. (b) Exponential taper. This design offers higher magnification factors than the linear taper. Its shape makes it more difficult to manufacture but its length coupled with a small diameter at the working end makes this design particularly suited to micro applications. (c) Stepped. For this design the magnification factor is given by the ratio of the end areas. The potential magnification is limited only by the dynamic tensile strength of the horn material. This is a useful design and easy to manufacture. Gains of up to 16-fold are easily achieved in a practical horn.

Horns or Velocity Transformers

The vibrating motion generated by the transducer is normally too low for practical use and so it is necessary to magnify or amplify this motion. This is the function of the horn which, like the transducer, is a resonant element in the compression mode. Normally, these are half a wavelength long, although, should the distance between the transducer and the sample being treated need to be increased, they can be designed in multiples of half wavelengths. This can also be achieved by screwing one horn into the other thereby building up the overall length. The most popular horn designs are shown in Figure 3.

Magnification and stress distribution are shown for the three types (Figure 4). Note the stress discontinuity in the case of the stepped horn. Great care must be taken when machining these since any marks in the nodal region will create 'stress raisers' causing metal fatigue in high magnification horns.

When choosing a material for acoustic horns, then, we look for the following characteristics:
(1) high dynamic fatigue strength;
(2) low acoustic loss;
(3) resistance to cavitation erosion; and
(4) chemical inertness.

In order of preference, suitable materials which fit the above are titanium alloy, aluminium, aluminium bronze and stainless steel. Titanium alloys are way ahead of the other two in each of the four required characteristics. Aluminium alloys are too soft for the irradiaion of liquids and, compared with titanium alloys, losses in aluminium bronze and stainless steel will result in end amplitudes reduced by factors of 0.75 and 0.5, respectively, assuming a given power going into the transducer. This is because the latter two materials are acoustically lossier and this will show up as heat, ie the horn will become hot and transfer heat to the reaction – an undesirable side effect.

Monitoring of acoustic input

In the industrial field, equipment is designed to undertake a particular application and vibrational levels are invariably predetermined. Nevertheless, these systems do contain some rudimentary monitoring. A meter indicating relative power supplied to the transducer is common but this does not normally indicate actual watts. One or two manufacturers do offer, in addition, a measurement of transducer amplitude. Industrially, this is quite adequate since either will indicate the consistency of machine performance. However, they are performing an industrial application and the final arbiter of this performance is the test or quality engineer, whose responsibility it is to obtain a consistent final product.

In the research situation, the end result is not necessarily known and therefore the performance of equipment cannot be judged by results. It would seem sensible therefore that a number of acoustic parameters should be mon-

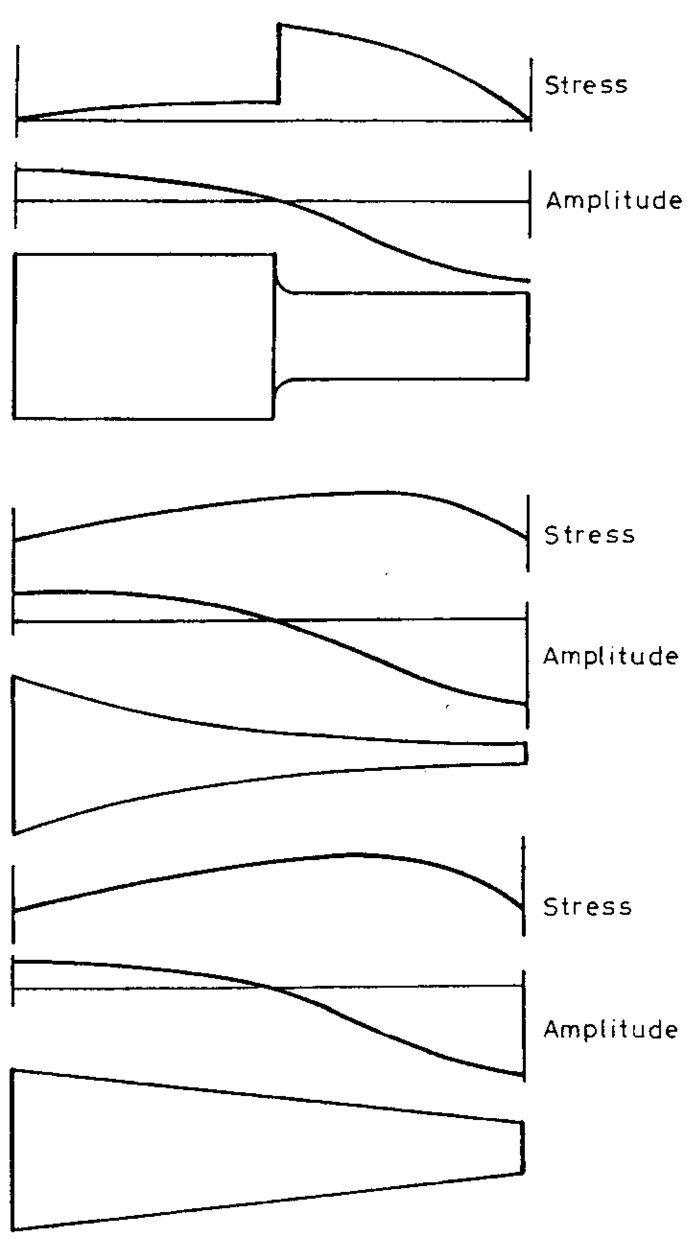


Fig. 4. Amplitude and stress curves.

itored which would ensure:

(1) that the day to day acoustic conditions are consistent:
(2) that the results obtained are comparable with those of other workers and based upon some absolute values; and
(3) eventually that production systems founded upon such research can be accurately specified in acoustic terms.

There are two basic parameters which should be known, the operational frequency and the acoustic power in the treated sample. Frequency is not normally critical within 5 – 10% and so the nominal frequency of the system quoted by the manufacturer will probably suffice. Acoustic power is more difficult to measure because of the power by demand characteristics of most ultrasonic systems. This means that the rated power of the generator cannot be used as an indication of acoustic power, since the power transferred will depend upon: (a) how heavily the transducer is loaded (this is a function of horn magnification); and (b) the area of the horn immersed in the treatment sample.

There are three possible approaches to the determination of acoustic power:

(1) Calorimetric method. This is simply the calculation of power input by measuring the rate of temperature rise in the system, taking into account its thermal capacity. It is a rather cumbersome method and to be used properly it should be undertaken each time a sample is treated in case there are system variations. Thus, it is not really a practical method.

(2) Measurement of vibrational amplitude. This is the direct measurement of the amplitude at the working face of the horn, and will give a parameter that is at least proportional to the acoustic power.

$$P_{ac} \propto 0.5\, \rho c\, \xi^2 \qquad \text{(Eq. 1)}$$

where

P_{ac} = acoustic power;
ρ = density of load;
c = load sound velocity; and
ξ = transducer amplitude.

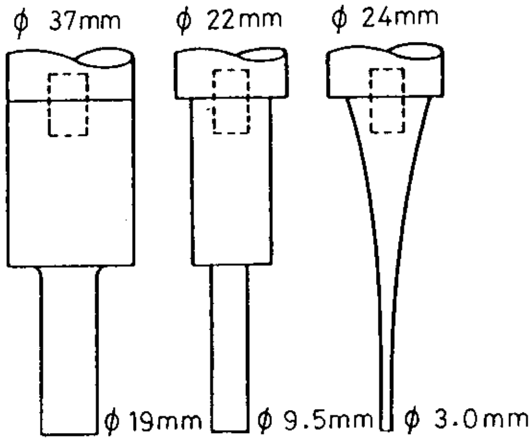
It does have the advantage that it can be continuously monitored but it cannot really be considered as an absolute method since ρ and c in a cavitating medium cannot easily be determined.

Amplitude measurement does offer a very sensitive measurement of acoustic change. It changes as the horn is immersed further into the treatment sample ie as it becomes more loaded. Additionally, it will give warning of any changes in acoustic transmission caused by (i) dirty interfaces between transducer and horn or horn and tip, (ii) total or partial fatigue in the horn, (iii) fatigue in the coupling stud between transducer/horn/tip and (iv) transducer faults.

A combination of the calorimetric method and measurement of vibrational amplitude might well be the most useful method of power monitoring and, therefore, control. In any event, by measuring amplitude we do have an indication of the acoustic power output rather than the electrical power into the transducer.

(3) Measurement of the real electrical power to the transducer. This can be converted to the acoustic power if the overall acoustic transfer efficiency is known. The use of a wattmeter to measure electrical power to the transducer can in certain circumstances, lead to a measurement of the true acoustic power transmitted to the sonicated sample. This can certainly be true of probe systems used for sonochemical treatment. If the system is driven in a controlled manner then we can derive the transmitted acoustic power from the unloaded and loaded electrical powers.

The acoustic power transmitted by a transducer/horn arrangement driven in such a manner is shown in Figure 5. In these examples the treatment sample was tap-water (80 cm^{-3}) at room temperature. A number of different



Amplitude (µm p.p)	46	72	96
Horn magnification	3.8	6	8
Radiating area (cm^2)	2.83	0.64	0.07
Transmitted acoustic power (W)	69	28	9 5
Power density ($W\ cm^{-2}$)	24.4	44	135
Gain/area product	10.75	3.84	0.56

Fig. 5. Data showing the acoustic power transmitted by various horn/transducer arrangements.

horns were screwed in turn to the same transducer and the results are as shown. (If the gain/area product ratio were made the same for each case then the transmitted acoustic power would be similar.) For the examples chosen, the energy density has been varied by selecting appropriate probe end areas. It has to be pointed out, however, that some limitations do exist, eg if the gain/area product is made too large then the electrical control system will be unable to handle it and the system will either stall out or the horn will exceed its dynamic fatigue limits and fracture.

In summary, we have seen that a measure of either, or both, amplitude and electrical power can offer a valuable means of checking the acoustic performance of the systems and of monitoring the transmitted acoustic power.

Methods of Measuring Amplitude

Directly by microscope. We can measure amplitude just by looking at the end of a free transducer with a microscope. A metallurgical microscope with a x15 calibrated eye-piece and a x10 objective will enable a measurement down to ~ 5 µm. Since most transducers will generate amplitudes of at least 10 µm and this value is magnified by the horn, quite accurate measurements can be made. The procedure is very simple: a small spot of aluminium paint is placed on the transducer and an individual metallic fleck is focused in the graticule. On turning on the power the rapidly vibrating spot appears as a line. The amplitude of vibration, that is the peak to peak displacement, is the overall length of the line minus the spot diameter.

Continuous monitoring. Having the ability to measure amplitude with a microscope is clearly impracticable during a sonochemical experiment. A method is required which provides continuous monitoring with a display. There are two possible approaches: electro-mechanical and purely electrical.

(1) electro-mechanical. The alternating stress in a resonant element is at a maximum in the centre (Figure 2). If a strain gauge is bonded to the centre of such an element then the output from this will be proportional to the displacement or amplitude of vibration. This output signal can be rectified and displayed for example on a meter. The meter can then be calibrated by the use of a microscope (see under 'Directly by microscope' above). It is also possible to derive a purely electrical signal that is proportional to transducer displacement and this possibly offers a more elegant solution since it eliminates the use of the strain gauge which can be a somewhat fragile element.

Using this method it should only be necessary to calibrate the meter once since any subsequent change in transducer amplitude due to loading will be accompanied by a proportional change in strain in the transducer/acoustic system. The meter will thus follow any induced changes of amplitude which occur either as a result of power input or load variation.

(2) Purely electrical. Electrical methods of measurement can be contained within the ultrasonic generator. Essentially this is a power amplifier which converts energy at the mains frequency to energy at a chosen ultrasonic frequency. Because of the very narrow operating frequency band of the transducer, it is essential that the amplifier tracks any changes in resonant frequency of the system. This can be done by sensing, with electrical means, the transducer motion in a similar manner to that just examined.

The same electrical signal used to display amplitude can be fed back into the amplifier and this will enable the power generated to follow any frequency changes in the transducer/acoustic system. This is very important because the resonant frequency of the transducer decreases as it becomes warm and lengthens. Changes in the treatment sample can also affect the frequency. Both of these effects would be sufficient to shift the system off resonance with an accompanying performance loss were it not for the automatic tracking, normally referred to as automatic frequency control (AFC).

Another desirable feature of this method is that it can be used to limit the transducer amplitude and thus ensure that it does not damage either itself or the coupled resonant elements due to overstress.

Cavitation Phenomena

There is little doubt that cavitation does influence the accleration of a chemical process and so an appreciation of the mechanism is necessary. The subject has been, and continues to be, covered by many workers and there is much detailed published work. Some important references considering much of the detail are given but the following gives a brief general explanation.

Cavitation may occur when applying high intensity ultrasound to liquids. In generating cavitation a sinusoidal pressure is superimposed on the steady ambient pressure.

Now all liquids contain small gas bubbles in suspension or gas entrained in colloidal solids. Their response to the alternating sound field may be violent or rather gentle, depending on pressure levels, frequency of the alternating pressure and other ambient conditions. The violent form is known as transient cavitation and the gentle form is known as stable cavitation. Stable cavities are bubbles that oscillate, often non-linearly, around some equilibrium size. They are relatively permanent and can continue to oscillate for many cycles of acoustic pressure. On the other hand, transient cavities usually exist for less than one cycle. If the acoustic pressure is great enough for the liquid to go into tension during the negative half-cycle, then the cavities will expand rapidly often to many times their original size. Following this on the positive half-cycle, they collapse violently often breaking up into many smaller bubbles. It is during this phase that the well known disruptive effects of cavitation occur.

Two aspects of cavitation that may be of interest are shown in Figures 6 and 7. Figure 6 illustrates the frequency dependence of the intensity required to produce cavitation. The example given is for degassed water at room temperature. It will be noted that the intensity required to produce vaporous cavitation above the frequency of ~ 100 kHz rises rapidly.

Figure 7 illustrates the effect of temperature on cavitation and its associated hysteresis effect. This example is for tap-water and the increase in intensity as the temperature is increased can be observed before it falls away at the boiling point. When the temperature is allowed to fall, an increase in intensity is found in the region of 50 – 60°C. This is quite a significant effect and appears to occur in all liquids.

Health and Safety Aspects

Cavitation effects, produced during the sonification of a liquid sample, result in the generation of a wide spectrum of noise. This noise is radiated into the atmosphere and consideration must therefore be given to the health and safety aspects associated with the use of ultrasound.

The frequency spectrum generated by a single source frequency, f_0, is shown in Figure 8. Note the strong subharmonic which gives a very audible level even for a 20 kHz system. Permitted exposure limits do vary from country to country but are normally found to have a

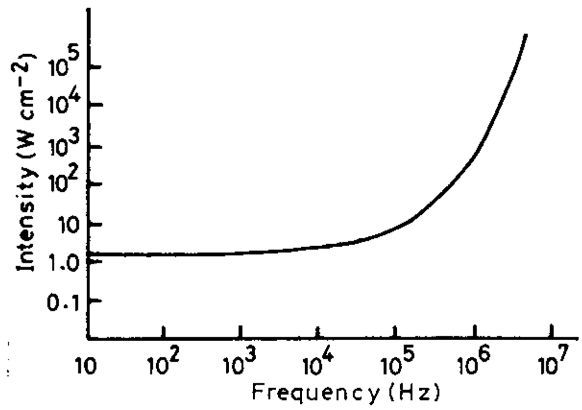


Fig. 6. Cavitation threshold for degassed water at room temperature.

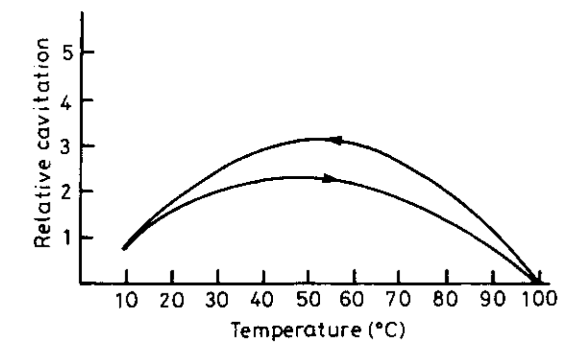


Fig. 7. Effect of temperature on cavitation in tap water and its associated hysteresis effect (redrawn from G Kurtze, Nachr. Akad. Wiss. Goettingen, 1958, IIA(1)).

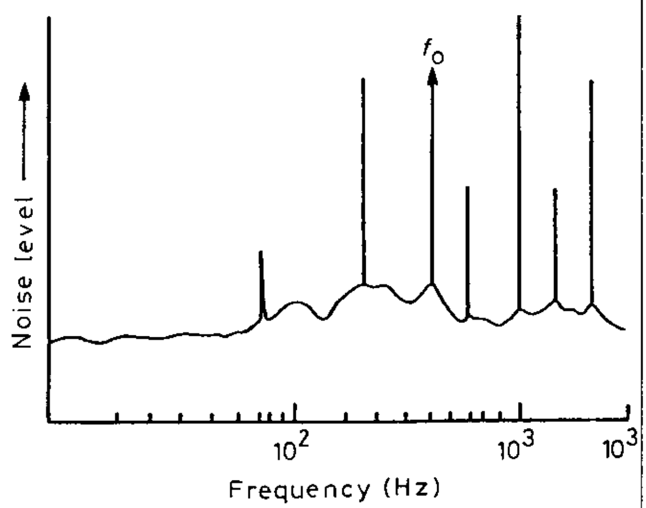


Fig. 8. Cavitation noise spectrum (Redrawn from R. Esche, Austica 2, Akus Beih, 1952).

maximum of between 85 and 90 dB(A) over an 8-hour period. Shorter exposure times permit higher pressure levels. If, for example, the exposure time is halved then the pressure limit may be doubled. This means that for a 4-hour exposure, then the limit would be increased by 3 dB(A), a 2-hour exposure by 6 dB(A) and so on, up to a maximum of 120 dB(A).

There are two ways of guarding against radiated noise: either acoustic ear-muffs or an acoustic screen around the apparatus. The first solution would be acceptable for one isolated worker with short exposure times, although muffs can become uncomfortable if worn for long periods particularly in a warm atmosphere. The second solution would take the form of a box lined with a proprietary sound absorbing material. The transducer and treatment sample would be housed within the box. A 6 mm thick Perspex door would permit observation of the sonication process. A well fitted door is essential, however, since noise will escape through any gaps.

Noise levels in excess of 100 dB(A) would not be uncommon at a distance of 1 m when processing small samples at 20 kHz without acoustic screening. It is certainly possible to reduce these levels to 75 dB(A) by a well designed screening box.

Large Scale Applications

In a production situation the volumes treated will be very much larger than those considered in the laboratory. Almost certainly the type of process will govern the choice of transducer energy density required and it could well be that some processes would be suited to a low intensity sonication, whereas others may need the higher intensity of the probe system.

In the case of low intensity treatment, the reacting liquids could be flowed in a controlled manner through an ultrasonic tank (Figure 9) and out over a weir to the next process. A number of such sonically activated stages could be connected in line. The tanks would be constructed in an appropriate grade of stainless steel or if plastic tanks are used then the transducer could be bonded on to a stainless or titanium plate and bolted with a gasket into the tank. Alternatively, a sealed submersible transducer assembly could be employed.

