Institute of Acoustics

acoustics BULLETIN

Volume 24 No 2
March – April 1999

acoustics
BULLETIN

Volume 24 No 2
March – April 1999

Contributions and letters to:
The Editor, 9 Abbots Park, St Albans, Herts. AL1 1TW
Tel 01727 851475 Fax 01727 843042
e-mail roy@cmrl.demon.co.uk

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, Oak Tree House, 26 Stratford Way, Watford WD1 3DJ

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, 77A St Peter's Street, St Albans, Herts. AL1 3BN
Tel 01727 848195 Fax 01727 850553
e-mail Acoustics@clus1.ulcc.ac.uk
Web site http://ioa.essex.ac.uk/ioa/

Printed by:
Unwin Brothers Ltd, UBL International, The Gresham Press, Old Woking, Surrey GU22 9LH.

Single copy £15.00 Annual subscription (6 issues) £85.00

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
I J Campbell MIOA
(Gracey & Associates)

President Elect
Professor M A A Tatham FIOA
(Essex University)

Immediate Past President
B F Berry FIOA
(NPL)

Hon Secretary
Dr A J Jones FIOA
(AIRO)

Hon Treasurer
K A Broughton IEng MIOA
(HSE)

Vice Presidents
D G Bull CEng FIOA
(Colchester Institute)

Professor R G White CEng FIOA
(University of Southampton)

Ordinary Members

A N Burd CEng FIOA
(Sandy Brown Associates)

Professor R J M Craik CEng FIOA
(Heriot Watt University)

Dr P F Dobbins CEng FIOA
(BAeSEMA)

C E English CEng FIOA
(Arup Acoustics)

Professor B M Gibbs FIOA
(University of Liverpool)

C J Grimwood MIOA
(Building Research Establishment)

Professor P A Nelson CEng MIOA
(ISVR)

Dr B M Shield FIOA
(South Bank University)

S W Turner FIOA
(Stanger Science & Environment)

Chief Executive

R D Bratby

Institute Sponsor Members

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

Key Sponsors

Brüel & Kjær
Harrow, Middlesex

CEL Instruments Ltd
Hitchin, Herts

Cirrus Research plc
Hunmanby, N Yorks

Sponsoring Organisations

A Proctor Group Ltd
Blairgowrie, Perthshire

AEARO
Stockport

Acoustic Air Technology
Weston Super Mare, Avon

Acoustic Consultancy Services
Glasgow

AcSoft
Leighton Buzzard, Beds

Building Research Establishment, Watford, Herts

Burgess - Manning
Ware, Herts

Castle Group Ltd
Scarborough, Yorks

Ecomax Acoustics
High Wycombe, Bucks

EMTEC Products Ltd
Hayes, Middx

Firespray International Ltd
Godalming, Surrey

Gracey & Associates
Chelveston, Northants

Hann Tucker Associates
Woking, Surrey

Industrial Acoustics Company
Winchester, Hampshire

LMS UK
Coventry, Warwicks

N+H Acoustics Ltd
Wokingham, Berks

National Physical Laboratory
Teddington, Middx

Oscar Faber Acoustics
St Albans, Herts

Salex Group
Colchester, Essex

Sandy Brown Associates
London

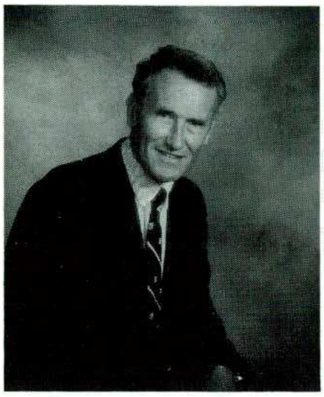
Shure Brothers Incorporated
Illinois, USA

Solaglas – Saint Gobain
Coventry, Warwicks

Spectrum Acoustic Consultants
Biggleswade, Beds

The Noise Control Centre
Melton Mowbray, Leics

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

As I write you this short note we are just completing the reports for the Annual General Meeting that will be held in conjunction with the 25th Anniversary Conference at the London Barbican Centre on the 13th May. It looks as though the Specialist Groups will be reporting increased levels of activity whilst the Secretariat will note that the relocation of the offices and installation of the computer system were all achieved to time and within budget. We are therefore coming to the end of a consolidation and reorganisation phase of our development and can now start to give more energetic consideration to moving forward with some of the various initiatives we have had in mind to develop the range of services we offer to members. I trust you will be at the Barbican Centre for both the Conference and to make your contribution to the debate as to the projects that we should choose to progress.

Over the past few months Professor Mark Tatham has been leading an Education Review team. They have been looking into the broad range of education activities; even thinking the unthinkable to put forward a discussion paper upon which the debate over our future direction in this area can be based. There is no doubt that promoting adequate and effective education programmes at all levels of the profession is one of the key reasons why the Institute exists and hence we are awaiting an important document. Similarly having achieved a standard it is important that members' knowledge remains in step with technical and administrative development. Our CPD programme is designed to achieve this objective and again proposals have been tabled to improve the take up among the membership that will be reported to you in the Bulletin. Our traditional methods of information dissemination have been via technical meetings and our publishing activities. We have for many years had a third information resource, our Library. As it is located in the office it has been open to members who are able to make the journey to St Albans. Alison Hill, our Librarian, has taken the lead in producing a development plan that sets out various options on how this service could be developed for the benefit of all the membership.

These are only some of the proposals as to how we move the IOA forward. As we may not be able to action them all at once; please make sure that any views you have are made known. You can contact us via the web page or even by the more traditional methods!

I look forward to your contribution and with kindest regards; I remain

Yours truly,

Ian Campbell

Editorial

I am sure readers will find the articles in this issue especially interesting. In their totality, they exemplify the sort of contributions that I have felt appropriate for a house journal serving a membership with a visibly diverse range of specialist interests.

The controversy over intelligibility continues in the Letters to the Editor section. The blue pages carry Calls for Papers for the 1999 Autumn Conference and Reproduced Sound 15. These proclaim the end of an era as the October/November events are being moved from the Hydro Hotel in Windermere to Stratford upon Avon. As the organiser of twenty plus Institute weekend residential conferences held in the Lakes, I naturally find this a sad change to report. The special arrangements offered to the Institute by the Hydro allowed the organiser to sleep peacefully while waiting for the usual flurry of very late bookings without worrying about lost room deposits. The reason lay in the hotel's fabled elasticity factor. With a topic that proved popular we could accommodate as many as two hundred and forty attendees - or were they sardines – (Speech and Hearing 1986) using the surrounding hotels. On other occasions we had as few as one hundred; yet this variability gave us no concern since, irrespective of numbers, we always had exclusive use of the hotel without charge for the public rooms. Perhaps potential delegates were put off by the long journey, but the distance was not entirely a bad thing; almost all delegates attended for the full conference adding to the coherence of the event. The hotel was getting a bit seedy and I suppose that is a good reason for looking elsewhere and it is certainly possible that the new venue in Stratford upon Avon will become, in the fullness of time, an established feature of the Institute year.

It is intended that the May/June issue of Acoustics Bulletin will carry pre-prints of all the keynote papers being presented at the Silver Jubilee conference. May I urge anyone who has not yet returned a form on behalf of their organisation for the 1999/2000 Register of Members to take action now.

Roy Lawrence FIOA

Points from Council and Standing Committee Minutes

Meetings Committee 23 November 1998

Reported: Attendance at Reproduced Sound 14 at Windermere, at 67 was 15-20 below the previous lowest attendance for this series. An unpopular topic area, studio acoustics, was thought responsible. Noise from Pubs and Clubs, University of the West of England attracted 60 delegates. Autumn Conference 1998: Speech and Hearing, Windermere reported to be a successful conference with 61 attendees. Practical Aspects of Measurement Protocols, NPL, Teddington cancelled due to insufficient number of delegates.

Considered: Future programme: Sonar Signal Processing, Weymouth, December 1998. Silver Jubilee Celebration, Barbican Centre, May 1999. Speech Intelligibility and STI, June 1999 and a number of suggestions for topics.

Agreed: That Mr Turner will contact group chairmen to seek views on the re-constitution of how the committee works.

Membership Committee 3 December 1998

Reported: Applications received for various grades were as follows (the numbers recommended for approval, or accepted, are in parenthesis)

Fellow 1 (1): Member 17 (14): Associate Member 24 (24): Associate 2 (2): Student 5 (4): Sponsor 3 (3).

Considered: The problems of providing electronic membership application forms.

Education Committee 3 December 1998

Clarified: That the new syllabus for the Certificate in Workplace Noise Assessment follows the revision of the HSE Guidelines.

Reported: The Certificate of Competence in Sound Transmission had been run at BRE with 5 students. A Business Plan and costings for a five-day course on the Measurement and Assessment of Hand-Arm Vibration is to be produced.

Council 17 December 1998

Reported: The Electroacoustics Group had been reconvened after a period of dormancy.

Agreed: That action on the Vice-President Groups and Branches in respect of including Audio in the activities be carried forward.

Reported: That the new computer system was largely complete.

Confirmed: A letter had been written to Mr D Playle thanking him for his efforts re Engineering Division.

Reported: That Mr Bull, Vice-President Groups and Branches had prepared an article for Acoustics Bulletin on reactivating the Industrial Noise Group.

Noted: That the Institute's position paper had been generally endorsed at the European Acoustical Association (EAA) board meeting in October 1998 and that Professor Peter Wheeler (a former President of the Institute) had been elected as the Association's next Managing Director.

Reported: That the EAA intended to publish a Directory of Suppliers and Services in due course.

Cathy Mackenzie HonFIOA

SONAR SYSTEMS FOR SEA BED IMAGING

Bryan Woodward FIOA

Introduction

Discovering the secrets of the sea has been a long-sought aim for decades, yet surprisingly few of these secrets have been revealed despite determined efforts by scientists and engineers using a variety of techniques. This paper is more concerned with the sea-bed than the sea itself because the sea-bed and the underlying sediments hold further secrets that present an even greater challenge to investigate. One way to study the sea-bed is to lower a television camera and observe it directly, but this may yield little information other than to give an idea of the topography, the presence or absence of sea life, or the location of debris such as wrecks. If the camera is mounted on a remotely operated vehicle (ROV) or on an autonomous underwater vehicle (AUV), it is possible to cover a large area and therefore to build up a better impression of what the sea-bed looks like. The problem with a camera is that it can only be used very close to the sea-bed, which usually involves an expensive operation to place it there, and in turbid water its use is ineffective.

Another way to study the sea-bed is to deploy an underwater acoustic system, generally referred to as a sonar, an acronym for *SOund Navigation And Ranging* that has now crept into general usage. Many types of sonar systems have been designed for exploring and surveying the sea-bed and for identifying and characterising sediments. All of them are active systems, because they operate in both transmit and receive modes, as distinct from passive systems that only work in receive mode. They are classified here under two main categories, 'non-penetrating' and 'penetrating'. The main feature of a non-penetrating system is that all the acoustic energy incident at the sea-bed is scattered, some of which is intercepted by a receiving transducer or array. Processing the received signals can yield some kind of 'image' of the sea-bed. This may be a 'one-dimensional' depth profile, ie the topography along a particular line, or a 'two-dimensional' plan view showing the presence, shape and orientation of natural features or objects. The main feature of a penetrating system is that some of the incident energy is scattered and some is transmitted into the sea-bed to be subsequently scattered from sub-bottom interfaces or absorbed. Processing the received signals in this case is much more complicated but can lead to a 'two-dimensional' sub-bottom profile, ie a sectioned view of the sea-bed and the underlying structure. Examples of non-penetrating systems are the conventional depth sounder, side-scan sonar, sector-scan sonar (which can be mechanically or electronically scanned), 'multi-beam' phased array sonar and synthetic aperture sonar. Examples of penetrating systems are the sub-bottom profiler, seismic profiler and parametric sonar.

Even the simplest type of sonar system, a conventional echo sounder, may be used to profile the sea-bed, something that can not be done conveniently with a camera. All that is necessary is to traverse the area of interest, transmit short pulses of sound vertically downwards and detect the echoes. The 'round trip' flight time of each pulse, from the instant it is emitted to the reception of its echo, when multiplied by the average velocity of sound in the water, gives the depth at some location. Modern echo sounders, as well as displaying the instantaneous depth numerically, provide a graphical display of the sea-bed profile along the track of the vessel. Depending on the frequency of operation and its power output, the sounder may also produce echoes from under the sea-bed, but is not usually suitable for studying the nature of the underlying sediments.

More sophisticated types of sonar may be used to produce two-dimensional images of the sea-bed. These include the side-scan sonar, the sector-scan sonar and the multi-beam phased array sonar. A side-scan sonar system usually has two horizontal linear arrays of elements that are mounted in a towed body, or tow-fish, in such a way that they transmit a fan-shaped beam, narrow in the vertical plane, on each side of the towing vessel's track. According to a well-known principle of acoustics, the longer the arrays the narrower are the two beams. Generally, the axis of each beam is inclined slightly downwards so that echoes are produced from different distances, typically from almost vertically down to almost horizontal. One system that has been used for many years for long-range surveying at oceanic depths is *GLORIA*, which uses a carrier frequency of a few kilohertz [1]. Most side-scan sonars have a graphical display that provides a two-dimensional image of the sea-bed, showing features such as rock formations, reefs and the position and orientation of wrecks and other man-made objects. The image is essentially a 'picture' of the sea-bed but it is usually distorted and needs an experienced eye to interpret the features. At low frequencies, say less than 20 kHz, the acoustic energy can penetrate the sea-bed but because of the long wavelength and large 'footprint' the spatial resolution is poor. Smaller footprints are possible if the sonar array is mounted on a deep-towed vehicle such as *TOBI* [1]. By using a higher frequency, say 100 kHz, there is less sea-bed penetration but better resolution of detail.

Perhaps the commonest type of scanning sonar is the mechanically-scanned version. This works on a 'ping-and-listen' principle, rather in the way a radar system operates. Most commercial systems can transmit while rotating through a sector or through a complete circle, either in the horizontal plane or inclined downwards at some angle. The echoes following each ping are processed to build up an image of the insonified area.

An electronic sector-scan sonar system usually has a wide-beam transmitting transducer or array and a narrow-beam receiving array comprising many elements. In a 300 kHz 'within-pulse' version designed and built at Loughborough University, the linear transmitting array comprises 75 elements mounted on a convex curve and the linear receiving array comprises 75 elements mounted on a flat base. Each transmitted pulse insonifies a 30° wide sector, giving rise to echoes at any angle within this sector and at any range out to a maximum determined by the pulse repetition rate of 4 Hz. A delay is introduced between the signal arriving at element 1 at one end of the array and at element 2; the same delay is also introduced between the signal arriving at element 2 and element 3, and so on all along the array. This clearly introduces a phase difference between the signals arriving at adjacent elements and means that at any instant the receiving array is sensitive to echoes arriving from only one direction. At a later instant, when the phase difference is altered, it is sensitive to echoes from another direction. With the correct phasing, the effect is to create a sensitivity 'beam' that scans continuously through the sector of the transmit beam. In the Loughborough University system the scanning frequency is 10 kHz. The system may be used as a 'look-ahead' sonar for detecting obstacles or to look sideways for mid-water targets, but it may equally well be used to look vertically downwards to image the sea-bed.

A more complex system working along broadly similar lines is the multi-beam phased array sonar. This has two multi-element linear arrays, which for sea-bed surveying may be mounted on the bottom of the hull of a vessel. The transmitting array is mounted along the fore-aft line and generates a 'fan-shaped' beam vertically downwards; this beam is wide in the port-starboard direction and narrow in the fore-aft direction. The receiving array is mounted at right angles to the transmitting array (and generally slightly astern of it) and therefore is sensitive to echoes arriving in a fan-shaped sector that is wide in the fore-aft direction and narrow in the port-starboard direction. Instead of just one phase delay being applied to all adjacent elements across the receiving array, which makes the receiver sensitive in one direction at a time, many phase delays are applied in parallel (as many as 128 in one commercial system) so that the receiver simultaneously processes signals from all directions within the insonified sector. With this system a two-dimensional plan-view image of the sea-bed is built up pulse by pulse.

Another system of interest but one still in the research stage for use at sea is the Synthetic Aperture Sonar (SAS), which is a specialised system that allows the imaging of finer detail than is possible by most other techniques [2–4]. This example of a 'non-penetrating' type of sonar system is presented in more detail below.

The side-scan sonar, sector-scanning sonar, multi-beam phased array sonar and synthetic aperture sonar are not generally suitable for sub-sea penetration because they operate at too high a carrier frequency. Systems that may be used to characterise sub-sea sediments include the seismic profiler [5–8], the sub-bottom chirp profiler [9], the parametric sonar [10–19] and hybrids such as the 'scatterometer' [1]. The seismic system is used to profile the sea-bed on a large scale, with penetrations of hundreds of metres or more; the others are used to profile on a smaller scale, typically tens of metres at the most. In the case of the sub-bottom profiler, either a single-frequency tone or a wide-band chirp may be used. The lowest frequencies, typically 5 kHz, obviously allow the deepest penetration and can give a picture of coarse stratification, but the higher frequencies, typically up to 20 kHz, offer the best depth resolution and can therefore show finer detail. The choice of frequency usually depends on the application. To illustrate a 'penetrating' type of sonar system, a brief description of the principles of the seismic profiler is presented below, together with a more detailed description of a parametric sonar system with a steerable beam.

Synthetic Aperture Sonar

Synthetic Aperture Sonar is of interest because it has the potential to produce high resolution, two-dimensional images of targets by synthesising the effect of a very long phased array [2–4]. The principle of aperture synthesis consists of storing successive echoes obtained from a moving platform, in practice a tow-fish but ultimately an AUV, then synthesising the effect of a large along-track phased array by correcting the phase excursions of echoes in a given direction and summing the sequence of echoes, hence providing high along-track (cross-range) resolution.

Traditional techniques such as side-scan sonar are good enough for general surveying and for identifying wrecks but do not have sufficient resolution for displaying particular features. The main reason for this low performance is the limited aperture size available with commercial systems. Synthetic aperture techniques are well advanced in radar and known as Synthetic Aperture Radar (SAR). By comparison, only a limited amount of research has been carried out on SAS and this has highlighted the main problems that prevent the direct translation of SAR techniques. These problems are that transducer motion produces smearing of the image, and ray bending produces a bias in the apparent direction of detected objects. The solutions used to eliminate these problems in SAR are auto-focus techniques that rely on contrast enhancement, but these are of limited success with SAS because of the relatively large transducer movements encountered in practice, together with very low towing speeds, narrow bandwidth and restricted range.

The aims of recent work at Loughborough University, carried out jointly with University College London, covered four main areas: (i) the design of signal processing algorithms to compensate for transducer platform movement and ray bending; (ii) the design of algorithms for interferometric reconstruction of three-dimensional surface images; (iii) the design of algorithms for moving target tracking using SAS; and (iv) testing an experimental system in the controlled environment of a sonar test tank.

Motion compensation

The approach to the problem of motion compensation was to consider that the true signal is effectively convolved with an error function that corresponds to the true trajectory of the transducer platform. At sea, with transducers mounted on a ship or in a towed array, waves can cause gross deviations from an assumed straight line trajectory that may be several wavelengths at the transmission frequency. One solution is to measure actual platform movement and do explicit de-convolution. The preferred solution, which obviates the need for accelerometers or inertial gyroscopes, is to perform blind de-convolution based only on measurements made by the transducer array itself. Three options were considered: (i) statistical de-convolution based on Higher Order Statistics (HOS), which is applicable to motion perturbations that are fairly predictable (eg cyclic) compared with the random nature of the data field; (ii) compensation based on frequency diversity, which requires separate measurements in different bands using the same transducer and may compensate for ray bending but not for motion errors; and (iii) compensation based on spatial diversity, which can provide multiple snapshots of the same data field and also allows for adaptive tracking of errors induced by motion.

Interferometric reconstruction

The interferometric processing consists of registering two images of the same scene taken at slightly different positions, and comparing the phases of the two images on a pixel-by-pixel basis. This yields a fringe pattern, which is a function of the interferometric baseline and geometry, the wavelength and the surface topography. Provided the baseline, geometry and wavelength are known, then in principle the surface can be reconstructed from the fringe pattern to the same spatial resolution as the original images.

The main problems are: (i) the two images suffer a degree of de-correlation due to the different angles of observation and the finite signal-to-noise ratio, which causes phase noise in the fringe pattern; (ii) 'shadowing' and 'layover' cause distortion of the sonar image with respect to the true surface; and (iii) there is an ambiguity between phase and topography, and the process of reconstructing the topography unambiguously ('phase unwrapping') is made more difficult in areas of rapidly varying topography and poor signal-to-noise ratio where the fringes may be closely spaced or indistinct. The approach was to simulate the imaging of arbitrary topographic scenes, taking account of the problems listed above, then to devise algorithms to reconstruct the original topography. The idea was to optimise the geometry and processing algorithms for the experimental part of the research.

Imaging moving targets

This is an important problem with SAS and has so far remained unsolved. Unlike for SAR, the situation is more complicated because the target is close enough to the synthetic array, which may be several kilometres long, that it presents different Doppler shifts to different parts of the array. This complicates the aperture synthesis processing. The problem may be approached by analysis, deriving expressions for the phase history of echoes as a function of the array-target geometry and motion, and using these to define the form of processing required to estimate the target motion and image the target. This algorithm can then be combined with that for the platform motion compensation to define the processing required in a practical SAS system, but further research is needed to fully achieve this aim.

Tank experiments

An important part of the research was to apply the various algorithms mentioned above for use with an experimental system, in the controlled environment of the test tank at Loughborough University. This provides a valuable test facility for the theoretical aspects of the project. An advanced SAS system was built for use in the tank, measuring 9 m long, 5 m wide and 2 m deep. It has a carrier frequency of 40 kHz, a maximum aperture of 4.5 m and a maximum range of 8 m. The platform carrying the transmit and receive arrays can be moved under computer control by two stepper motors; a third stepper motor is used to introduce across-track motion errors.

The transmitted pulse is generated by a signal generator that can be connected to a computer bus by an interface card. The system can be programmed to generate either a sinusoidal pulse with adjustable amplitude, carrier frequency, pulse length and repetition rate, or more complicated signals such as a weighted pulse or a chirp. The transmitted pulse is fed to the transmitter array by a power amplifier to ensure maximum power transfer. The system allows the feasibility of generating high resolution SAS images, including three-dimensional images, by extracting features and training the system to identify certain objects automatically using neural networks. This is an area of research in which many problems remain unsolved.

Seismic Profiler

Seismic profiling is a means of studying the stratification of sub-bottom layers on a large scale, that is to depths of perhaps hundreds of metres or even kilometres [5]. The applications include geological mapping, environmental studies and surveying for cable routes and pipelines. The basic requirement is a sound source with a high Source Level and a receiving array of geophones to detect reflected and scattered pressure impulses. This type of profiling is attributable to the fact that sound waves propagate with little attenuation in media with elastic properties. Any abrupt changes of acoustic impedance causes refraction and reflection and the generation of compressional and shear waves, referred to as *P-waves* and *S-waves* respectively. Measurements of the arrival times of the detected acoustic signals are used to work out the sub-bottom geological structure [6].

The velocity of P-waves in the top 50 metres of sediment is typically 1450 – 2200 m/s, whereas the velocity of S-waves is much lower, between about 10 m/s and 400 m/s. Much of the information on sediment structure comes from the timed returns of reflected and refracted

P-waves. There is usually a good correlation between shear velocity and shear strength, an important parameter in geophysical studies, especially for applications such as the construction of oil and gas production rigs where sea-bed stability is a vital factor. In some places, sediments are too soft to be sheared so no shear wave data can be obtained. The commonest method of determining shear strength is to take a core from the sea-bed and make measurements in the laboratory but by removing the sample there may be some change in the sediment properties; this is why an in-situ method is preferred [7].

One way this problem has been addressed is to study interface waves, such as Rayleigh, Stoneley and Scholte waves, which propagate along the water/sea-bed interface [8]. The idea is that since the velocity of such boundary waves is linked with the shear wave velocity of the top sea-bed sediment, information about the shear strength of the sea-bed can be obtained without disturbance. By contrast, there seems to be little dependence on the state of gas saturation in sediments, such as those found in the Arkona Basin in the Baltic Sea.

Low frequency seismic sources (20 – 200 Hz) are used for penetration sediments to depths of the order of kilometres, while higher frequency sources (100 Hz – 10 kHz) are used for penetration to depths of hundreds of metres. Typical source durations are 0.1–1s and sources include boomers and sparkers, which are omni-directional transducers that can generate stable pressure signals.

Other sources include explosives and mechanical devices such as air guns and water guns. The array of geophones is either towed behind a vessel or from a sledge that is itself towed along the sea-bed by the vessel. In one system, the sledge stops briefly for each measurement while the vessel steams at a constant speed*. The array is normally in the form of a streamer comprising many geophones in an oil-filled plastic tube that is transparent to sound. A problem with such an array is that it is subject to noise from flow, turbulence, bubbles, waves and ship noise.