If high intensity treatment is needed it is possible to couple a probe transducer into a flow pipe by means of a 'T' section. A number of such transducers could be employed in this manner (Figure 10). The actual number and position in the process line would need to have been determined during the process development phase.

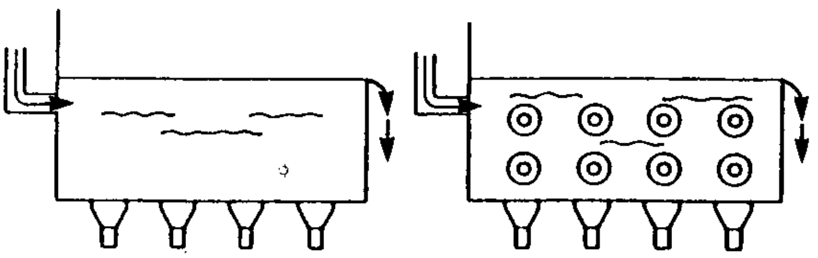


Fig. 9. Low intensity production processing

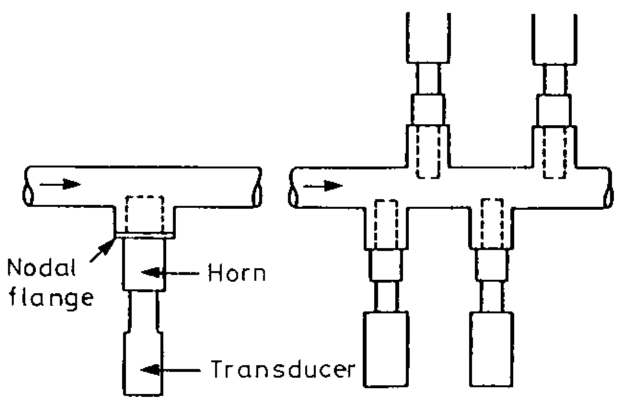


Fig. 10. Large volume treatment using high intensity process.

Acknowledgement

The author wishes to thank Dr T J Mason of Coventry Lanchester Polytechnic for the encouragement to present and publish this lecture.

References

[1] E A NEPPIRAS, Ultrasonics International 1973 Conference Proceedings, Butterworths, Borough Green, UK, (1973).
[2] A P HULST, On a family of high-power transducers, Ultrasonics International 1973 Conference Proceedings, Butterworths, Borough Green, UK, (1973).
[3] R ESCHE, Acustica 2, Akust. Beih., AB 208, (1952).
[4] E A NEPPIRAS, Phys. Rep., 61, No 3, (1980).
[5] Various authors, Ultrasonics, series commencing Volume 22, No 1, (1984).

This article is reproduced, by permission, from 'Sonochemistry', edited by Prof T J Mason, Royal Society of Chemistry, Cambridge, 1990. ❖

INTERNATIONAL STANDARDS: COMMITTEE MEETINGS IN LONDON, NOVEMBER 1994

Roger F Higginson FIOA

Introduction

Most members of the Institute make reference to standards every day in their work, but probably few are familiar with the origins, the development, and in some cases the politics, of the documents that they use. There are many different kinds of standard, originating from different organisations; in the main, nowadays, the national standards in the field of acoustics are reproductions of international documents. The two principal worldwide (as opposed to European) international organisations for production of standards are the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). Each of these has a large number of committees made up of national delegates. Many of the committees in both organisations have an interest in aspects of acoustics, aside from those with the word 'acoustics' in their title, covering areas such as ultrasonics, audio engineering, vibration, and so on. However, two committees with a broad range of responsibilities for acoustical standardisation are Technical Committee 29, Electro-acoustics, of IEC (IEC/TC 29), and Technical Committee 43, Acoustics, of ISO (ISO/TC 43). The latter has Sub-Committee 1 (SC 1), with the title Noise, and Sub-Committee 2 (SC 2), with the title Building Acoustics. Meetings of the main committees are held at roughly 18-month intervals and, during November 1994, IEC/TC 29, ISO/TC 43 and ISO/TC 43/SC 1 met at the new BSI headquarters in West London.

IEC/TC 29

Broadly, this committee covers instruments and equipment for acoustical and audiometric measurements and hearing aids. The newly-appointed chairman is Professor Knud Rasmussen, of the Danish Technical University, and altogether about 50 delegates attended the meeting, from 16 countries. The UK delegation had 8 members, with Mike Martin (ex-RNID) as leader and others from NPL, measuring instrument manufacturers and BT. Other delegations had a similar spread of representation from research organisations and industry. The meetings, including working groups, ran for a full week, with most of the business taken up in progressing the activities of the 14 working groups. A number of draft standards based on the discussions will be circulated through BSI during 1995, and in some cases the final versions will be published:

• Final drafts of parts 3 and 4 in the new series of standards on measurement microphones; part 3 will be the primary method for free-field calibration of laboratory standard microphones, and part 4 will give specifications for working standard devices. The new standards should be published as IEC 1094-3 and -4.

• The final draft of a new standard to replace IEC 225, giving specifications for octave band and fractional-octave band filters. The new standard should be published as IEC 1260.

• The final draft, and eventually publication, of a revision of IEC 118-1, about hearing aids with induction pick-up coil input.

• A new draft of a revision of IEC 118-2, describing measurement of the frequency response of hearing aids

with automatic gain control.
• New drafts of additional parts in the IEC 118 series on hearing aids, one describing electromagnetic compatibility and immunity to radio frequency fields, another giving dimensions of electrical connector systems.
• The first draft for a coupler configuration for the calibration of audiometric earphones in the extended high frequency range.
• The first draft of a single new standard to replace IEC 651 and IEC 804, giving a completely new specification for all kinds of sound level meters.
• The final draft of a new standard to replace IEC 561, giving performance requirements for noise measurement systems used for noise certification of transport aeroplanes. The standard should be published as IEC 1265.
• The first draft of a new standard on digital control of hearing aid parameters, for use in connection with programmable aids.
• The first draft of a revision of IEC 942 on sound calibrators, describing methods of testing performance.

Until now, standards from TC 29 have been driven by developing technology and the requirements of acoustical measurement methods for instrument specifications. Pressures to fulfil regulatory requirements have tended to be experienced indirectly through those for the measurement methods. The discussions at this meeting took a new turn as the direct requirements were voiced from European Directives on electromagnetic compatibility of electrical and electronic appliances and the performance of medical devices. New work in these areas was initiated and this seems likely to become pre-eminent for the future.

ISO/TC 43 and TC 43/SC1

TC 43/SC 1 is responsible for standards on methods relating to noise, and TC 43/SC 2, which did not meet at this time, covers methods for building acoustics. The two sub-committees are now practically autonomous of the parent committee, TC 43, which deals with various general acoustical measurement questions, such as reference quantities, loudness, alarm signals, hearing thresholds and audiometric test methods. However, since TC 43 and SC 1 have the same chairman (Professor Klaus Brinkmann, from Germany) and secretary (Leif Nielsen, from Denmark) they always meet one after the other and this report covers them both.

About 45 delegates from 14 countries attended the meetings, with 4 from the UK, led by Roger Higginson and with others from NPL, ISVR and HSE. The meetings, including working groups, ran for a further week, again with most of the business taken up progressing the activities of the 4 working groups of TC 43 and 25 of SC 1.

As indicated previously, the driving force for development of many measurement and test procedures is to support legislation, especially in recent times from European sources. A whole raft of standards is being produced by TC 43/SC 1 relating to machinery noise emission, in connection with EC Directive 89/392. These include revision of the ISO 3740 series on determination of sound power levels using sound pressure, revision of ISO 6926 on reference sound sources, development of the new ISO 9614 series on determination of sound power levels using sound intensity, development of the new ISO 11200 series on determination of emission sound pressure levels, production of a new version of ISO 4871 on noise declaration and verification, and of a new ISO 12001, giving guidance on the drafting of noise test codes. There are also many standards and guideline documents in production on noise reduction, relating both to individual machine types and to workshops. There is not space here to give full details on all these, but they have been catalogued elsewhere (see 'Directives, Standards, and European Noise Requirements', Noise/News International, September 1994). Another new series of standards is being produced on structure-borne sound from machines, which will have the number ISO 10846, in a number of parts.

Another major area of activity for SC 1 is that of road vehicle and traffic noise; standards are in preparation for measuring the influence of road surfaces on traffic noise (ISO 11819), the effects of temperature and tyre selection on vehicle noise measurements (ISO 13471), and characterisation of pavement texture (ISO 13473). Work is also in progress on
• extension of the ISO 4869 series on hearing protectors,
• a new standard on the sound emission of stationary audible warning devices (ISO 13475),
• a new standard on the insertion loss of outdoor noise barriers (ISO 10847),
• revision of ISO 3381 on noise inside railbound vehicles,
• revision of ISO 3891 on aircraft noise heard on the ground,
• revision of ISO 5129 on noise inside aircraft,
• revision of ISO 1996–2 on measurement of environmental noise, and
• review of the frequency weighting characteristics of sound level meters.

Work has been completed and new standards should appear shortly on the scanning method for sound intensity (ISO 9614–2), sound propagation outdoors (ISO 9613–2), isolated bursts of sound emitted by machinery (ISO 10843), and noise on board vessels (ISO 2923).

In TC 43 itself, there is work to revise ISO 7029, on hearing thresholds for otologically normal persons, and to add new parts to the ISO 389 series of standards on reference zeros for calibration of audiometric equipment. In view of the extent of the work programmes of these two committees, it is impossible to review them all in detail here and to be specific about the expectations for production of new draft standards in coming months. There will be many documents to come for appraisal by BSI committees. They will be channelled through BSI/EPC/1, 'Acoustics', and its various sub-committees, and those with an interest can expect to be called upon to provide comments and votes. The next full meetings of IEC/TC 29, ISO/TC 43 and SC 1 are planned to be held in South Africa in the early part of 1996.

Roger F Higginson FIOA is Director of Higginson Acoustics Ltd

WORKING WITHIN THE SAVANTE NETWORK OF EC HUMAN CAPITAL AND MOBILITY PROGRAMME

Nicole D Porter MIOA

Background

The European Community's R & D programmes aim to improve Europe's technology base, to underpin the production by European industry of world-leading products, and to enhance the quality of life of its population. The Third Framework Programme was agreed at the December 1989 Research Council in Brussels and formally adopted in April 1990. It was the 'Third generation' of EC R & D programmes and involved funding of 5.7 BECU. The programme covers the following areas:

(i) Enabling technologies:
- Information and communications technologies
- Industrial and materials technologies

(ii) Management of Natural Resources:
- Environment
- Life sciences and technologies
- Energy

(iii) Management of Intellectual Resources:
- Human capital and mobility

Since January 1994, NPL have been participating in the Sound and Vibration Network in Europe (SAVANTE) under the EC Human Capital and Mobility Programme. The scheme enabled a six-week exchange visit to the Istituto di Acustica 'O M Corbino' (IDAC), Rome with a short visit to CEMOTER, Ferrara under topic area 7 and 8 'Environmental Noise and Subjective Acoustics' to carry out research into the subjective assessment of masked detectability thresholds of amplitude and frequency modulated tones.

In this article, I hope to inform others of the scheme, the type of work undertaken in some other European Institutes and give some brief observations about my personal experiences in participating in the programme.

EC Human Capital and Mobility Programme

The central objective of the EC Human Capital and Mobility (HCM) Programme is to increase the quantity and quality of the human resources that will be required for research and technological development by the EC Member States in the coming years. The programme covers four activities:

1. The development of a Community system of research training grants on both an individual basis and an institutional basis.
2. The creation and development of scientific and technical co-operation networks.
3. Provision of access for researchers to large scale scientific and technical installations.
4. The launching of a Community system of R & D Euroconferences.

The HCM budget breakdown is as follows in MECU's as published in Physics World [1]:

Fellowships	213.1
Networks	193.8
Large installations	53.7
Euroconferences	12.5
Administration	15.0
East-West co-operation	30.0
TOTAL	518.1

The aim of the networks is to support exchange activities or joint projects between five or more research groups or institutions from different EC countries. The grants awarded are intended to cover 100 % of the marginal costs of each project (60% for the subsistence and mobility cost of the researchers themselves, 40 % for certain expenses related to research and administration).

To date, under the HCM programme, the European Commission has concluded more than 3,500 contracts, which has helped over 10,000 researchers pursue research in a laboratory of their choice across the Member Countries. The programme has become established as the Commission's foremost training and human resources development programme for researchers. The aims of the future programme, Training and Mobility of Researchers (TMR), show continuity in the four areas of activity, but with the following changes:

1. Institutional grants will be discontinued.
2. The Commission intends to provide a more substantial contribution to each laboratory in a research network.
3. The Commission propose to expand support for access to large scale installations in order to improve their exploitation.
4. In addition to continuing development of the Euroconference programme, this activity is being expanded to cover the funding of summer schools and practical training courses.

The SAVANTE Network

The Sound and Vibration Network in Europe (SAVANTE) is a network of 14 laboratories in 13 countries and was designed to facilitate staff exchanges, training programmes and joint projects in seven topic areas. The overall co-ordinator is the Institute of Sound and Vibration Research (ISVR), Southampton (led by Dr John Walker) with the seven co-ordinating laboratories for the topic areas as below:

- Sound absorption and transmission in layered media – *Katholieke Univ., Leuven*
- Random and non-linear vibration – *Trinity College, Dublin*
- Advanced signal processing in acoustics and vibration – *ISVR, University of Southampton*

- Structural acoustics – *Technical University of Berlin*
- Noise and vibration control at source – *TNO, Netherlands*
- Electroacoustics – *Delta, Denmark*
- Environmental noise, subjective acoustics, psycho-acoustics – *National Physical Laboratory, UK.*

As shown above, NPL is the co-ordinating laboratory for the last topic area in which the other partners are: Istituto di Acustica 'O M Corbino', Rome; Universidade de Aveiro, Portugal; Universidad del Pais Vasco, Bilbao, Spain; ISVR; Institute fur Technische Akustik (ITA), Berlin, Germany.

Within this topic area there have been a number of exchanges leading to progress in various research projects. These include the modelling of the assessment of vehicle interior noise quality with an artificial neural network. This work is being undertaken by Dr Giovanni Brambilla of IDAC, and Holger Prante and Rolf Diehl of ITA, Berlin using various materials including recordings made by ISVR. A paper will be given at Euronoise '95 detailing the results [2].

Another project concerns the assessment of complex tones in environmental noise which was the area of research I was working on whilst at IDAC. Francesca Pedrielli of CEMOTER, Ferrara, Italy is due to visit NPL this year to take part in this project. Claudia d'Almeida from Portugal is working with Dr Ian Flindell at ISVR on the assessment of industrial noise.

Istituto di Acustica 'O M Corbino' (IDAC)

IDAC is one of the 298 institutes and research groups forming the network of laboratories of the National Research Council of Italy (CNR). Initially its activities were orientated towards electroacoustics, in particular towards condenser microphones and their calibration, telephone receivers and artificial ear devices. From the 1950s the research moved towards ultrasonics and in particular the study of sound propagation in solid and liquid media. Significant work was carried out into the 'Bordoni effect' relating to the dissipation of elastic energy in metals due to imperfections in the crystal lattice, the influence of cosmic rays on acoustic cavitation, high resolution acoustic interferometry and the design and realisation of high power ultrasonic transducers. The main areas of activity are now: environmental acoustics, physical acoustics, digital signal processing, and electroacoustic transducers. Its four research groups comprise: Environmental acoustics and electroacoustics, Solid state acoustics, Surface acoustic waves, and Ultrasound and acoustic technology.

CEMOTER

The Institute for Earth Moving Machines and Off-Road Vehicles, (CEMOTER) at Ferrara is another research institute of CNR, Italy. Its work involves the study of structural and functional characteristics of machines, power transmissions, ergonomics, comfort and safety (noise and vibration, soil-vehicle interaction, and regulation and certification for each of these topics). The work into advanced acoustics concerns external intensity maps, internal intensity fields, intensity spectra of cyclic events and virtual representation of sound fields.

As part of their sound intensity work, CEMOTER have been using signal generation techniques from the Musical Audio Research Station (MARS) system, a specialised digital system for real time audio applications. It is a development system for real time digital signal processing such as sampling, signal analysis and synthesis, and sound effects in the domains of time, frequency and space. The system has been entirely developed by the Italian Bontempi-Farfisa Restack Institute: IRIS. MARS was conceived as an interactive and integrated environment for audio research and musical production. The hardware contains a sound generation board, a DAC/ADC board with 4 analogue inputs and 8 analogue outputs. The MARS software is in two parts, the real time operating system and the user interface supported by the host computer.

My Work on Environmental Noise at IDAC

A three-year programme of research, sponsored by the UK Department of Environment, was recently completed at NPL into the assessment of industrial noise. This examined the requirements of a general noise assessment method and developed a fundamentally different approach to assessing environmental noise based on the analysis of the actual acoustic features present. The work

First meeting of Topic Groups 'Environmental Noise & Subjective Acoustics' of SAVANTE network at NPL with guests from ISVR, Universities of Aveiro and Bilbao.

has led to a need to define objectively the magnitude of physical features in the noise in terms of the subjective impact of the noise. A full account of the acoustic feature model can be found in the November / December 1993 issue of Acoustics Bulletin or in reference [3].

The final stage of the work focused on the determination of the sensory detection threshold of tonal features. A method had been developed by the Institute of Sound and Vibration Research, Southampton which was limited to the detection of a single discrete tone in broadband background noise [4]. In order to extend this method to more complex noise, at least three areas were identified as requiring further investigation: (i) effects of the upward spread of masking, (ii) effects of modulation, (iii) estimation of the background spectrum.

The first of these was initially examined for simple two tone complexes in background noise for two tonal prominences within the same critical band [5].

Modulation (frequency and amplitude) of tonal environmental noise is common and can be caused by factors such as atmospheric absorption, climatic conditions, rotating fan blades, random gearing of machinery etc. Modulated tonal noise can be perceived as tonal but may appear in spectral analysis as 'wide band tones' due to inadequate spectral resolution and the existence of side bands. In order to pursue further the development of the acoustic feature model, it was decided to examine more closely the masked detection threshold of simple modulated tones by reviewing recent literature and carrying out subjective listening tests. The work at IDAC was concerned with carrying out these subjective listening tests relating to the perception of amplitude and frequency modulated tones.

General Observations

It is important to recognise the commonalities amongst scientists within Europe. On arriving in Italy, I spoke no Italian and anticipated that language would be a major barrier to my research and hinder the success of my visit. I soon realised that this was not the case especially since mathematics and physics are universal and independent of the actual language one speaks. This was typified on several occasions including the explanation of signal analysis using diagrams and using Windows on the computer (same icons, different words). Other examples of the ease of communication were shown outside the realms of acoustics when I visited aerobics classes (same actions, different commands) and when I managed to order a meat dish in a restaurant by imitating a cow! Throughout my stay humour always served as a good fundamental link between researchers and non-verbal communication proved to be all-important whilst working away from NPL. I certainly became aware of how technology is improving co-operation and communication, given the instant contact that was available with NPL and others in the UK and Europe through e-mail and fax connections. However, visiting other researchers and discussing issues is more than just using modern telecommunication links: it serves to break down formal barriers caused by different cultures. It shows that doing research work abroad not only enhances the individual's perception of 'real-world problems' in acoustics, but also increases their creativity in solving them.

Working at IDAC with other researchers in subjective acoustics together with another SAVANTE member from Berlin (also visiting IDAC) proved to be very stimulating. It gave the opportunity to discuss the planning of the experiments, their past experience using various test methods, the most suitable equipment and the implications of the results. Although we have all been working in acoustics in our respective countries, we had differing opinions and there was much to be gained from sharing them. In my view this type of interchange serves to meet the central objective of the HCM programme by improving the quality of the research.

The scheme enabled direct access to other products and instrumentation on the EC market. Setting up the test parameters for my experiment required the use of a digital system to generate the sound stimuli. There has been some discussion in the UK on the best system for generating signals for these types of experiments. A benefit of working in Italy under this scheme was access to a different system, MARS, ideal in this application and not available in the UK. CEMOTER entered into the spirit of collaboration in allowing use of their system. Furthermore in order to achieve a flat frequency response over the required frequency band, it was necessary to use electrostatic earphones. Another example of successful networking within the EC was shown when these were provided on loan from HEAD Acoustics, Germany throughout the duration of my stay.

Concluding Remarks

Having had an active involvement in this European scheme, my experiences showed the value of co-operation in Europe. We can learn from our EC partners, work well together and form useful European links. I hope that the scheme will continue to grow and prosper in the future allowing more institutions and researchers to benefit. I enjoyed my experience and wish to acknowledge the financial support of the EC and central support from ISVR, and to express my warm thanks to the staff at IDAC, especially Dr Giovanni Brambilla, and Holger Prante from ITA, Berlin, who was at IDAC during my stay.

References

[1] C RIZZUTO, Physics World, September 1993, 37.

[2] G BRAMBILLA, G AMADASI & H PRANTE, An artificial neural network for the classification of passenger vehicle interior noise, Proceedings of Euronoise '95, Lyon, France.

[3] N D PORTER, I H FLINDELL AND B F BERRY, An acoustic feature model for the assessment of environmental noise, Proc IOA Vol 15: Part 3 (1993), 1015–1024.

[4] I H FLINDELL, The detection of discrete tones in broadband background noise in respect of typical residential exposure to industrial noise, ISVR Contract Report 92/35, Dec 1992.

[5] N D PORTER, The assessment of industrial noise – subjective listening tests and objective assessment procedures, NPL report RSA(RES)0024C, Dec 1994.

Nicole Porter MIOA is at the Acoustics Branch, National Physical Laboratory, Teddington, UK

SURREY HONOURS POLISH ACOUSTICIAN

Robert C Chivers FIOA

On December 9th the University of Surrey awarded the degree of Doctor of the University, honoris causa, to Professor Zenon Jagodzinski of the Technical University of Gdansk. The links between Gdansk and Surrey have been active for over 20 years. They started when the author, of the physics department at Surrey, met Prof Jagodzinski and Dr Andrzej Stepnowski at the 8th ICA in London in the summer of 1974. The topics of collaboration have ranged in research from ultrasonic scattering by fish and tissue volumes to transducer field characterisation, and in teaching from experimental underwater acoustics to musical acoustics.

About six years ago I discovered Professor Jagodzinski's name in the Archive at the University of Surrey. During the Second World War, the Polish Government in Exile set up a 'Council of Academic Studies' with facilities for young Polish people whose studies had been interrupted by the war, to complete them, so that they could go back and play their part in the rebuilding of Poland after the War. These facilities were located at a number of places in the UK and covered the disciplines of architecture, economics and science and engineering. Just after the War, in agreement with the British Government, the Council of Academic Schools of Science and Engineering formed the basis of the Polish University College which was in South London. In 1953 the need for the College had passed, and the physical assets and a number of the teaching staff were fused into the then Battersea Polytechnic. In the course of time, this became the Battersea College of Advanced Technology and, in 1966, the University of Surrey, which relocated to Guildford. As the 14th graduate of the Polish University College, Professor Jagodzinski is, in some measure, an *Old Boy* of the University!

While the contemporary activities indicate the continuing benefit of Professor Jagodzinski's links to the University, he is primarily being honoured for the contribution he has made to Polish and international science. Owing to the changed political situation in Eastern Europe just after the war, very few of the graduates of the Polish University College did, in fact, return to Poland. (Regrettably there appear to be no systematic records of the careers of these graduates, although a significant number have achieved eminence in their fields in both Europe and the USA.) Thus Professor Jagodzinski represents one of the very few people who fulfilled the original aims for which the Polish University College was established – in using his knowledge and skills to contribute to the regeneration of his native country.

After studying Architecture for a year at the Technical University of Lwow (which is now in Russia), Professor Jagodzinski turned to Electromechanical Engineering, still at Lwow, and moved in 1938 to the newly established Department of Telecommunications at the Technical University of Warsaw. When War broke out, there were a few exams and a thesis remaining for the completion of his studies. As a Second Lieutenant, he was captured in the first few weeks at the Bzura river battle, and spent most of the War as a prisoner of war in camps of the Third Reich. During this time he continued his studies, and gave lectures to his colleagues on problems of Radio Communications (not one of the subjects most favoured by the Camp Authorities!). In addition he wrote two books, *Theory of Electromagnetic Waves* and *Frequency Conversion*. The manuscripts of these were entrusted to a Red Cross official when the camp was liberated. Unfortunately the official later had to abandon them as he fled for his life, but the manuscripts were somehow safely returned to the author – in 1986!

At the Polish University College, Professor Jagodzinski wrote his thesis on *A 400 Watt Radio Transmitter*, which was supervised by Professor J J Hupert, then a Lieutenant-Commander in the Polish Navy and Senior Research Officer at the Admiralty Signals Establishment at Haslemere. He returned to Poland in 1948 and, while employed by the Marine Radio Service in Gdynia, lectured at the Technical University of Gdansk on Maritime Radio Systems and Radio Direction Finders. The Marine Radio Service, which still exists today, was set up to help

Prof P Dowling (Vice Chancellor of Surrey University), Prof Z Jagodzinski, HRH Duke of Kent (Chancellor of the University, Dr R C Chivers

the port authorities and shipyards with the installation, repairs and maintenance of radio equipment on ships. The ships recovered by Poland (often salvaged from the harbours) came from different parts of the world, with radio equipment (transmitters, receivers, direction finders, echosounders, sometimes radars) produced in different countries (German, British, Russian, American) to different standards, often incomplete, with tangled cabling and no spare parts, circuit diagrams or instruction books! The importation of equipment was economically impossible at that time, even if it had been available so, as Professor Jagodzinski puts it, 'All this mess had to be kept going, in accordance with the requirements of the International Convention of the Safety of Life on the Sea'. A design department was formed, led by Professor Jagodzinski, which rapidly developed their own radio equipment, automatic distress signal receiver, and echo-sounders. The first transducers for the last of these were turned up on a lathe by Professor Jagodzinski out of nickel plates bolted together to form a block.

In the early 1950s the field of radio engineering was in rapid development and new radio aids were introduced in both marine and air navigation. The scope of his lectures at the Technical University increased accordingly and, in 1955, he was appointed Associate Professor in charge of a new department of Radio Navigation. In the late 1950s he developed an automatic digital radio direction finder. At that time the idea of using digital signal processing to obtain an angular phase for the measurement was quite new. The first device based on this principle was manufactured in Poland, and was awarded the gold medal in the 'Leipziger Messe' in Leipzig. A modern version is standard equipment today on ships in Poland and several other countries. Subsequently, Jagodzinski has been active as a national advisor on the radio equipment installed in the country's airports, in particular the International Airport at Warsaw – Okecie. He was the consulting engineer on the choice and installation of the modern (imported) equipment which included radio communication transmitters and receivers, radio aids to navigation (VOR, DME), the instrument landing system, and radars. However, parallel to his interest in radio navigation systems, Jagodzinski has had a deep interest from the beginning in underwater acoustics.

The original reasons for this were intensely practical. Not only was it necessary accurately to sound the port areas in order to clear away the concrete debris from demolished buildings and wave-breakers, but the many wrecked vessels lying in the Bay of Gdansk and the Southern Baltic Sea had to be located and removed. To help in these tasks, Professor Jagodzinski designed a sonar system with which some 50 wrecks were found. Some of the ships that were not too badly damaged were repaired and later used in the Polish Mercantile Marine. The salvage operation introduces specific instrumental requirements for the divers operating from the salvage ship. While aqualung systems (which now, of course, are commonplace) gave the diver freedom from attachment to the ship, the result was also to sever a communication line. In shallow, muddy waters he is also practically blind. To overcome these problems from the late 1940s to the early 1950s Professor Jagodzinski designed two devices. The first was a hydrotelephone in which an ultrasonic wave is used as a carrier for the modulating audio signals. Now extensively used in underwater operations, this device was one of the first devices, or perhaps even the first device, of its kind in the world. The second device was aimed at the problem of poor visibility. Although the diver may be helped, in principle, with an ultrasonic echolocating system, the extreme shortness of the distances often involved can preclude the use of conventional pulse techniques. Thus Professor Jagodzinski and his colleagues designed a frequency modulated sonar with an acoustic indication of distance. This had the form of a small handheld device, like a torch, with which any reflecting object could be easily found.

Jagodzinski has continued and indeed even increased his activities in acoustics, particularly in underwater acoustics over the years, with a view to meeting the needs of the merchant fleet and related industries. In 1964 he was appointed as a Professor at the Technical University of Gdansk. More than 200 students have obtained their MSc degrees under his supervision, 10 have obtained their PhDs and these are the scientists who are now leading the research, development, and design of new underwater acoustic systems in Poland, (three of them have recently been appointed as Professors at the Technical University). Since 1969, following a reorganisation of the University, this was largely carried out in the Hydroacoustic Establishment run by Jagodzinski within the Institute of Telecommunications with a staff of up to 40. Included in its activities are the fundamental physical phenomena of ultrasound, the propagation of ultrasonic waves in the sea, transducer theory and measurements, the design of different sonar systems, communication systems, underwater position fixing, Doppler systems and other ultrasonic devices for use in marine navigation, fishing and oceanotechnic operations. The work of the Establishment has included a significant amount of classified activity. (It is some measure of his success in this, that four of the fourteen National Honours he has received have been awarded for National Defence.) Whereas keeping abreast of the latest developments in electronics and circuitry is critical for success in this area, Professor Jagodzinski has always regarded the transducer as the key element in any underwater acoustic system, and has been concerned from the time of constructing transducers with his own hands, with the theory, measurement, and operating conditions of ultrasonic transducers. He is currently writing a textbook on the subject. This has been one of the areas of mutual interest with the University of Surrey.

With such a strong and efficient team to continue the work, he retired in 1983 at the age of 70, but it is not his style to be inactive. He has continued to act as a consultant to the group, to take part in conferences at home and abroad (including our own Institute meetings), to write papers, and to be an active member of Scientific Councils in Poland. These latter include being Vice-Chairman of the Acoustical Committee of the Polish

Academy of Sciences, a member of the Polish National Scientific Committee on Ocean Research, and a member of the Council of the Institute for Fundamental Technological Research of the Polish Academy of Sciences (Warsaw), the Council of the Institute of Oceanology (Sopot), the Council of the Institute of Highsea Fisheries (Gdynia), and the Council of the Polish League of Noise Abatement (Warsaw). He is also a very active member of the Polish Acoustical Society (which is the meeting forum for all Polish acousticians, and the sponsor of their international activities). Having established the regional branch of the Society in Gdansk in 1972, he was elected President of the Society from 1981 to 1987. In this capacity he did much to coordinate the activities of the regional branches and professional groups of Polish acousticians. It was a period of extreme political and economic crisis, which made it hard to keep the organisation running smoothly during those years. Jagodzinski worked strenuously to ensure that all the activities and meetings were held in spite of the many difficulties. In all those years, the only meeting which had to be cancelled was the Annual Open Seminar in Acoustics in 1982, due to the Martial Law that was in operation.

He has been active in conference organisation and in stimulating international links, having been Chairman of the organising committee of the annual Symposia on Hydroacoustics held near Gdansk since their commencement in 1984. He helped establish the long term formal collaboration between the Polish Acoustical Society and the Groupement des Acousticiens de Langue Francaise (GALF) (now the Societé Française d'Acoustique – SAF), and in the mid 1970s initiated and effectively developed a close cooperation between the underwater acoustics group in Gdansk and their counterparts at the Wilhelm Pieck University in Rostock (which includes a series of conferences on Hydro- and Geo-Acoustics).

Professor Jagodzinski's contribution to his country has clearly been exactly in line with the aspirations of the founders of the Polish University College, and we at Surrey have been privileged to have benefited from his scientific understanding, his didactic wisdom, his perceptive humour, and his gentle courtesy over so many years.

I am grateful to Professor Jagodzinski for permission to publish these details of his activities and hope that some of the readers of the Bulletin find some interest in the problems facing scientists in Eastern Europe in the immediate Post-War years, and the way they were overcome. It should be mentioned, for completeness, that Professor Jagodzinski had no political activities or party membership.

The open seminar in Acoustics is the annual, broadly-based meeting of the Polish Acoustical Society. The Institute for Fundamental Technological Research in Warsaw is one of the leading national centres in acoustics and theoretical mechanics. The main themes of acoustics which are strongly represented there are ultrasonics (of many types), speech acoustics and noise problems.

Robert Chivers FIOA is in the Physics Department at the University of Surrey

MEETING NOTICE

London Branch
and
Industrial Noise Group

NOISE IN BUILDING SERVICES

Church House Conference Centre, London

Wednesday 15 March 1995

Programme

10.00	Registration & coffee
10.30	A REVIEW OF PREDICTION METHODS FOR BUILDING SERVICES NOISE, AND THEIR ACCURACY, *Bob Peters, NESCOT*
11.00	NOISE CRITERIA IN BUILDING SERVICES DESIGN, *Neil Jarman, Vernon Cole Associates*
11.30	SITE AS A LABORATORY – A COMPARISON OF FIELD TEST RESULTS WITH THEORY, *Alan Fry, Salex Group*
12.30	Lunch
2.00	WOULD YOU PUT A FAN IN A VEAL CRATE ? (- the manufacturer supplies a quality product wiith accredited data, but where does responsibility end for the way in which the fan is installed and used - a discussion paper), *Neil Jones, Nuaire Ltd*
2.30	THE APPLICATION OF ACTIVE NOISE CONTROL TO HVAC SYSTEMS, *Geoff Leventhall, Digisonixs Inc*
3.00	Tea
3.30	NOISE CONTROL OF BUILDING SERVICES IN AUDITORIA, CASE STUDIES: THE NEW GLYNDEBOURNE OPERA HOUSE AND THE ANVIL, BASINGSTOKE, *Helen Thornton, Arup Acoustics*
4.00	DRAFT ANC GUIDELINES FOR THE MEASUREMENT AND ASSESSMENT OF NOISE FROM COMPLETED BUILDING SERVICES INSTALLATIONS, *Adrian James (1), John Miller (1) & Jeremy Newton (2), (1) Independent Consultants, (2) BDP Acoustics*
4.30	Discussion and close of meeting

❑ I wish to attend the meeting on **Noise in Building Services**

Full Name:
Organisation:
Address:

Tel No: Fax No:

❑ I enclose a cheque for the delegate fee ❑ Please invoice me

❑ Members £75 + VAT = £88.12 ❑ Non-members £95 + VAT = £111.62

I cannot attend the meeting. Please send me a copy of the proceedings

❑ £18 (members) ❑ £25 (non members)

Institute of Acoustics, Agriculture House, 5 Holywell Hill, St Albans, Herts AL1 1EU
Tel: + 44 (0)727 848195 Fax: + 44 (0)727 850553
Registered Charity no. 267026

FORTHCOMING MEETINGS

Programme published

International Conference

Sonar Transducers '95

(Organised by the Underwater Acoustics Group)

University of Birmingham

3–5 April 1995

Abstracts may still be submitted

1995 Spring Conference

ACOUSTICS '95

Environmental Noise and Vibration

(Organised by the Environmental Noise Group)

Britannia Adelphi Hotel, Liverpool

9–11 May 1995

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.

1995 Autumn Conference

Methodology, Standards and Measurement in Acoustics

Hydro Hotel, Windermere

26 – 29 October 1995

It is intended that the programme for this conference will be a mixture of contributed papers on recent developments, tutorial and workshop sessions and practical work in groups.

11th International Conference

Reproduced Sound 11

Hydro Hotel, Windermere

16 – 19 November 1995

All aspects of the reproduction of sound will be covered

INSTITUTE DIARY 1995

2 MAR
IOA Medals & Awards, Council
St Albans

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

7 MAR
InterNoise '96 Committee
St Albans

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

15 MAR
London Branch mtg: Building Services Noise
London

16 MAR
CEng Interviews
St Albans

23 MAR
Eastern Branch mtg Environmental Noise and the Law
Bury St Edmunds

29 MAR
Midlands Branch mtg Low Frequency Environmental Noise
Coventry

29-30 MAR
CEng Interviews
St Albans

30 MAR
Physical Acoustics Group mtg
Telford

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

- MAR
Southern Branch mtg Railway Noise Calculations
Gatwick

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

5-6 APR
CEng Interviews
St Albans

11 APR
Diploma Examiners Meeting
St Albans

11 APR
Scottish Branch & Environmental Noise Group Workshop – Environmental Noise Assessment
Glasgow

26 APR
London Branch mtg: Acoustic Intensity
St Albans

26 APR
Eastern Branch mtg: The Ear and Hearing - Latest Developments
Colchester

27 APR
IOA Publications, Meetings Committee
St Albans

4 MAY
IOA Membership, Education Committee
St Albans

9-11 MAY
ACOUSTICS '95 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

20 MAY
Eastern Branch Dinner:
Dedham

25 MAY
London Branch mtg Noise and Statutory Nuisance Act
London

25 MAY
IOA Medals & Awards, Council
St Albans

- MAY
Southern Branch mtg User Perspectives on PPG24
Oxford

7 JUN
Eastern Branch mtg: Long Distance Sound Propagation
Braintree

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

15-16 JUN
IOA Diploma Examinations
Accredited Centres

20 JUN
Reproduced Sound 11 Programme Committee
St Albans

21 JUN
London Branch mtg Occupational Noise
NESCOT, Epsom

23 JUN
IOA CofC in W'place Noise Ass't Advisory Committee
St Albans

30 JUN
IOA CofC in Environmental Noise Mm'nt Advisory Committee
St Albans

12 JUL
Midlands Branch mtg

21 SEP
IOA Publications, Meetings Committee
St Albans

28 SEP
IOA Membership, Education Committee
St Albans

- SEP
Southern Branch mtg Lesser Known Techniques in instrumentation/measurement
ISVR Southampton

5 OCT
IOA Medals & Awards, Council
St Albans

13 OCT
IOA CofC in Workplace Noise Assessment exam
Accredited Centres

26-29 OCT
Autumn Conference
Windermere

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

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

16-19 NOV
Reproduced Sound 11
Windermere

20 NOV
IOA Publications, Meetings Committee
St Albans

23 NOV
IOA Membership, Education Committee
St Albans

29 NOV
Midlands Branch mtg

MEMBERSHIP

The membership of the following corporate members of the Institute has lapsed

Anani, J K
Au Yeung, C J
Bannell, J L K
Bland, M J
Brennan, E
Campbell, I W
Chan, L C
Cheng, C K
Ferguson, J H
Mathys, J M G
Rabouhi, K
Roper, R G
Tattersall, J D
Tucker, P S
Wong, M C J

Contact has been lost with the following members; information on their present whereabouts would be helpful:

Chan, Hung
Dodson, Alan
Evans, David
Harris, Fraser
Lindsey, Stephen
Tam, Kam Hay
Yeung, Wing Yau

CALL FOR PAPERS

International Conference

Sonar Signal Processing

(organised by the Underwater Acoustics Group of the Institute of Acoustics)

University of Technology Loughborough Leicestershire UK

18-20 December 1995

This will be the fourth in a series of conferences on Signal Processing in Sonar which have been held at Loughborough University of Technology under the auspices of the Underwater Acoustics Group of the Institute of Acoustics. Much of what was said in the previous Call for Papers is equally true today – the rapid development in hardware, the reduced size and increased power of processors, the insatiable demands of the engineers designing the signal processing systems.