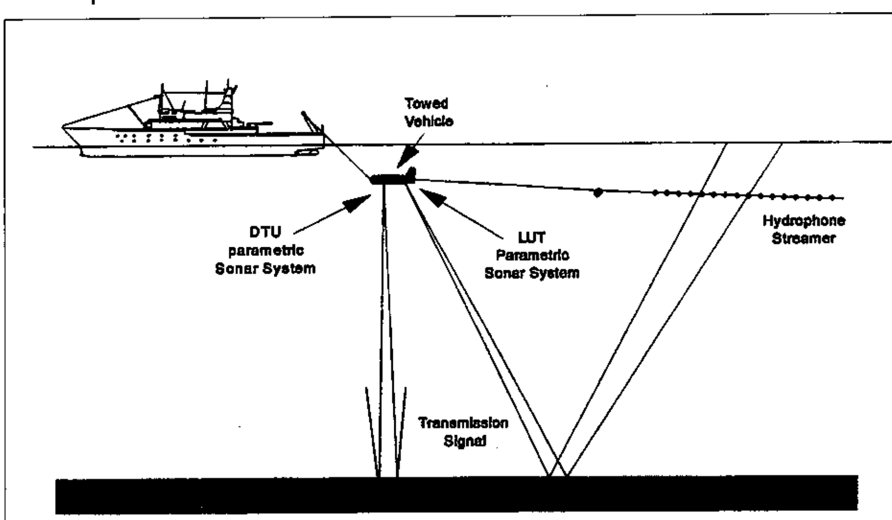


Fig. 1. Deployment of a parametric sonar array and hydrophone streamer

Parametric Sonar

A parametric sonar system makes use of the non-linearity of acoustic wave propagation in water [10–19]. The principle of operation is to drive a transducer array at two *primary* frequencies, f_1 and f_2, near the resonance frequency f_0 of the array, where $f_0 = (f_1 + f_2) / 2$, to generate new waveforms, the lowest of which is at the *difference* frequency, or *secondary* frequency, $f_d = f_2 - f_1$. The generation of this secondary frequency waveform along the transmitted beam direction gives rise to the concept of a *virtual end-fire array*, the effective length of which is given by $(2\alpha)^{-1}$, where α is the small signal attenuation coefficient in nepers/metre. At primary frequencies of 20 kHz, 40 kHz and 80 kHz, the virtual array lengths are approximately 1500, 400 and 100 metres respectively for transmission in sea water.

The advantage of a parametric sonar is that it can generate a sidelobe-free, narrow beam at the difference frequency, using an array that is small compared to one that would be needed to generate the same frequency directly. A further advantage is that it allows sediment penetration to depths of several metres at difference frequencies of less than 10 kHz. The disadvantage is that it operates at a very low efficiency, about 1%, a figure that depends directly on the step-down ratio $f_0{:}f_d$. The low efficiency therefore necessitates the generation of high-power primary frequency waveforms. This means that the *Source Level* at the difference frequency is typically 40 dB less than either of the two primary frequency Source Levels for a typical step-down ratio of 10, eg a difference frequency of 7.5 kHz from primary frequencies centred on 75 kHz. (*Source Level* is defined as $10 \log_{10} P_a + DI$, referenced to 1 metre from the acoustic source transducer or array, where P_a is the transmitted acoustic power in watts and DI is the Directivity Index, which depends on the geometry of the source].

In several recent European Commission projects**, a narrow beam was needed for accurate profiling of the sea-bed to characterise sediments and to detect and identify buried objects. As the difference frequency beamwidth is approximately that of the primary frequencies, the beamwidth defines the dimensions of the array. For a step-down ratio of 10 (ie $f_0{:}f_d$), the active surface area of the array need only be 1/100th of that of a conventional linear array for the same beamwidth.

This is a big advantage in terms of expense, size, weight and handling of the array at sea. The array consists of a titanium plate with 729 integral elements, resonant at 75 kHz and arranged in a 27 x 27 matrix with approximately 0.75 spacing. It has an area of $20\lambda \times 20\lambda$, with a resultant −3 dB beamwidth of 3° x 3° and a bandwidth of 6 kHz. The transmit Directivity Index is 35 dB so for an acoustic power of 10 kW the maximum predicted Source Level for a single carrier frequency is SL_0 = 246 dB re 1μPa at 1 m. The array provides 13 resolvable beams, each about 3° wide, within its phase-steerable sector; since the inter-stave spacing at 75 kHz is 1.5λ the scanned sector is ±18°, which allows a wide variety of incidence angles to be selected in order to apply inverse algorithms to compute sediment characteristics from measured compressional and shear wave data. The programmed signals transmitted may be continuous sine wave pulses, 'raised cosine' pulses, and linear frequency modulated pulses (*chirps*).

The scenario for sea trials conducted at various sites off the coast of Brittany, France is shown in Figure 1. The array, together with other systems, has been deployed at depths of 10–20 metres in a tow-fish specially designed and built by *IFREMER*, the French Oceanographic Institution. A 40 metre seismic hydrophone streamer is towed some 25 metres behind the tow-fish to detect forward-scattered signals from the seabed. The mechanical mounting arrangement, shown in Figure 2, allows three possible fixed angles for the transmission axis, 10°, 15° and 20° with respect to vertical, when the dynamic steer angle is programmed to be 0°. When the beam is steered vertically downwards to the sea-bed, the array may also be used in a back-scatter depth sounding mode.

Instabilities in the motion of the tow-fish, such as pitch, roll, yaw, heave, swell and surge, can lead to a departure from the desired sea-bed incidence angle. Any error in this angle may lead to a misalignment of the streamer with respect to the scattered signals. This in turn may produce either no data at all or data that yields spurious results when applied to the inverse algorithms that are applied to quantify the sediment parameters. Sensors are therefore attached to the array to monitor the pitch, roll and depth of the tow-fish to correct for some of the instabilities.

Since the beam cannot be steered athwartships, there is no correction for roll; but if the roll angle of the fish exceeds about 3° the forward-scattered signals would not be detected by the hydrophone streamer so transmission for such angles can be temporarily halted. For any pitching of the fish, the beam angle is dynamically adjusted so that the angle of incidence at the sea-bed remains unchanged. The hardware of the system allows the individual addressing of eight separate sections of the available memory that store the required waveforms to provide a series of phase-steered signals for a range of angles. When the sensors attached to the array detect a change of pitch, the appropriate waveform is selected and the beam is therefore steered to compensate for the movement. A series of eight signals allows near-instantaneous correction of the beam direction due to the sensed movement. With eight possible angles and a total phase steer capability of ±18°, the angular separation of the beams is 4.5°.

A further consideration is the problem of alignment of the sonar beam and the streamer when the sea-bed is sloping and several methods have been studied to determine the slope. The simplest method is by depth sounding, which can be done by periodically steering a primary frequency beam vertically downwards. A more complex method is to steer two primary frequency beams at different angles, say one slightly fore of vertical and one slightly aft of vertical, then measure the time difference, which in turn allows the slope to be determined. A suitable way to do this is to correlate the envelopes of the two back-scattered signals; the two narrow beams would make the array appear like a Doppler sonar but instead of measuring a frequency difference, a time difference is measured. The method is therefore similar in principle to the operation of a correlation velocity log.

Although a parametric sonar system is fairly complex and is difficult to deploy, it allows the study of sediments remotely, since it can operate near the sea surface to examine the characteristics of sediments on the continental shelf.

Conclusions

Many types of sonar system have been designed for the detection of objects underwater and for the surveying or imaging of the sea-bed. There are many variations on a theme available and there is no one system or technique

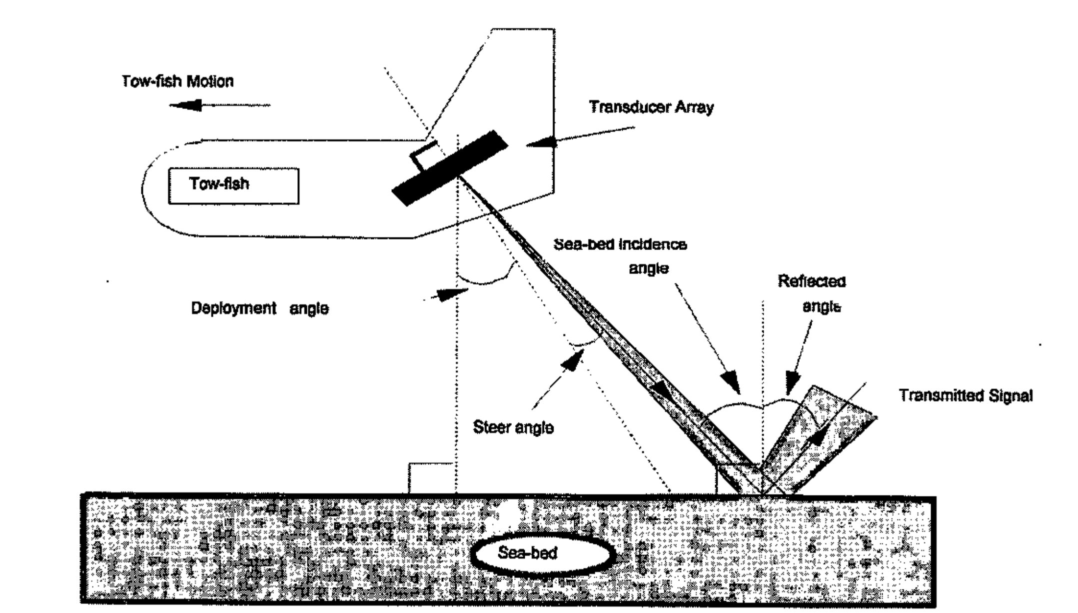


Fig. 2. Configuration of electronically steered parametric array in a tow-fish

that is 'better' than all the others: the measurement capability or precision depends to a large extent on the application considered. Whatever the technique used it is always necessary to consider what result is expected; the resolution achievable, whether coarse or fine, is invariably of paramount importance and worth special consideration [20].

In this paper, the various sonar systems have been arbitrarily categorised as 'non-penetrating' and 'penetrating' to distinguish between types that are mainly used for imaging the sea-bed and those that are mainly used to profile sub-bottom sediments. One of the major challenges to sea-bed exploration is to find a technique or a combination of techniques to enable sediments to be identified and characterised without the need to take cores or to disturb the sea-bed directly. This has been a major research theme of the European Commission's *MA*rine *S*cience and *T*echnology (*MAST*) programmes**. In the *MAST* programme research described here the broad aim has been to design new, remotely operated systems for characterising the sea-bed and the sub-bottom structure entirely by acoustic means. While the use of non-penetrating systems such as the side-scan sonar have been used routinely for decades to image the sea-bed, it remains a major challenge to determine the exact nature of the underlying sediments using penetrating systems such as the parametric sonar. The ultimate objective is to develop an acoustic technique such that following the propagation of a coded ping or a series of pings, the scattered or reflected acoustic signals may be analysed to reveal the nature of the sea-bed parameters directly without recourse to direct non-acoustic techniques that are used now. Present techniques, although advanced and sophisticated, are a long way from achieving this objective. Future applications of this technology may include dredging, material exploitation, sedimentology, propagation modelling and the detection of buried objects.

References

[1] M L SOMERS, 'The IOSDL acoustic scatterometer for sediment studies', Proc 2nd European Conference on Underwater Acoustics, Copenhagen, 497–502, (1994)

[2] J CHATILLON, M E ZAKHARIA & M E BOUHIER, 'Wideband synthetic aperture sonar: advantages and limitations', Proc 1st European Conference on Underwater Acoustics, Luxembourg, 709–712, (1992)

[3] L J CUTRONA, 'Comparison of sonar performance achievable using synthetic aperture techniques with the performance achievable by more conventional means', JASA, 58, 336–348, (1975)

[4] P T GOUGH, 'A synthetic aperture sonar system capable of operating at high speed and in turbulent media', IEEE J Oceanic Eng, 11, 333–339, (1986)

[5] P G SIMPKIN & P GEO, 'Seismic profiling in shallow water – a novel approach', ProcIOA, 15, 279–283, (1993)

[6] S E DOSSO & G H BROOKE, 'A high-resolution geoacoustic study in the Canadian high Arctic: sea-bed characterisation using non-linear acoustics', Proc 2nd European Conf on Underwater Acoustics, Copenhagen, 857–862, (1994)

[7] F THEILEN, F C KOGLER, K VAN BOCXLAER, M DE BATIST, T MISSIAEN, G G ORI, G OLLIER, T M McGEE & P BRUSSAARD, 'GISP – Geophysical In-Situ Probe', Proc 1st European Conf on Underwater Acoustics, Luxembourg, 481–484, (1992)

[8] J M HOVEM & S A FRIVIK, 'Marine geotechnical investigations using interface waves', Proc 2nd European Conf on Underwater Acoustics, Copenhagen, 869–874, (1994)

[9] S G SCHOCK, L R LeBLANC & L A MAYER, 'Chirp sub-bottom profiler for quantitative sediment analysis', Geophysics, 54, 445–450 (1989)

[10] P J WESTERVELT, 'Scattering of sound by sound', JASA, 29, 199–203, (1957)

[11] P J WESTERVELT, 'Parametric acoustic arrays', JASA, 35, 535–537, (1963)

[12] B V SMITH, 'An experimental study of a parametric end-fire array', J Sound Vib, 14, 7–21, (1971)

[13] W L KONRAD & M B MOFFETT, 'Specialised drive waveforms for the parametric acoustic source', Proc Oceans 77, Los Angeles, 16–19, (1977)

[14] J G WILLETTE, 'Harmonics of the difference frequency in saturation limited parametric sources', JASA, 62, 137–138, (1977)

[15] T G MUIR, L L MELLENBRUCH & J C LOCKWOOD, 'Reflection of finite amplitude waves in a parametric array', JASA, 62, 271–276, (1977)

[16] M B MOFFETT & R H MELLEN, 'Effective length of parametric acoustic sources', JASA, 70, 1424–1426 (and errata 71, 1039), (1981)

[17] B WOODWARD, J C COOK, A D GOODSON & P A LEPPER, 'A phase-steered parametric array for sub-bottom profiling', Proc 6th Int Conf on Electronic Engineering in Oceanography, Cambridge, UK; IEE Conference Publication No 394, 77–82, (1994)

[18] B WOODWARD, A D GOODSON, J C COOK & P A LEPPER, 'Sea-bed characterisation using non-linear acoustics', Proc 2nd European Conf on Underwater Acoustics, 875–880, (1994)

[19] S ENGLEBRECHT, N G PACE & L BJØRNØ, 'The interaction of a parametric array with the sea-bed', Proc 2nd European Conf on Underwater Acoustics, 893–898, (1994)

[20] M L SOMERS, 'Resolving the issue, a look at resolution and related topics in sonar' in Man-Made Objects on the Seafloor, Discovery, Investigation and Recovery, Proc Society for Underwater Technology Int Conf, London, 1–2 Feb, 41–58, ISBN 0-906940-26-5, (1995)

* The research on synthetic aperture sonar described in this article was funded by the Engineering and Physical Sciences Research Council under Grant GR/J71106 (Loughborough University) and Grant GR/J81082 (University College London) and by the Defence Evaluation and Research Agency under Agreement 2170/128.

**The research on parametric sonar described here was funded by the European Commission under MAST-II contract MAS2-CT91-0002C (REBECCA), International Scientific Cooperation contract CI1*-CT94-0093 (ACUSTICA), MAST-III contract MAS3-PL95-0009 (DEO) and MAST-III contract PL96-1111 (SIGMA).

Acknowledgements

The author is indebted to the following colleagues for their many and varied contributions: Paul Connelly, Professor Colin Cowan, David Goodson MIOA, Professor Hugh Griffiths FIOA, the late Professor Roy Griffiths FIOA, Paul Lepper and Dr Tahsin Rafik.

Bryan Woodward FIOA is Professor of Underwater Acoustics and formerly Head of the Department of Electronic and Electrical Engineering at Loughborough University. ❖

A CONTROLLED-REFLECTION LISTENING ROOM FOR MULTICHANNEL SOUND

Robert Walker FIOA

Introduction

Listening is an integral part of all sound production operations. Despite the very significant advances of modern sound monitoring and measurement technology, those essentially objective methods remain unable to tell us what the programme will really sound like to the listener at home. The human ear alone is able to judge the aesthetic or artistic quality of programme material and, indeed, certain aspects of the technical quality. However, it is self-evident that both the acoustic environment and the electro-acoustic properties of the loudspeakers will have a large influence on the perceived sound and must be controlled in order to allow consistent subjective assessments to be made.

The auditioning of audio systems or processing algorithms also requires careful control of the listening conditions if reliable and repeatable results are to be obtained. That is especially true for tests which are to be carried out by different organisations or where the tests will be spread over a significant period of time. Internationally-agreed test procedures may remain in use for many years, during which time the test arrangement may be dismantled and reconstructed. Especially in these days of international collaboration, tests are frequently carried out in more than one test location.

The three main components of the sound field in the vicinity of the listener are the direct sound, the early reflections and the later reflections which merge to form the reverberant field. All these components are functions of both time and frequency.

International Recommendations ITU-R BS 1116 [1] and EBU Rec R22 [2] (Tech Doc 3276 [3]) include fairly closely-controlled acoustic parameters for listening rooms for critical listening. The room acoustic parameters included are the usual ones of room size, shape and reverberation time. In addition, the Recommendations specify the maximum permissible levels of early reflections. For multichannel listening, with four or more loudspeakers, the control of early reflections is complicated by the large number of combinations of potential sources and reflecting surfaces.

This article describes the acoustic design of a new listening room intended to meet those ITU and EBU requirements. It does not include any discussion of the non-room related aspects of the Recommendations, such as the objective performance of the loudspeakers. It should also be noted that the two Recommendations are essentially identical, with only a very few differences. In all the following, any reference to the Recommendations should be assumed to refer to either one.

The new listening room was constructed at the BBC's Research and Development Department in an existing double-skin shell which was already in use as a listening room and which offered reasonable insulation from exterior noises.

The room was essentially completed by the end of August 1997. It is believed to satisfy all of the acoustic requirements of BS 1116 and Tech Doc 3276 for a high-quality sound control room/reference listening room. It has already been used for a number of subjective test programmes involving multichannel sound systems.

The article includes a brief discussion of the measurement of early reflections and gives the results of measurements made during the commissioning and adjustment of the room. It also illustrates some of the effects on early reflections of different means of reflection control.

Room Size and Shape

The limits given in the Recommendations for room size cover a reasonably broad range. In practice, for multichannel listening the minimum floor area is set by the loudspeaker arrangement and the minimum permissible distances from the loudspeakers to the wall surfaces. The recommended layout for the five monitor loudspeakers for multichannel reproduction is given in Figure 1 [4]. The admissible limits of the base width, b, are from 2.0 to 4.0 m. If the monitor loudspeakers are not built into the wall, the distance of their acoustical centres from the surrounding walls should be at least 1 m.

Room proportions have a pronounced effect on the uniformity of low-frequency responses, especially in relatively small rooms. Historically, ratios of dimensions satisfying some 'golden' rule have been used. For the purposes of international standardisation, the use of a

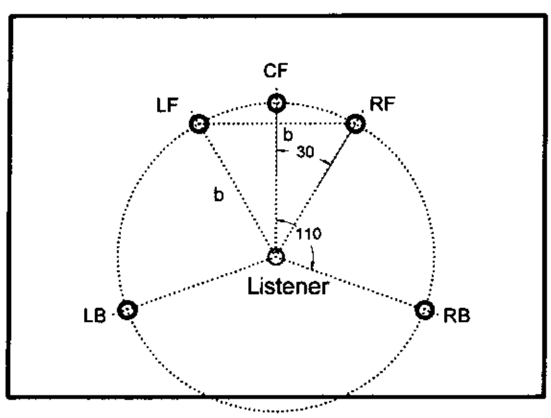


Fig. 1. Loudspeaker layout for five-channel multichannel sound.

restricted selection of possible room shapes is not practicable. Few organisations would be able to justify the construction of special rooms and, where the space available was larger, it would not necessarily be beneficial to reduce the size of the space simply to fit one or other of the special ratios (there is, in any case, little agreement about what the actual optimum shape is). Accordingly, as part of the work of drafting those Recommendations, a new approach was produced giving a much wider choice of reasonably-proportioned room shapes [5,6]. The specification does not necessarily lead to the optimum room shape for a given volume; it should, however, lead to room responses which are in practice not much worse than the optimum. Every room, irrespective of shape, is ultimately subject to some degree of low-frequency response irregularity.

In the Recommendations, the limits for the room proportions are given by:

$$1.1w/h \le l/h \le 4.5w/h - 4$$

where:

l = larger dimension of floor plan
w = shorter dimension of floor plan and
h = height.

In addition, both l and w must be less than $3h$ and ratios of l, w and h which are within ± 5% of integer values should be avoided.

For the new listening room, the available space in the new room was only just adequate to meet the layout requirements for the recommended five-channel loudspeaker arrangement and to meet the requirements for the room shape. The room floor plan was 6.76 m x 4.94 m, giving a floor area of 33.4 m². The free height to the structural ceiling was 3.2 m. The room dimensions resulted in the following proportions:

$$1.69(1.1w/h) \le 2.11(l/h) \le 2.93(4.5w/h - 4)$$

Early Reflections

Measurement and specification

The measurement of early reflections is a complex issue [7,8]. The unavoidable limits on combined time/frequency resolution mean that the simultaneous and complete identification of time delay, bandwidth and amplitude for an acoustic event is not possible.

The conventional way of describing the characteristics of acoustic or audio systems is as functions of frequency. However, all real signals, whether acoustic or otherwise, are inherently functions of time – in the sense that the signal only exists at all as some measure of a physical attribute, which may or may not vary with time. The concept of the frequency domain is a mathematical abstraction, with no physical existence. It is well known that the impulse response of a linear, time-invariant system theoretically contains all of the information necessary to specify the system response fully. However, the impulse response is a time domain function. In practice, it may or may not effectively be limited in the frequency domain, depending on the equipment used to measure it.

For all of these reasons, it is important to understand the transformations from time domain to frequency domain and, in particular, the inherent resolution limits of the joint frequency-time space. Many commercial measurement systems are, at best, unclear about the limitations of the transformations which are being carried out between the time and frequency domains and the weighting functions being applied. They can give seriously misleading results under some circumstances. For present purposes (and in the EBU Tech Doc 3276) it is assumed that a measurement system with well-defined Fourier Transform windows with a time resolution of about 1–2 ms and a (commensurate) frequency resolution of about 500 Hz will be adequate to describe the acoustic room responses from about 1 kHz upwards. Those are the main frequencies giving rise to the directional information which might be disturbed by early reflections. For the results presented here, a MLSSA measurement system was used. The bandwidth was set to 10 kHz (30 kHz sampling), the FT window to 'half-Hann' of length 128 samples giving a half-amplitude time resolution of about 2 ms and a frequency domain sample spacing of 234 Hz. The results were further filtered by a one-third octave filter in the frequency domain.

The Recommendations specify that levels of reflections earlier than 15 ms relative to the direct sound should be at least 10 dB below the level of the direct sound for all frequencies in the range 1 kHz to 8 kHz.

Control

For multichannel listening, with five loudspeakers and six main room surfaces, there would be 30 first order reflections and 150 second-order reflections. Clearly, to achieve any significant degree of control it is necessary to reduce that large set of potential reflections down to something manageable. As a start, most of the second-order reflections can be ignored on the basis of the total time delay and natural attenuation with distance. With a loudspeaker/listener distance of 2 m any reflection with a total path longer than 6.34 m will already be attenuated by at least 10 dB relative to the direct sound by the effects of normal spreading loss. In any reasonable room, this condition will ensure the elimination of all of the potential second-order reflections from the wall surfaces, without having to assume any additional attenuation by the wall treatment. It will also eliminate many of the cross-reflections, that is, those from a source on the opposite side of the room from the reflecting wall. The earliest second-order reflections involving the ceiling or floor might have a path length around 5.5 m, but those surfaces must be treated sufficiently to attenuate the first-order reflections anyway. All of this assumes that there is no acoustic focusing, no excessive off-axis source directivity and no other effects which could increase the relative reflection strength. In practice, some margin of additional attenuation would be desirable to accommodate those types of imperfections.

In all of the design of the reflection control for the new room, no allowance was made for any causes of additional attenuation. The loudspeakers were assumed to be omnidirectional. In practice, virtually all loudspeakers

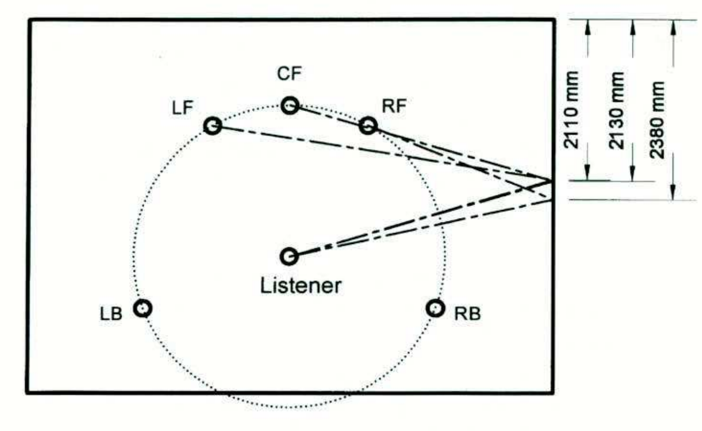


Fig. 2. Potential reflections from front loudspeakers via right-hand wall.

become significantly directional at 1 kHz and above. This would have the effect of reducing the amplitudes of potential reflections from surfaces behind the loudspeakers. There are also some occurrences of obstruction; for example the reflection from the Centre-Front loudspeaker in the rear wall is obstructed by the listener's body (although not by a measurement microphone).