The purpose of the conference will be to review the present state of this rapidly developing subject and to report on new developments and future trends. As previously, the presentation of practical systems and results will be encouraged and a poster/ demonstration session will be a key feature of the conference.

Prospective authors are invited to submit a 200 word abstract not later than 17 June 1995. Successful authors will be notified by mid-July 1995. Complete manuscripts may be up to 8 pages long, including diagrams, and must be prepared in the correct camera-ready format. Special paper will be provided. All manuscripts must be in the hands of the conference secretary by 23 September 1995. Those arriving after this date will not be printed. The conference proceedings will be published in book form in Volume 17 of the Proceedings of the Institute of Acoustics (1995) and copies will be available at the beginning of the conference.

The conference will be chaired jointly by Professor J W R Griffiths FIOA and Professor H D Griffiths FIOA. It will take place at the University of Technology, Loughborough, which is situated on a very pleasant open campus close to the town. Full board and accommodation will be available, both in a student hall of residence at very reasonable rates and in a new residential building with en-suite facilities. Although the weather in the UK in December is not at its best we hope the excellent facilities on campus will provide some compensation.

For those of you who have been before we know you will want to come again. We also look forward to welcoming many new faces.

Send your abstracts, and address any questions regarding the conference programme, to Professor J W R Griffiths, Dept of Electronic and Electrical Engineering, Loughborough University of Technology, Loughborough, Leicestershire LE11 3TU, UK.

Institute of Acoustics, Agriculture House, 5 Holywell Hill, St Albans, Herts AL1 1EU

Tel: + 44 (0)727 848195 Fax: + 44 (0)727 850553

Registered Charity no. 267026

'COMPETENCE AND COMMITMENT'

The Engineering Council's proposals for a new system of engineering formation and registration

At a press conference held in London on January 18 1995 the Engineering Council, taking into account the major developments in national education and training, launched 'Competence and Commitment', a document with far reaching proposals for new standards of professional competence and commitment that will take the United Kingdom engineering profession into the next century and place engineering at the forefront of modern professionalism.

The speakers were Sir John Fairclough FEng, Chairman of Council, Dr David Fussey CEng, Vice-Chancellor of Greenwich University and Chairman of the Council's standing committee for the engineering profession and Professor Keith Foster CEng, Director, Engineering Profession at the Council.

Some of the messages contained in the document 'Competence and Commitment' are as follows. The register of The Engineering Council exists to promote best practice for the public benefit. Registration will require engineers and technicians to demonstrate and maintain both:

- the competence to perform their professional work to the necessary standards and
- the commitment to maintain that competence, to work within professional codes and to participate actively in the profession.

A major thrust will be to develop and assess competence in three parts: foundation learning, specialist learning and competence in employment against the background of clearly defined occupational standards. Flexible pathways and provision, when adequately specified, will be welcomed. Lifetime learning, supported by evidence of continued commitment of individual engineers to their continued professional updating and adherence to the Council's professional codes, will also be required.

The document takes into account the wide range of responses to an earlier discussion document 'Review of Engineering Formation' published by the Council in 1993. It is in the form of a short policy statement supported by explanatory papers.

The new document makes clear that the expected educational preparation for each of the three categories – Chartered Engineer, Incorporated Engineer and Engineering Technician – must be enhanced.

Under the proposals, in order to satisfy the new requirements at Chartered Engineer (CEng) level, for instance, candidates will require an honours degree level foundation, plus specialist development to master's level or equivalent. Candidates for Incorporated Engineer (IEng) will require an HND or GNVQ Level 4, plus specialist development to degree level or equivalent. Finally Engineering Technician (EngTech) will require a GNVQ Advanced Level foundation plus HNC level or equivalent.

The document also establishes exemplar entry requirements for a range of programmes and calls for a more coherent system of post-14 education in which the best attributes of GCSE and A-Level, GNVQ and alternatives to both, are considered in a broad and integrated framework.

In addition it is proposed that UK candidates for the prestigious European Engineer (Eur Ing) title will, in future, have to be fluent in a European language other than English up to NVQ Level 3 based on the language lead body standard.

The Council will not be prescriptive about the methods, routes or techniques to be used by individuals for registration, by education and training providers for teaching and assessment, or by nominated and awarding bodies for the assessment of individuals. But, under the proposals, the Council will expect any organisation with which it works in connection with the formation and registration to have an effective quality assurance policy and formal quality management system.

The revised criteria for registration to replace the Council's existing SARTOR (Standards and Routes to Registration) document will be developed during 1995 as part of the transition to the new Engineering Council structure. Some outlines of how a revised system of registration will operate are, however, already apparent.

It is proposed that registration will be based on compliance with 'standards of competence', which at the higher levels, are developed by the four industry standing conferences of the Engineering Occupations Standards Group (EOSG), the co-ordinating NVQ/SVQ lead body for engineering at professional, managerial and technical levels.

The emerging NVQ and SVQ system will, the Council claims, make a major contribution to the new system. Initially profiles of units of competence may be specified until the higher level NVQ structure is settled. The proposals have a major contribution to make to the development of the NVQ system when applied at the higher and professional levels.

The existence of varied means of delivering education and training implicit in the NVQ/SVQ system must not, however, compromise the operation of a registration system operating to uniform standards. It must, therefore, be possible to show all the various pathways and their intersections on the same map. In addition, there should be a single national credit framework for all engineering related education, whether in school, at higher education and further education levels and at work.

John W Tyler FIOA

Free copies of 'Competence and Commitment' are available from The Engineering Council, 10 Maltravers Street, London WC2R 3ER. Send SAE with 80p stamp.

Speech & Hearing
3 – 6 November 1994, Windermere

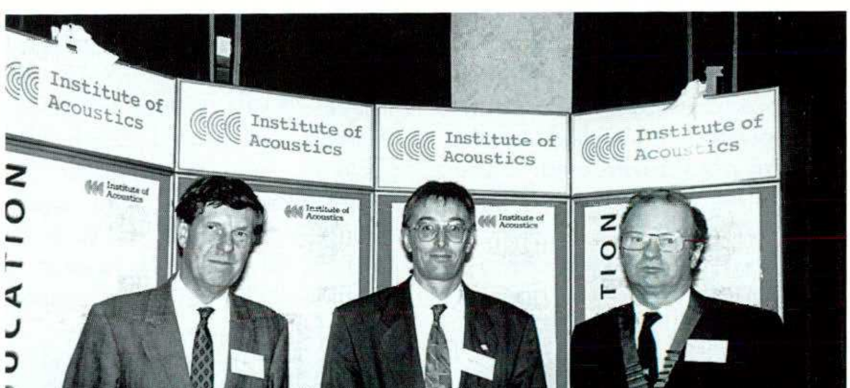
In November members of the Speech Group made their biannual pilgrimage to Windermere for the Auturnn Conference at the Hydro Hotel. Perhaps for the first time ever, it did not rain.

The first session on Speech Recognition had seven speakers covering a wide range of topics. Mike Tomlinson from DRA Malvern showed how the addition of visual cues could improve speech recognition in noise and Denis Johnston from BT Laboratories described a study of human recognition ability. The latter showed that machines still have some way to go before they will match human performance. Continuing the theme of improving basic performance, Harry Fairhurst from Liverpool University described a noise robust speech coding using the bispectrum and Wendy Holmes from DRA discussed an extended form of hidden Markov model in which segments are explicit. In the area of large vocabulary recognition, Julian Odell from Cambridge University described the HTK Recognition System which has a vocabulary of 65,000 words and can handle speech from any speaker. Finally, two speakers described language modelling problems. Kevin Johnson from Durham University proposed some techniques for repairing errors in spontaneous speech and Jerry Wright from Ensigma described an approach to integrating n-gram language models with context-free grammar rules.

The Friday morning poster session had a good variety of papers to whet the appetite of delegates after morning coffee. From a voice controlled hedgehog, via Punch and Judy to auditory modelling and speech rehabilitation, almost all areas of research were represented. An interesting paper from Kevin Baker (De Montfort University) and Sandra Whiteside (Sheffield University) found evidence to suggest that voiced/unvoiced consonants in whispered speech can be identified in the absence of vocal fold vibration and meaningful contextual information. Principal component analysis as applied to the compression of facial images by Michael Brooke and S D Scott of Bath University was demonstrated in the context of visual speech intelligibility by means of a video recording. The use of subword units in speaker independent telephone speech-recognition was reported by R Y John and David Pearce (GEC) who found that best error rates of 6.6% and 6.8% for male and female speakers respectively. James Angus and Robert Smart from York University provided a working demonstration of a voice controlled Sonic the Hedgehog Sega game. Eddie Rooney et al. from Edinburgh reported an autonomous speech rehabilitation system for the hearing impaired which incorporated a number of modules which increased in sophistication. It was, though, a pity that the demonstration provided was not a fully working system given the known difficulties. A comparison of pitch analysis by inverse filtering and auditory filtering by Fabrice Plante, Georg Meyer and Bill Ainsworth (Keele University) demonstrated that that inverse filtering gave better results than the auditory model in all noise levels. Paul Callagan, Richard Morgan and Robert Garigliano (Durham University) presented their work on prosodic assignment in a large scale natural language processing system which they claim provides more information than contemporary text-to-speech systems but more work is needed. Female operatic and belt singing voice qualities were compared by Michelle Evans and David Howard of York University who noted differences in modes of vocal fold vibration. Altogether it was a stimulating and varied session.

After lunch Roger Moore was presented with the Tyndall Medal by Alex Burd, the President of the Institute. Roger then gave a fascinating lecture on Speech Pattern Processing: from 'Blue Sky' Ideas to a Unified Theory? in which he outlined the development of his ideas on speech processing and his hopes for the future. This was accompanied by a word spotting system demonstration which informed the audience about which parts of his talk were concerned with Speech Science and which with Speech Technology.

The Tyndall Lecture was followed



Bill Ainsworth (Conference Organiser), Roger Moore (Tyndall Medallist) and Alex Burd (Institute President) by a short session on various aspects of Nonlinear Phonology. William Edmunson (Birmingharn University) presented a paper written by himself and Jon Iles on Pantome: an architecture for speech and natural language processing which attempts to avoid the limitations of viewing speech as a sequence of units. Mark Huckvale from University College London described a different nonlinear architecture; one based on tiered layers. He demonstrated how such a model could be used to implement a speech recognition system. Lastly Mark Tatham from Essex University argued that speech production is the result of many overlapping processes and to explain language differences some of these must be under cognitive control.

There were nine posters in the Friday afternoon session, covering a wide range of subjects in the field of auditory phonetics and speech technology. Mike Pont and Kien Seng Wong from Leicester University demonstrated a system for simulating the auditory evoked response to various stimuli. The system can be used to simulate both normal and impaired hearing. Ian Gransden and Steve Beet (Sheffield University) found an improvement in recognition performance when combining auditory representations, when compared to the case where the representations are taken separately, or the linear discriminant analysis combination of them. They felt that the robustness of the combined representations was surprising, given the simplicity of the adaptation mechanism used. Christine Cheepen and James Monaghan (University of Hertfordshire) reported on work with disabled children and ASR. They found that ASR enabled some of the children to show a marked improvement in literacy skills, as the keyboard had been difficult and tiring for them to use. This was the case, however, only for those without any cognitive deficiency. I Gibson and David Howard (York University) presented a system of voice analysis for an advanced synthesis system. The aim was to produce sounds which were useful both in electroacoustic music and also in a more commercial environment. The system allows voice input to control the synthesised F0, amplitude, and timbre. John Holmes presented a system for speaker-independent recognition of connected digit strings. The performance was found to be equally high for widely varying accents of English, and yet the amount of training data was much the same as for the conventional method. The system used an HMM-like structure, but with explicit duration modelling instead of transition probabilities. David Howard, James Angus and Graham Welch presented the SINGAD system for training children over the age of four years to pitch notes accurately. They found that girls learned more rapidly, but the boys caught up by the end. A certain proportion of children seemed unable to learn the skill, despite using intonation patterns correctly in speech. Reinier Kortekaas (IPO), Georg Meyer (Keele University) and Dik Hermes (IPO) used Dutch speech data to test an automatic vowel onset detection algorithm. This was being investigated as a possible method of automatic speech segmentation, as part of a continuous speech recognition system. They found that using 26-channel input gave only slightly better results than using 2-channel input. Niel Todd (Manchester University) and Guy Brown (Sheffield University) aimed to use prosody to improve the performance of a spoken language understanding systern. They found their 'rhythmogram' to be a powerful tool for linguistic analysis, based on auditory rhythm perception. John Openshaw, John Mason (University of Wales, Swansea) and John Oglesby (BT Labs). found that Gaussian white noise significantly affected speaker identification performance. Only keyboard clicks were more difficult for a system to deal with, for a given signal-to-noise ratio.

On Saturday morning a generally high-quality and varied complement of twelve posters was displayed. The importance of the steady progress which typified the session was well illustrated by the careful experimental work of Karen Stromberg, Celia Scully (Leeds University), Piere Badin (ICP, Grenoble) and Christine Shadle (Southampton University) on aerodynamic patterns in fricative production. The results increase our basic understanding of articulation and acoustic sources in speech production. Sheffield University was well-represented. A multispeaker corpus designed around a crossword task was described by Malcolm Crawford and members of the ILASH group; it was a neatly planned and executed data collection exercise. P Moakes and Steve Beet exhibited a radial basis function network that was used to predict pitch period and hence, through the prediction residual, to detect pitch pulses in voiced speech. They found that good perforrnance could be maintained in noisy speech through the introduction of recursive elements into the network. The complementary strengths and weaknesses of HMM recognizers and neural net classifiers led Dave Abberley and Phil Green to investigate the use of both together in speech recognition. They were able to show that combining the outputs of the two devices could produce small improvements in recognition rates that may be worth further exploration.

David Ollason's poster on variable pool-size, tied parameter systems using sub-word units for speech recognition represented a further contribution by BT Labs to the issue of building HMMs that possess phonetic context-sensitivity, but whose parameters can be estimated using only limited quantities of training data. The results suggested that significant gains could be achieved. Sengan Short and Russell Collingham (University of Durham) exhibited a concise outline of a metric for assessing speech recognition performance that takes into account the semantic distance between recognised and spoken utterances. This interesting idea was expressed in set theoretic terms. The design of a suitable experimental platform to test its effectiveness was not, however, discussed. Just one demonstration, by Rob Series, was included among the exhibits. It illustrated the relative ease with which applications could be designed on-line, using DRA's Aurix speech recognition system. Its capability at best was impressive, despite the noise levels in the room and the usual perversity of computer hardware.

From Keele University, a detailed presentation by Georg Meyer and Ian Dewar described the investigation of pitch extraction using models of the cochlear nerve and cochlear nucleus. The results suggested that onset units in the nucleus could extract fine detail that is absent from the nerve representation and may form the next level of feature extraction. Fabrice Plante and Bill Ainsworth pursued the search for effective formant-tracking by exploring several parametric methods. Their work included attempts to define objective criteria for comparing different methods, but they concluded that a single, general-purpose formant-tracking algorithm remains a Utopian dream at present. The University of York contributed two software packages. An inexpensive screening tool for the assessment of noise-induced hearing loss was presented by James Angus and Ariya Priyasantha. It measured auditory bandwidths by superimposing tones on comb-filtered noise without employing any special-purpose hardware. David Rossiter and David Howard described user-configurable software for creating real-time visualisations of a number of voice source and acoustic output qualities. The package has been applied to the assessment and training of singers, but it was a pity that an ideal opportunity for a demonstration was missed. The most interesting inspiration for a project arose from broadcasters needing to recognise the names of MPs called during debates. James Monaghan (University of Hertfordshire) reported a pilot study showing the extraordinary ways irl which listeners can confuse spoken proper names.

Six papers were presented in the Speech Synthesis session – two of them by Iain Murray (Dundee). The Dundee papers were concerned with modelling vocal emotional effects and conversation patterns to improve communication using synthesis for non-vocal people. Clearly it would be a considerable improvement if synthesisers could speak in ways which plausibly sound as their users might if not disadvantaged. Andrew Breen (BT Labs) reported on further work on segment duration estimation for the purpose of improving timing relationships in synthesis. William Edmonson (Birmingham) read a paper by Jon Iles and himself describing their latest work in feature driven synthesis. They claim that synthesis quality from formant synthesisers is improved by basing the synthesis model in 'articulatory control' of the synthesis, derived from a careful choice of feature representation of what is to be spoken. Richard Sharman reported on his work at IBM on concatenative speech synthesis. He has developed algorithms for dealing with waveform concatenation to produce a high quality output using subphoneme segments. Finally, Briony Williams (Edinburgh) told us more about her diphone synthesis of Welsh using the PSOLA concatenative technique. Her paper was detailed, covering all aspects of Welsh text-to-speech synthesis including the range of the diphone set, the letter-to-sound rules needed and how the prosodics are handled.

The session on Speech Synthesis was a great success, and reflected strongly the considerable progress currently being made in this field – not only from the point of view of the technological developments, but also in the way in which current advances in phonological and phonetic theory are filtering through into synthesis as a simulation of human speech production.

Eleven posters were presented on Sunday morning. Sandra Whiteside (Sheffield University) reported a laboratory-based experiment to identify temporal differences between sentences read by men and women. Tony Watkins and Susan Boegli from Reading University also reported work involving male and female speakers. In this case the experiment focused on sentences produced by male and female voices (and a male imitating a female), where vowel sounds were switched from a 'male sentence' to a 'female sentence' and vice versa. Paul Garner and David Howard described the development of a PC-based system to extract contours which indicate the relationship between fundamental frequency and larynx closed quotient. The operation of the system was illustrated by the contours produced by a set of word initial voiced and unvoiced plosives. Sheila Mair and Celia Scully (Leeds University) reported on the development of an articulatory model of 't' and 'ch' as produced by 10 speakers of RP English. J W Devaney and Colin Goodyear described experiments using acoustic reflectance techniques enhanced by optimisation procedures to model the vocal tract shape in natural speech.

In other posters Cliff Parris, Danny Wong (Ensigma) and Francois Chambon (ENST) compared three direct methods for evaluating the linear prediction filter from spectral amplitudes and described a new iterative technique with significantly better performance than the direct methods. L Baghai-Ravary, Steve Beet and M O Tokhi from Sheffield University described a flow-based prediction method of modelling speech dynamics. David Howard, Paul Garner and Andrew Tyrrell (York University) presented details of an implementation of a model of the peripheral hearing system which produces a 3-D waterfall spectral display output. Sengan Short and Russell Collingham (Durham University) described how weak semantic selection and semantic context can be used complementarily to disambiguate spontaneous speech in an automatic speech recognition system. There were two posters from Sheffield University on auditory scene analysis. Martin Cooke, Malcolm Crawford and Phil Green showed one way in which a recognition system could cope with occluded speech and Jon Barker and Martin Cooke outlined some general principles for mapping multidimensional data sets on to sound, using a simulated network of traffic flow to demonstrate their theoretical points.

The final session of the conference was rather a mixed bag, gathered under the title of Analysis and Perception of speech. It began with a paper by Christine Cheepen of the University of Hertfordshire on the Phonological Signalling of Topic Movement in Conversation. Conventionally, speech corpora are annotated at the phonological and lexical levels, but now that speech research is moving further towards being able to handle real conversational speech, the need arises to annotate at a much higher level. Christine has taken the bull by the horns and left a tape recorder running in her kitchen to get genuine spontaneous speech. She has analysed the clues that can be obtained from pitch, loudness, speed and rhythm, and she was able to demonstrate to us most convincingly how these signalled a change of topic when the talker broke off completely from what she was saying to apologise to the cat for nearly sitting on it. Next, we moved to a much lower level of analysis for a paper by Daryl Godsmark and Guy Brown of Sheffield University on a Computational Model of Context-Sensitive Auditory Organisation. The context of this work is the theory that complex sounds are perceived by a process, known as auditory scene analysis, in which features of the short-term spectrum are grouped in a manner analogous to the perception of visual scenes. The paper described a model for this perceptual grouping which can be evaluated in comparison with the results of subjective experiments in which the perceived groupings of sequences of tones are observed. It was explained that the model is capable of explaining a wide range of observed phenomena, and is now being extended to handle far more complex scenes.

Descending even further from the level of Christine's cat into the nitty gritty of speech production, the third paper, by Mike Brookes and D Chan of Imperial College was about Determining Speaker Characteristics from Inverse Filtering. Voiced speech signals are the result of exciting the resonances of the vocal tract with pulses of air from the larynx. It has long been regarded as theoretically possible (but in practice, extremely difficult), to determine the source airflow waveform by inverse filtering. Because this is the principal determinant of voice quality it can be used as a means of speaker identification. The paper described a number of improvements in both the inverse filtering process and in the model used to characterise the source waveform, and demonstrated that the technique could be useful for text-independent speaker identification. Continuing the theme of speaker identification, Mike Carey and Eluned Parris of Ensigma Ltd. presented a paper on Phoneme Matching Techniques for Speech Identification Problems. In order to make use of utterances without having to know what words the utterances contained, they recognised the utterances as phoneme sequences, not constrained to form words. The recognition was done with a set of speech models trained on different speakers, speakers of different gender, or speakers speaking different languages. By measuring which set of models gives the most probable explanation of the utterance, they have been able to show that this technique can be used for speaker, gender or language identification. Finally, Elizabeth Rohwer of LINKON Corporation, and her colleagues John Lear and Richard Rohwer described a Large Speaker Identification and Verification Experiment based on measurement of the overall characteristics of the speech using linear prediction cepstra This was tested on a very large database of 630 speakers. They showed that excellent speaker verification performance (approximately 0.5% error) could be obtained when testing with sentences designed to expose dialect variations, however, the fact that the results are independent of dialect supports the view that these measurements are measuring the physical characteristics of the speaker.

This report was compiled by Bill Ainsworth, Michael Brooke, Christine Cheepen, David Howard, Laurie Moye, Mark Tatham, Briony Williams and Steve Young.

Southern Branch

Thirty-one members and 14 guests attended the recent meeting of the Southern Branch at the Civic Offices, Basingstoke, on the evening of the 29th November 1994. Dawn Langdown (Basingstoke & Deane Borough Council) organised a very successful programme of four speakers to cover a wide range of general interests. Dennis Bayliss (CEL Instruments Ltd) brought along a definitive collection of historic sound level meters, and described the historical development of his current employer. Tim Clarke (Bristol City Council) described the mediation approach which is increasingly being adopted in Bristol to deal with large numbers of neighbour noise nuisance cases. Peter Frazer (Basingstoke and Deane Borough Council) described the development of the current round the clock out of hours complaints service at Basingstoke, and the various ways which have been tried to encourage and retain staff co-operation. Steve Turner (TBV Science) rounded off the evening with a lighthearted look at Public Inquiries and the art of presenting evidence and surviving cross-examination.

There was a general consensus amongst those present that the activities of the Southern Branch were definitely worth pursuing, and 14 members volunteered to form a new committee to organise a programme of meetings for the next year.

Ian H Flindell MIOA

The Institute Diploma Examination

John Bowsher FIOA

Report on the 1994 Examination

The numbers of candidates gaining Merits, Passes or Fails in each Module are shown for each Centre in the Table of Results. The total number of candidates was 175 (218 last year) and the overall pass rate 80.7% (82.6% last year), including all projects. Candidates who did not submit their project report by the set date are shown to have failed in the project.

Matters of administration proceeded particularly smoothly this year and both I and Jeff Charles, the Deputy Chief Examiner, were assisted in their work by the office staff in checking every script for arithmetical and other errors in marking. There were very few problems for the Chief and Deputy Chief Examiner at their final written paper moderating session in August.

In the 1994 Diploma, the General Principles of Acoustics Module was again assessed partly by course work. Laboratory reports and assignments set throughout the year were graded and contributed 20% of the total mark. The overall practical effect was to raise the mean mark on the paper by 1.5% and reduce the standard deviation from 19.6 to 14.1. Although coursework formed a 'hurdle', no candidates failed the whole paper for this reason.

Particularly pleasing is the increase in numbers, and their performance in the Diploma examinations, of those studying by means of the Institute's Tutored Distance Learning Programme. This is proving a valuable provision, particularly as the continuance of courses at Accredited Centres come under threat as teaching staff retire and are not replaced.

Council has appointed Dr Robert Chivers FIOA of the physics department at the University of Surrey as Chairman of the Education Committee in succession to Dr Roy Lawrence who continues as Deputy Chairman.

Preparations for a syllabus revision are under way, a Diploma Working Group has examined afresh the whole structure of the Diploma and the Education Committee plan to have a new syllabus ready in time for the 1996 Diploma examinations. The Chief Examiner and the Education Committee Chairman would welcome views from the membership on the future and role of the Diploma, particularly as it is currently the main route for satisfying the Institute's academic requirements for corporate membership. Comments from Diploma holders would be particularly valuable as these would give some insight into the user's viewpoint.

	General Principles of Acoustics			Architectural and Building Acoustics			Law and Administration			Noise Control Engineering			Sound Reproduction			Transportation Noise			Vibration Control			Project			Overall		
	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail	Merit	Pass	Fail
Bristol	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3	1
Colchester	4	14	0	0	0	0	2	10	1	0	17	1	0	0	0	0	0	0	1	5	0	3	15	0	10	61	2
Cornwall	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	1	1	1	0	0	0	0	2	3	1	6	5
Derby	0	20	5	0	0	1	1	12	2	0	14	1	0	0	0	3	20	5	0	0	0	1	16	12	5	82	26
Heriot-Watt	0	4	0	0	1	0	0	3	0	1	0	0	0	0	0	1	2	0	0	0	0	0	2	2	2	12	2
Leeds	1	6	3	0	0	0	2	5	4	1	7	2	0	0	0	0	0	0	0	0	0	2	10	4	6	28	13
Liverpool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
NESCOT	3	20	1	3	3	1	4	14	1	2	18	0	0	0	0	1	5	3	0	0	0	2	19	11	15	79	17
Newcastle	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	8	2	4	8	2
Sheffield	1	4	1	0	1	0	0	0	0	0	4	1	0	0	0	0	0	0	2	5	1	0	4	2	3	18	5
South Bank	0	16	3	1	5	4	0	7	4	0	6	0	0	3	1	1	10	0	0	0	0	1	16	4	3	63	16
Ulster	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	15	0
Distance Learning	3	5	0	0	0	0	0	5	2	1	0	0	0	0	0	1	7	0	0	0	0	3	4	1	8	21	3
	12	104	14	4	11	6	9	59	15	7	66	5	0	3	1	8	46	9	3	10	1	15	98	41	58	397	92

Diploma in Acoustics and Noise Control
Grades awarded to 1994 candidates from each centre

1994 Diploma Pass List

Tutored Distance Learning
Hewett, M
Lavender, D A
McCaffrey, C
McLoughlin, K
Taylor, N D
Nicholas, A R
Nutt, D
Peers, R P
Shaw, I D
Speich, N J
Staveley, P W M
Thompson, P
Wain, S J H

Bristol
Ribbons, J H

Derby
Abbey, C S
Bodycote, S E J
Christie, R A
Delaney, D J
Francis, D J
Halliday, D W
Haynes, D R
Hubbard, P F
Laws, E J
Marston, D J

Colchester
Brown, D W
Brown, G
Buckingham, J
Day, C
Fritsch, H B
Gardiner, R
Grimley, A P
Harker, R
Hegerty, J S
Jones, F M
King, P
Moore, A R
Mudd, A L
Muggleworth, S D
See, K A
Wallace, J E S
Whitington, R A

Cornwall
Jewell, E T
Roberts, M J

Heriot-Watt
Conlon, E P
Johnston, E

Leeds
Atkins, P
Hudson, K A
Johnson, F M
Moule, A P
Richmond, W
Roberts, G M
Roberts, R L
Spaven, W M
Towse, K M
Widdowson, D

Liverpool
Matthews, A

NESCOT
Ashton, K L
Barber, M
Blakey, G S
Boase, S A
Collins, P
Cooper, J
Cox, S A
Dawson, P G
Dubet, M A E
Freeman, J J
Garthwaite, K
Pieris, A C
Richards, J K
Smith, P Q
Wedgbury, S J
Williams, T P J
Woodman, M J
Zeolla, F N

Newcastle
Gray, J

Sheffield
Freeman, P
Mackenzie, R G
McCabe, J F
Walker, H G

South Bank
Atkins, N D
Blessitt, R J
Bryan, R J
Clift, P J
Ellis, P R
Hennissen, W
Omar-Ali, F F
Papaker, F M
Ward, J A
Wastell, K
Wilkins, S L

Ulster
Campbell, U M

Diploma in Acoustics and Noise Control

Tutored Distance Learning

This mode of study is primarily intended for students who have difficulty attending a conventional course. The tuition pattern involves the programmed distribution of written material and exercises supported by a schedule of tutorial contacts and laboratory work. In addition candidates have to satisfactorily complete an investigative project.

Face-to-face tutorial arrangements are normally based on meetings in small groups with an approved tutor at regular intervals. Because of the variable travelling distances involved, these are arranged at several centres.

There are two course commencement dates each year. The first is in April for which the teaching programme extends over four academic terms. The second course begins in the October and lasts for three terms. Both courses prepare candidates for the IOA examinations in the June of the following year.

For the April entrants the General Principles of Acoustics module is taught during the summer and autumn terms, with the two optional modules and the project in the spring and summer terms. For October entrants the General Principles of Acoustics module is taught during the autumn term and part of the following spring term. The two optional modules and the project occupy the rest of the spring term and the following summer term.

The normal minimum requirement for admission to the Distance Learning Course is a degree in a science, engineering or construction-related subject or an Environmental Health Officer's Diploma; other qualifications may be acceptable.

Students electing to follow this method of teaching face the same examination and course work requirements for the award of the Diploma as those studying by the conventional route.

The award of the Diploma immediately satisfies the requirements for election to the non-corporate grade of Associate Member of the Institute, conferring the use of the designatory letters AMIOA.

The award of the Diploma also satisfies the academic requirements for Corporate Membership of the Institute. Election to the grade of Member (MIOA) involves in addition the fulfilment of certain experience requirements which usually amount to three or more years spent in a responsible role in a position directly related to acoustics, vibration or noise control.

Information on the Distance Learning Scheme may be obtained by contacting the Institute office.

Inter•Noise '96

The following is the text of an announcement to be published by the International Institute of Noise Control Engineering in the next issue of Noise/News International.

The Silver Jubilee of the Inter•Noise conferences will be marked by an International Congress and Technical Exhibition hosted by the Institute of Acoustics from Tuesday 30 July through to Friday 2 August 1996. The congress is sponsored by the International Institute of Noise Control Engineering.

The venue chosen is the recently refurbished Britannia Adelphi Hotel in Liverpool. The hotel dates from 1826 and is a reminder of the importance of Liverpool as the main European trading and emigration port on the Atlantic seaboard. It was reconstructed in 1912 to cater for transatlantic liner clients and has historical connections with many famous visitors including Charles Dickens. The Edwardian elegance has been maintained and blended with features expected of a modern conference venue. Facilities include 3 restaurants, 4 bars, a health club with gym, sauna, solarium and swimming pool, a night-club and unrivalled conference and banqueting rooms.

The General Chairman of the Congress is Bernard Berry from the National Physical Laboratory assisted by an organising committee representing the academic and commercial sides of the acoustics and noise control discipline in the UK. Nicole Porter of NPL chairs the Technical Programme Committee and, in keeping with the importance of the silver jubilee occasion, particular attention is being paid to the technical sessions, with work already in hand to ensure that they contain unique and relevant material of interest to noise and vibration control professionals. An Announcement and Call for Papers will be issued in May 1995 and abstracts will be requested for submission by December 1995.

An International Advisory Committee of eminent noise control specialists is being assembled to ensure the quality and international relevance of the papers presented. The growing importance of international trading blocks such as the European Union and the North American Free Trade area and the effect they are having on the harmonisation of legislation will be a key strand running through the technical sessions. In what is essentially a regulations driven industry, the effects of regulatory changes are having a profound technical impact so to ensure that legislators are fully briefed on the technical aspects of their free trade and fair competition programmes, invitations have been extended to key political figures.

The city has a lot to offer the international visitor as a modern cultural centre steeped in the historical connections between the old and the new worlds. The congress hotel is located close to the historic waterfront where the River Mersey flows into the Irish Sea. Here the Albert Dock has now been completely redeveloped as a commercial and cultural centre and offers an interesting insight into the history of the area. With museums and many other attractions, delegates and accompanying persons will find an abundance to fascinate them. The social programme planned includes the opening reception within the Merseyside Maritime Museum which includes the 'Emigrants to the New World' exhibition that vividly portrays the lot of those who left Europe to populate the Americas, contrasting what they left behind with what they found on arrival.

The Conference Dinner will be held in the St George's Hall; this dates from 1842 and has been described as one of the most important public buildings of the past 200 years in the United Kingdom. The accompanying persons programme is planned to include the Beatles Magical Mystery Tour, Mersey ferry cruises and organ visits to the Anglican and Roman Catholic Cathedrals. The Anglican Cathedral is a magnificent neo-gothic building and is the largest cathedral in the country with the heaviest and highest ring of bells. It took 75 years to complete and is home to the largest church organ in the country. Nearby is the city of Chester, famed for its unique medieval buildings and the complete city wall with evidence of every period of history since Roman times.

Communications with the city of Liverpool are excellent. There is a regional airport with regular connections to London and Manchester International Airport is only one hour away by direct train. The hotel itself adjoins the main rail station that is part of the inter-city network connecting with all parts of the UK and from Northern Europe via the Channel Tunnel. Motorway links to the city are also available allowing those who wish to stay out in the countryside easy access to the Congress venue.

Those wishing to extend their stay will find that they are conveniently located to explore the dramatic scenery of North Wales, the English Lakes, the Peak District and Scotland. Alternatively crossing the Irish Sea offers the chance to explore at first hand the origins of Liverpool's (and America's) Irish community. To the east, past the mills that turned American cotton into fine linen, there is the peaceful beauty of the Yorkshire Dales while to the south the visitor can find tangible evidence of the industrial archaeology of the UK at such places as Ironbridge Gorge which is credited with being the cradle of the Industrial Revolution. Indeed a veritable treasure trove awaits those from overseas whose experience is limited to the geography and peoples of London and the south-east areas of England.

Further information on the Congress, the Exhibition and the associated activities can be obtained from the Institute of Acoustics. ❖

Report

A Study of Environmental Low Frequency Noise

John W Sargent MIOA

Introduction

The Department of the Environment has received a small but steady flow of complaints about low frequency noise for many years. In 1988 DOE funded a review of the disturbance caused by low frequency noise, which included a survey of the complaints received by Local Authorities. The survey indicated that the total number of complaints to all Local Authorities at that time was about 500 per year. Positive identification of the noise source causing these complaints was made in slightly less than 90% of cases.

In 1992 a research contract, under the direction of the Building Research Establishment, was placed with Sound Research Laboratories to investigate some of the unsolved cases and, as a result of the experience gained, provide practical guidance for those professionals who have to deal with similar problems. Sound Research Laboratories sub-contracted audiological studies on a sample of the complainants to the Audiological Unit of Addenbrookes Hospital.

The Study Sample

Contact was established with over 380 complainants. Some of these were people that contacted Sound Research Laboratories (SRL), the Building Research Establishment (BRE) or the Department of the Environment directly as a result of the publicity. However the majority were referred by Environmental Health Officers (EHOs) who had first investigated the complaint.

A simple questionnaire was produced to gather the relevant information on each case in a consistent format which could be easily accessed. A total of 385 questionnaires were sent out during the project and of these 273 were returned completed. In these questionnaires a total of 295 sufferers were listed. Of the sufferers 111 were male and 184 female, that is, 38% male and 62% female. The most common descriptions of the noise used the words 'droning', 'distant plane', 'lorry', 'diesel engine', 'generator' and 'motor hum'. Other words used are 'turbine', 'whine', 'high pitched "sissing" ', 'whistle' and 'hissing'. Some descriptions use a number of these words. In a few cases the sufferers have said it was too difficult to describe.

The sample for site investigation was chosen using information from questionnaire data. The sample includes male and female complainants. Cases were chosen in various geographical areas from the south coast of England to Ayrshire in Scotland and from Bristol in the west of England to Ipswich in the East. Both rural and urban cases were included in the sample. As the work progressed investigations were concentrated on cases where more than one person in the same household were reported to have heard the noise. Cases where, from details given, the complainant was suspected of suffering from tinnitus were not included in the sample.