The early reflection problem is thus reduced to that of dealing with a few first-order reflections from each source. Some parts of the room surfaces had to be considered in detail and had to be specially treated. Those were the parts of the wall surfaces which could potentially generate a first-order image, 'visible' in the listening area, of any of the five loudspeakers. Figure 2 shows the loudspeaker layout in the room. It also shows the three potential reflections from the front loudspeakers via the right-hand side wall. It shows that the potential reflection points on the walls are clustered into comparatively small regions.

Figure 3 shows the complete first-order reflection pattern for all loudspeakers (including the cross-reflections which may already be attenuated adequately by their path length); the clusters of potential wall reflection points can be clearly seen. The additional attenuation required to reduce the reflected sound to below −10 dB relative to the direct sound was more than could be achieved by either absorption or diffusion. It was therefore necessary to angle portions of the wall surfaces in order to redirect the first-order reflections away from the main listening area [9,10,11,12]. Studies of the potential reflection patterns showed that the angled portions could be confined to only nine segments of the total wall surface and that the angles required could easily be achieved within the normal thickness of acoustic treatment. The angles were chosen on the geometric basis of a 2 m diameter exclusion circle around the reference listening position*.

The centre section of the rear wall presented a more difficult problem. The angles required to redirect the sound horizontally were extreme and the panels would have projected much too far into the room. Initially, that 2 m wide area was treated with acoustic diffusers (2-D primitive root diffusers). However, subsequent measurements showed that although the overall attenuation of the reflections was adequate, some diffraction peaks exceeding the specification did occur. It is a well-known feature of number-theoretic diffusers that such peaks will occur [13] and this was actually observed in this case. Whether the result would have been subjectively significant is unclear, but they certainly caused the specification to be contravened. The rear centre section was then replaced by a set of angled flat panels, which reflected the sound vertically, either down to the floor or up to the ceiling.

Figure 4 shows the completed wall design (for half of the room), including angled panels, areas of both deep and shallow acoustic absorption (see the Results section below) and the 2 m circle of 'exclusion'. The redirection of one potential reflection from the left hand wall is illustrated.

The control of reflections via ceiling and floor is much more difficult. Floors usually have to be flat, strong and relatively hard. The floor is also the surface which provides the earliest and strongest reflection. In this case, the

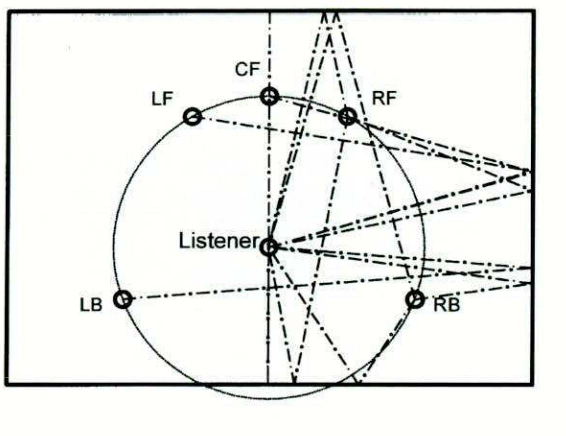


Fig. 3. Complete set of first-order wall reflections (for half-room).

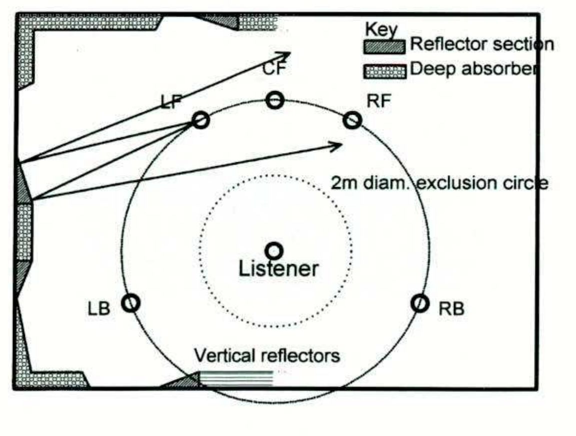


Fig. 4. Layout of reflecting panels & acoustic treatment, showing control of reflection from Left-Front loudspeaker.

only practicable solution was to provide large, portable floor units made of thick acoustic absorption with angled surfaces, to stand on the floor between the listeners and each of the sources. In fact, at the time of writing, those units had not been constructed and temporary provisions could be made when necessary. In practice, such units would be obstructive and cumbersome and would only be used for the most critical tests where the exact letter of the recommendation had to be observed**.

The acoustic design for the ceiling (see below) and its distance from the source/listener meant that reflections from the ceiling would be attenuated sufficiently without additional control.

Results

Figure 5 shows the time-frequency response for the Left-Front loudspeaker, as measured at the reference listening position for the room as first built. The frequency range below 1 kHz is not part of the specification – it is included here for completeness and to illustrate that lower-frequency 'reflections' cannot be controlled in this way; they probably cannot be controlled in any other way either. Also, in all of these MLSSA plots the direct sound amplitude was equalised to remove most of the loudspeaker irregularities. The nominal direct sound reference level was therefore 0.0 dB. For instrumental reasons, the actual displayed direct sound level usually lay between 0.0 dB and – 0.5 dB. In the following discussion all amplitudes are given relative to 0.0 dB. The 'floor' of the displayed amplitude range was set to –16 dB, well below the specified limit, otherwise very little of the reflection responses would have been visible.

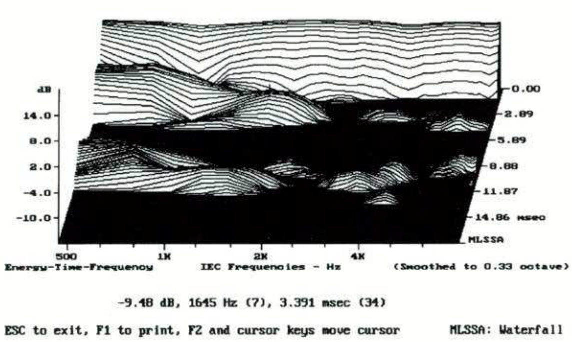


Fig. 5. Time-frequency response, Left-Front loudspeaker, initial construction.

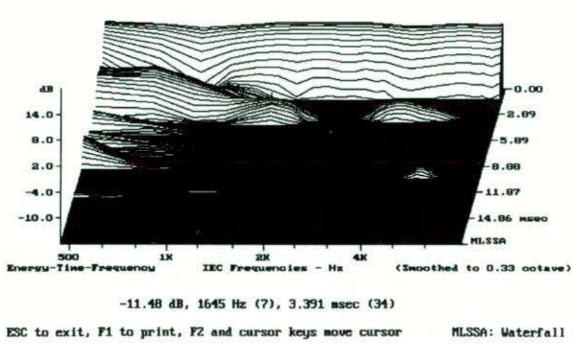


Fig. 6. Time-frequency response, Left-Front loudspeaker, after replacement of rear wall diffusers.

In Figure 5 at about 1600 Hz/3.4 ms (highlighted by the cursor), there is a peak reaching up to –9.5 dB due to the floor reflection. There is also a scatter of irregular peaks over the whole frequency range, at about 10 ms. The amplitudes are all well below –10 dB but they were caused by the diffraction from the diffusers on the rear wall. At that off-axis angle a flat surface would have produced no reflections. Figure 6 shows the effect of replacing the diffusers by flat reflecting panels directing the sound to either floor or ceiling. Almost all of those peaks were removed (at least to below –16 dB). Figure 7 shows the effect of placing a floor reflector/absorber between the source and the listening position. The peak in Figure 5 was reduced to below –16 dB for frequencies above 1 kHz. The remaining low-frequency peak in the floor reflection response just meets the –10 dB/1 kHz specification.

The effect of the diffusers is illustrated better by Figures 8 and 9. Those are the responses for the Centre-Front loudspeaker, at an angle which would have given a strong reflection from a flat surface. Figure 8 shows the response with the diffusers. The response shows a moderately regular structure with peaks at about 6.5 kHz and 3.0 kHz, and for all frequencies below about 800 Hz (the design lower limit of the diffuser panels). The highest of those peaks measured about –6.2 dB – well above the specified limit. Figure 9 shows the response after the diffusers had been replaced by vertically angled reflectors (and with the floor reflectors/absorbers). The residual reflections from the final rear-wall structure were well below the –10 dB limit, even for the Front-Centre loudspeaker.

Reverberant Field

After the positions of reflecting panels had been fixed, the remaining internal acoustic treatment was designed

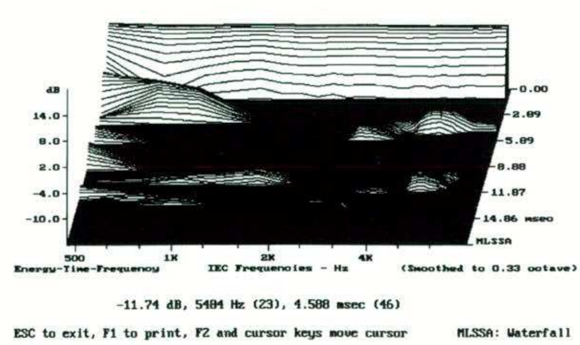


Fig. 7. Time-frequency response, Left-Front loudspeaker, with floor reflector.

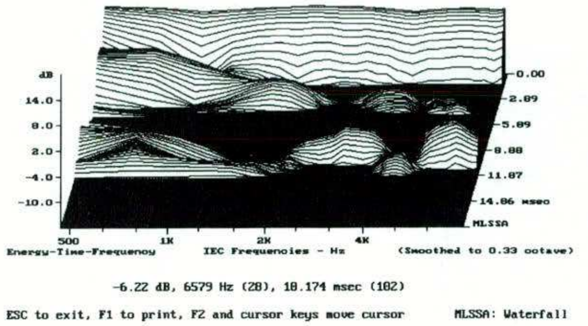


Fig. 8. Time-frequency response, Centre-Front loudspeaker, initial construction.

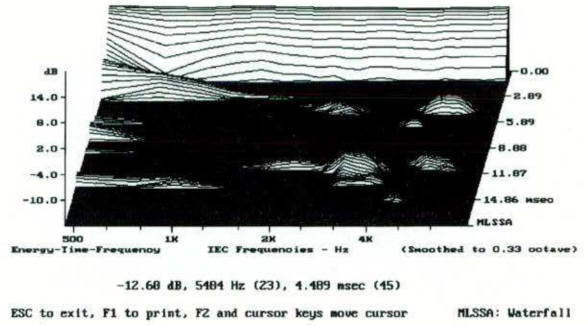


Fig. 9. Time-frequency response, Centre-Front loudspeaker, after replacement of rear wall diffusers and with floor reflector.

to meet the requirement for the overall (average) reverberation time, using conventional absorbing materials fixed to the floor, walls and ceilings. The wall design led naturally to an alternating sequence of deep and shallow treatment as shown in Figure 4. Fortunately, the requirements for low-frequency, mid-band and high-frequency acoustic treatment fitted almost perfectly with the available space.

All of the deep treatment was in the same form as had been recently developed for the treatment of large TV studios [14]. It consisted of standard industrial metal studs (as used in metal-framed partition walls) 180 mm deep. The space was filled entirely with medium-density glass-wool. The front surface was covered approximately in equal proportions with metal mesh (for protection against accidental damage) and 1.0 mm steel sheet to provide low-frequency absorption. The shallow treatment was 3 mm perforated hardboard over 25 mm glass-wool. It was intended to provide selective mid-band absorption to control frequencies around 400 Hz (where there was a lack of overlap in the low and high frequency absorption responses of the deep treatment). The whole wall surface was then covered with stretched fabric, spaced 6 mm from the main treatment to avoid excessive high-frequency absorption.

The ceiling was treated with modular acoustic boxes. That was partly to give a degree of flexibility to adjust the final reverberation time. The boxes were also much easier to fix to the ceiling than the type of treatment used for the walls. The visible ceiling surface finish was formed from stretched fabric on thin frames, supported by a standard 1200 x 600 mm suspended ceiling grid, 500 mm below the structural roof. The combination of fabric, 600 mm airspace and acoustic boxes gave more than adequate attenuation of the first-order ceiling reflection.

The floor treatment consisted of standard carpet tiles laid on a heavy, access floor. The first-order floor reflection was significant and required additional moveable absorbers/reflectors, as described above.

According to the Recommendation, the nominal reverberation time, T_m, for the $^1/_3$ octave bands from 200 Hz to 4 kHz should be in the range 0.2 – 0.4 s.

$$T_m = 0.25\left(Room\ Volume\,/\,Ref.volume\,(100)\right)^{1/3}\ \text{s}$$

For this room of 106 m^3, that gives a nominal target value of 0.255 s.

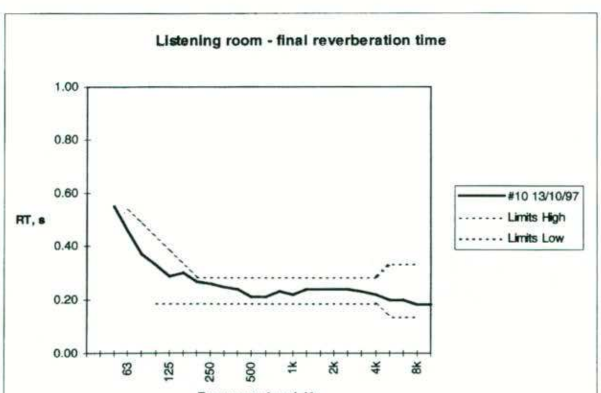


Fig. 10. Overall reverberation time, with tolerances.

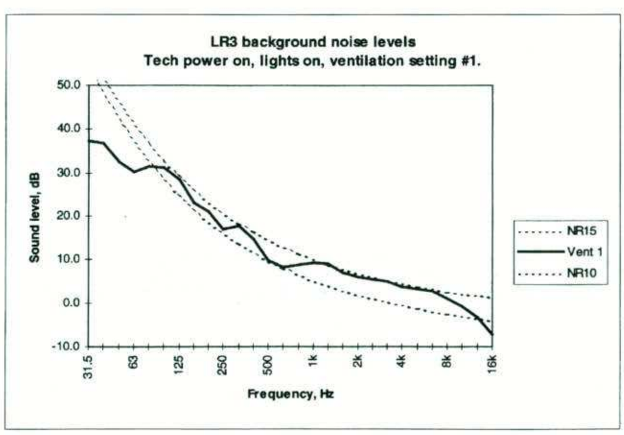


Fig. 11. Overall background noise level, ventilation and technical power on.

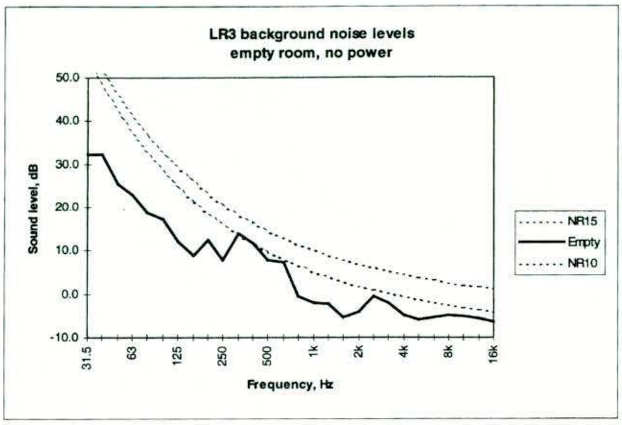


Fig. 12. Overall background noise level, all power off.

Figure 10 shows the final reverberation time characteristic, together with the tolerances. The final average value was 0.236 – 0.238 s, depending slightly on the measurement technique.

Background Noise

The Recommendations require that sound pressure level of the continuous background noise should not exceed NR15 and should preferably not exceed NR10. It should not be perceptibly impulsive, cyclical or tonal in nature. In the existing room there was no possibility for improvement of the sound insulation. The room had, in any case, been in use for many years as an experimental listening environment suffering only very occasional disturbances from nearby vehicle movements (these were onsite and therefore subject to control) and overflying aircraft.

The main contributions to the room background noise came from the heating and ventilation system and from the fluorescent light fittings installed as working lights. When the room is in use as a listening environment, an alternative incandescent lighting system, incorporating dimmers and producing much less noise, is used.

Figure 11 shows the background noise level with ventilation and technical power on. It just manages to meet NR15. Figure 12 shows the background noise level with all power off. It easily meets NR10. The ventilation system is fully variable, and can be set to produce somewhat lower noise levels, or switched off altogether if no heating is required. The noise levels at all frequencies above 630 Hz were, by a large margin, entirely due to the inherent electrical noise level of the loudspeaker amplifiers radiated by the loudspeakers. (The loudspeaker gains at the time were set to produce the standard output levels of 85 – 10 log(n) dB for reference input level [1,3]).

References

[1] ITU BS 1116, Methods for the Subject Assessment of Small Impairments in Audio Systems, Including Multichannel Sound Systems, International Telecommunication Union, Geneva, (1998)

[2] EBU Rec R22 – 1997, Listening Conditions for the Assessment of Sound Programme Material, European Broadcasting Union, Geneva, (1997)

[3] EBU Document, Tech 3276 (2nd edition – 1997), Listening Conditions for the Assessment of Sound Programme Material, European Broadcasting Union, Geneva, (1997)

[4] ITU BS 775-1, Multichannel Stereophonic Sound System With and Without Accompanying Picture, International Telecommunication Union, Geneva, (1996)

[5] R WALKER, 'Optimum Dimension Ratios for Studios, Control Rooms and Listening Rooms', BBC Research Department Report, RD1993/8, (1993)

[6] R WALKER, 'Optimum Dimension Ratios for Small Rooms', 100th AES Convention, Copenhagen, (1996)

[7] R WALKER, 'Controlled Image Design: The Measurement of Time-Frequency Responses', BBC Research Department Report RD1995/3, (1995)

[8] R WALKER, 'The Measurement of Time-Frequency Responses in Small Rooms', JAES draft paper under review (submitted September 1997)

[9] R WALKER, 'Controlled Image Design: The Management of Stereophonic Image Quality', BBC Research and Development Department Report RD1995/4, (1995)

[10] R WALKER, 'Controlled Image Design: Results from the First Installations', BBC Research and Development Department Report RD1995/5, (1995)

[11] R WALKER, 'A New Approach to the Design of Control Room Acoustics for Stereophony', 94th AES Convention, Berlin, (1993)

[12] R WALKER, 'Early Reflections in Studio Control Rooms: The Results from the First Installations', 96th AES Convention, Amsterdam, (1994)

[13] P D'ANTONIO & J H KONNERT, 'The Reflection Phase Grating Diffuser: Design Theory and Application', JAES, 32, 4, April 1984, 228–236, (1984)

[14] M D M BAIRD, 'A Wideband Absorber for Television Studios', BBC Research and Development Department Report RD1994/12, (1994)

* *Of course, real sound propagation does not follow the simple geometric pattern implied by this. It is subject to the rules of diffraction. This simple geometric approach is reasonably valid for objects of more than 0.5 m in extent and for those frequencies most important in the localisation of sound direction (1 kHz and above). In practice, it has been shown to be a realistic design procedure [9,11]. The use of a relatively large 'exclusion zone' allows for some degree of diffraction.*

** *It is the author's view that, because a floor reflection is so much part of everday experience, it may well be less disturbing than lateral reflections. There is, however, very little objective evidence for that.*

Acknowledgements

This article is based on a paper presented at Reproduced Sound 14, November 1998 and is published by permission of the British Broadcasting Corporation. The assistance of Malcolm Baird and Ken Taylor of BBC R&D Department with the detail construction, project planning and project management is also gratefully acknowledged.

Bob Walker FIOA is at the Research and Development Department, British Broadcasting Corporation, Kingswood Warren, Tadworth, Surrey, KT20 6NP.

INGEMANSSON ACOUSTICS: PAST, PRESENT AND FUTURE

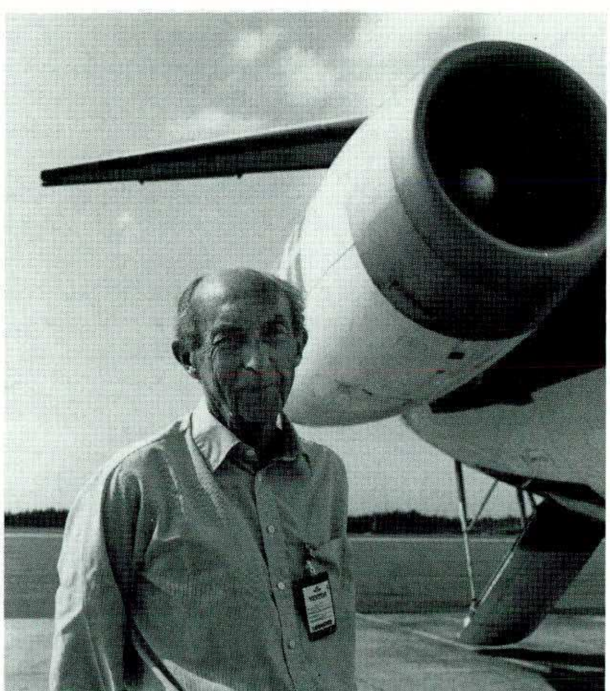
Hans Elvhammer

Introduction

The Swedish company 'Ingemansson' – with the registered name Ingemansson Technology AB – is one of the leading European consultant companies in acoustics, noise and vibration. In addition to the consulting services, Ingemansson has a sales and support department offering market-leading noise and vibration analysis tools. A course program for building acoustics, noise and vibration is also available to customers who want to improve their knowledge and competence.

Research and Development work has always been a crucial Ingemansson activity, in order to further develop field expertise and to preserve the company's position at the front line. A close relationship with universities, particularly Chalmers University of Technology in Gothenburg and the Royal Institute of Technology in Stockholm is an important element of a permanent process.

Ingemansson's head office is located in Gothenburg; in addition there are eight offices in Sweden and Denmark. It is an independent company owned by Mr Birger Lindeblad, a private entrepreneur who keenly promotes high professional standards among the company's more than 100 employees.



Stig Ingemansson

The Early Days

In the mid-1950s Stig Ingemansson started the first consultant engineering company in Sweden specialising in noise and vibration control. In doing so he established the acoustician as a natural partner in building projects. He was at that time a lecturer in acoustics at Chalmers University and in 1996, at the age of 75, was honoured at the celebration of the company's 40th anniversary. Today the company is one of the world's largest acoustic consulting firms. Thanks to his pioneering work many Swedes live in quieter homes, are less disturbed by traffic as well as aircraft noise and are working in less noisy industrial premises.

The result of a man's life-work is very often the fruit of pure coincidence and this was the case for Stig Ingemansson: He had originally intended to become an electronic engineer, but – since there were no such jobs available when he graduated – he accepted a temporary post as an assistant lecturer in building acoustics at Chalmers. Here he had the opportunity of working with Uno Ingard who sowed the seeds of Stig's interest in acoustics.

Uno had arrived from studies in the USA where he had the opportunity of working in an acoustic consulting company – probably the world's first in this – where he had acquired extensive knowledge and experience in applied acoustics. Together they set up courses in acoustics at Chalmers and also they built an acoustic laboratory.

The Growth of Ingemansson Acoustics

Uno Ingard returned to USA and Massachusetts Institute of Technology where he had received a professorship in physics with acoustics. Stig, who has never had much interest in academic life, began to consider the possibilities for starting a consulting firm as he had noted the need for acoustical advice by building enterprises, industries etc which frequently contacted the department at Chalmers. Believing that there must be room for at least one consultant engineer in Sweden, he established Ingemansson Acoustics in Gothenburg in 1956 and started a tremendous race.

Interesting and urgent projects flowed rapidly into the new company and the size of the company had to be constantly increased. By 1968 the number of employees had already passed 30 and since then there has been an ever growing demand for its services.

A 'flying start'

Jet aircraft noise problems were severe during the 1950s and protests from residents living near airports, test facilities etc forced authorities and companies in the aircraft

Checking a silencer for military aircraft run-ups (1960)

business to take measures against noise. Ingemansson Acoustics received large orders for the design and construction of ground run-up silencers for jet engine test cells, for assisting town planners in their land-use planning work around airports and for designing buildings with improved external sound insulation etc.

Silencer construction design was a very difficult task due to the aerodynamic and material durability requirements that were to be met at large flow velocities and temperatures of around 800–900 degrees C. The solutions were obtained in cooperation with experts in other fields – early examples of an ongoing process at Ingemansson which we have found to be very useful in many projects.

Sound insulations problems in apartment houses

In order to improve the living standard in Swedish homes, Parliament decided to engage in the mass production of apartment houses in the years around 1960. Very soon, however, it was apparent that many of these houses showed extremely poor sound insulation between apartments. The next important roll of Ingemansson Acoustics was to find out why problems occurred and how to solve them.

The main reasons for bad insulation were found to be the use of new materials and untested constructions, leading to flanking transmission – a rather unknown phenomenon at that time. Sound leakage due to poor quality workmanship was also a contributory issue.

Stig and his colleagues combined their theoretical knowledge and experience at practical solution of problems with the knowledge of building experts. Soon it became possible to eliminate the most serious problems and, subsequently, evolve new 'safe' constructions.

Ingemansson Quality Policy

Although Stig Ingemansson no longer plays an active part in the company's affairs, his thoughts and objectives on consulting activities are still the guidelines for younger engineers. I think it is true to say that Ingemansson have a reputation for providing practical and efficient solutions to a customer's problem and the experiences referred to here form the bedrock of that reputation.