Site Investigations

Investigations were generally conducted within the sufferer's property as this was usually the place where the noise was heard. The investigations would normally be made in the evening and sometimes into the early hours of the morning as in most cases it was reported that the noise was less noticeable during the day.

The outline of the investigation procedure was as follows:

i) Initial interview with sufferer.
ii) Investigator listens for noise.
iii) Tests, such as tone matching, to try to establish more about the nature of the noise heard.
iv) Measurements of the ambient noise levels to try to identify the specific noise causing the noise nuisance. Narrow band (1/24th octave) real time analysis was normally used however in some cases an FFT (Fast Fourier Transform) Analyser was used.

A total of 31 cases were investigated as part of this project, 26 cases by SRL and a further 5 by BRE. Experience of a further two cases carried out by SRL for other clients has also been used with the clients' permission.

Of the 26 cases investigated by SRL there were only 3 cases where the noise could be positively detected by measurement and/or was audible to the investigator. In two cases the noise complained of was consistent with the 100 Hz noise emitted by electrical sub-stations nearby. In the other case there was a narrow band of measured noise centred on 104 Hz which although at a low level was audible to the investigator. This frequency being slightly higher than 100 Hz is unlikely to come from an electricity sub-station and the noise was still found to be present when the local electricity board switched off the nearby sub-station. This noise was not audible or detectable outside the house. There were another 7 cases where for a variety of reasons there was some evidence to suggest that a low level low frequency noise may occasionally be present that could be related to the noise complained of. If noise measurement had been possible over a long period of time it may have been possible in some of these cases to identify the noise that related to the source of the problem. In most of these cases it is suspected that the sufferer has been sensitised to the noise at some time in the past when it was louder and more continuous. In none of the cases investigated by BRE could a noise be detected in the complainant's residence that related to the noise heard by the complainant. Although in one case it was thought possible that a low level noise from a local pumping station may have been present at times in the past and sensitised the complainant.

In the two cases SRL carried out for other clients there was little doubt about the source of the noise, measurements being used to confirm the sources and to provide information on which to base recommendations.

Audiological Investigations

Comprehensive audiological testing was undertaken with 10 complainants and for 2 cases of non-complaining spouse or family member. In only 3 cases was tinnitus indicated. True hyperacusis, being hypersensitivity and annoyance from all sounds, was indicated in one case, but an additional 3 showed specific hypersensitivity to the noise of their complaint. In one case there was strong evidence that a noise was indeed present as the noise was heard by the whole family and only in one bedroom. Subsequent measurements confirmed the presence of a noise in this particular room. In one case the wife was the principal complainant, but during audiological tests she was able to hear the noise of complaint clearly in a sound-proof room and was therefore said to have tinnitus. The husband was also a complainant, but he had normal hearing and was unable to hear the sound in the sound-proof room. The conclusion made was that his wife's complaint had drawn the husband's attention to low frequency sound in the environment, and so he had become convinced of the complaint and shared the distress. There was also a second case with similar circumstances and symptoms.

The report from the audiological scientists concludes that categorising low frequency noise (LFN) complainants would be spurious if it did not lead one to options for treatment or therapy. A detailed consideration of this area is far beyond the scope of the original brief to the audiologists involved, but a thumbnail sketch may be helpful. A patient with tinnitus may be helped with a hearing aid or white noise generator (previously known as a tinnitus masker). The use of white noise generators in the treatment of hyperacusis is becoming popular and has seen some success. In cases of specific hypersensitivity then cognitive therapy may be utilised.

Conclusions

From the results of this study low frequency noise complaints would appear to fall into the following main categories:

1. Complaints where noise relating to the noise complained of can be measured.
2. Complaints where the complainant is suffering from tinnitus.
3. Complaints where the complainant is suffering from hyperacusis.
4. Complaints where the complainant would appear to be hypersensitive to the specific noise of their complaint and where no noise relating to that experienced by the complainant can be measured.

Some of the cases in the first category will have noise levels which are lower than those generally regarded as likely to cause a nuisance.

Cases in the second and third categories relate to medical diagnosis and should lead to medical care for the complainant. The suffering of one person may affect other family members.

Complaints that fall into the fourth category will need further research as it is not clear if the cause is in some way related to the noise climate within the complainant's dwelling, or solely a medical condition, or a combination of both.

Recommendations

As a result of the experience gained from this research the following recommendations are made :

* That EHOs, acoustic consultants or others investigating LFN complaints have normal hearing.
* That LFN complainants are treated with respect and that care is taken not to speculate about sources or diagnoses.
* That comprehensive noise surveys be undertaken before an audiological opinion is sought and that these be available to the audiological scientist. A suggested protocol for carrying out low frequency noise investigations is given in Annex 1.
* That the Department of Health consider how specialist tinnitus clinics might be involved in the treatment and therapy of LFN complainants.
* That therapy and treatment be available to these patients who are suffering considerable and genuine distress.
* That low frequency noise complaints to Local Authorities should be monitored to assess the continuing scale of the problem.
* That further investigations are carried out on complaints of low frequency noise, to build up a clearer picture of the causes of complaint, particularly in cases where the complainant appears to show a hypersensitivity to the noise of their complaint but no noise relating to this can be measured.

Annex 1 – Proposed Low Frequency Noise Investigation Protocol

The professional investigator's first visit must be handled with care, particularly if no noise is obvious at this time. The investigator should treat the complainant with respect. Any hostility created during the first visit will probably cause an entrenched reaction that will continue for a considerable time, preventing the best course of action being taken early. The raising of possible diagnoses or sources with the complainant can be very unhelpful unless, or until, there is positive proof of the source of the problem.

A 'Decision Tree' has been developed, which should be seen as a guide, to be used in conjunction with the following recommended approach. It does not guarantee the outcome of a low frequency noise investigation and a number of decisions will have to be taken by the professional based on what they find at the time. The 'Decision Tree' is shown in Figure 1.

Recommended investigation protocol:

i) Visit sufferer: Keep an open mind, discuss the problem with the sufferer including the history, background details and the way the sufferer perceives the noise.

The history should include the following:

* Start of the complaint
* Type of noise heard
* Duration of noise
* Complainant's belief about source
* Effect of complaint on quality of life
* Do family members hear the noise?
* Do neighbours hear the noise?
* Is the complainant sensitive to other sources of noise?

If there has been any history of noise nuisance problems in the area where the sufferer resides then the local Environmental Health Department are likely to be aware of these problems.

ii) Listen for noise: The investigator should have normal hearing and listen carefully for the noise causing the complaint. Make sure that the complainant can clearly hear the noise at the time the investigation is carried out. This will often mean carrying out investigations during the evening, or at night, when other intrusive noise is at a low level. If the noise complained of is heard then measurements can be carried out immediately and appropriate action considered. However, it is expected that a lot of these problems will fall outside the normal bounds of statutory legislation.

If the noise complained of cannot be heard by the investigator, noise measurements will need to be taken to ascertain whether or not there is a noise present that relates to that heard by the complainant.

iii) Noise measurements: It is considered extremely unlikely that a conventional sound level meter will be adequate to investigate low frequency noise complaints and the use of such equipment is not advisable. Therefore the investigator should obtain a frequency analyser, which if it can operate in real time and has narrow band capability (at least 1/24th octave bandwidth) will allow the investigator to observe the characteristics of the ambient noise prevailing at the time.

Characteristics should be looked for that relate to the noise experienced by the complainants at the time of the measurement such as increases and decreases in the intensity of the noise, and places in the dwelling where the noise is loudest.

Observing the frequency spectrum in real time can give a significant amount of information, which would be lost if only a time average was used. Modulation at a particular frequency associated with 'beating' can be seen easily in real time and may guide the investigator towards what to look for as a possible source.

iv) If nothing is found: If no noise is heard or measured that relates to that heard by the complainant then one must carefully consider what to do. If it is felt that the measurement has been undertaken at a time when the noise was not at its worst, then another visit will be required. The possibility of the complaint relating to a previous source that has now abated should also be borne in mind.

If the investigator is convinced that there is no noise either heard or measured that relates to the complaint then the complainant needs to be referred to an audiological specialist. The 'Decision Tree' is provided for the guidance of the investigator. Any diagnosis about the complainant's hearing system is clearly outside the competence of most investigators and opinions about the complainant's hearing should be avoided. In particular, the sufferer should not be told they have tinnitus and told to go to the nearest Ear, Nose and Throat hospital. Instead, they should be told that the investigator has not been able to measure the noise which they have described and they feel that the sufferer should be examined by an audiological specialist, as their hearing system may be involved in the complaint.

Expertise to deal with such cases would not be found in most Ear, Nose and Throat Departments or Audiology Units and referral to such agencies may compound any problem. Specialist Tinnitus/ Hyperacusis Clinics, such as are found in London (UCH/Middlesex), Nottingham (General Hospital) and Cambridge (Addenbrookes) are known to have the appropriate expertise.

'A study of environmental low frequency noise' by J W Sargent MIOA, Building Research Establishment, Garston, Watford. WD2 7JR Telephone: 01923 894040 Fax: 01923 664010 (October 1994). This report was prepared for Local Environment Quality Division of the Department of the Environment and is published in full here by permission. Crown Copyright 1994

Can a noise be heard by investigator? —Yes→ Find the source
No
Can a noise be measured? —Yes→ Find the source
No
Does the complainant hear the noise in most places that are otherwise quiet? —Yes→ Refer to Audiological Specialist (Tinnitus possible)
No
Is the complainant hypersensitive to other noise? —Yes→ Refer to Audiological Specialist (Hyperacusis possible)
No
Can other people hear the noise? —Yes→
1. Noise may be present but not detected during measurement – remeasure
2. All are mistaken: functional
3. A noise has been present previously

No →
1. Noise may be present but not detected during measurement – remeasure
2. Possibly tinnitus
3. Possibly functional
4. Noise may have been present previously

Brief descriptions of terms used above:
Tinnitus: Any sound heard by the complainant that is generated by their auditory system.
Hyperacusis: Abnormal discomfort caused by sounds that are usually tolerable to other listeners.
Functional: A complainant has become convinced of the presence of a noise when none is in fact present. This is not indicative of psychological abnormality.

Fig. 1. Decision tree for low frequency noise.

News from BSI

British Standard Implementations

BS ISO 9902 : 1993 Textile machinery acoustics – Determination of sound pressure levels and sound power levels emitted by textile machines – Engineering and survey methods. No current standard is superseded.
BS ISO 3743 : Acoustics – Determination of sound power levels of noise sources – Engineering methods for small, moveable sources in reverberant fields.
BS EN 3743–1 : 1994 Comparison method for hard-walled test rooms. No current standard is superseded.

Amendments

BS 6288 : Magnetic tape sound recording and reproducing systems.
Part 2 : 1990 Specification for calibration tapes [IEC 94–2 : 1975]. Note that this amendment implements EN 60094 : 1993 as a British Standard and dual – numbers BS 6288 : Part 2 : 1990 with BS EN 60094–2 : 1994.

BS EN Publications

BS EN 60651 : 1994 (equivalent IEC 651 (including Amd.1). Specification for sound level meters. This describes instruments for the measurement of certain frequency and the time weighted sound pressure levels and specifies sound level meters of four degrees of precision, designated types 0, 1, 2 and 3. This supersedes BS 5969 : 1981.
BS EN ISO 9000 : Quality management and quality assurance standards.
BS EN ISO 9000–1 : 1994 (Formerly BS 5750 Part 0 : Section 0.1). Guidelines for selection and use.
BS EN ISO 9001 : 1994 (Formerly BS 5750 Part 1). Quality systems – Model for quality assurance in design, development, production, installation and servicing.
BS EN ISO 9002 : 1994 (Formerly BS 5750 Part 2.) Quality systems – Model for quality assurance in production, installation and servicing.
BS EN ISO 9003 : 1994 (Formerly BS 5750 Part 3). Quality systems – Model for quality assurance in final inspection and test.
BS EN ISO 9004 : 1994 (Formerly BS 5750 Part 0; Section 0.2). Quality management and quality assurance standards.
BS EN 60118 Hearing aids
BS EN 60118–0 : 1993 (Formerly BS 6083 : Part 0 : 1984) Methods for measurement of electroacoustic characteristics [IEC 118–0]. This amendment implements Amendment A 1 : Feb 1994 to EN 60118–0 : 1993.
BS EN 60118–7 : 1993 (Formerly BS 6083 : Part 7 : 1985). Methods for measurement of performance characteristics of hearing aids for quality inspection on delivery [IEC 118–7]. This amendment implements Amendment A1 : Feb 1994 to EN 60118–7 : 1993.
BS EN 61102 : 1994 Specification for measurement and characterisation of ultrasonic fields using hydrophones in the frequency range 0.5 MHz to 15 MHz. This amendment implements Amendment A1 : 1994 to EN 61102 : 1993.

British Standards Reviewed and Confirmed

BS 6415 : 1983 Specification for audio-frequency calibration tape for transverse track video recorders.

British Standards Withdrawn

BS 5750 : Quality systems, Part 0, Part 0 Section 0.1 and 0.2, Part 1, Part 2, Part 3 (1987). Superseded by BS EN ISO 9000–1, 9004, 9001, 9002, 9003 : 1994.
BS 5969 : 1981 Specification for sound level meters. Superseded by BS EN 60651 : 1994.

European New Work Started

Hearing protectors: Hearing protectors in impulsive noise. Ear-muffs with reproduced sound. Amplitude sensitive ear plugs.

Draft British Standards for Public Comment

94/204034 DC Amendment 2 to IEC 118–2 Hearing Aids – Part 2 : Hearing aids with automatic gain control circuits – Amendment 2 : Measurements using broadband signals. (Possible amendment to BS 6083 : Part 2 : 1984 (1990)) [IEC 29 (Secretariat) 276].
94/204054 DC Amendment 1 to EN 60118 Hearing Aids – Part 2 : Hearing aids with automatic gain control circuits. (Possible amendment to BS 6083 : Part 2 : 1984 (1990)) [IEC 118–2 : 1983/A1 : 1993 IEC 29 (Central Office) 163] (prEN 60118–2 : 1993/prA1 : 1993).
94/204075 DC Coupler configurations for the calibration of audiometric earphones in the extended high frequency range. (Possible new British Standard) [IEC (Secretariat) 277].
94/204471 DC Handbook of audio and video signals [IEC 84/3C (Secretariat) 335/257].
94/204768 DC Revision of IEC 118–1 Hearing aids-Part 1 : Hearing aids with induction pick-up coil input. [Possible new British Standard BS EN 60118–1 to supersede BS 6083 : Part 1 : 1984 (1990)] [IEC 29 (Central Office) 213].
94/408218 DC BS 5750 Quality systems. Part 11 : Guidelines for quality plans (ISO/DIS 9004–5 Quality management and quality system elements – Part 5 : Guidelines for quality plans).
94/502625 DC BS ISO 10843 Acoustics – Methods for the physical measurement of single impulses or bursts of noise. (ISO/DIS 10843).
94/204787 DC IEC 645–4 Audiometers – Part 4 : Equipment for extended high-frequency audiometry. [Possible new British Standard (BS EN 60645–40)] [IEC 29(Central Office) 215].
94/205587 DC IEC 1119–4 Digital Audio Tape (DAT) cassette system – Part 4 : Character pack format [IEC 60A (Secretariat) 158].
94/205693 DC IEC 1094–3 Measurement microphones – Part 3 : Primary method for free field calibration of laboratory standard microphones by the reciprocity tech-

nique. (Possible new BS) [IEC 29 (Secretariat) 279].
94/205711 DC EN 61094–1 [Reference document IEC 1094–1 : 1992 and Corrigendum : February 1994] Measurement microphones – Part 1 : Specifications for laboratory standard microphones. (Possible new British Standard) (prEN 61094–1).
94/503112 DC Revision of ISO 717 Acoustics – Rating of sound insulation in buildings and of building elements – Part 2 : Impact sound insulation (ISO/DIS 717–2) (prEN 20717–2).
94/705606 DC ISO 8662 Hand-held portable power tools – Measurement of vibrations at the handle – Part 14 : Stone-working tools and needle scalers (ISO/DIS 8662–14).
94/705607 DC ISO 8662 Hand-held portable power tools – Measurement of vibrations at the handle – Part 9 : Rammers (ISO/DIS 8662–9).
94/207289 DC IEC 118–XX Hearing aids – New Part : Electromagnetic compatibility for hearing aids – Immunity to radio frequency fields [Possible new British Standard (BS EN 60118–XX)] [IEC 29/77B (Secretariat) 281/138].
94/400413 DC ISO 14010 Guidelines for environmental auditing – General principles of environmental auditing. (Possible new British Standard) (ISO/CD 14010).
94/400414 DC ISO 14011 Guidelines for environmental auditing – Audit procedures – Part 1 Auditing of environmental management systems. (Possible new British Standard) (ISO/CD 1401 1–1).
94/400415 DC ISO 14012 Guidelines for environmental auditing – Qualification criteria for environmental auditors. (Possible new British Standard) (ISO/CD 14012).
94/208497 DC Procedures for manufacturer approval and quality management. (Possible new British Standard) [IEC 47A (Secretariat) 341].
94/408410 DC BS 6079 Guide to project management. Part 1 : Project management principles.
94/408411 DC BS 6079 Guide to project management. Part 2 : General project management structure.
94/408412 DC BS 6079 Guide to project management. Part 3 : The detailed project management processes.
94/708624 DC ISO 10815 Mechanical vibration – Methods for measurement of vibration generated internally in railway tunnels by the passage of trains.

Other Documents not Issued as DPCs

EN 60651 : 1994 Sound level meters. CENELEC has published EN 60651 : 1994 (due to the conversion of HD 425 S1 : 1983 into a European standard, and amendment A1 : 1994). The text of the amendment A1 has not been issued as a draft for public comment by BSI. As a consequence of implementing the European Standard, BS 5969 : 1981 will be renumbered as BS EN 5969 : 1994, incorporating the amendment A1.
EN 60118 Hearing aids – Part 2 : Hearing aids with automatic gain control circuits. CENELEC has adopted HD 450.2 S1 : 1984 (IEC 118–2 : 1983) for conversion into EN 60118–2, which is currently at the voting stage as prEN 60118–2 : 1993. HD 450.2 S1 : 1984 is identical with BS 6083 : Part 2 : 1984 (1990) which will be renumbered as BS EN 60118–2 after the HD conversion has been ratified.

IEC Publications

IEC 651 Sound level meters – Amendment 1 : to IEC 651. Corrigendum : March 1994 to Amendments 1(1993) to IEC 651.
IEC 1183 : May 1994 Electroacoustics – Random-incidence and diffuse-field calibration of sound level meters. This will be implemented (as BS EN 61183) when harmonised by CENELEC.

ISO Standards

ISO 3744 : 1994 (Edition 2) Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering method in an essentially free field over a reflecting plane. This will be implemented as BS ISO 3744 : 1994 to supersede BS 4196 : Part 4 : 1981.
ISO 5948 : 1994 (Edition 2) Railway rolling stock – Ultrasonic acceptance testing. This will not be implemented as a BS; UK voted against.
ISO 7626–5 : 1994 Vibration and shock – Experimental determination of mechanical mobility – Part 5 : Measurements of impact excitation using an exciter which is not attached to the structure. This will be implemented as a dual-numbered BS.
The above information, provided by Ms Nicole Porter of NPL, was announced in the May to August 1994 editions of BSI News. Information from September 1994 to February 1995 will be given in the next edition of the Bulletin.

Hansard

25 October 1994
Vehicle Noise: Offences
Lord Montagu of Beaulieu: asked Her Majesty's Government:
How many prosecutions there were during 1993 for excessive exhaust noise emitted by (a) motor cars; (b) motor cycles; and (c) commercial vehicles; and how many convictions resulted.
Viscount Goschen: My Lords, it is not possible to give the detailed statistics requested but I am able to give provisional figures for all vehicle noise offences in England and Wales for 1993. They were: 7,857 prosecutions and 5,352 convictions.
Lord Montagu of Beaulieu: My Lords, I thank my noble friend for that reply. Will he agree with me that the British Public are becoming increasingly frustrated with the noise emitted by motorcycles whose owners have been tampering with their exhausts, removing them altogether or maintaining them badly? Would it not help if the Government were to give a stronger lead to the enforcement of existing regulations, let alone the new ones coming from Brussels, in order that the machines may be taken off the road and have their silencers improved? Finally, will my noble friend agree that unless the rules are enforced it

brings the whole law into disrepute?
Viscount Goschen: My Lords, I can reassure my noble friend that the Government take the issue of vehicle exhaust and other noise extremely seriously. We recognise that many members of the public have anxiety about perhaps a small number of especially noisy motor cycles. That is why we have brought forward regulations to control the construction of replacement silencers. We have also addressed the issue of noise from new machines. I agree with my noble friend that enforcement is equally important.
Lord Strathcarron: My Lords, is my noble friend aware that when motorcycles leave the factory they are commendably quiet? In many cases, they are quieter than a motor car. It is a very small minority of motorcyclists who tamper with the exhaust or sometimes fit a replacement exhaust because they cannot afford the high cost of replacing the original exhaust system. Will my noble friend agree that it is quite wrong to tar all motorcyclists with the same brush?
Viscount Goschen: My Lords, I agree with my noble friend on that point. The issue of tampering is important, the problem is largely caused by a small number of irresponsible motorcyclists who have perhaps fitted racing-type silencers or have tampered with the original device. That is why the enforcement of the law on the issue by police is extremely important.
Lord Jenkins of Hillhead: My Lords, is the noble Viscount aware that if this is a matter of a very small minority, that small minority get about to a quite remarkable extent?
Viscount Goschen: My Lords, the advantage of riding a motorcycle is being able to get about quickly.
Lord Carmichael of Kelvingrove: My Lords, in my experience, the motorcyclists who 'get about' all seem to try to get about between midnight and 2 am. I have had experience of the problem. One night, in a street in Glasgow I spoke to a passing policeman and suggested to him that he could radio to another officer on patrol, who could catch the lad involved before he got home; and that was done. Does the Minister accept that is a way to deal with the problem? It is nearly always at night that one hears the really excessive noise. Does the Minister agree that such patrols on the part of the police would very soon make motorcyclists riding on particular routes realise that what they were doing was not worth a candle?
Viscount Goschen: My Lords, I agree with the noble Lord that enforcement is not exactly straightforward. It is a matter for the police, who have to make an operational decision. There are of course difficulties with measuring noise; but I agree that the small minority of those riding motorcycles which have very loud exhausts can be spotted. Perhaps the motorcycles have had holes drilled in the exhausts or have the wrong type of silencer fitted. That is why we have brought forward regulations and measures to make the job of the police easier: namely, by requiring a particular marking on silencers that have been approved.
Lord Cledwyn of Penrhos: My Lords, does the Minister agree that the emissions from exhausts are far more dangerous than the noise? What steps are the Government taking to control emissions?
Viscount Goschen: My Lords, I agree with the noble Lord that the issue of gas emissions from exhausts is an extremely serious one. I would also say that his question is different from the one that we are considering. We are taking a number of measures to address this important issue.

3 November 1994
Channel Tunnel Rail Link
Ms Jowell: To ask the Secretary of State for Transport what representations he has received regarding compensation for people living alongside rail lines being used by channel tunnel passenger and freight services who are affected by increased noise and vibration; and if he will make a statement.
Mr Watts: A number of representations have been received. The Land Compensation Act 1973 provides for compensation to be paid in certain circumstances when the value of property is reduced as a result of physical factors such as noise and vibration arising from the use of new or altered public works or where there has been a change of use in respect of the works – other than an intensification of an existing use. It is for people who believe they have claims for compensation to submit them to the responsible authority, in this case Railtrack, for consideration. Further information is given in a guide recently produced by Railtrack for householders who may be considering claims. A copy is being placed in the Library.

21 November 1994
Railways (Noise)
Mr Sims: To ask the Secretary of State for Transport when he expects to lay before the House the draft Noise Insulation (Railways and other Guided Transport Systems) Regulations, 1993; if these will apply to intensification of use of existing lines as well as newly constructed lines; and if he will make a statement.
Mr Watts: Many of those who responded to public consultation on the draft regulations suggested that they should apply to existing lines as well as to new lines. This is one of the issues that we are considering, and a decision will be announced as soon as possible.
Mr Sims: I thank my hon Friend for that reply. Is he aware of the genuine concern felt by many residents of the London borough of Bromley who live close to railway lines – which was demonstrated by two recent, well-attended public meetings – about the noise generated by the channel tunnel traffic which is now going through the borough and which is likely to increase and continue night and day throughout the next decade?
May I plead with my hon Friend seriously to consider allowing the regulations that I mentioned to apply to intensification of use on existing routes? Alternatively, does he accept that opening the channel tunnel has turned what were, in effect, suburban railway lines into intercontinental routes – into what are, to all intents and

purposes, new lines?
Mr Watts: As I said, that is one of the questions that we are considering very carefully, and I am taking a close personal interest in it.
My hon Friend will be aware that two miles of noise barriers have been erected in Kent – in the borough of Bromley, in fact – under joint arrangements between the borough and Railfreight Distribution. He will also be aware that, when electric locomotives for freight haulage are introduced early next year, there should be a significant reduction in the level of noise generated by such traffic.

30 November 1994
Aircraft Noise
Mr Jim Cunningham: To ask the Secretary of State for Transport (1) if he will make a statement about aircraft noise; and what proposal he has in relation to noise at small airports; (2) when he proposes to implement the recommendations of the review of air noise legislation contained in his latest report; (3) what interim proposals he has to deal with aircraft noise; (4) what assessment he has made of the local weakness in present planning legislation used by local authorities to deal with aircraft noise.
Mr Norris: Airports can bring substantial economic and social benefits to their surrounding areas, but aircraft noise can also cause annoyance. It is important therefore, that aerodrome and aircraft operators minimise the disturbance to local communities caused by their operations, so far as is practicable and reasonable. All larger aerodromes and many small ones already take measures to reduce noise disturbance.
Aerodromes are also subject to planning legislation in the usual way, and it is for the local planning authority to assess all the relevant factors when considering planning applications. It is possible to exercise a measure of control over aircraft noise by way of conditions attached to planning permissions. Because aerodromes vary greatly in size, types of operation, and in their local circumstances, measures to minimise noise nuisance are best developed and monitored locally.
In March last year, following extensive consultation, the Government published their conclusions on new measures to control aircraft noise. The Government announced their intention – Official Report, 25 March 1993, column 706-7 – to introduce new legislation to give aerodromes powers to prepare and enforce noise amelioration schemes. These arrangements would build on the existing, mainly voluntary system of control. The Government will introduce the new legislation at a suitable parliamentary opportunity. There are no plans to introduce interim measures, but consideration is being given to producing national guidance on mitigating aircraft noise.
Mr Jim Cunningham: To ask the Secretary of State for Transport when he proposes to introduce restrictions on aircraft engine noise requirements on airports.
Mr Norris: Under existing legislation, all civil jet aircraft operating into all United Kingdom airports must carry a noise certificate demonstrating compliance with standards agreed by the International Civil Aviation Organisation. Civil propeller-driven aircraft certificated after 6 October 1977 are also required to comply with such standards. These standards are included in The Air Navigation (Noise Certification) Order 1990.
Mr Jim Cunningham: To ask the Secretary of State for Transport what requests he has had from (a) airport authorities and (b) members of the public for noise mitigation schemes.
Mr Norris: The information requested can be obtained only at disproportionate cost.
Mr Jim Cunningham: To ask the Secretary of State for Transport when he plans to introduce legislation to outlaw old aircraft.
Mr Norris: The Government have no plans to prevent aircraft from flying purely on the grounds of their age. The United Kingdom has, however, implemented directive 92/14/EEC, which requires older, noisier jets, the so called "chapter 2" types, to be phased out between 1995 and 2002. This legislation builds on earlier action to ban non-noise certificated jets and to prevent the addition of chapter 2 types to the United Kingdom register.

9 December 1994
Environment
Noise Policy
Mr Matthew Taylor: To ask the Secretary of State for the Environment how many staff in his local environment quality division now work full-time on noise policy matters.
Sir Paul Beresford: Four staff in the local environment quality division work full time on policy matters relating to noise and other statutory nuisances.
Mr Matthew Taylor: To ask the Secretary of State for the Environment what research he has undertaken or commissioned on the effectiveness of the current noise control framework in dealing with neighbour noise complaints.
Sir Paul Beresford: An inter departmental working party comprising officials from my Department, the Home Office, Lord Chancellor's Department, territorial Departments and representatives of the local authorities and police, is reviewing the effectiveness of current neighbour noise controls and will be making recommendations to Ministers in the new year.
The working party will consider available evidence on the effectiveness of current neighbour noise controls, including surveys by local authorities, voluntary bodies and research institutions.
Mr Matthew Taylor: To ask the Secretary of State of the Environment what plans he has to set targets for reducing noise exposure as part of his sustainable development strategy.
Sir Paul Beresford: Planning policy guidance note No. 24, 'Planning and Noise' issued in October 1994, recommends exposure levels for new residential development near transport and other noise sources. A copy of PPG24 is in the Library.
A number of EC directives ensure the progressive reduction in noise from road vehicles, aircraft and a variety of

machinery and equipment.

Mr Matthew Taylor: To ask the Secretary of State of the Environment what research he has undertaken or commissioned on the contribution of poor sound insulation to neighbour noise complaints.

Sir Paul Beresford: My Department has commissioned the Building Research Establishment to study a small sample of complaints about poor sound insulation between dwellings. The research was carried out between 1992 and 1994. The information gained will form part of a continuing review of the regulations for sound insulation.

Mr Matthew Taylor: To ask the Secretary of State for the Environment (1) what is his estimate of the proportion of the population currently exposed to night-time noise levels of (a) more than 65 decibels, (b) between 55 and 65 decibels and (c) less than 55 decibels; (2) what is his estimate of the proportion of the population currently exposed to daytime noise levels of more than 65 decibels.

Sir Paul Beresford: From noise measurements carried out at 1000 dwellings in England and Wales during the 1990 national noise incidence study it is estimated that at night (a) less than 1 per cent. of the population are exposed to noise levels 65 dB LAeq (23.00–07.00), (b) 13 per cent. are exposed to levels between 55 dB and 65 dB LAeq (23.00–07.00) and (c) 86 per cent to levels less than 55 dB LAeq (23.00–07.00). It is estimated that 10 per cent of the population are exposed to daytime noise levels of more than 65 dB LAeq (07.00–23.00).

Copies of an information paper reporting the findings of the study, which was carried out by the Building Research Establishment, are in the Library.

Extracts provided by Rupert Taylor FIOA

Book Reviews

Noise and Noise Law: A Practical Approach
Melville S Adams and Francis McManus
Wiley Chancery Law, 1994, 207 pp. ISBN 0 471 93708 8, £19.95

The changes in legislation, guidelines and standards over recent years and an increasing interest in environmental issues have created a need for an introductory book that has good coverage, is easily readable and is up-to-date. This book fulfils those requirements well. It is aimed at legal practitioners, EHOs, builders and other professionals who deal with noise in their work. Assuming no prior knowledge of the subject it introduces basic acoustics, frequency analysis, weighting networks and noise parameters. The chapter on the human ear includes hearing damage risks and the provisions of the Noise at Work Regulations 1989. Internal noise ratings and criteria are described including the noise insulation requirements of the Building Regulations 1991. Environmental noise covers community annoyance and sleep disturbance with detailed sections on noise from road traffic, railways and aircraft including military aircraft and recent research by NPL on noise from low flying exercises. The section on legal controls covers environmental and occupational noise. The elements of private nuisance are first outlined together with defences and remedies. The provisions of the Environmental Protection Act 1990 and the Control of Pollution Act 1974 are then examined under the headings of noise nuisance, construction noise, loudspeakers in streets and noise abatement zones. Other statutory controls such as planning and licensing laws and The Land Compensation Act 1973 are included. The differences between Scottish laws and those of England and Wales are described throughout.

With a few exceptions the authors have achieved the difficult task of striking a balance between keeping the technical level comprehensible to the layman and including enough detail to be of use and interest. Sound insulation in buildings is given a relatively large number of pages yet there is no explanation of sound insulation or sound absorption or the physical factors that govern these properties. This particular area often confuses non-acousticians. The book does not claim to be exhaustive and topics of interest such as outdoor noise propagation and vibration are omitted. Perhaps excluding little used noise criteria and rating methods would have allowed coverage of more topical subjects like quarrying, waste disposal and windfarms. In examining BS4142 : 1990 the authors appear to misquote and misrepresent the Standard. For example, it has not been recalled for review nor does it contain a rating level at which complaints are 'highly likely'. The Standard does not give a rating of the affect of noise on the community nor is it intended for the assessment of nuisance. The Section on law is brief and many aspects are described but not explained. A lot of cases are referenced but few details are given which is a pity as case histories add interest. The subtitle 'A Practical Approach' could be misleading. There are worked examples of decibel calculations and octave spectra conversions etc but the book does not teach the reader how to use a noise meter, investigate or report a noise case or properly word a noise abatement notice. It is well presented and very readable, even enjoyable, and will prove extremely useful for anyone, including the diploma level student, who needs an introduction to the subject. For those who already have the technical knowledge this book is still good value just for its up-to-date coverage of noise law.

G A A Rock MIOA

Handbook of Noise and Vibration Control
Publisher: Elsevier Advanced Technology, 1992
ISBN 1 85617 079 9

This is the sixth edition of this work and it has changed considerably over the years. It continues to have advertisements mixed in with the text but these do not distract greatly from the reference material and even add usefully in places.

The book is nearly 500 pages of collected information between hard covers, divided into 10 sections of variable length and coverage.

The initial sections, typically, deal with definitions, introductions to theory and measurement techniques. Subjective matters (both for noise and vibration) are dealt with early, together with legislation. Vibration measurement and analysis are covered in some detail. Most expected material is included and is presented in a clear and concise manner. The Handbook makes generally good use of diagrams, but these are sometimes of variable quality, apparently from a number of origins.

The book has an intentional leaning towards machinery noise and vibration. The applications sections, which occupy nearly 50% of the book, deal with generation mechanisms and offer both good design practice ideas as well as suppression methods. The latter includes a chapter on noise cancellation techniques.

Building acoustics, covering partition transmission loss, absorption characteristics, ventilation and glazing are covered in reasonable depth, with theory and practice in both domestic and commercial environments. Useful details of reduction opproaches and construction options are provided. There is a chapter devoted to the acoustics of auditoria that gives a useful introduction to the subject.

One section covers machine balancing and vibration isolation, together with tool noise. These are dealt with quite thoroughly, covering typical standards, foundation design and isolation mountings of various types.

The final sections deal with legal aspects of noise and vibration. A comprehensive listing of standards and codes of practice is included. The book is equipped with a reasonable index and provides a convenient reference source of information for a wide range of people.

Bernard J Challen MIOA

New Products

DYNAMIC STRUCTURES & SYSTEMS LTD

SYSNOISE

Numerical Integration Technologies, Leuven, Belgium, have announced the latest version 5.2 of their SYSNOISE software for finite element and boundary element acoustic modelling.

New and extended features include capabilities for sensitivity analysis, allowing analysts to identify the changes needed in a structure (such as altered material, thickness, or stiffening) to improve its acoustic performance, for example to reduce the radiated noise. A link to experimental data acquisition means that measured vibrations can be used in noise calculations and diagnostics. Special post-processing capabilities for visualising acoustic results have also been added within SYSNOISE, as well as links to industry-standard pre- and post-processors. Engineers in automotive, aerospace and many other applications will benefit from these capabilities in producing more refined vehicles, machinery and consumer products.

Special features of the menu-driven graphical user interface (GUI) are 'Wizards' – sequences of dialogue screens which guide the user through the data-preparation and analysis procedures, with prompts and remarks along the way. Even new users can then easily approach complex modelling and solution tasks.

The VIOLINS program for analysing multi-layered vibro-acoustic materials has also been built into SYSNOISE 5.2, with its own section in the GUI. VIOLINS is used to assess the noise absorption behaviour of multi-layered lining materials and the noise transmission properties of panels treated with damping and other trim, as well as design the materials themselves by considering alternative properties for different layer and different assembly sequences.

Complex fluid-structure interaction and inter-lay behaviour is taken into account.

RAYNOISE

Numerical Integration Technologies have also announced the latest version 2.1 of their RAYNOISE software for geometrical acoustic modelling.

Users can now control RAYNOISE not only by a command language but also by a menu-driven graphical user interface (GUI) with all commands prompted by pull-down menus and dialogues, with continuous help and comments. Data entered interactively are nonetheless logged for audit and re-use.

New and extended modelling features include calculation of statistical reverberation times (based on a rapid algorithm to derive the mean free path of an enclosed space) and the optional addition of a statistical tail to reverberation echograms. A triangular beam method can be used as an alternative to the conical beam method, and phase information can be applied to determine interference patterns.

Surface properties can include not only frequency-dependent absorption coefficients, but now also diffusion properties, based on a hybrid random-number algorithm for the scattering effect. Speech transmission index (STI) can be calculated based on modulation transfer functions.

Computational efficiency has also been improved compared to the previous software revision, with up to 25% speed-up, and user-selectable levels of results storage to optimise disk space.

Engineers, consultants and architects will benefit from these capabilities in producing improved acoustic designs for auditoria, railway stations and other public spaces and industrial buildings, and environmental noise impacts from factories and power plant, roads and railways.

For more information contact Numerical Integration Technologies' UK representative: Dynamic Structures & Systems Ltd., Aizlewood's Mill, Nursery Street, Sheffield S3 8GG. Telephone: 0114 282 3141. Fax: 0114 282 3150.

QUANTITECH

New RION Sound Level Meters

Three new RION sound level meters are now available from Quantitech in the UK. The new RION NL-05 and NL–15 Integrating Sound Level Meters utilise advanced technology for simple operation. The NL–05 Type 2 Industrial Grade Meter is said to use its 60 dB dynamic range to measure Noise at Work action levels at the touch of a button. The RION NL–15 is a precision grade meter delivering precise measurements for Noise at Work regulatory compliance. Four measurement modes (L_p, L_{max}, L_{eq} and L_E) ensure that both instruments offer versatile performance without complicated, time consuming operation. The set-up panel is easily accessible, yet protected during operation by a sliding cover.