An important element of the 'Ingemansson quality policy' has always been a continuous striving to raise the theoretical and practical skill of the staff members and to improve their professional qualifications.

Ingemansson Today

The word Acoustics makes most people think of good musical quality in the concert hall, church or any other room. At least, this is the case for those who had no reason to enter deeply in this special technical area. Acoustics today is, however, a considerably broader field and the complete acoustician has – literally – more than one string to his or her bow.

About 35,000 commissions can be found on Ingemansson's list, starting in the early 1950s with 'Task No 1: Machine noise control in a linoleum flooring factory'. From this tiny start the Ingemansson task volume has gradually expanded and today it contains building projects, infrastructure projects, industrial external and internal noise projects, noise and vibration measurements, product development and many other areas.

In line with the above mentioned quality policy, Ingemansson has today a clearly defined quality strategy which is governing the company activities. Ingemansson is accredited according to Euro Standard EN 45 001 for more than 100 different types of acoustic and vibration measurements and checks. The company is also quality certified according to ISO 9001.

Noise and vibration issues are of rapidly growing importance in the development of vehicles, machines and other products. This tendency is partly due to the attention given to these questions in the European Union's directives for occupational health, for machine safety and for specific products.

Ingemansson is taking an active part in the expected evolution towards more demanding and qualified services required by the customer, in part by continuously investing in new and more advanced design tools and also in system sales and customer support.

Ingemansson Automotive – presented below – is a further development of the automotive department within Ingemansson Technology AB.

Ingemansson Experience – Examples

Many of the commissions are still rather small; trouble shooting, construction component design, control measurements are typical examples. They are often completed within a few days. Other jobs extend over years or even decades! A few of the more important projects are presented here.

Occupational noise – work in branch group projects

Already in the early sixties, the branch organisations in Sweden's pulp and paper industry realised that systematic work methods had to be established if it was to be possible to lower the extremely high noise levels in workplaces and that meant going further into the noise control engineering field. A new method of tackling the problems was introduced. A 'Branch Project Group' consisting of representatives from the employer's confederation and labour union was established; Ingemansson was engaged as the acoustic consultant and practical work immediately started in some paper mills with severe workplace noise problems.

Soon, results indicated that the work was successful. Ingemansson organised the project and was the driving force, in cooperation with production management/personnel and maintenance personnel. The major requirement here has been to find noise control measures which are acoustically effective but which pay due regard to issues of machine operation, service and maintenance.

Manufacturers and suppliers of equipment for paper mills were also contacted at an early stage so that project results could be implemented in the machine design process. For some constructions, changes could be made in time for the next delivery: eg paper machine perforated suction rolls in old machines were extremely energetic noise sources, emitting a shrill tone. Ingemansson designed a new drilling pattern for the rolls which manufacturers immediately adopted. The result was that the disturbing tone completely disappeared and within a few years practically all paper machines in Sweden were equipped with silenced rolls.

Naturally, in many other cases it proved to be a long-term process to change the machine construction design. Furthermore, at the same time there was a thrust towards building faster machines which conspired against efforts at lowering noise levels. Faster paper machines require more powerful motors, gears, vacuum pumps, drier ventilation fans etc which normally lead to a rise in noise levels. In spite of this, thanks to the introduction of modified components, silencers, enclosures etc, it is today possible to build new paper machines and cellulose mills where workplaces are only half as noisy than in the oldest ones. That is to say noise levels are now about 10 dBA lower.

A detailed description of noise control activities, experiences and results from each individual project was compiled by Ingemansson and was distributed free of charge to all mills in the branch, safety officers and also to suppliers of machines for the paper industry. The documentation and case studies from reference mills gave rise to a tremendous interest in noise control among management and production people in the Swedish paper industry and also abroad. Most mills today have introduced noise reduction to some degree on their production equipment.

New objectives for noise control

The Branch Project Group activities were financed by the governmental Work Health Fund. When the group ceased after nearly two decades of continuous development, Ingemansson continued the work for individual companies. The objectives and conditions for noise control have radically changed during recent years due to the automation and efficiency improvement undertaken in the mills. When a new plant is planned today, very strict demands on production efficiency, mechanical strength, economy and environment have to be met. Also new reasons for 'silence' may be found.

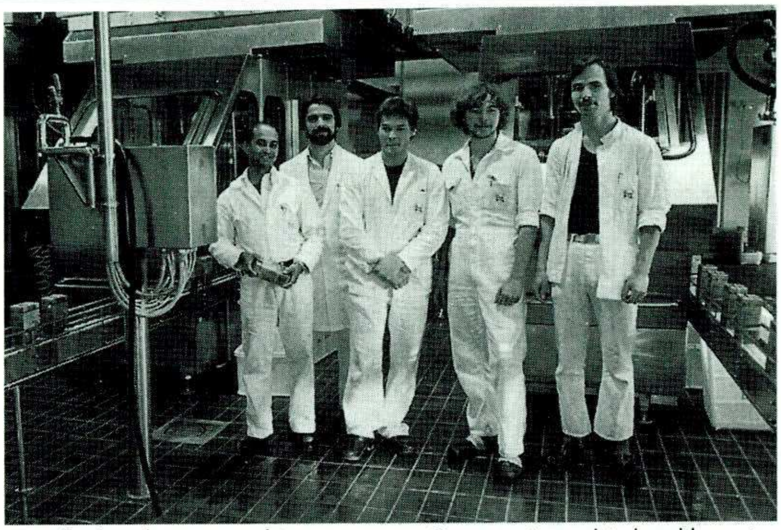
The paper industry today is manufacturing ecological products which are recycled to a large extent. However, in order to sustain the long term credibility of the environmental image of their products, it is necessary for companies to reflect this thinking in the production processes and work environment. In this respect low noise and vibration levels are important factors. Low noise levels in production rooms, which allow for undisturbed conversation when customers are visiting, is another aspect of the overall environmental image. When 'silent' plants are planned nowadays improvements usually follow situations where machine suppliers and personnel from the mill work together with Ingemansson through the whole project.

A systematic analysis of all noise sources and all reasonable possibilities for noise reduction is performed at the outset of the project, thus ensuring that no source of significance is omitted. This method was used in a recent paperboard machine project (machine length is 300 meters!) where measured sound levels at full production speed vary between 75 and 85 dBA close to the machine tending side which may well make it the quietest machine of this type in the world!

Successors in Many Industrial Branches

The positive results obtained in paper mills were inspiring people in other industry branches to start project groups with the same organisational constitution, for instance in mechanical engineering, concrete element, textile and food industries etc. Ingemansson has been working as acoustical consultant in six of the groups.

Modern paper machine; the size of machine and paper rolls is impressive



Satisfied packaging machine operators. Conversation unhindered by noise

The very active and successful group in the food industry was involved in the planning of a new dairy outside Stockholm. Ingemansson had already been working with the special noise sources and hygiene requirements in a dairy and was well placed to give practical advice on how to design a quieter plant.

The majority of the staff in a modern milk distribution dairy work in the packaging hall. The noise level in conventional halls is around 90 dBA near the milk packaging machines. A new machine design from TetraPak (Sweden) has been developed in cooperation with Ingemansson; this involves some mechanical construction changes and equipping the machine with an enclosure. This is also beneficial for in-line cleaning of the machine in which jet spray nozzles for liquid detergent are mounted inside the enclosure necessitating good sealing. Sixteen machines were installed close to each other and the sound level at 1 meter from the machine surfaces is around 75 dBA. It is understood that the dairy is judged to be among the quietest in world.

Stadium Shaken by Bruce Springsteen

One of Ingemansson's more spectacular jobs is the problem concerning structural safety of the Ullevi Stadium in Gothenburg. At a sellout Bruce Springsteen concert, the enthusiastic public caused large vibration amplitudes when they jumped in time to the music. The whole stadium – football ground, stands, roof, offices and service areas – shook as the forces generated by the rhythmic bouncing of thousands of fans impacted the clay on which the construction rests. The phenomenon was unforeseen when the stadium was built in the 1950s.

Effective reinforcement in the clay

Due to the risk of damage and on account of concerns over personal safety, rock and roll concerts were prohibited. Contractors were employed to reinforce the ground and more than 100 concrete piles, with diameters of 1.2 meters and larger were cast in place, reaching through the clay to the rock below. The longest piles measure about 55 meters. A garage with room for 700 cars is resting on the piles and is supporting the new football ground.

Ingemansson's main task was to determine the vibration transmission properties of the ground and building constructions before and after construction work. It was also of vital importance that measurements could show that Ullevi afterwards was safe for concerts.

It was necessary to generate vibrations in the football ground and in the stands which could be measured at distances up to more than 200 meters and for this large excitation forces and very sensitive vibration sensors were needed. The measurement problems were further exacerbated by the low frequencies involved which were 2 to 2.6 Hz, arising from the 120 to 156 beats per minute generated by the concert audience. The solution to this part of the project was to use different types of vibration exciters; the largest, which weighed 20 tons, was a standard cargo steel container filled with 16 tons of concrete. This was lifted by a hydraulic actuator at one end and rocked vertically at the same frequency as the jumping audience. A large number of excitation and measurement positions were used in order to enhance the precision of the test method.

Ullevi stadium is safe!

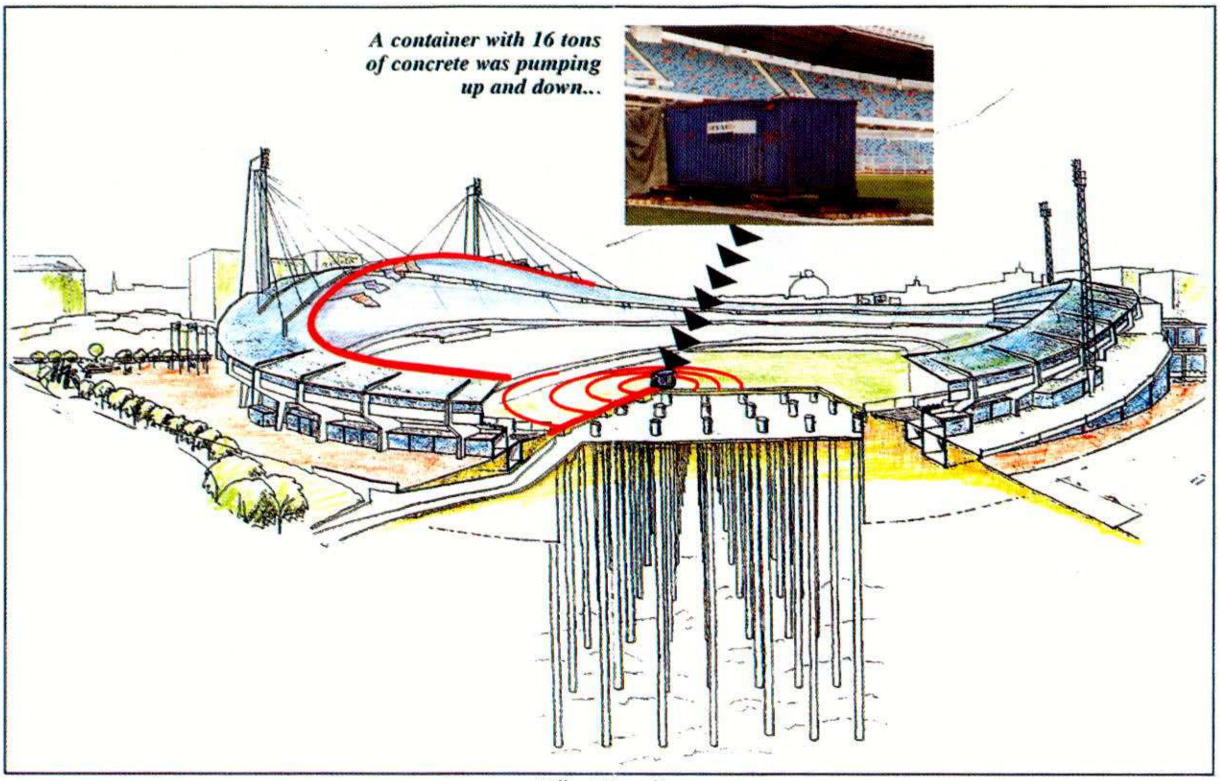
The primary vibration problem caused by the jumping audience on the football ground is now eliminated. In addition, vibration from the audience jumping on the stands has been reduced by damping arrangements applied on the roof beams and supporting cables and also by viscohydraulic dampers. Ingemansson was appointed as consultant through all the phases of vibration measurements and reduction.

Today, Ullevi stadium is safe for the full range of top-ranging events, from football and athletics championships to mega-star rock concerts.

Ingemansson Automotive Moves into a New Era

It is apparent to everyone working in acoustics that retrospective measures, taken to correct mistakes in the past, are seldom very efficient. This is true in buildings where, for example, it may be almost impossible to create a break in a propagation path in a construction form that has already been completed in a solid manner. But even more important today is the need to effectively reduce the number of noisy products that are flowing onto the market, including household machines, production equipment, vehicles etc. In most cases there is nothing that can be done if the basic design is acoustically wrong.

As described earlier in this article, Ingemansson has been working on product development in cooperation with manufacturers and designers on many projects. For several years a separate group of engineers has specialised in this field and in 1998 Ingemansson made an important step forward through the creation of an affiliated company Ingemansson Automotive, specializing in solving product noise, vibration and harshness problems for car manufacturers etc. Actually, experience in this



Ullevi Stadium

field started back in 1959 when Ingemansson had the first assignment for Saab. At that time Saab was a very small car producer and today is owned by GM. Since then there has been a wide range of assignments involving idle vibrations, root tracking, complete vehicle modal analysis, brake squeal and judder, noise and vibration in power-steering systems, operational deflection shapes, force input through mounts, exhaust noise calculation, pass-by noise contribution, tuned dampers, hybrid modelling and more.

This exemplifies the complexity of noise phenomena in car production and also indicates the demand for highly skilled personnel when problems must be solved.

NVH: a new challenge to a product development engineer

NVH stands for Noise, Vibration and Harshness which are factors which play an increasingly important role in modern automotive products including road vehicles, aircraft, trains and ships. In the constantly escalating competitiveness facing all manufacturers within today's automotive industry, unpleasant and thus unwanted noise and vibrations must be effectively suppressed or, better still, eliminated.

However, this is not enough. Successful enterprise, and ultimately the customers in the 21st century, also require an attractive sound quality as a natural part of a product's characteristics. For instance, the doors of a premium car must produce a sound when closing which inspires confidence and the exhaust sound of any vehicle should enhance the desired brand image. In other words, sound becomes an important part of the competitive edge. Hence, early implementation of NVH engineering in the product development process is now generally seen as a profitable investment. Ingemansson Automotive is now working in close operation with the automotive industry and their system suppliers, developing new products which are not only quieter and vibration-free but which also provide the desired attractive acoustic qualities.

In addition to traditional consulting assignments, services also include taking the complete function responsibility. The development is then often accomplished in cooperation with, for instance, mechanical engineering consultants specialising in the automotive field, since customers look for complete package solutions.

Vibro-Acoustic Engineering – a Complex Discipline

Vibro-acoustic engineering of automotive products is a very complex discipline. A high educational standard is an indispensable prerequisite and most Ingemansson Automotive engineers have at least a Master of Science degree from a university of technology, and several a PhD in engineering. Furthermore, Ingemansson is the Scandinavian representative for the LMS CADA-X testing technology and CAE software. This means that tools are available not only to help customers understand and solve complex NVH problems but also to turn the art of acoustic engineering and vibration optimisation into a strategic competitive advantage.

Prospects for Acoustic Consulting Services

More than 40 years have passed since Stig Ingemansson opined that 'there was room for one acoustic consultant in Sweden'. Today, there are about 200 employees in independent consulting firms and many more working with acoustic problems in the manufacturing industry.

The need for more advanced acoustical services is predicted to grow in the future, so prospects for the Ingemansson business are taken to be positive. But how will the market for acoustical services develop technically and strategically? Some clear tendencies can be seen in the Ingemansson crystal ball. Technically, the use of more qualified calculation/prediction methods is an obvious requirement as already indicated in the section about Ingemansson Automotive. Not only product development will be subject to the customer's demand for reliability and quality. In building acoustics, new combinations of construction elements and materials are to be checked prior to their use in buildings, if only to avoid the type of disastrous sound insulation that once occurred in Swedish apartment houses. Another field, where reliable prediction and measurement methods are necessary because of the enormous economical consequences, concerns noise and vibration from infrastructure installations: road, railway, underground railway etc. Measures for the reduction of disturbances through noise screening, improved window insulation, vibration isolation of tracks and so forth have to be optimised in order to keep taxpayers' costs at a reasonable level.

In conclusion, it seems inevitable that the requirements in respect of the educational level of acoustic consultants will be raised. At the same time this will have to be balanced by the acquisition of broad-based practical experience if problems are to be solved efficiently and at reasonable cost. These two factors are pointing towards the advantage of working in teams and project groups, combining employees with different abilities and knowledge. Ingemansson, I believe, is large enough and has qualifications and technical resources to meet this challenge.

Strategical development

Strategically, international competition in the service sector will dramatically increase. New EU rules for state and community purchase procedures, as well as possibilities offered through IT to inform 'the whole world', eg on an invitation to tender, are already obvious and will force consultants to adapt to the new situation.

At the same time IT is providing the technical consultant with ever-widening possibilities for using far-reaching know-how and valuable experience in a large geographical market. The future winners in the technical consultant branch will no doubt be among those who have managed to create a geographically widespread network comprising own units and cooperative partners. This will enable the members to take full advantage of their combined knowledge and experience and thus be able to offer the most effective team in every project proposal.

Ingemansson is a Research and Development company which, I believe, is very favourably positioned within areas such as technical progress, national planning, common weal – subject to an ever growing interest in Europe. We are concentrating on future.

Hans Elvhammer is a Consulting Engineer with Ingemansson Technology AB, Göteborg, Sweden ❖

ELSTREE FILM STUDIOS

Andy Munro MIOA

Introduction

In early 1997 Munro Associates was approached with an invitation to bid for the design of new sound stages at Elstree Film Studios, which had been purchased in 1996 by Hertsmere Borough Council in order to ensure its future as a major British movie making facility. Considering that the studios had hosted such major productions as *Star Wars*, *Indiana Jones* and, more recently, *Saving Private Ryan*, it was not wishful thinking to propose that additional shooting and recording capability should be designed to the highest standards and even improve upon existing performance criteria. The client's requirements were clearly aimed at a flexible, expandable complex which could offer exceptionally high sets which would be both fully and continuously ventilated, and quiet enough to record, even under a megawatt of lighting; an oxymoron by existing standards.

Design Brief for Stages 5 & 6

Stage size and orientation

It had been determined that the minimum required area for each stage was 1500 m^2 and that two stages were required, with the option of two more in the foreseeable future. The stages should be sound proofed to a degree which would attenuate normal external traffic and site noise and therefore enable sound recording in all normal day to day circumstances.

The most useful dimensions are almost but not quite square, giving the widest shooting angle in each plane. The stages should be in line and directly interconnecting for future operational flexibility although this should not compromise acoustic separation between the stages as they would normally be used independently of each other.

Height to grid

A clear working height of 15 m was required for set construction although some lighting would be rigged below this datum. The structural truss design and spacing would determine the lighting grid level and the two were to form an integrated structure in order to reduce steel requirements and to avoid unnecessary redundancy and duplication. Cat walks and safe access must also be provided to all areas at grid level together with stairs and fire exits. Due regard must be taken of CDM requirements.

Acoustic properties

The initial target reverberation time for each stage was set at one second. This was based on the volume and mean free path data available and the realistically achievable absorption coefficients for walls and soffits. This assumed no useful absorption at floor level although this would often be a factor in creating a localised acoustic environment.

The background noise level on the floor of each studio should be NC20; it was necessary that all the elements of the design were optimised for this noise level if it was to be achieved as any weakness in the building envelope or in the building services could have contributed to a failure to meet the noise criteria.

Ventilation

Research had shown that few stages are provided with satisfactory ventilation and that normal filming operations are often compromised by high temperatures on the set and the need to open loading doors and switch on noisy extract fans. It was decided to design a ventilation system which used the massive under floor slab area to provide a constant flow of air at low noise level and at outside air temperature. Velocity control would be used to regulate cooling load and comfort factors and independent background heating was to be provided. Heat extract was to be at roof level, through attenuators mounted in the side wall elevations. Design calculations were to be provided at the earliest possible stage in view of the structural implications of the floor and roof design.

Power

It had been verified that each stage may require up to a megawatt of electrical power in extreme circumstances and so a feeder of 1000 amps per phase per studio should be considered the minimum provision and 1500 amps may be advisable. Various voltages may be required on the set and an accessible distribution system should be provided for each studio. Internal power distribution is normally set for each production and cable trunking and safe grid level trays should be provided at regular points along each wall and truss line.

Services

Apart from specialised services for the studios each stage would require water and normal electrical services for cleaning, maintenance and working. Flood lighting should provide a good working light level of 500 Lux. The ancillary accommodation will require all the usual services with provision for at least 100 staff.

Lighting

As camera lighting is set for each production it is necessary to provide only power and a grid for fixing each lighting unit. Power supply and ancillary lighting had already been detailed by others, including a completely new sub station and high voltage transformer.

Ancillary accommodation

A number of dressing rooms and receptions areas were to be designed with due regard for acoustic isolation from the stages, especially lifts and stairs.

Access and escape

Each stage was required to offer direct access to heavy goods vehicles and large pre-fabricated scenery. It was decided to make each main door five metres high. As

Walls								
1/1 Octave band	31	63	125	250	500	1000	2000	4000
Maximum noise on site (HGV)	80	80	80	80	75	70	65	60
Studio noise level (NC20)	69	52	40	31	24	20	16	14
Isolation required of wall	11	28	40	49	51	50	49	46
Sound reduction from wall	34	40	46	52	58	64	70	76
Nominal safety margin	23	12	6	3	7	14	21	30
Roof								
1/1 Octave band	31	63	125	250	500	1000	2000	4000
Corrected noise level at roof	70	70	70	70	65	60	55	50
Studio noise level (NC20)	69	52	40	31	24	20	16	14
Isolation required of roof	1	18	30	39	41	40	39	36
Sound reduction of woodwool	21	27	37	42	45	47	56	62
Nominal safety margin	20	9	7	3	4	7	17	26

Table 1 Results of preliminary survey; all values are in dB

large numbers of people were to be anticipated for audience shows and exhibitions it was necessary to provide rapid egress for up to one thousand, including adequate disabled facilities.

Preliminary Works

Munro Associates was appointed in August 1997, to undertake a full acoustic design and Anthony Evans & Partners were contracted as Architects. A preliminary design scheme had already been submitted and this was based on a double skin shell with a woodwool slab inner envelope which would double as both cavity wall leaf and internal acoustic absorption. This decision was made after a detailed study of the cost effectiveness of various schemes, as well as consideration of the long term effects of scenery building, water cannons and minor explosions!

Site survey

A detailed appraisal of noise generated at the proposed site was carried out during normal working hours. Care was taken to ensure flights to a nearby airfield were passing within the corridor most likely to cause interference although heavy goods traffic and engine revving proved to be the loudest local source. The noise levels were compared to the requirements to meet NR20 and then checked against the sound reduction index of a single, 140 mm homogeneous concrete block wall. The result is shown in Table 1. The performance of a reinforced woodwool slab roof was also compared to the isolation requirement and it was found that two, 150 mm reinforced slabs, each screeded on one side only, and laid with the maximum cavity depth between them (see detail) could only achieve the results shown in Table 1. As the wall performance would be increased by the inner woodwool shell it was clear that the roof would be the limiting factor. The final performance of the building shell would be improved by the following factors which made it safe to adopt the proposed envelope;

- Extra steel cladding to roof and walls
- Distance from roof to stage floor
- High sound absorption in the worst case 250 and 500 Hz bands.

In addition to the outer wall isolation, the inner woodwool acoustic shell was designed to give an additional cavity wall advantage by virtue of a screed on the inside leaf. The exposed outer surface (facing the studio) was to be left unsealed to give as much absorption as possible. The properties of the chosen slab, which was 50 mm thick with 150 mm edge reinforcement were as in Table 2.