All setting data is retained, even when the unit is switched off, ensuring replicable measurement conditions. A built-in RS-232 interface enables direct print out of stored results and downloading onto a PC. For accurate, high-quality level recording the NL–05 and NL–15 are fully compatible with the new LR-06 level recorder.

The RION NL–14E has been specifically developed to meet the noise monitoring needs of the construction industry. Five L_Ns (L_1, L_5, L_{90}, L_{95}, L_{99}) are tailored to the demands of site monitoring. A wide range of time settings allow measurements from 10 seconds to 24 hours at a time.

Six automatic measurement modes and data storage ensure reliable unattended operation. A built-in RS-232C computer interface enables convenient downloading of results. The NL-14 is manufactured to meet IEC 804 and IEC 651 Type 1 requirements.

For further details, please contact Roberto Lorenzetto, Quantitech Ltd, Unit 3, Old Wolverton Road, Old Wolverton Milton Keynes MK12 5NP. Tel: 0908 227722. Fax: 0908 227733.

Items for this section should be sent to John Sargent MIOA at BRE, Garston, Watford, Herts, WD2 7JR.

News Items

IAC Ltd

Audiology rooms

The picture below shows a paediatric audiology room used for testing the hearing of children aged 0–16 at the Nottingham Children's Hearing Assessment Centre. It is one of 18 new audiology rooms at Ropewalk House, a new outpatients department recently opened by the Queen's Medical Centre University Hospital NHS Trust.

Constructed by Industrial Acoustics Company (IAC) several of the rooms have triple walls. IAC has reduced ambient noise levels within these rooms to over 10 dB below the level set by the current ISO standard (8253).

The audiology rooms, distributed on three floors, range in size from a small booth with a floor area of 2.5 m^2 to rooms measuring 4.4 m by 6.7 m. Given the wide variety of work carried out by the hospital's specialists including its pioneering research in the field of paediatric audiology and paediatric cochlear implantation, it was necessary to adjust the acoustic specification of individual rooms to suit different activities. All the rooms have the same basic construction elements – walls, ceilings and floors are built from prefabricated modular steel acoustic panels from IAC's Moduline range, into which high performance acoustic doors and windows have been incorporated. The inner rooms have concrete floating floors to achieve the correct level of structural isolation. IAC completed the installation of all 18 rooms in less than 10 weeks including the provision of all interior decoration – stretch fabric wall coverings, false ceilings and carpeting. The company also provided duct silencers to reduce air conditioning system noise emissions to below ambient room levels.

IAC has specialised in the design and construction of audiology rooms for over thirty years and has built more than 100,000 rooms for hospitals, clinics, universities, hearing centres and research organisations worldwide.

Noise Control Centre

Fine tuning the Disney sound unit

The mobile ADR (automatic dialogue replacement) unit working on the new Disney series being made at Bray Studios is in almost constant use whilst servicing a production of this kind so any adjustment that may need to be made to compensate for unwanted resonance or reverberation has to be effected immediately. Such a fine tuning exercise needed to be completed in the shortest possible time whilst maintaining the high standards of the interior decor.

The controller of the film unit called in the Architectural Division of The Noise Control Centre based in Wokingham, Berkshire. On the same day as the call, the unit was surveyed, the acoustic system proposed and a quotation presented. On the second day the specified materials were prepared and on the third day they were installed by The Noise Control Centre's own team. The acoustic package was based upon MELATECH sound absorbing panels and tiles. The wall panels installed in both the voice booth and control desk area were fabric covered in a coordinated colourway to match the original decor. Pyramid profiled MELATILES were selected for the ceilings throughout the unit.

The Controller commented...'we were very impressed that we were able to call upon the services of a specialist company at such short notice with such a successful outcome. At no time was our production schedule disrupted which was very fortunate as disruptions in this business can be very expensive indeed'.

Halcrow Fox

East London Line extension

Halcrow Fox's noise section have been commissioned by London Underground Ltd to undertake a detailed noise assessment of the proposed East London Line Extension from Whitechapel to Dalston. The project manager for Halcrow Fox, Mike Forsdyke, reports that the project is one of the first studies to apply the latest drafts 'Calculation of Railway Noise' and 'Noise Insulation Regulations for Railways and Other Guided Systems'. The study will incorporate any revisions to these standards in due course.

A computer model has been developed to calculate facade noise levels in accordance with the above methodology. A Noise Map has been prepared to identify dwellings eligible for noise insulation and, in addition, environmental noise impact drawings have been prepared to show noise changes experienced by sensitive uses adjacent to

the route. The study has included noise surveys of existing rolling stock as well as an assessment of night-time service facility operations. Environmental mitigation measures are being recommended where appropriate.
For further information please contact Mike Forsdyke (0171 603 1618).

Deane Austin Associates

High-tech indoor shooting ranges given high-spec acoustic insulation

A large air handling unit to remove cordite smoke and lead contaminants from three highly technical indoor shooting ranges presented a considerable design challenge in terms of noise and vibration reduction and severe weight, space and access restrictions.

The unit with a required air flow of 11.6 m^3/s supply and 13 m^3/s extraction was purpose-designed as a joint venture by Air Condition Machinery (ACM) – responsible for thermal and air flow design – and the noise and vibration control specialist consultancy, Deane Austin Associates (DAA). A maximum noise rating of NR 35 at 2 m distance in all directions from the unit was specified.

The final acoustic design using two- and three-stage reduction actually achieved a lower NR, largely owing to a unique method of applying the acoustic insulation around the supply and return fans and to the main enclosure. DAA claim that during commissioning tests the acoustic enclosure was so effective that the customer doubted that the air handler fans were running.

Under a separate contract, DAA acoustically designed the architectural finishes in the firing ranges to prevent noise being heard in other parts of the building and outside at nearby flats.

The air handler, sound attenuators and other acoustic components were built by Nendle Acoustics. Sector Limited, the international shooting range consultancy, was responsible overall for the project and the main contractor was Higgs and Hill.

Kirby Charles Associates

SoundPLAN noise and air pollution evaluation launches UK Helpline

From 1 February 1995 all SoundPLAN users will be able to call a new dedicated 'Helpline' on 01909 560281. Kirby Charles Associates, the UK distributor for SoundPLAN, have a fully trained SoundPLAN person on hand to answer operating questions on the noise and air pollution evaluation software.

Kirby Charles Associates will also be launching in February a full bureau service that will allow SoundPLAN users to have their plots and projections printed out in full colour up to A3. Larger prints will be available by arrangement.
Further details on these developments are available from Kirby Charles Associates, Dinnington Business Centre, Outgang Lane, Dinnington, Sheffield. S81 7QY. Tel: 01909 560416/560281. Fax: 01909 560291.

Law Report

Regina v Secretary of State for Transport, ex parte London Borough of Richmond upon Thames and others. Queen's Bench Division (Mr Justice Latham).
20 December 1994.

A decision by the Transport Secretary setting new quotas for night flights from Heathrow and other airports, was unlawful because it failed to take into account that, contrary to the policy set out in a consultation paper and press notice, its effect would be an overall increase, not reduction, in the noise levels experienced by local residents.

The High Court granted a judicial review application by the London Borough of Richmond, the Royal Borough of Windsor and Maidenhead, Tandridge District Council, the London Borough of Hillingdon and Slough Borough Council, and declared unlawful decisions made by the Transport Secretary on 12 October 1993, 1 February and 6 May 1994, in relation to night flying restrictions at Heathrow, Gatwick and Stansted airports.

Richard Gordon QC and Alan Maclean (Richard Buxton, Cambridge) for the applicants; Ian Bumen and Mark Shaw (Treasury Solicitor) for the minister.

MR JUSTICE LATHAM said the decisions had been taken to give effect to proposals set out in a consultation paper published in January 1993. Every aircraft type was given a quota count dependant upon its noise characteristics from 0.5 for the quietest, through 1, 2, 4, 6 to 16. The last two, being the loudest, were effectively prohibited from night flying. The limit for the rest was based on a total quota count for the summer and winter seasons.

The applicants said the minister's decisions implementing the proposals were unlawful or irrational for various reasons, the main one being that they were made in breach of an undertaking by the minister, giving rise to a legitimate expection, that he would only use his powers under section 78 of the Civil Aviation Act 1982 to improve the noise climate around the airports, or at least ensure it was not made worse.

In fact, the effect of the proposals would be an increase in noise levels. The applicants also said they had a legitimate expection of a full and fair consultation process and that they were misled.

The consultation paper stated in para 34: 'In keeping with the undertaking given in 1988 not to allow a worsening of the noise at night, ideally to improve it, it is proposed that the quota for the next five years based on the new quota system should be set at a level so as to keep overall noise levels below those in 1988.'

It added: 'For Heathrow the proposed summer noise quota is 7,000. The 1988 summer quota for Heathrow would have been about 8,000 if calculated on the new basis.'

The summer maximum for Heathrow in 1988 was 2,780 movements, on which basis the consultation paper calculated a quota count of 8,000 in comparison with the proposed new quota of 7,000.

In fact the actual number of movements over summer 1988 at Heathrow was 1,800, for which the equivalent noise quota would probably have been less than 7,000.

In other words, far from there being an improvement over noise levels of 1988, the new quotas, if fully utilised, would produce an increase in noise, contrary to the minister's stated policy.

The applicants were entitled to assume the consultation paper provided a real comparison (as indeed it did with the Gatwick figures). In this respect, it was materially misleading. Consultation based on a misleading document could not be said to be full and fair consultation in the sense which the applicants could legitimately expect.

However, the issue went further. The respondent emphasised in a press notice that noise levels would be below those of summer 1988, which could only sensibly be read as meaning noise levels actually experienced in 1988. The respondent failed to take into account the fact that his proposed quotas would result in higher noise levels at Heathrow, contrary to his expressed policy.

A minister was entitled to decide to depart from previously stated policy, provided he made a rational decision which took into account relevant considerations. That must include a recognition that he was departing from stated policy.

For these reasons the decisions were unlawful.

Paul Magrath, Barrister:

Reprinted from *THE INDEPENDENT* of 5 January 1995. ❖

Letters to the Editor

Views expressed in Letters to the Editor are not necessarily shared by the Editor or the Institute. Letters may be shortened for space reasons or at the discretion of the Editor.

The Editor
Acoustics Bulletin
Sir,

The main feature articles in the November – December 1994 Acoustic Bulletin have motivated me to put my index finger on the PC keyboard.

Firstly it is difficult to comprehend how the finite element analysis described in the article on loudspeaker design by Julian Wright can give meaningful results when the crucial effect of damping is ignored.

Secondly, with reference to the article by Andrew Middleton entitled 'An Investigation of an Electric Motor Noise and Vibration Problem', there are simpler and clearer ways to present the study of run up and run down recordings of vibration measurements.

A careful study of the effect of the fundamental and harmonic exciting forces as they sweep through the many natural frequencies, while being forced or free wheeling, can reveal vital clues to enable the cause of the problem to be established and a remedy achieved. Vibration spectra should always specify the band width of the signal and indicate whether the amplitude is rms or peak. Not only is it necessary to bolt the motor down, it is advisable to closely simulate the stiffness of the site support structure and foundations, especially for large motors.

For acoustic investigations it is necessary to take sound measurements with the motor on load. The magnetostriction-generated sound power can dominate the acoustic performance of the motor. The British Standards which allow motor acoustic performance on no load are worse than meaningless and useless.

Yours sincerely,
Ian Watson FIOA
SNV Consultants
Glasgow

The Editor
Acoustics Bulletin
Sir,

The article 'Radiation Impedance Calculation by Finite Element Analysis' by Julian Wright (Acoustics Bulletin, November/December 1994) provided some interesting insights into the use of acoustic FE and BE analysis for a particular application. However, there are some points which are unclear to us, and some aspects of the specific modelling approaches which seem to be dictated mainly by the limitations of the particular software which he has used, and could give a distorted impression of the use of these methods. Perhaps the author could comment on the following:

Coupled Analysis:
The introduction to the article refers to coupled fluid-structure interaction, yet the examples shown are all 'uncoupled' analyses (ie purely acoustic response, without any 'feedback' from the acoustic field to alter the vibrations of the structure). Since it is the acoustic impedance alone which is to be derived (equation 12) why not calculate it directly? The disc and cones are excited by a unit force, but all displacements are constrained to be equal; it would be easier to apply a uniform unit velocity boundary condition, in a pure acoustic calculation, and then to integrate the pressure distribution over the surface, to derive the impedance.

Acoustic Finite Elements and the 'Coupling Membrane':
Using acoustic finite elements for an exterior calculation (free-field or half-space) is usually unsatisfactory for various reasons, so having finite elements in the 'near field' (Figures 2 to 5) seems rather curious. One is calculating an infinite or semi-infinite field, so boundary elements should be used. (An alternative is 'wave envelope elements' but space precludes discussing these here). Boundary elements can normally be applied directly to the surface of a vibrating object, so the complicated arrangement of acoustic finite elements linked to boundary elements via a 'negligible' (?) membrane (which introduces its own difficulties such as lack of continuity in the results) is dictated by limitations of the specific program, not theory.

The restriction does not apply in the program which we use (SYSNOISE). This program also has the Variational boundary element method, as well as the Collocation method used by Julian Wright. The Variational approach has fluid on both sides of the elements and allows completely arbitrary mesh topologies, such as open structures, holes, fins or ribs, t- and x-shaped intersections, all with boundary elements alone. (No finite element fluid regions are needed, with their attendant problems of mesh-generation and increased problem size).

Mesh Refinement and Calculation Times:
A 'minimum element dimension' of 13 is quoted, or three elements per wavelength: we assume these are second-order elements, since we would consider that six linear elements per wavelength at the maximum frequency is a reasonable refinement of the mesh. Perhaps this could be confirmed.

The PC computer used for the calculations is described, but it would be interesting to know some of the calculation times taken to produce the curves shown, although these times are of course influenced by the size of the numerical problem (including overdetermination points, if used) the integration order (or BE 'quadrature') and the computer speed and memory, as well as the software algorithms and program efficiency.

We plan to make some calculations similar to those shown in the article and hope that these might be published in a short technical contribution to a future edition of the Bulletin. Meanwhile, we hope our comments will add to the understanding of these powerful modern methods for acoustic prediction amongst the Bulletin's readers.

Yours faithfully
C F McCulloch MIOA
Dynamic Structures & Systems Ltd
Sheffield

Letters to the Editor

The Editor
Acoustics Bulletin
Sir,

May I respond to the letters above.

I fear that Mr Watson has missed the point. The loudspeaker model of Figure 16 does indeed include damping. The purpose of the Finite Element model is to establish the effect of the air upon the piston. The mechanical properties of the piston are irrelevant (save to avoid ill-conditioning in the calculation) as they are removed anyway (equation 12).

Mr McCulloch is quite incorrect in his assertion that my models were 'uncoupled'. If that were so, the acoustic field would have no influence upon the piston velocity and the resulting radiation impedance values would have been zero! I remain to be convinced that the 'pure acoustic' approach would be 'easier'. However, I look forward to his publication with an open mind.

I deliberately and carefully validated my method by first solving a problem with a known analytical solution – that of the disc piston. Mr McCulloch does not substantiate his assertion that the use of acoustic finite elements in the near field is 'unsatisfactory'. I would be pleased to see a list of references. I would be interested to know how the SYSNOISE boundary element can operate without an excluded volume in the case of, say, (one side of) a concave cone piston in an infinite baffle. If I understand the method correctly, the variational boundary element would only work for both sides of a finite baffle.

The continuity problem associated with the membrane is discussed and detailed in the original article (pp12 and 15) as are the benefits of removing the fluid finite elements (p13). I understand from PAFEC Ltd that a Beta-version is now available which obviates the requirement for the membrane.

I can confirm that second-order fluid finite elements and boundary element patches were used, and apologise for the omission. The question of requisite mesh density is an interesting topic in its own right. My approach is always to progressively refine the mesh until consecutive results are converged within a predetermined tolerance: I would be interested in Mr McCulloch's thoughts and advice.

Typical computation times (on the specified PC hardware) were as follows:

Mesh #1: 0.5 minutes/frequency
Mesh #2: 4 minutes/frequency
Mesh #5: 5 minutes/frequency
Mesh #7: 7 minutes/frequency
Mesh #9: 4 minutes/frequency

I have no intention of arguing over the relative merits of different commercial software. If Mr McCulloch has questions about the algorithms rather than about the contents of my paper then I suggest he contacts PAFEC Ltd directly. The purpose of my paper was purely to highlight these exciting developments to my colleagues within the Institute. The most important point is that Acoustic Finite Element Analysis can produce credible, useful data which was previously unobtainable.

I would like to conclude by thanking Mr McCulloch for his interest in my paper: I feel sure that he has achieved his aim and added to the awareness of Acoustic Finite Element Analysis amongst the readership of the Bulletin.

Yours faithfully,
J R Wright MIOA
Celestion International Ltd
Ipswich

The Editor
Acoustics Bulletin
Sir,

Thank you for the opportunity to reply to Ian Watson's comments on my article. Many of his comments I agree with, in particular that it is advisable to bolt motors down when you test them. I also agree that if one were writing a report one would be careful to state the bandwidth of the analysis and whether the result is peak or RMS. In fact the bandwidth is stated in the article. Because order analysis is used the bandwidth appears as an order resolution, which was, as stated on page 19, 0.125 order.

However he seems to have missed the point to a large extent. Life tends to be as you find it. I found a situation in which motors had traditionally been tested in a poor manner (not bolted down) but despite this my clients had been able to find excessive vibration on one motor of a batch that they recognised as a problem. The point of this article is that you are faced with such situations and you must make the best of it. Despite the poor testing conditions order analysis enabled the cause of the problem to be deduced very easily – the badly fitted bearing. It would have been far more difficult to be certain of this using frequency analysis.

I take issue with the statement that there are simpler and clearer ways of presenting this study. Admittedly Figures 1 and 3 would have been much better in colour, but printing limitations prevented this. However, the ability to scan right across the full range of data from a whole acceleration run using PLATO (as shown in Figure 1) is a brilliant aid to understanding quickly what is there. The implication that you can do a theoretical study on the forces and responses for this type of problem is nonsense. Who knows what the forces are that are produced by an arbitrarily mis-fitted bearing. In situations like this you are presented with a problem, rough and ready measurement conditions and told you have one hour to find out what it is and recommend a solution. Diagnosis from the best practical measurements you can make is the only viable method.

Finally, I thoroughly agree with Ian Watson that there is little value in off-load motor noise measurements. In particular, they can be very worrying to a customer when he is sold a motor on the basis of the off-load noise running on a 50 Hz supply, but the real application involves PWM variable speed control. A 20 dB plus increase in motor noise is almost inevitable.

Yours sincerely
A H Middleton FIOA
Anthony Best Dynamics Ltd
Bradford on Avon