Floor design

The design of the floor was originally intended to create a series of large tunnels, through which air could be fed to a series of grills around the perimeter. Each section was to have a span of three metres at which the floor would have a natural frequency of 40 Hz and a static deflection 0.05 mm for a live point load of 3 kN. This was checked in order to avoid camera shake during live action such as a moving cart. Unfortunately it was discovered that the site was contaminated with asbestos

1/3 Octave band	100	125	160	200	250	315	400	500
Sound reduction index (dB)	27	28	29	28	27	27	29	32
Absorption coefficient		0.3			0.4			0.7
1/3 Octave band	630	800	1000	1250	1600	2000	2500	3150
Sound reduction index (dB)	35	35	34	32	31	32	36	38
Absorption			0.8			0.6		0.7

Table 2 Acoustic Properties of Woodcemair (from AIRO test L/1120/9/A)

MEETING NOTICE

ADVANCES IN TRANSPORTATION NOISE

(Organised by the London Branch)

Commonwealth Conference Centre, London

28 April 1999

Programme

09.30 *Registration*
10.00 Noise assessment for mixed noise sources *C Cobbing & M F Rickaby, London Borough of Hillingdon*
10.30 Noise on London Underground - perceptions of the visually-impaired *A McKenzie, Consultant*
11.00 Improving speech intelligibility in underground stations *B M Shield, South Bank University*
11.30 *Coffee*
12.00 Modelling noise from elevated railway structures *A Lawrence, W S Atkins Noise & Vibration*
12.30 Trackelast undersleeper pads - a cost effective answer for vibration reduction *H M Kenyon, Tiflex Ltd*
13.00 *Lunch*
14.00 Model investigation of the efficiency of railway noise barriers *D C Hothersall, K V Horoshenkov, P A Morgan & M J Swift, University of Bradford*
14.30 Effectiveness of novel-shaped bunds in reducing traffic noise *G Watts, TRL*
15.00 *Tea*
15.30 The optimisation of porous asphalt road surfaces to maximise sound absorption *Prof A R Woodside, J O Hetherington & G A L Anderson, University of Ulster*
16.00 Regulatory controls for protecting new dwellings from external noise *J Charles, J Miller & D O'Neill, Bickerdike Allen Partners*

Advances in Transportation Noise - 28 April 1999

Name:

Organisation:

Address:

Tel: Fax: Email:

☐ I enclose a cheque for the delegate fee

☐ Members £95 + VAT = £111.63 ☐ Non-Members £125 + VAT = £146.88

Cancellations received after 6 April 1999 will be payable in full.

Please return this form to the Institute office.

Institute of Acoustics, 77A St Peter's Street, St Albans, Herts AL1 3BN
Tel 01727 848195 Fax 01727 850553 email Acoustics@clus1.ulcc.ac.uk Registered Charity No 267026

CALLS FOR PAPERS

International Conference
(organised by the Building Acoustics Group)

AUDITORIA 2000
Manchester: September 1999

This international biennial conference is being held in central Manchester, over a weekend in early autumn 1999. Papers will be presented on the latest thinking in auditorium design and visits arranged to some of Manchester's new performance venues, including:

- Bridgewater Concert Hall : Based on a combination of vineyard terracing and shoebox design.
- Nynex Arena: The largest covered arena in Europe.
- Royal Exchange Theatre - The refurbishment of a circular theatre constructed in glass together with a new studio theatre.
- Lowry Centre: The UK's first purpose-built cultural centre combining performing & visual arts (including a 1650 seat theatre for opera, ballet & drama and a 400 seat flexible theatre).

For information about this conference or offers of contributions please contact the organisers:
Raf Orlowski, Arup Acoustics, St Giles Hall, Pound Hill, Cambridge CB3 0AE Tel: 01223 355033 Fax: 01223 361258 Email: Raf.Orlowski@arup.com
Mike Barron, Fleming & Barron, Combe Royal Cottage, Bathwick Hill, Bath BA2 6EQ Tel: 01225 826715 Fax: 01225 826691 Email: M.Barron@bath.ac.uk

---

One-Day Meeting
(organised by the Industrial Noise Group)

HAS NOISE AT WORK WORKED?
Birmingham, October 1999

The Noise at Work Regulations came into force on 1 January 1990. The Industrial Noise Group are to mark this tenth anniversary with a one day meeting. The aim of the meeting is to review the progress made in the last ten years and develop the Acoustic Industry's view of the way ahead.
Specific topics will include:

- Workplace Noise Exposure Assessment
- Present and Future Policy
- The View of the Insurance Industry
- Views from Manufacturing and Service Industries
- Managing the Implementation of the Regulations
- Non Auditory Effects
- Legal Aspects
- Health Surveillance and Rehabilitation
- Sources of Noise Information
- Education, Training and "Competence"

If you would like to contribute a paper on one of these topics, please send an abstract of no more than 200 words to the meeting organiser by 30 April 1999.
If you are interested in contributing to the event as a delegate please register your interest with the Institute of Acoustics office. Full details will be available in May 1999.

Meeting Organiser: Andrew Raymond, Philip Dunbavin Acoustics Ltd, Vincent House, 212 Manchester Road, Warrington, Cheshire WA1 3BD Tel: 01925 418188 Fax: 01925 417201 email: PDA_Ltd@compuserve.com

Institute of Acoustics, 77A St Peter's Street, St Albans, Herts AL1 3BN
Tel 01727 848195 Fax 01727 850553 email Acoustics@clus1.ulcc.ac.uk Registered Charity No 267026

25th ANNIVERSARY

THURSDAY 13 MAY 1999

KEYNOTE LECTURES SESSION COMMENCING 10.00 AM

Specialist Groups review the current status of the science

Measurement and Instrumentation
Milestones in acoustical instruments • Dudley Wallis, Cirrus Research plc
Speech and Hearing
Let's talk speech • Prof Roger Moore, DERA Malvern
Underwater Acoustics
Underwater acoustics during the life of the Institute • David E Weston, Consultant
Building Acoustics
Building acoustics – art or science • Duncan Templeton, BDP Acoustics
Electroacoustics
Electroacoustics – where two worlds meet • Ken Dibble, Ken Dibble Acoustics
Industrial Noise
Progress in industrial noise control • Dr Bob Peters, Applied Acoustic Design
Musical Acoustics
Sounds interesting • Dr Murray Campbell, University of Edinburgh
Physical Acoustics
An engineering view of physical acoustics in the UK • Prof Richard Challis, University of Nottingham
Environmental Noise
Information overload? • John Seller, Building Research Establishment

PARALLEL TECHNICAL SESSIONS COMMENCING 2.30 PM

Industrial Noise

The contribution of SEA to the control of industrial noise *Prof Frank Fahy, University of Southampton*
Active noise control - how it works in practice *Dr Geoff Leventhall, TechnoFirst*
Health and safety legislation - where now *Keith Broughton, Health and Safety Executive*
Practical experience in the modelling of factory sound fields *David Lewis, Unilever Research*
An engineering approach for the acoustic characterisation of aperture devices *Prof Bjorn Petersson, University of Loughborough*

Measurement and Instrumentation

A new intensity probe consisting of a pressure microphone and a particle velocity sensor *Prof Eric Druyvesteyn, University of Twente and Hans DeBree, MESA Research Institute of Twente, The Netherlands*
Development of measurement microphones for harsh environments *Gunnar Rasmussen, GRAS Sound and Vibration, Denmark*
Development of a-measurement system for very low sound pressure levels *Ole Herman Bjor and Gustav Bernhard Ese, Norsonic AS, Norway*
From sound level meter to sound meter, *Dr Paul Darlington and P J Duncan, University of Salford*
The VAS: a new non-contact sensor for measuring surface vibration *Prof Frank J Fahy, ISVR University of Southampton*

Musical Acoustics

Some observations of the output and distribution of organ sound *Dr Peter Comerford and Dr Lucy Comerford, University of Bradford*
Orchestral noise hazards, *Alison Wright-Reid, Consultant*
Modelling the friction of rosin *Dr Jim Woodhouse, University of Cambridge*
Acoustical parameters for stringed musical instruments *Dr Bernard Richardson, University of Wales*
Measurement of musical wind instruments using acoustic pulse reflectometry *Dr David Sharp and Jim Buick, Open University*

MEETING NOTICE

Measurement and Instrumentation Group

Getting A Grip On Hand-Arm Vibration

The National Motorcycle Museum, Birmingham

Tuesday 29 June 1999

Hand-arm vibration is now becoming recognised as a significant contributor to long-term health problems like Reynaud's Disease. Many attempts have been made to quantify vibration levels that give rise to health problems but only recently have guidelines been issued. In the UK the Health and Safety Executive has launched a major awareness campaign and published guidelines and action levels. In the EU the Physical Agents Directive, although stalled for some time, now looks set to introduce similar levels that could be covered by legislation. Instrumentation is available to measure the necessary information, but measurement techniques often leave much to be desired, and the difficulty in cross-checking measurements taken is well known.

The aim of this one-day meeting is to present a series of papers describing measurement-making in all its aspects as applied to sources of hand-arm vibration. Problems often experienced and practical methods to solve them will be addressed. Information on the legal and insurance consequences of vibration exposure in the workplace and on the medical effects will be included. There will be an exhibition of relevant instrumentation.

Presentations will include:

Real-world hand-arm vibration measurements versus manufacturer's data, *Peter Barker, Wimtec Environmental Ltd.*

Experience in assessing instruments against ISO 8041 'Human response to vibration - measuring instrumentation', *Liz Brueck, HSL.*

Vibration measurement of power hand tools used in the shipbuilding industry, *Simon Clampton, Marconi Marine (VSEL) Ltd.*

Vibration measurement and risk management for a public utility - a case study, *Iain Critchley, Peninsular Acoustics.*

On-site vibration assessment, accuracy and repeatability, *Kevin Hill, Glasgow City Council.*

A hand-holding guide to the measurement and CE marking of vibrating products, *Neal Hill, European Process Management Ltd.*

Measurement and evaluation of human exposure to hand-transmitted vibration - recent work on International and European standards, *Chris Nelson, HSE.*

Measurement uncertainty in the evaluation of hand-arm vibration exposure in the workplace - an introduction to ISO 5349-2, *Paul Pitts, HSL.*

Frequency analysis for hand-arm vibration measurements, *Tim South, Leeds Metropolitan University.*

Power on the land - an environmentally unfriendly handshake, *Richard Stayner, RMS Vibration Test Laboratory.*

Pains, Trains and Roto-Peens - Implementing a hand-arm vibration management programme, *Graham Twigg & Steve Fitchett, Tecforce Ltd.*

This meeting will be followed by the Measurement & Instrumentation Group AGM.

Getting a grip on hand-arm vibration - 29 June 1999

Name:

Organisation:

Address:

Tel: Fax: Email:

Please register me as a delegate. I enclose a cheque for the delegate fee:

☐ Members £95 + VAT = £111.63 ☐ Non-members £125 + VAT = £146.88

Cancellations received after 1 June 1999 will be payable in full. Please return this form to the Institute of Acoustics.

Institute of Acoustics, 77A St Peter's Street, St Albans, Herts AL1 3BN
Tel 01727 848195 Fax 01727 850553 email Acoustics@clus1.ulcc.ac.uk Registered Charity No 267026

CONFERENCE NOTICE

THE BARBICAN, LONDON

Speech & Hearing

The meaning of speech waveforms *Prof Mark Tatham, University of Essex*

Talking and listening machines - an introduction to speech technology *Dr Stephen Cox, University of East Anglia*

From phonemes to phones - speech technology applications *Denis Johnston, British Telecom Research Laboratories*

From acoustics to documents: How continuous speech dictation technology made the transition from the research lab to the High Street *John Bridle, Dragon Systems UK Ltd*

Panel discussion: The future of speech technology *Prof Roger Moore, DERA Speech Research Unit*

Underwater Acoustics

Modelling the performance of sonar arrays in complex, range dependent environments *Richard J Brind, DERA Winfrith*

Synthetic aperture sonar *Prof Hugh Griffiths, University College London*

Acoustic scattering from the sea bed *Gary Heald, DERA Bincleaves*

Finite element modelling of underwater acoustic transducers *James Dunn, University of Birmingham*

Sonar sensitivity of scintillating sound signals in the sea *Dr Peter Dobbins, BAeSEMA*

Building Acoustics

Sources of structure-borne sound *Prof Barry Gibbs, Liverpool University*

Building acoustics measurements *Carl Hopkins, BRE*

Building isolation *Tony Alder, Silvertown UK Ltd and Dr Keith Fuller, Rubber Consultants*

Architectural acoustics - research into practice *Dr Raf Orlowski, Arup Acoustics*

Acoustics of porous concrete *Dr Robin Wilson, Nottingham University*

Electroacoustics

Speech Intelligibility - some results from subjective experimentation *Peter Barnett, AMS Acoustics*

The balloon dance in electroacoustics *Dr James Angus, University of York*

Measuring the future - a review of the state of the art electroacoustic measurement techniques *Peter Mapp, Peter Mapp Associates*

Loudspeaker developments *Julian Wright, Celestion Ltd*

Audio and digital broadcasting into the 21st Century *Allan Mornington-West, Consultant*

Environmental Noise

EU Noise indicator: the DGXI working group position paper *Dr Ian Flindell, University of Southampton*

Noise from Pubs & Clubs - the good management guide *Alistair Somerville, Edinburgh City Council*

Birmingham noise mapping - a progress report *John Hinton, Birmingham City Council*

Guidelines from the IOA/IEA Noise Impact Assessment Working Party *Stephen Turner, Stanger Science & Environment*

Sleep disturbance and sleep prevention - what we know now, *Nicole Porter, NATS*

Registration commences at 9.00am and the President's Address opens the conference at 10.00 am. A Celebration Luncheon is at 1.00 pm and the Institute Annual General Meeting will be at 5.35 pm followed by the President's Reception.

Contact the Institute office for a registration form.

Institute of Acoustics, 77A St Peter's Street, St Albans, Herts AL1 3BN
Tel 01727 848195 Fax 01727 850553 email Acoustics@clus1.ulcc.ac.uk Registered Charity No 267026

CALLS FOR PAPERS

1999 Autumn Conference
(Organised by the Environmental Noise Group)

ENVIRONMENTAL NOISE ISSUES FOR THE NEW MILLENNIUM

Stratford Victoria Hotel, Stratford upon Avon
17 - 18 November 1999

The 1999 Autumn Conference will examine the future of noise over the next few years, with emphasis on sustainability. For example: How does noise fit in with an integrated transport policy and the rejuvenation of town centres, whilst meeting likely EU, national and local authority noise requirements, and individual expectations? If we improve the noise environment, are there any implications for other environmental disciplines?

You are invited to contribute a paper on your experience in any of the following themes:

Integration: How well are the noise effects integrated into the decision making process?
Regulation: Are current regulations and standards effective? How should they be developed?
Prediction: How meaningful and useful are the models we use?
Insulation: How are we meeting the current standards and rising to the emerging challenges?
Instrumentation: Are we making the most of the new generation of sound level meters?
Innovation: What is the latest research on environmental noise?
Education: What are the effects of noise on teaching. How well are we teaching the effects of noise?

Please send your 100 word abstract to the Institute office to arrive by 31 May 1999.

15th Residential Week-end Conference
(Organised by the Electroacoustics Group in collaboration with APRS, AES, ISCE & PLASA)

REPRODUCED SOUND 15

Stratford Victoria Hotel, Stratford upon Avon
18 - 21 November 1999
Technical Programme Committee Chairman : Julian Wright FIOA

Call for papers on topics relating to the following:
- Listening Environments
- Loudspeakers
- Microphones
- Amplifiers
- Audio Processing
- Systems Engineering
- Broadcast Sound
- Virtual Audio

Please send abstracts of not more than 200 words to the Institute office by 25 June 1999. Notification of acceptance will be mailed by 23 July. Papers which the authors wish to have refereed must be submitted by 27 August. Final papers for the proceedings must be received by 1 October 1999.

Institute of Acoustics, 77A St Peter's Street, St Albans, Herts AL1 3BN
Tel 01727 848195 Fax 01727 850553 email Acoustics@clus1.ulcc.ac.uk Registered Charity No 267026

CALL FOR PAPERS

International Conference

(Organised by the Underwater Acoustics Group)

STOCHASTIC VOLUME AND SURFACE SCATTERING: RECENT DEVELOPMENTS IN UNDERWATER ACOUSTICS

Robinson College, Cambridge 15-17 December 1999

It is now over 10 years since our last conference on the theme of fluctuation effects in underwater acoustics, and a review of new developments in the field is overdue. Theoretical understanding of random volume scattering has progressed to the point where many of the major problems have been solved. Comparisons of predictions and experimental observations, however, show that further questions must be addressed in order for volume scattering theory to provide a complete explanation.

The purpose of this conference will be to review the present state of this continually evolving subject and to report on new developments and future trends. Keynote speakers will include Terry Ewart and Eric Thorsos from the Applied Physics Lab, University of Washington. Particular themes of the conference will include, but are not restricted to

Theories of stochastic volume and surface scattering.

Theories of related oceanographic and geophysical phenomena.

Measurements of acoustic fluctuations and coherence, or related oceanographic and geophysical phenomena.

Degradation of arrays, beamformers, phase-conjugate arrays, sonar systems and communication systems, as well as techniques for overcoming such effects.

Relevant contributions from other fields - astronomy, radar, laser optics etc.

The conference proceedings will published in Vol 21 of the Proceedings of the Institute of Acoustics, and copies will be available at the start of the conference. This publication carries ISSN and ISBN numbers, and papers are classified as refereed and non-refereed. Additionally, authors of relevant papers of appropriate quality may be asked to contribute to a special issue of a well respected journal based on the theme of this conference.

Prospective authors are invited to submit an abstract of up to 300 words as soon as possible, indicating if they wish the paper to be refereed, and whether their proposed paper is better suited to oral or poster presentation. Successful authors will be notified within one month of receipt of their abstract. Complete manuscripts may be up to 8 pages long, including diagrams, and must be in the correct camera ready format (an MS Word template file will be available).

Papers for refereeing must be submitted by 12 July 1999, and all final manuscripts must be in the hands of the conference organisers by 27 September (those arriving after this deadline will not be printed).

All enquiries relating to this meeting should be addressed to either of the conference organisers:

Dr Barry J Uscinski
DAMTP
University of Cambridge
Silver Street
Cambridge CB3 9EW
Tel: +44 (0)1223 337876
Fax: +44 (0)1223 337918
E-Mail: bju1@damtp.cam.ac.uk

Dr Peter F Dobbins
BAeSEMA
PO Box 5
Filton
Bristol BS34 7QW
Tel: +44 (0)117 918 8056
Fax: +44 (0)117 918 8422
E-Mail: InstAcoust@aol.com
or:peter.dobbins@baesema.co.uk

Abstracts should be sent to Peter Dobbins at the above address, preferably by e-mail.
The latest conference information will found at the Underwater Acoustics Group web site: http://members.aol.com/InstAcoust/underwater/

MEMBERSHIP

The following were elected to the grades shown at the Council meeting on 4 March 1999

Fellow
Fillery, M E
Mapp, P A

Member
Blacklock, D J
Boltezar, M
Chiles, S G
David, A
Delaney, C M
Fleming, D W
Gascoigne, C M
Hall, R
Humpheson, D
Moulton, D L
Reed, A
Reynolds, A W
Smith, A P
Truman, C E
Tsinikas, N P
Wharton, A J
Wright, M C M

Associate Member
Argoti Morales, M A
Backhouse, J
Chan, K W
Court, M P
Dalton, E J
Diggins, J R
Do O'Monteiro, D M
Franklin, D P
Hodson, C S
Jobling, B
Murphy, M J
Nealon, K M
Pickering, G D
Raper, J
Rickard, G S
Rogers, S
Rowland, J C
Stayner, R M
Tait, J R
Tittmar, P S L
Tudball, S L
Vincent, N M
Wallace, R

Associate
Clark, R A
Durrant, M F
Green, D G
Hargrave, J M
Hayward, M R
John, A S
Meikle, J
Raggatt, R
Stringer, R P

EDUCATION

Certificate of Competence in Workplace Noise Assessment

The following were successful in the February 1999 examination

Amber
Leonard, J

Colchester
Armstrong, G J
Crockford, P
Cuncliffe, M R
Klein, A
Morgan, M K
Morgan, S
Mottram, C J
Orme, S
Symons, K
Wright, R M

EEF Sheffield
Burton, D R
Carson, G M
Haigh, D R
Hoyes, A E
Monaghan, S
Stocks, R A
Tye, J A
Watkins, A J

Staffs
Bishop, M G
Burton, E
Smith, G R

Ulster
Boylan, A
Burke, D
Calvert, S
Campbell, H L
Clarke, G A
Cooke, D
Fairgrieve, M
McCartney, S D
McCullough, M T
Sims, G N

INSTITUTE DIARY 1999

13 APR
Executive Committee
St Albans

15 APR
Meetings Committee, Publications Committee
St Albans

19-21 APR
Underwater Acoustics Group Conference: Sonar Transducers 99
Birmingham

22 APR
Education Review Committee
St Albans

28 APR
London Branch 1-day Mtg: Advances in Transportation Noise & Vibration
London

6 MAY
Distance Learning Sub Committee, Education Committee
St Albans

13 MAY
IOA 25th Anniversary Conference
Barbican, London

13 MAY
Annual General Meeting

14 MAY
IOA CofC in W'place Noise Exam
Accredited Centres

19 MAY
London Branch Evening Mtg: Have Dog – Will Travel
London

20 MAY
Membership Committee
St Albans

11 JUN
IOA CofC in Env Noise Measurement Exam
Accredited Centres

12 JUN
Eastern Branch Evening Cruise on a Thames Barge

15 JUN
Midlands Branch Evening Mtg: Dose/Effect – EU Noise Policy Working Group 2
Coventry

16 JUN
London Branch Evening Mtg: Noise Mapping
London

17 JUN
Executive Committee, Medals & Awards Committee, Council
St Albans

and so it was deemed necessary to build a solid floor over the site which involved the least possible soil removal. Vibration measurements showed that a fully floated floor was not required and indeed would have been prohibitively expensive. The floor was to be covered with two layers of marine plywood in order to facilitate the fixing of scenery without damaging the concrete screed. It was estimated that this would give approximately 150 additional Sabines of absorption across the frequency spectrum.

Ventilation

It was decided to design the ventilation system to work above ground level with two large perforated socks at the corners of the north wall. This would run almost the full height of the studio and be of two metre diameter, giving a total supply area of 100 m^2. Variable velocity fans were specified to offer some control over working temperature and noise levels. Exterior ducting of 18 metres to each sock, plus both primary and secondary silencers would give the required noise reduction. Extract was to be at roof level with a return feed to the air handling unit for winter heating. The system was designed to remove all the hot air under full lighting loads, and to give more conventional re-circulatory ventilation when rigging and working without lights.

It had been noted that conventional sound stage design relied on massive, noisy extractor fans and open doors which severely compromised the acoustic performance of the building. There was also evidence of extremely high temperatures building up during unventilated periods with fires occurring on occasions!

Final Acoustic Design

Although the manufacture's data was well tried and tested, several factors were different in both application and design of the system. In particular the roof slabs were to be fixed with the troughs facing each other and only one inner surface and the top (outer) surface sealed with screed. The stiffness and hence low frequency isolation performance was dependent on both the steel truss design and the fixing of the slabs and this could not be modelled without considerable analysis which was judged to be unnecessary, given the reasonable safety margin for isolation.

The walls slabs were more conventionally coated, with the screed on the cavity side but they were independently mounted in a steel frame which was not fixed to the outer block wall (see detail drawings in Figures 1 and 2). This was done to maximise de-coupling and hence isolation but the effect on low frequency absorption was difficult to model. It was decided that the performance would be better than in a rigid, fixed wall. Although air absorption would be significant is was ignored, given that only high frequencies would be affected.

Initial test results.

Table 3 shows a comparison of initial test data and the original design calculations. A corrected value for the acoustic absorption is indicated which allows an appraisal of the real performance of the woodwool shell. In most respects there is good correlation between pre-

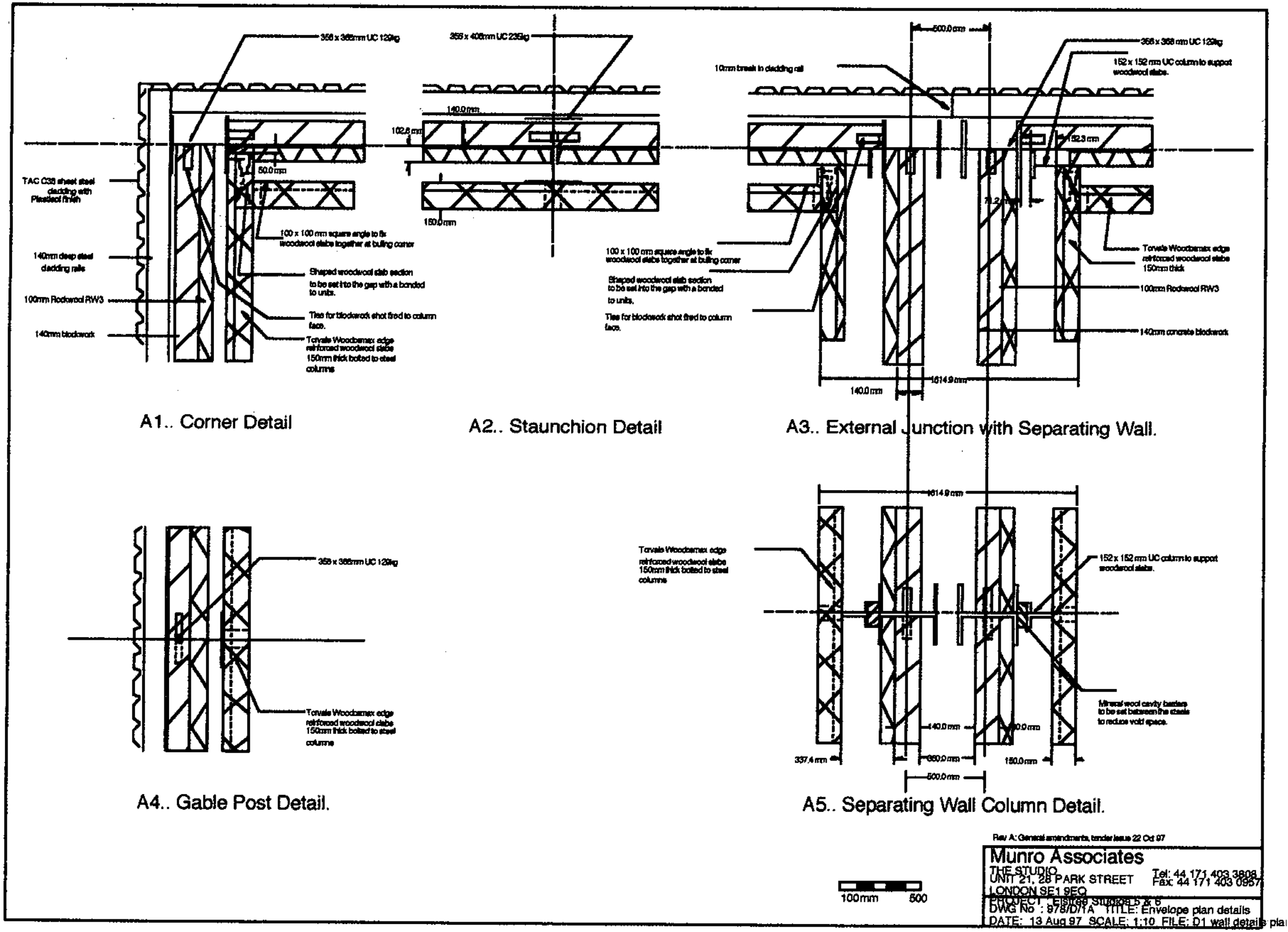
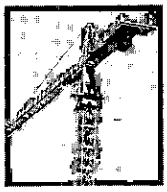


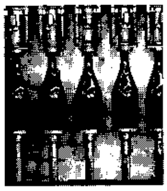
Fig. 1. Examples of construction details

PDA

Batteries not **included**

ACOUSTIC
CONSULTANTS





***PDA** offers a flexible approach to work in a non-hierarchical environment. We think that you would find working for us professionally satisfying and fun.*

Our workload is very diverse and can be unusual. We believe that the work is interesting and challenging giving responsibility for both the technical and financial viability of projects.

We are well equipped with instrumentation for both sound and vibration measurement, and all staff are provided with a modern computer and current software.

PDA believes strongly in training and is committed to CPD. Marketing and sales opportunities are available for those who are interested in this area.

We offer a competitive salary, fully resourced company car or car allowance, profit related bonus, private medical care, permanent health insurance and contributions to your personal pension.

PDA is located in Warrington and is close to both Manchester and Liverpool City centres. The Peak District, the Lake District and Wales are all within easy reach.

If we sound like a company you would like to work with, please call or write to Jo Webb and tell her what you would like to do and what you have done.

Architectural Acoustics

Environmental Noise

Occupational Noise

Hand-Arm Vibration

Vibration Measurements

Legal Services

Building Services

ANC
THE ASSOCIATION OF NOISE CONSULTANTS

Philip Dunbavin Acoustics Ltd.
Vincent House · 212 Manchester Road · Warrington · Cheshire WA1 3BD
Tel: 01925 418188 Fax: 01925 417201

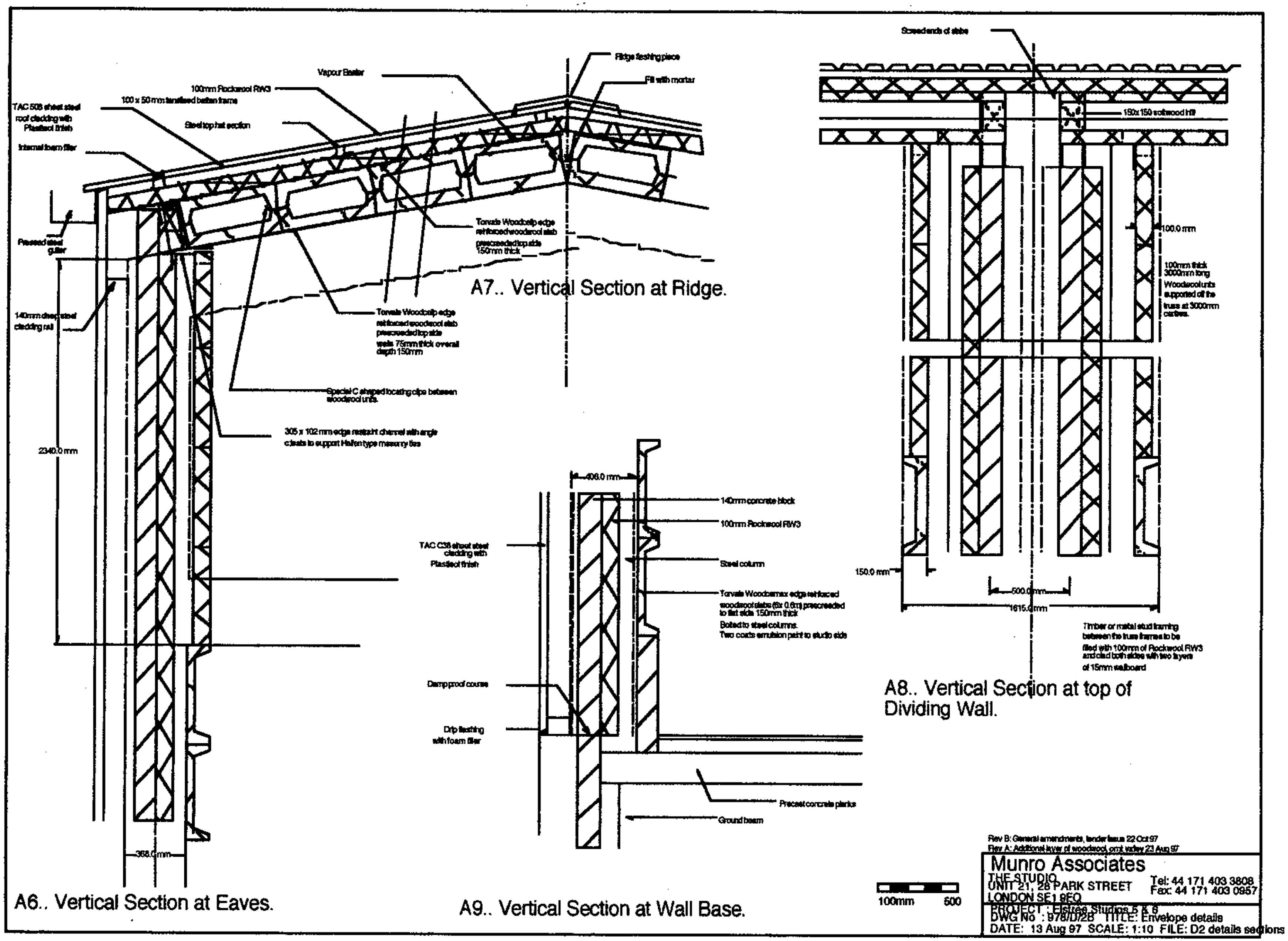
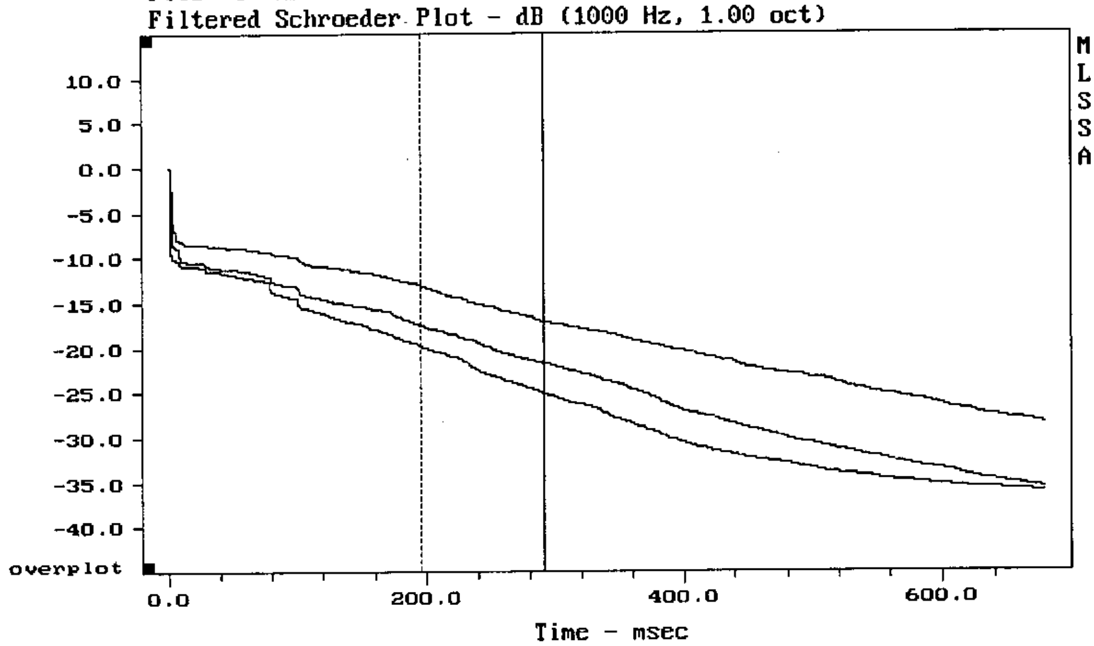


Fig. 2. Construction details continued.

File: C:\APPS\MLS\MLS\ELSRT1.TIM 2-25-99 11:37 AM
Filtered Schroeder Plot - dB (1000 Hz, 1.00 oct)



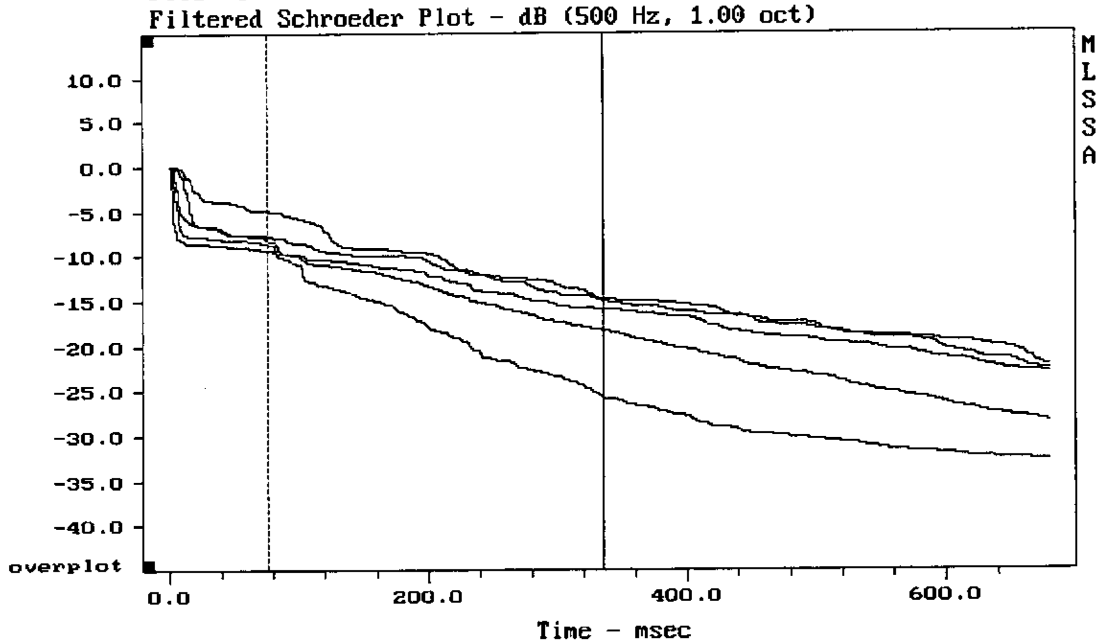
T60 reverberation time = 1.487 secs (r = -0.997)

TIME DOMAIN MENU: Go View FFT Waterfall Acquisition Setup Transfer Macro
Overlay Calculate Printer DOS Units Library Info Quit

F1 for Help MLSSA: Time Domain

Fig. 3. Schröder plot showing decay slopes from 63 Hz to 500 Hz

File: C:\APPS\MLS\MLS\ELSRT1.TIM 2-25-99 11:37 AM
Filtered Schroeder Plot - dB (500 Hz, 1.00 oct)



T60 reverberation time = 0.977 secs (r = -0.995)

TIME DOMAIN MENU: Go View FFT Waterfall Acquisition Setup Transfer Macro
Overlay Calculate Printer DOS Units Library Info Quit

F1 for Help MLSSA: Time Domain

Fig. 4. Schröder plot showing decay slopes from 1 kHz to 4 kHz

freq	$S_f{*}\alpha_f$ floor	$S_w{*}\alpha_w$ walls	$S_r{*}\alpha_r$ roof	$S\alpha$ total	α_{ave}	T_{60calc}	T_{60test}	α_{ave1}
63	148.2	524	296	968	0.17	4.19	2.18	0.33
125	148.2	785	445	1378	0.25	2.94	1.91	0.38
250	148.2	1047	593	1788	0.32	2.27	1.98	0.37
500	148.2	1833	1037	3018	0.54	1.34	1.20	0.60
1000	148.2	2094	1186	3428	0.61	1.18	1.56	0.47
2000	148.2	1571	889	2608	0.47	1.56	1.46	0.50
4000	148.2	1833	1037	3018	0.54	1.34	1.23	0.59

Table 3. Showing the Sabine calculation for the reverberation times, T_{60calc}, the measured values, T_{60test}, and α_{ave1}, the apparent average absorption coefficient

diction and performance with the following exceptions;

- The low frequency reverberation time is considerably less than the simple prediction and this was inevitably a consequence of using a frame construction with large panels capable of random vibration and resonance, as well as a certain percentage of leakage into the cavity wall. There is a general lack of data available on the low frequency (less than 100 Hz) performance of large panel walls and the fact that the averaged absorption coefficient was almost doubled to 0.33 is a very useful property where noise control and modal damping is a design goal. Fortunately the stages required as little reverberation as possible and so the result was deemed a success.
- The reverberation time at 1 kHz was higher than predicted and this was estimated to be the result of the large amount of exposed steel channel along the edge of each panel plus the large amount of steel in the roof space, for walkways and lighting.

As the reverberation was less than predicted at 500 Hz it was agreed that the design data was changed by the type of construction and mounting of the panels, which did not conform exactly to the manufacturer's original test certificates.

Overall the preliminary results were acceptable and the high frequency absorption was much as predicted with evidence of additional air absorption above 4 kHz.

Final Test and Commissioning

File ELSRT1 in Figure 3 shows the reverberant decay plots (Schröder) for $^1/_1$ octave bands from 63 Hz to 500 Hz. The lowest curve, at 500 Hz, was measured at just under 1s while the other curves are all of the same gradient and show no evidence of strong echoes or secondary decay slopes. The second Schröder plot (Figure 4) shows the decay slopes from 1 kHz to 4 kHz. Again the absence of strong discontinuities in the gradient indicates good diffusion and distribution of reflected energy. This was borne out by more traditional testing with hand claps and dropping of heavy objects.

Sound isolation

At the time of writing some work was yet to be finalised to door seals and ventilation systems were not fully installed but early indications were that the building did meet its background noise requirement of NR20 in the presence of normal site traffic. Plane and truck noise was inaudible and the noise spectrum of the ventilation followed the NR20 curve when measured at a distance of 10 m.

Summary

The new stages are a major addition to the facilities at Elstree and they are the highest in Europe with the lowest noise floor in normal operation of any in the UK, of this size. The use of woodwool as a combined barrier and acoustic tuning material is not new but to use it exclusively was a challenge, dictated by budget and structural constraints. The final design proved to be both practical and cost effective. The performance has been proved to meet the client's demands and I look forward to seeing the Elstree Studios credit on many future, British made movies.

Acknowledgements

Particular acknowledgement and appreciation is due to the following, for design team contribution; Anthony Evans, Architect (overall project); Clive Glover, Architect for Munro Associates; Bob Wiles NTP Quantity Surveyors; Alan Philpott, FCR M & E Consultants; Gary Redman DFP Structural Engineering.

Andy Munro MIOA is at Munro Associates, Unit 21 Riverside Workshops, 28 Park Street, SE1 9EQ ❖

QUIET NIGHTCLUBS

Philip R Dunbavin MIOA

Almost by definition a quiet nightclub is a contradiction in terms. When I refer to a quiet nightclub, I mean one in which the requirements of the Noise at Work Regulations are satisfied. The industry has recognised for some time the difficulty of compliance with the Noise at Work Regulations. The British Entertainment and Discotheque Association Ltd (BEDA) produced guidelines for compliance which, I think it is fair to say, have not been universally welcomed in all clubs. The approach to compliance is expressed in the statement:

'given that the wearing of ear muffs and similar methods of hearing protection is not a feasible proposition in the majority of clubs, and certainly inappropriate to DJ's and artistes, the compliance policy is geared towards reducing the actual noise levels in the workplace and reducing the amount of time spent in a noisy area.'

Puzzlingly perhaps, local Environmental Health Officers rather than the Health and Safety Executive are responsible for policing the industry. Whilst, in my view, EHOs are not as cohesively organised as the HSE on a national scale, there has been a visible rise in interest in enforcement of the Noise at Work Regulations in nightclubs across the country.

Reducing noise levels by causing the volume to be turned down is an approach that is understandably unpopular and frequently resisted. Controlling exposure by staff rotation, whilst fine in theory, assumes that a quiet area can be found in the venue and that staff have sufficient skill levels to be moved between activities.

This article illustrates an approach to the problem employing acoustical rather than behavioural means. It describes a case history of a venue in the south east of the country which, in common with many modern venues, actually has two clubs in one building. Club 1 caters for the younger age group of eighteen to twenty four, whilst Club 2 is for the over twenty fours. The first club is located on the ground floor with a mezzanine floor overlooking the dance floor. The second is at first floor level. Club 1 has four bars and Club 2 only one.

In 1997 we carried out a full occupational noise survey in the venue, a process that brought unique problems. In our experience it is always advisable to carry spare wind shields for your microphone as they provide the clientele with considerable amusement if purloined. Such is the flavour of acoustic reality these days. Having survived, Table 1 shows the results of the survey.

Club 1	$L_{EP,d}$
Cashier	69.6
Cloak Room	69.6
Diner	85.8
Bar 1	93.7
DJ	98.6
Bar 2	90.3
Bar 3	95.5
Glass Collector, ground floor	96.3
Bar4	93.2
Glass Collector, bar 4	95.2
Club 2	$L_{EP,d}$
Glass Collector, bar 5	98.1
Bar 5	95.9
DJ	99.8
Doormen between the two clubs	86.5
Cashier	76.6
Cloakroom	95.3

Table 1

The exposures reported are based on measurements over the entire evening because in our experience the sound levels in clubs generally do not reach their maximum until after 23.30 hrs. Most of the exposures measured were significantly greater then the Second Action Level of 90 dBA $L_{EP,d}$ These numbers tell an alarming story which needed some serious consideration.

Fig. 1.

This venue has some added problems all of which are exacerbated by lack of space. Figure 1 shows that Bar 5 is only two paces from the dance floor and this proximity of bars to the dance floors was common throughout. Even worse, the cloakroom for Club 2 was equally close to the dance floor. The concept of a 'quiet area' was impossible to realise in such a small venue.

The two clubs, whilst physically quite small, had virtually no acoustic absorption apart from that provided by people and returned mid-frequency reverberation times of about one second. The

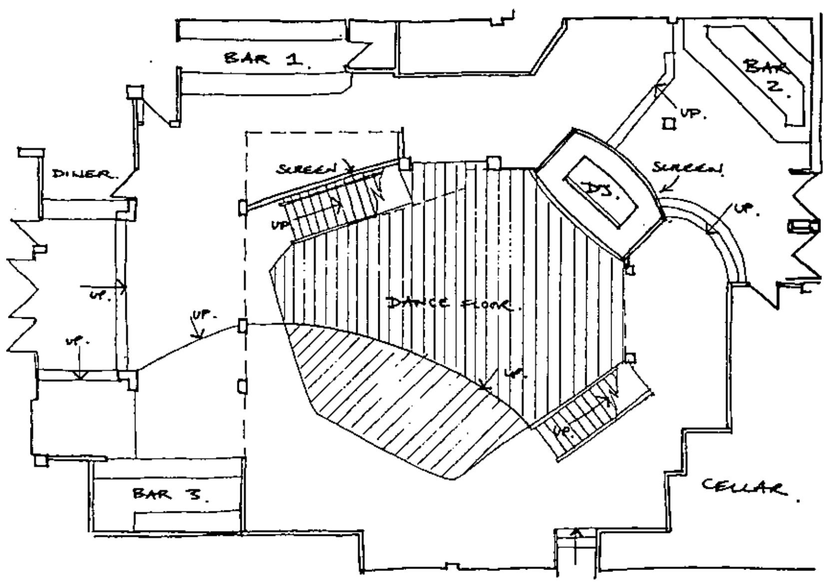


Fig. 2. Club 1. Floor plan.

effect of this was to produce a sound field in which the reverberant field dominated the direct field over a very large fraction of the room area There was consequently little attenuation with distance. A by-product of this generally low direct to reverberant ratio was that the music system did not sound particularly good, a feature which many would doubtless agree is found in many nightclubs.

An ideal opportunity presented itself for introducing measures to modify the direct to reverberant ratio in the clubs during a complete refit. Periodically all clubs refurbish their internal finishes and decor which take considerable wear and tear in normal or perhaps abnormal usage; in this case we were almost given a free hand to introduce as much noise control as the refurbishment budget would permit.

Figure 2 shows the ground floor layout of Club 1; it must be remembered that there is a mezzanine floor above Bars 1 and 2 upon which Bar 4 is located directly above Bar 2. Figure 3 shows the revised layout for Club 2 where the following modifications were introduced:

- The cloakroom was moved, together with the paydesk, to directly next to the entrance and it is separated from the dance floor by a wall.
- The bar was moved from the position now occupied by the raised seating area to the opposite wall increasing the distance between the bar and the dance floor. All the loud speakers were orientated to point away from the new bar.
- The entire ceiling area was faced with acoustically absorbent material. Figure 4 shows the black coloured acoustic ceiling tiles over the raised seating area. As much of the wall areas as practical were also covered with acoustic absorbent faced with a purple cloth. This can be seen to the right of Figure 4.
- Figure 5 shows a view of the bar from the raised seating area. The bass bins in the column are now mounted on vibration isolation mounts and are direct radiators. The vibration isolation mounts reduce the amount of low frequency energy entering the structure which could otherwise produce unpleasant buzzes and rattles in fixtures and fittings.
- Figure 6 shows that the absorbent ceiling extends right underneath the bar and the bar opening is kept to the minimum commensurate with operational requirements.

In Club 1 the same treatments were applied with a few additional measures:

- The wall areas which were out of reach of the clientele were finished with a sprayed acoustic absorber.
- Some wall areas and ceilings under the bars were finished with mineral wool behind galvanised perforated sheet steel. This is an unusual finish but one that met with the approval of the interior designer.

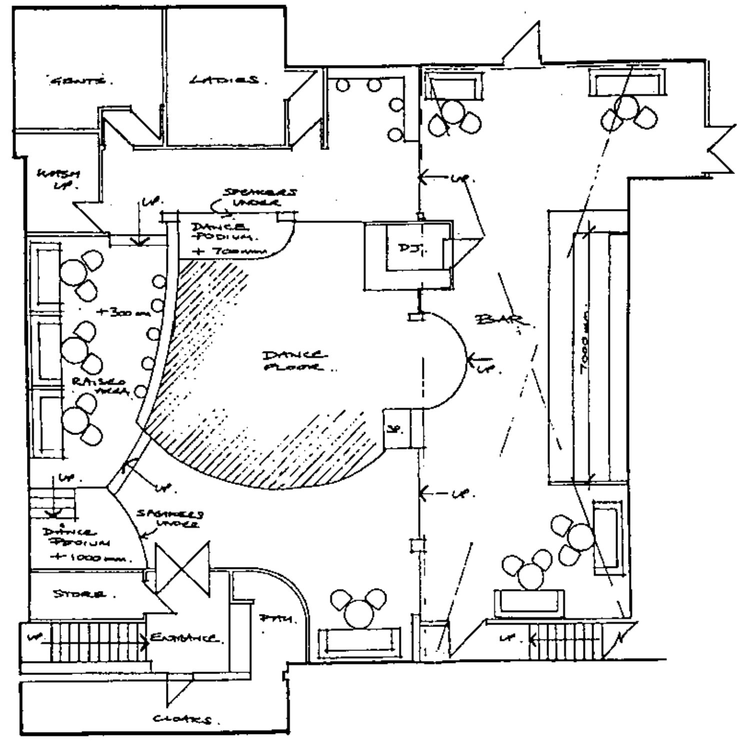


Fig. 3. Club 2. Floor plan.

Fig. 4.

Fig. 5.

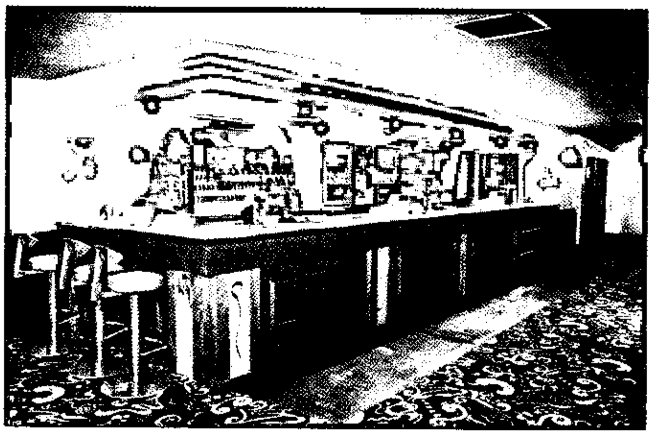


Fig. 6.

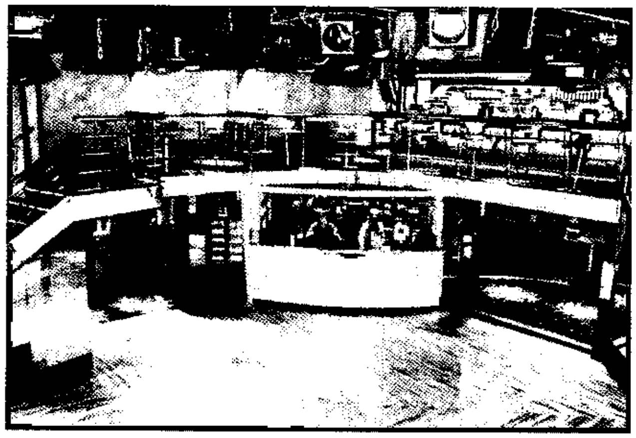


Fig. 7.

- A large glass screen was introduced in front of Bar 1 at the side of the stairs to screen the bar from the dance floor.
- The DJ's console was built as an acoustic screen to provide some screening to Bar 2.

Figure 7 shows the DJ console which totally obscures the bar behind. Bar 4 can also be seen in this photograph on the mezzanine. The sound system was based on downward-facing loudspeakers with very narrow directivity patterns and these can be seen at the top of Figure 7. The basic idea was to direct the sound only onto the dance floor with as little overspill as possible.

Figure 8 shows the schematic of the control system. As with Club 1 the bass bins were mounted on vibration isolation mounts in dummy cabinets at dance floor level. We carefully set up the sound systems using the type of music preferred and played in the clubs. The system was set to produce a typical music level of 103 dB L_{Aeq} on the dance floor and carefully equalised. The result was a very loud but very crisp and clear sound. The DJs expressed the view that, in their language, 'it sounded much louder than previously'.

We resurveyed the employee noise exposure after the club had reopened under conditions of loudness that were acceptable to the clientele; the results are shown in Table 2.

Club 1	$L_{EP,d}$
Cashier	72.1
Cloak Room	72.1
Diner	86.3
Bar 1	86.6
DJ	98.2
Bar 2	89.0
Bar 3	88.4
Glass Collector, ground floor	96.8
Bar4	89.1
Glass Collector, bar 4	94.5
Club 2	$L_{EP,d}$
Glass Collector, bar 5	97.0
Bar 5	86.9
DJ	97.3
Doormen between the two clubs	86.5
Cashier	77.5
Cloakroom	73.7

Table 2

The only employees who now have exposures above the Second Action Level are the glass collectors and the DJs. The glass collectors are perfectly able to wear hearing

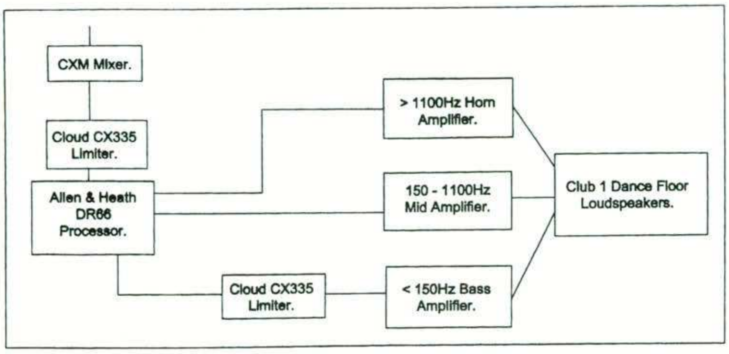


Fig. 8. Club 1. Sound system schematic.

protection in the form of ear plugs since their job does not involve communication.

The DJs may be their own worst enemies in that their high exposures frequently come from the monitor loudspeakers which they insist on using as a private discotheque at excessive levels. Given the proximity of the DJs to the dance floor these monitor loudspeakers must be totally unnecessary. Unfortunately, I get the impression that DJs can be temperamental 'artistes' and reluctant to perform without their beloved monitors.

From the clientele point of view the sound system is very good and they do not have to scream at the bar staff in order to get a drink. The level on the dance floor was 103 dB L_{Aeq} which reduced to 89 dB L_{Aeq} behind Bar 3. This is shown in octave bands in Figure 9.

In physically larger venues the same techniques are even more effective and easier to implement. These basic measures can be designed into new night-clubs and retrofitted to virtually any club undergoing refurbishment.

Philip Dunbavin MIOA is Principal Consultant with Philip Dunbavin Acoustics. PDA is a member of the Association of Noise Consultants ❖

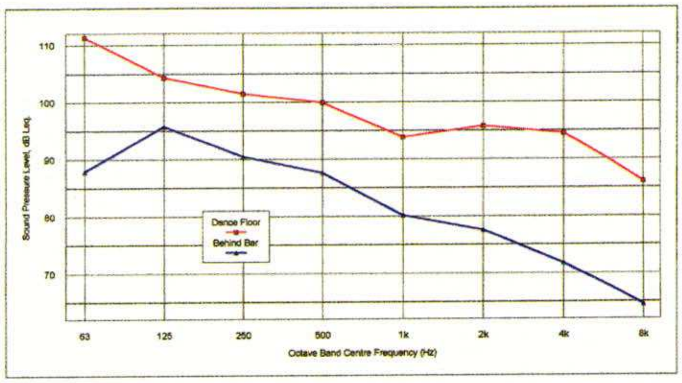


Fig. 9. Spectra on the dance floor and behind the bar.

Medals and Awards

The Institute of Acoustics annually honours people whose contributions to acoustics have been particularly noteworthy. Nominations and suggestions are invited for the medals listed and for Honorary Fellowships. Members should write in confidence to the President via the Institute office. Details of the Awards are given below.

Rayleigh Medal

John William Strutt, Third Baron Rayleigh (1842-1919) is remembered as a most versatile physicist, both as an experimentalist and as a theoretician. A graduate, fellow and finally Chancellor of Cambridge University, he was early elected to Fellowship of the Royal Society of which he was President from 1905 to 1908. He received the Nobel Prize for physics in 1904.

Rayleigh's work covered practically every branch of physics and he was the co-discoverer of the rare gas argon. In acoustics, he published over 100 articles and his book *The Theory of Sound* remains a land mark in the development of the subject.

The Rayleigh Medal, of gold-plated silver and bearing the portrait of Lord Rayleigh, is awarded without regard to age to persons of undoubted renown for outstanding contributions to acoustics.

The award is normally made to a United Kingdom acoustician in even numbered years.

The Institute is pleased to have honoured these acousticians with the Rayleigh Medal:

P H Parkin UK 1975
L M Brekhovskikh USSR 1977
E G S Paige UK 1978
E A G Shaw Canada 1979
P E Doak UK 1980
K U Ingard USA/Sweden 1981
G B Warburton UK 1982
E J Skudrzyk USA/Austria 1983
J E Ffowcs-Williams UK 1984
P J Westervelt USA 1985
E J Richards UK 1986
M R Schroeder Germany 1987
D G Crighton UK 1988
H E von Gierke USA 1989
F J Fahy UK 1990
M Heckl Germany 1991
Sir James Lighthill UK 1992
M Bruneau France 1993
E F Evans UK 1994
R H Lyon USA 1995
K Attenborough UK 1996
L Bjørnø Denmark 1997
W A Ainsworth UK 1998

Tyndall Medal

John Tyndall (1820-1893) was active in acoustics before Rayleigh, and Rayleigh actually succeeded Tyndall as Professor of Natural Philosophy at the Royal Institute.

Born in County Carlow, Ireland, he studied chemistry, physics and mathematics at Marburg University (under Bunsen) and was elected a Fellow of the Royal Society in 1852. Later he investigated the acoustic properties of the atmosphere and his volume of lectures *On Sound* has been reprinted many times.

Tyndall was a distinguished experimental physicist but is remembered primarily as one of the world's most brilliant scientific lecturers.

The Medal named after him, a silvergilt medal, is awarded to a citizen of the UK, preferably under the age of 40, for achievement and services in the field of acoustics.

The following is the list of recipients:

M E Delany 1975
H G Leventhall 1978
R K Mackenzie 1980
F J Fahy 1982
R G White 1984
J G Charles 1986
M F E Barron 1988
N G Pace 1990
S J Elliott and P A Nelson 1992
R K Moore 1994
S N Chandler-Wilde 1996
J E T Griffiths 1998

A B Wood Medal

Albert Beaumont Wood was born in Yorkshire in 1890 and graduated from Manchester University in 1912.

In 1915 he became one of the first two research scientists to work for the Admiralty on antisubmarine problems and he later designed the first directional hydrophone for use in submarine detection.

He was well known for his many contributions to the science of underwater acoustics and for the help he gave to his younger colleagues.

The A B Wood Medal and Prize, instituted after his death and as a result of the generosity of his friends on both sides of the Atlantic, is aimed at younger researchers whose work is associated with the sea.

The silver medal, parchment scroll and cash prize were awarded from 1970, prior to the formation of the Institute of Acoustics, by the Institute of Physics. The award is made alternately to acousticians domiciled in the UK and in the USA/Canada.

Recipients of the A B Wood Medal

P A Crowther UK 1976
P R Stepanishen USA 1977
A D Hawkins UK 1978
P H Rogers USA 1979
I Roebuck UK 1980
R C Spindel USA 1981
M J Buckingham UK 1982
P N Mikhalevsky USA 1983
M J Earwicker UK 1984
T K Stanton USA 1985
P D Thorne UK 1986
D Chapman Canada 1987
V F Humphrey UK 1988
M G Brown USA 1989
A P Dowling UK 1990
M B Porter USA 1991
C H Harrison UK 1992
M D Collins USA 1993
T G Leighton UK 1994
N C Makris USA 1995
G B Deane USA 1997

R W B Stephens Medal

The R W B Stephens Medal is awarded in memory of Dr R W B Stephens, the first president of the Institute of

Acoustics. His key interests lay in physical acoustics and ultrasonics but he influenced generations of students through his continuing work in education.
The medal is awarded in alternate years for outstanding contributions to acoustics research or education.
The winner of the medal would normally be invited to give a lecture at either the Spring or Autumn Conferences. **The medal has been awarded to:**

R C Chivers UK 1997

Honorary Fellowships

Honorary Fellowships are awarded to distinguished persons intimately connected with acoustics, or a science allied thereto, whom the institute wishes to honour for exceptionally important services in connection therewith, and any distinguished person whom the Institute may desire to honour for service to the Institute or whose association therewith is of benefit to the Institute, shall be eligible to become Honorary Fellow of the Institute.

The total number of Honorary Fellows shall not exceed 2 per cent of the number of persons elected as Corporate Members of the Institute. **Honorary Fellowships have been conferred upon the following:**

W P Mason USA 1974
H Bagenal UK 1975
D G Tucker UK 1975
R W B Stephens UK 1977
L Cremer Germany 1977
R B Lindsay USA 1977
Sir James Lighthill UK 1978
W A Allen UK 1978
E J Richards UK 1978
J Lamb UK 1980
W Taylor UK 1980
F Ingerslev Denmark 1981
C A Taylor UK 1985
Sir Brian Pippard UK 1985
P V Bruel Denmark 1986
C M McKinney USA 1986
J Moir UK 1986
M E Delany UK 1989
P Lord UK 1992
B L Clarkson UK 1993
D W Robinson UK 1993
A Dove UK 1994
G H Vulkan UK 1994
J M Bowsher UK 1995
J N Holmes UK 1995
W W Lang USA 1996
D T Sugden UK 1996
F J Fahy UK 1998
C M Mackenzie UK 1998

Branch News

North-west Branch

In September 1998, the AGM was held at the welcoming BDP conference room in Manchester. There were no huge changes to the committee make-up, although a new Secretary had to be hastily found following Andy Turnbull's resignation. This post is now being ably filled by Paul Michel, Environmental Health Officer with St Helens MBC. The present committee waits with interest to hear from other likely members.

The main event at the AGM was a presentation by Duncan Templeton and Judith Ruttle of BDP Acoustics entitled *Design of Acoustic Environments in Some Alternative Educational Buildings*.

After a general introduction to the guidelines contained in the Department for Education and Employment's *Guidelines for Environmental Design in Schools*, Duncan and Judith described the acoustic design of the Tonbridge School Chapel and City of Leeds College of Music.

Refurbishment of the Tonbridge School Chapel following a fire was really a rebuilding exercise. Duncan described how a variable sound system was introduced to enable choirs or speakers to operate from a number of different positions in a vast building so that they were clearly heard throughout the chapel. It was also necessary to introduce quiet ventilation systems in the form of fan coil units in the timber panelling.

City of Leeds College of Music is a new building containing a small recital hall, a recording suite, and many practice and teaching rooms. The multi-storey building form created a requirement for high degrees of sound insulation between areas to enable flexibility of use. Judith presented the target and actual performance figures for separating building elements. The increase in performance by adding a lightweight box-in-box form to a 'shell' practice room was shown, together with performance figures for multi-layer, floor-to-floor, separating structures.

In December 1998, we were treated to a presentation by Dr Graham Day, Consultant Audiologist of the South Manchester NHS Trust on *Tinnitus*. After a brief introduction on the hearing mechanism and the types of hearing loss that can be sustained, Graham went on to describe the various forms of tinnitus. Apparently, about 12% of the UK population are affected by tinnitus.

To help people manage their tinnitus, which could at worst lead to personal desperation, there is a need to break the psychological vicious circle. Most suffers can overcome annoyance themselves; if this cannot be achieved suffers can generally be helped with a hearing aid or masker. Graham then described tinnitus retraining therapy techniques for hyperacusis and phonophobia affecting the remaining suffers.

An interesting question time addressed a number of points including how EHOs should deal with tinnitus suffers complaining of noise nuisance from external sources.

Peter Sacre MIOA

Noise at Work in the Entertainment Industry was the subject of an evening meeting on 28 January 1999. Jo Webb of Philip Dunbavin Acoustics and Andrew Asbury of Sound Research Laboratories tackled this thorny problem with the help of some illuminating case studies.

The presentation commenced with Andrew summarising the requirements of the Noise at Work Regulations, including the requirements to reduce noise exposure, the use of hearing protection, ear protection zones, the assessment of risk and definition of reasonably practicable.

Then Jo described the first case study. This concerned a two venue discotheque and the starting point was the British Entertainment and Discotheque Association's *Guidelines for Management of Noise at Work*. This suggests various noise control measures including volume regulatory devices and contracts with DJ's for them to use house amplification systems rather than their own. New guidelines are expected soon. Following a requirement from an Environmental Health Officer a noise survey was carried out. This revealed that in one of the venues even the staff at the food servery were above the First Action Level, whilst the DJ, the bar staff, and the glass collector were above the Second Action Level. Recommendations included the glass collector wearing ear plugs, moving the speakers away from the bar, providing wall and ceiling acoustic absorption, reducing the bar opening apertures, and screening the bars. Much of this was worked in at a major refurbishment, with a significant improvement in levels. The other venue had similar levels, problems and solutions. The cloakroom attendant had levels dramatically reduced by separation of the cloakroom from the function room. Speakers were pointed away from the bar, and much use was made of acoustic tiles, sprayed acoustic plaster, and industrial grade perforated metal clad absorbers.

Andrew then illustrated the problems encountered at a performing arts college. A noise survey required by the HSE had revealed high exposure levels for both teachers and students. Much of the work was taking place in small, reverberant rooms and for periods that varied and were hard to quantify. Examples of noise levels were given. The members of a rock band individually contributed between 102 and 108 dBA. Less expected were levels from the brass section of 100–104 dBA, woodwind 91–97 dBA and even the vocalists 81–84 dBA. Amongst noise control actions being tried are to be timetables aimed at actively reducing exposure to staff and students, education about noise induced hearing loss, the provision of hearing protection, ear protection zones, reducing the reverberation times of the rooms, noise limiters for the rock bands, electric drum kits, and customised (and expensive) ear protectors. Students may also have to practice more away from the college.

Our thanks to Andrew and Jo for interesting and informative talks, and as ever, to Building Design Partnership for providing the excellent venue.

Paul Michel MIOA

London Branch

The London Branch has started 1999 with two meetings drawing larger than normal attendances. The first, in January, was addressed by Gregory Stone QC on *Being an Expert Witness*. Since most acousticians are called on from time to time to be an expert witness and, even if we don't think that we are bad at it, most of us would like to become better at it and fall victim to smart QCs less often, the opportunity of being put on the right track by one of the QCs was an opportunity not to be missed. We were told of some of the pitfalls that could await us and some of the seemingly innocuous types of questions that we might be asked in order to prove that we are not really so expert after all. It was interesting to see how counsel size up their expert witnesses and judge that if a potential expert witness is easily moved to revise his evidence during a conference, it is more than likely that the opposing counsel will be able to shake his evidence during cross-examination. At the end of the talk I for one felt that I was better equipped to go into the arena, but I suppose the proof of how much I learned will come in the result of the next Public Inquiry. As a measure of how popular this talk was I should say that not only were a few members standing in the corridor to hear it but also the pub that we went to afterwards ran out of beer.

Our February meeting traditionally takes the form of a half-day visit. Always wanting to be ahead of the times, our visit this year was to the Millennium Dome one year (or two years if you take a different view of the calendar) before the new millennium. The site is constantly changing and on arrival we discovered that the building in which we were to meet had been physically moved around the site between the details being sent to us and the date of the visit.

We had two excellent talks during the afternoon. Tanya Ross of Buro Happold, structural engineers working on the project, spoke on the engineering aspects of the dome: how it is designed, what it is made of, why it doesn't fall down etc. We learned that the original idea for the millennium exhibition was a series of pavilions, but when the likely weather conditions on 1 January 2000 and the exposed nature of the North Greenwich peninsula were considered, it was decided that an umbrella was needed. The Dome is as near to the world's biggest umbrella as is possible. We also learned that the hole in the roof of the Dome (that I had always assumed was something significant to do with the Millennium) was there because the ventilation shaft for the Blackwall Tunnel had got there first. The tunnel could not be moved and there was nowhere else for the Dome to go so the ventilation goes through the exhibition area. Tanya gave a fascinating description of the problems that are involved in the structure of so large a dome and the difficulties in providing adequate ventilation and other services to a unique building.

Angela Thompson of the Symonds Group, the acoustics consultants, then spoke of the acoustics work that had been involved. These have ranged from how to keep the sound systems in the exhibits operating intelligibly while there is a show taking place in the main arena, through what will the shows in the main arena sound like in the residential areas of the three neighbouring boroughs, to what will a hailstorm sound like in an enormous tent. The work is not finished, but Angela left us in no doubt that those in the Dome will be able to hear what is going on clearly and properly and those living around will not hear it.

We then visited the Dome itself. From the outside I found it rather unimpressive: it doesn't look much bigger than the tent Billy Smart used to have when I was a child. Once inside we realised that the designers had borrowed some design features from the Tardis. With no exhibit yet in place the inside seems much larger than the outside. Viewed from high up the double-decker bus that is in there looks like a Dinky toy.

The London Branch meetings are normally held in Holborn at 6 pm on the third Wednesday of the month. If you would like to receive details of them by e-mail, please send your e-mail address to Londonioa@aol.com.

Tony Garton MIOA

Scottish Branch

The first event of 1999 was held in the University of Strathclyde, Glasgow on 24 February and took the form of a meeting on the subject of classroom acoustics. There were two presentations; the first, *Classroom Acoustics Research – Results from Surveys* was by Sharon Airey of Heriot-Watt University and the second *Classroom Acoustics – The Way Ahead* was given by David Mackenzie of the same university.

Sharon qualified as a primary school teacher before joining Heriot-Watt and has been involved in the school research project for some three years liaising with the schools, carrying out measurements, undertaking analysis of results and giving presentations on findings.

Sharon's presentation covered many areas such as open plan, mainstream and special schools classrooms. The importance of consonants in speech intelligibilty was highlighted, and examples of typical classroom background noise levels were provided. A variety of noise sources were suggested as being contributory factors in the overall classroom ambient noise level including heating/ventilation systems. These noise sources were suggested as being contributory factors towards stress, concentration, performance, behaviour and hearing and understanding in the classrooms. Throughout the presentation the benefits of Sharon's background as a primary school teacher were obvious, and made for a very interesting perspective on the subject.

David Mackenzie is a Lecturer in the Department of Building Engineering and Surveying and originally became involved in the subject of classroom acoustics some four years ago when some preliminary investigations highlighted the fact that there was a very great lack of information on the subject. David expanded on subjects covered by Sharon and made reference to various applicable British Standards and guidance, including *Building Bulletin 87: Guidelines for Environmental Design in Schools.*

Problems of noise transmission from upstairs to downstairs classrooms were discussed and problems from external noises such as road traffic, railway noise and in one instance lawnmower noise from a bowling green situated near a test school were given as illustrations. The importance of audibility (not inaudibility for a change), clarity and intelligibility as requisites in the classroom environment were given and factors affecting these areas were discussed including room dimensions, construction and shape.

David indicated that as a result of the work undertaken at Heriot-Watt on this subject, enquiries were being received on a daily basis and this was reflected in the lively discussion session which followed the two presentations.

John Nicol MIOA

The Institute Library

Introduction

Not all IOA Members may be aware that the Institute has a library, situated at the Institute offices in St Albans and open both to members and to non-members during normal office hours. The librarian is available to assist visitors or telephone enquirers on Monday and Wednesday mornings and, for members, at other times by arrangement. The library originated as a collection of journals received on a reciprocal basis for Acoustics Bulletin; review copies and conference proceedings passed to us by members; and donations from members. We are very grateful to all these donors, without whose generosity the library would be very considerably smaller.

The classification system used is that originally developed by the BEPAC Acoustics Special Interest Group, which has been extended to encompass all areas of interest to IOA Members. This was chosen for its practical approach and ease of application, within different specialist areas of acoustics.

Library Stock

Together with copies of all IOA publications, we have around 150 books; various reports, including over 80 NPL reports; and the proceedings of some specialist meetings and of Internoise and other general acoustic conferences. A list of the journals we hold is available from the Institute offices and includes Acustica, the Journal of Sound and Vibration (JSV) and the Journal of the Acoustical Society of America (JASA).

We are currently working on improving our stock of items relating to guidelines and legislation, such as Standards and Codes of Practice. This is a difficult area and members' suggestions of new or long-standing publications (including material on the Internet) which should be held by the Institute are very welcome. We have membership of BSI and receive Update and Business Standards.

There are still many gaps in our library; help in filling them – either by suggesting publications of particular use or through donations of copies of your own publications or of items you no longer need – would be very welcome. We are particularly looking for the following to complete our sets:

Proceedings of Internoise 80, 84, 85 and 89.
JASA; volumes before 26; some in volumes 49–56
JSV some in volumes 8–30; most of volumes 41–104

Archives

As well as holding items relating to the development of the IOA and a number of donations of mainly historical interest from the late Professor R W B Stephens, the library has recently been given some of the books and work papers of the late Hope Bagenal. These include early copies of Sabine's Collected Papers on Acoustics, Fitzmaurice and Allen's Sound Transmission in Buildings and Wood's Acoustics (vol 2), and correspondence and drawings relating to Hope Bagenal's acoustic work for the Royal Festival Hall, the Fairfield Halls, Croydon, St John's Smith Square and other buildings in the years 1934–1973. Plans are now under way to accommodate these archive items together in one area of the library.

Services

We do not yet operate a loan system; whether we introduce such a service, for members only, depends to some extent on the level of interest demonstrated in response to this article.

Members who can do so are encouraged to come and browse; St Albans is a 20-minute journey by train from London and is close to the M1 and M25. It is advisable to let us know if you propose coming to use the library, to ensure that the librarian will be there if needed and that the library is not in use for other purposes.

Photocopying

Photocopies of most items held in the library will be made on request, currently at a cost of £5 per article or equivalent (not exceeding about 10 pages). Please give the fullest details you can about your request – 'a paper on loudspeakers by Brown, or possibly White, given at an Autumn Conference' counts as a search and will be charged as such (see below).

If you are sent a copyright form please fill it in and return it; for this your own, original signature is required (faxing is not acceptable). A literature request and copyright form is included with this Bulletin for you to photocopy for future requests to us.

Searches

We can search the library database by title, word in title, author etc and by subject classification. However, although we can tell you whether we have the Internoise 1992 Proceedings, we cannot tell you whether those Proceedings contain anything on a particular subject; likewise for the journals we hold. The Institute's own Proceedings are listed by full title of paper and therefore, provided the paper titles accurately reflect the significant content of each paper, a search on two or three words will normally tell you what there is on a given subject. Please suggest search words for this, especially in physical acoustics about which your librarian is particularly ignorant!

This database, which extends back to the 1984 Proceedings, was set up before we had introduced subject classifications and therefore we unfortunately cannot do general subject searches. The charge for a search, covering both databases and a brief manual search of likely other sources, is currently £5 (£10 to non-members). Such searches are by no means exhaustive and therefore cannot be used as evidence of a lack of research on any given topic.

If you think the IOA library can help you with a current project, please telephone on Monday or Wednesday morning, or Fax the librarian, acknowledging that you are aware of the charge for any photocopies or search you request.

Alison Hill, Librarian

Hansard

12 January 1999
Aircraft Noise
Fiona Mactaggart: To ask the Secretary of State for the Environment, Transport and the Regions what research he has (a) commissioned and (b) evaluated into the impact on health of noise from aircraft, with particular reference to night-time noise; and what plans he has to reduce permitted noise levels.
Ms Glenda Jackson: We have commissioned a research trial on the effect of aircraft noise on sleep disturbance, and research commissioned jointly with the Department of Health will include some study of the non-auditory health effects of aircraft noise. No research results are available for evaluation yet. We expect to publish a supplementary consultation paper on aircraft noise limits early in the new year.

14 January 1999
A404(M) (Noise Amelioration)
Mrs May: To ask the Secretary of State for the Environment, Transport and the Regions when he expects to be able to announce his decision on the funding of noise amelioration measures on the A404(M) following the recommendation of the independent report commissioned by the Highways Agency.
Ms Glenda Jackson: In our White Paper *A New Deal For Trunk Roads* we announced that we intended to set aside budget for the purpose of providing noise mitigation measures for some of the most serious and pressing cases along existing roads. We also said that we would make a separate announcement regarding the criteria to be used. These criteria are still being finalised and we will make a statement setting them down as soon as we can. It is important that the selection criteria we choose are as fair as possible. Decisions on individual cases such as the A404(M) must wait until those criteria are published.

21 January 1999
Quieter Road Surfaces
Lord Moran asked Her Majesty's Government: What progress is being made with the provision of quieter road surfaces on motorways and major roads
The Parliamentary Under-Secretary of State, Department of the Environment, Transport and the Regions (Lord Whitty): Quieter noise surfaces are being specified as a matter of course for all new trunk roads, including motorways, for contracts awarded since the announcement of the new policy in the report *A New Deal for Trunk Roads*.
They are also being used where appropriate when existing roads need to be resurfaced in areas where noise is a particular concern. Quieter road surface materials have been extensively trialled by the Highways Agency in the preceding two or three years in response to a rapidly evolving market in these innovatory materials.

25 January 1999
Road Noise
Mr Jenkin: To ask the Secretary of State for the Environment, Transport and the Regions, pursuant to paragraph 2.70 of the White Paper, *A New Deal for Transport*, what indicators he proposes to publish to measure the impact of road noise (a) in urban areas, (b) in suburban areas and (c) in rural areas.
Ms Glenda Jackson: As stated in paragraph 2.70 of the White Paper, noise is one of the areas where further work is needed to ensure that indicators are appropriate and effective. This work is being taken forward in conjunction with current work on noise indicators by the European Commission which aims to harmonise methods of calculating noise exposure as part of a proposed Framework Directive on Noise. It would be premature for us to reach conclusions about noise indicators until that work is further advanced.

8 February 1999
Motorway Noise
Mr Fallon: To ask the Secretary of State for the Environment, Transport and the Regions when he expects to announce details of the revised criteria and ring-fenced annual budget for the Highways Agency for new measures to reduce motorway noise.
Ms Glenda Jackson: We announced in *A New Deal for Trunk Roads in England* that we propose to establish revised criteria and a ring-fenced annual budget to provide noise mitigation on some existing trunk roads. We will make an announcement on this shortly.

22 February 1999
Night flights
Dr Tonge: To ask the Secretary of State for the Environment, Transport and the Regions what plans he has to commission independent research into the effects of night flights on people living around Heathrow Airport.
Ms Glenda Jackson: Our intention to commission a new research trial on the effect of night-time aircraft noise on sleep disturbance was announced on 27 February last year, when the first stage consultation on night restrictions at Heathrow, Gatwick and Stansted airports was published.

The trial is expected to focus on methodologies, assessing experimental and analytical techniques – and their limitations – which are related to the measurement of sleep disturbance. The findings of the trial will help us decide whether to proceed with a full-scale study of sleep disturbance, and to determine what should be included in any such study. The trial will be based at Manchester Airport, which provides a suitable combination of densely populated communities close to the airport with a spread of aircraft noise throughout the night. It may be extended to Heathrow if actual noise levels in the early morning at Manchester prove insufficient for the purposes of the trial. If, on completion of the trial, we decide to continue with more detailed research, the question of where that study would be based is one of many issues which would need to be considered at that time, based on objective research considerations. A steering group, which includes community and industry representatives, has been established to oversee the trial and expert advice is obtained from a technical group made up of specialists in relevant scientific fields. Further peer group advice will also be sought from a panel of international experts. Detailed proposals for the trial will be announced following completion of discussions with these groups.

Dr Tonge: To ask the Secretary of State for the Environment, Transport and the Regions if he will list the studies used in preparing the latest departmental consultation document on night flights at Heathrow, Gatwick and Stansted airports.

Ms Glenda Jackson: The second stage consultation paper on night restrictions at Heathrow, Gatwick and Stansted, issued on 17 November 1998, Official Report, column 492, refers at Appendix D to the following studies:

1. Aircraft Noise and Sleep Disturbance: final report, DORA Report 8008 (£3.50)
2. Aircraft Noise and Sleep Disturbance: designated night data for sites surveyed in the main phase of the study, DORA Communication 8004 (£1.50)
3. Noise Disturbance at Night near Heathrow and Gatwick Airports: 1984 check study, DR Report 8513 (£2.50)
4. Noise Disturbance at Night near Heathrow and Gatwick Airports: Critique of the technical issues raised by consultees during the 1986 Public Consultation, DORA Report 8715 (£3.00)
5. Report of a Field Study of Aircraft Noise and Sleep Disturbance, Department of Transport 1992 (£11.00)
6. Night Noise Contours: a feasibility study, National Physical Laboratory 1997.

Also referred to in the consultation document are:

7. Night-time Ground Noise, DORA Report 9850 October 1998 (£20.00)
8. Assessment of Revised Heathrow Early Mornings Approach Procedures Trials, DORA Report 9823, November 1998; and
9. historical daytime noise exposure contours for Gatwick, Heathrow and Stansted airports prepared by DORA on behalf of the Department; those for 1996 being the most recent available at the time the consultation paper was issued.

Reference was also made to the Heathrow Runway Alternation Trials – Research Among Local Residents, Final Report, March 1998, prepared by MVA for the Heathrow Airport Consultative Committee. In addition the consultation document includes information on such matters as usage of the noise quotas and movement limits since October 1993 and the main points made in the responses to the preliminary consultation, some of which referred to studies carried out.

Advice on how to obtain copies of each document or to consult reference copies free of charge, was given in the consultation document.

Extracts provided by Rupert Taylor FIOA

BSI News

New and Revised British Standards

BS 7698: Reciprocating internal combustion engine driven alternating current generating sets.
BS 7698-10: 1999 Measurement of airborne noise by the enveloping surface method. No current standard is superseded.

BS EN Publications

BS EN 1746:1999 Safety of machinery – Guidance for the drafting of the noise clauses of safety standards. No current standard is superseded.
BS EN ISO 10846: Acoustics and vibration – Laboratory measurement of vibro-acoustic transfer properties of resilient elements.
BS EN ISO 10846-1:1999 Principles and guidelines. No current standard is superseded.
BS EN ISO 10846-2:1999 Dynamic stiffness of elastic supports for translatory motion – Direct method. No current standard is superseded.
BS EN ISO 11690: Acoustics – Recommended practice for the design of low-noise workplaces containing machinery.
BS EN ISO 11690-3:1999 Sound propagation and noise prediction in workrooms. No current standard is superseded.
BS EN 61400: Wind turbine generator systems.
BS EN 61400-11:1999 Acoustic noise measurement techniques. No current standard is superseded.

British Standard Implementations

BS ISO 16063: Methods for the calibration of vibration and shock transducers.
BS ISO 16063-1:1998 Basic concepts. Supersedes BS 6955-0:1988.

Amendments to British Standards

BS ISO 362:1998 Acoustics – Measurement of noise emitted by accelerating road vehicles – Engineering method. Corrigendum No 1.

New Work Started

No number: Non-destructive testing – Acoustic emission during proof testing.

International New Work Started

ISO 5347: Methods for the calibration of vibration and shock transducers. Part 20: Primary vibration calibration by the reciprocity method.

Drafts for Public Comment

98/233494 DC: Draft IEC 61973:Edition 1. Ultrasonics – Field characterisation – Test methods for the determination of thermal and mechanical exposure parameters for the purposes of defining the safety classification of medical diagnostic ultrasonic fields (IEC document 87/150/CDV) (Possible new British Standard).

CEN European Standards

EN 583-1:1998 Non-destructive testing – Ultrasonic examination – Part 1: General principles.

EN 1032: Mechanical vibration – Testing of mobile machinery in order to determine the whole-body vibration emission value – General. Amendment A1:1998 to EN 1032:1996.

EN ISO 389: Acoustics – Reference zero for the calibration of audiometric equipment.

EN ISO 389-3:1998 Reference equivalent threshold force levels for pure tones and bone vibrators.

EN ISO 389-4:1998 Reference levels for narrow-band masking noise.

EN ISO 5135:1998 Acoustics – Determination of sound power levels of noise from air-terminal devices, air-terminal units, dampers and valves by measurement in a reverberation room.

EN ISO 10846: Acoustics and vibration – Laboratory measurement of vibro-acoustic transfer properties of resilient elements.

EN ISO 10846-1:1998 Principles and guidelines (ISO 10846-1:1997).

EN ISO 10846-2:1998 Dynamic stiffness of elastic supports for translatory motion – Direct method (ISO 10846-2:1997).

EN ISO 11690-3:1998 Acoustics – Recommended practice for the design of low-noise workplaces containing machinery – Part 3: Sound propagation and noise prediction in workrooms (ISO/TR 11690-3:1997).

CENELEC Publications

EN 61400-11:1998 Wind turbine generator systems – Part 11: Acoustic noise measurement techniques (IEC 61400-11:1998). Implemented as BS EN 61400-11:1999.

ISO Standards

ISO 6393:1998 (Edition 2) Acoustics – Measurement of exterior noise emitted by earth-moving machinery – Stationary test conditions. Will be implemented as BS ISO 6393:1998.

ISO 6394:1998 (Edition 2) Acoustics – Measurement at the operator's position of noise emitted by earth-moving machinery – Stationary test conditions. Will be implemented as BS ISO 6394:1998.

ISO 10534-2:1998 Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes – Part 2: Transfer function method. Will be implemented as BS ISO 10534-2:1998.

ISO Publications

ISO 10068:1998 Mechanical vibration and shock – Free, mechanical impedance of the human hand-arm system at the driving point. Will not be implemented as a British Standard as UK opinion is that there is no evidence that its content can be usefully applied.

This information was announced in the January and February 1999 issues of BSI Update, copies of which are kept in the Institute library.

Book Review

ANC GUIDELINES - NOISE MEASUREMENT IN BUILDINGS
Part 2: Noise from External Sources within Buildings
Price £7.50

This 'standard' aims to plug a large gap in an area where there is no national or international standard. It is primarily for use by the developers or intending users of a wide range of building types. One finds that there are numerous parties with limited expertise on issues relating to noise who draft internal sound level requirements. These are often not adequately detailed or imprecise. Many specifications simply list internal dBA or NR levels, lacking even the measurement parameter details.

The guidelines are not intended for application by laymen, but are there for use by experienced consultants, probably when called in to arbitrate or pick up the pieces.

It would be sensible for Specifiers to link their internal criterion requirements to the ANC Measurement Guidelines. In the case of a dispute, relating to measurement issues, these guidelines could only be applied if they are included in the specification or if all the parties concerned subsequently agreed to it.

The guidelines provide a very comprehensive set of measurement requirements for the various types of external noise sources, including transportation noise, industry, construction, commerce and leisure.

The document covers terms and definitions, measurement equipment requirements and parameters, criterion applications (though it does not set specific criteria levels), specification issues (though it does not provide model specifications) and measurement information to be reported.

The document is very technical in content but concise, and necessarily so if it is to adequately serve its purpose. It is also, by and large, straightforward and sensible for applications in the field (though I have not yet tried to apply it myself).

At £7.50 the cost is considered very reasonable. A typical British Standard with the same degree of technical content would probably be priced at about £100.

S Peliza MIOA ❖

Research in Progress

Open University

Department of Environmental and Mechanical Engineering, Faculty of Technology

The Prediction of Noise Arising from Moving Directional Sources in a Complex Environment

A hybrid numerical prediction code has been developed from the Boundary Integral Equation and Fast Field Program methods. So far it has been used to study the influence of atmospheric refraction on noise barrier performance. The code will be used to predict sound propagation over variable impedance surfaces or topography from moving sources. An analytical result for ground effect in the presence of a moving source is being used to predict A-weighted noise levels from moving broad-band sources.
Duration: Three years from 1/1/97
P I: Dr Kai Ming Li and Professor K Attenborough
Researchers: Dr S Taherzadeh (Research Fellow), M Buret (Research Student)
Funding: EPSRC £108,607, OU Studentship £12,000

Sound Propagation in Suspensions and Emulsions

A coupled-phase theory for propagation in emulsions, allowing for compressible particulate phase and heat transfer, has been extended to include particle interactions. Further work will include particle size distribution effects.
Duration: 2 years from 1/6/97
P I: Professor K Attenborough
Researcher: Dr J Evans (Research Fellow)
Collaborator: Dr Kai Ming Li
Funding: EPSRC £49,601, OU £4,000

Acoustical Monitoring of Particulate Flows

Studies have been made of acoustical methods of monitoring airborne particulate flows at high concentrations. Current activity is concerned with measuring and predicting particle shape and roughness effects at audio- and low ultrasonic-frequencies.
Duration: 1997-1999
P I: Professor K Attenborough
Collaborator: Dr S Woodhead, University of Greenwich
Funding: EPSRC £78,008

Modelling the Acoustic Behaviour of Porous Materials

By treating porous materials as concentrated suspensions, it has proved possible to obtain predictions of their acoustical properties that depend only on the volume fraction of solid and constituent particle characteristics.
Duration: 1998-2000
P I: Professor K Attenborough
Researcher: Dr O Umnova (Research Fellow)
Collaborator: Dr Kai Ming Li
Funding: EPSRC £65,210

Determination of Soil Properties from Measurements of Acoustic-to-Seismic Coupling

Measurements of short range propagation and acoustically-induced seismic signals are being used to determine physical properties of soil including porosity, air permeability, tortuosity and elastic constants.
Duration: 1995-1999
Supervisor: Professor K Attenborough
Researcher: N Harrop (Research Student)
Funding: EPSRC Quota Studentship

Influence of Sound Propagation Effects on Animal Behaviour

The extent to which acoustic communications between animals are influenced by propagation conditions is being reviewed.
Duration: 1999-2002
Supervisor: Professor K Attenborough
Researcher: M Walby (Research Student)
Funding: EPSRC Quota Studentship

Acoustical Pulse Reflectometry

The signals returned from impedance changes in the system of interest are being used to determine both the input impedance and profiles of tubular systems including musical instruments.
Duration: 1999-2002
Supervisor: Dr D Sharp
Researcher: student to be recruited
Funding: OU competitive studentship

University of Essex

Department of Electronic Systems Engineering

Three-Dimensional Personal Audio Workspace – 'Sound-bubble'

Duration: 3 year project 1 October 1995 to 30 September 1998
Supervisor: Professor M O Hawksford
Chief investigator: R Tan

Techniques for Spatial Audio Delivery

Duration: 1 year project 1 October 1997 to 30 September 1998
Supervisor: Professor M O Hawksford
Chief investigator: Dr M Reed

Pending Project: Spatial Audio for Distributed Systems

Duration: 3 year project
Supervisor: Professor M O Hawksford
Chief investigator: TBA

University of Bradford

Department of Civil and Environmental Engineering

Acoustic Performance of Noise Barriers

(with Dept of Mathematics and Statistics, Brunel University)
The performance of noise barriers of complex form and in complex environments is being studied using boundary integral equation numerical models and experimental models. Use of barriers to attenuate road and rail noise is under investigation.
Duration of project: 1996-1999
Supervisors: Dr D C Hothersall, Dr S N Chandler Wilde and Dr K V Horoshenkov
Researcher: P A Morgan
Funding: £121,000 EPSRC research grant

Poroelastic Materials for Noise Control

(with Department of Engineering Design and Manufacture, University of Hull)
Development of mathematical models to describe the mechanical and acoustical properties of elastic frame porous media. Development of new elastic frame porous materials for applications in noise control.
Duration of project 1997-2000
Supervisors: Dr D C Hothersall, Dr K V Horoshenkov and Professor A Cummings
Researcher: P Leclaire
Funding: £134,000 EPSRC research grant

Efficiency of Louvred Noise Barriers
Measurement of the efficiency of noise barriers constructed from vertical louvres by experimental modelling at a scale of 1:20. The effects of louvre angle and surface treatment are being considered.
Duration of project: 1998-1999
Supervisors: Dr D C Hothersall and Dr K V Horoshenkov
Researcher: D De Gusmao
Funding: £27,000 Transport Research Laboratory

Porous Sound Absorbing Materials
Study of the production of porous materials from recycled rubber and plastic products. Measurement of the physical and acoustic properties of the materials. Optimisation of the performance for noise control applications.
Duration of project: 1996-1999
Supervisor: Dr K V Horoshenkov
Researcher: M J Swift
Funding: EPSRC research studentship

Prediction and Abatement of Transport Noise
Development of improved methods of prediction of transport noise at long range, of noise levels in the region of tunnel entrances, and of the effects of noise barriers. Propagation of road traffic noise in complex urban environments.
Duration of project: 1998-2001
Supervisor: Dr D C Hothersall
Researcher: S Martin
Funding: EPSRC research studentship

Effects of Porous Materials on the Performance of Distributed Mode Loudspeakers
The effects of porous materials on the emission and propagation characteristics of planar, or distributed mode loudspeakers will be studied using mathematical modelling and experimental methods.
Duration of project: 1999-2002
Supervisor: Dr K V Horoshenkov
Researcher: to be appointed
Funding: £33,000 NXT Ltd research studentship

University of Birmingham

School of Electronic and Electrical Engineering

Active Sonar Pulse Design
To predict the performance of a range of broadband active sonar pulse designs in a realistic operating environment. This programme also includes the development of optimal range-Doppler normalisers.
Duration of project: 63 months
Supervisor: P Atkins
Researcher: R Pallaud
Funding: DERA

Broadband Acoustic Scattering Signatures of Fish and Zooplankton
The aim of this programme is to model the acoustic target strength of a range of marine creatures and to validate the predictions with experimental measurements using an ultra-wideband (25 kHz – 3.2 MHz) active sonar.
Duration of project: 36 months
Supervisor: P Atkins
Researchers: T Francis and C Bongiovanni
Funding: EU Contract No MAS3-CT95-0031 (BASS)

Shallow Water Communications
To investigate methodologies of transmitting compressed video images through a highly reverberant shallow water channel.
Duration of project: 36 months
Supervisors: P Atkins and L S Wang
Researcher: T Collins
Funding: DERA

Code Division Communication for Highly Reverberant Channels
The investigation of code division modulation techniques applied to shallow water channels and the applicability of RAKE receiver structures to high data rate communication systems.
Duration of project: 36 months
Supervisor: P Atkins
Researcher: S Hooper
Funding: EPSRC studentship

Efficient Numerical Methodologies for Novel Wideband Transducer and Array Design Problems
Investigation of further finite element and related advances in associated numerical techniques to improve the efficiency and utility of transducer design codes to tackle the challenge of ultra wideband (many octaves) active sonar design.
Duration of project: 36 months
Supervisors: D Hardie and P Atkins
Researcher: S Morgan
Funding: DERA studentship

University of Salford

Department of Acoustics and Audio Engineering

Reduction of Aircraft Noise by Nacelle Treatment and Active Control (RANNTAC)
This is a major European project funded by the EU Brite Euram programme. The overall objective of RANNTAC is to acquire the technology necessary to support the design and manufacturing of turbofan engine nacelles featuring innovative noise reduction devices to enable an extra attenuation on engine noise sources. Salford works together with partners in a consortium of 16 industrial companies (including Rolls-Royce of UK, Aerospatiale of France etc) and 6 research institutions. Our specific role is to develop an innovative absorptive liner design concept.
Duration of Project: 1998-2000
Supervisor: Dr Y W Lam
Funding: £96,000 for Salford, EU Funding

Auralisation Requirements for Auditoriums
The aim of the project is to investigate the requirements on the input data for accurate auralisation of auditorium acoustics.
Duration of Project: 1997-1999
Supervisor: Dr Y W Lam
Researcher: K Lin

The Influence of Surface Diffusion on the Acoustics of Javanese Gamelan Concert Halls
The project is to determine the optimum room acoustics requirements for the Javanese Gamelan music. The effect of surface diffusion over the frequency range of the music will be of particular interest.
Duration of Project: 1999-2001
Supervisor: Dr Y W Lam
Researcher: J Sarwono
Funding: PhD studentship from the Asian Development Bank

Hearing Loss in the Built Environment: The Experience of the Elderly
This pilot project will use new qualitative research methods to determine the extent and type of acoustic problems faced by

elderly people with a hearing loss in the built environment. The long term aim of the work is to provide technological and design solutions to the problems found.
Duration: 1999-2000
Supervisors: Dr W J Davies, Dr T J Cox, Dr B J Longhurst, Mr A T Kearon
Researcher: Dr C L Webb
Funding: £35,000 EPSRC research grant

The Perception of Reverberation in Small Rooms for Critical Listening
This project studies the perception of music in small rooms such as recording studio control rooms and listening rooms. The aim is to provide guidance to designers on the sensitivity of listeners to changes in the sound field.
Duration 1998-1999
Supervisor: Dr W J Davies
Researcher: Mr T I Niaounakis

Auditorium Stage Acoustics
This project aims to translate the psychoacoustic requirements of musicians into guidelines on stage design for auditoria. The work involves scale model tests and subjective tests with musicians.
Duration: 1998-2001
Supervisor: Dr W J Davies
Researcher: Ms R Bermond

University of Cambridge

Department of Engineering

Vibration Generated by Underground Railways
The design of floating track slab for vibration isolation of railways is de-mystified by means of analytical modelling of the vibration field around railway tunnels.
Duration of project: 1996-1999
Supervisors: Dr H E M Hunt and Professor D E Newland
Researcher: J A Forrest
Funding: PhD studentship plus industrial support

Base-Isolation of Buildings
Optimizing the effectiveness of vibration-isolation for whole buildings using steel springs and rubber blocks.
Duration of project: 1998-2001
Supervisors: Dr H E M Hunt and Professor D E Newland
Researcher: J P Talbot
Funding: EPSRC PhD studentship plus industrial support

Fault Identification in Axisymmetric Structures
Modal testing is used to locate faults in cylinders which is normally a complex procedure owing to closely-spaced natural frequencies.
Duration of project: 1997-2000
Supervisor: Dr H E M Hunt
Researcher: T Marwala
Funding: PhD studentship plus industrial support

University of Liverpool

School of Architecture and Building Engineering

Prediction of Environmental Noise from Construction and Open Site Industrial Activities
The aim of this project is to develop a method for the prediction of open site industrial noise which is both simple and where an estimate of the accuracy of the prediction is included. The method will be in an accessible form for use at the project planning stage by the parties involved in potential noise complaints, including contractors, developers, environmental health officers and planners. Early predictions of potential noise level, using data in a 'lumped' form, will avoid later more detailed calculations and the possibility of litigation and costly remedial action.
Principal Investigator: Professor B M Gibbs
Co-investigators: J Lewis and Professor D J Oldham
Research Assistant: D Waddington
Funding: EPSRC grant of £127,029

Controlling Urban Noise in Naturally Ventilated Buildings
Natural ventilation systems (NVS) must be designed to allow ease of airflow at the building inlet, throughout the building's ventilation path and through the building outlet. Without careful design this also will allow noise transmission from external sources to potentially sensitive areas of the building. This project aims to develop NVS with low noise incursion. This will give designers scope to exploit the economy of use and other desirable aspects associated with NVS in locations with noise concentration, such as urban areas.
Principal Investigators: Professor D J Oldham, Professor S Sharples and Professor N J Bowman
Research Assistant: M de Salis
Funding: EPSRC Grant of £141,403

Circulation Pumps as Structure-Borne Noise Sources
This programme is to investigate circulation pumps as structure-borne sound sources. The study will lead to a characterisation and the development of a method of rating pumps. Such methods are not presently available, either as national or international standards. The problem has been recognised by the major UK manufacturer of central heating pumps and the Acoustics Research Unit at Liverpool University and preliminary collaborative work has shown that such a fundamental study is required.
Principal Investigator: Professor B M Gibbs
Research Assistant: Qi Ning
Funding: EPSRC grant of £147,712

Environmental Vibration and Noise in Buildings
An investigation of the relationship between field measurement of environmental vibration level and the resultant vibration and noise in buildings nearby. This involves the development of a transfer-function measurement technique using existing external sources. The special case of rail induced vibration and noise is being studied.
Supervisor: Professor B M Gibbs
Research Student: A White
Funding: PhD Studentship sponsored by Liverpool City Council

Expert Systems for Environmental Noise Control
The solution of complex environmental noise problems often presents a severe challenge to all but the most experienced noise consultant. In this project the collective experience of members of the ARU are being used to create a knowledge based system for use by relatively inexperienced designers.
Supervisor: Professor D J Oldham
Research Student: H G A Ibrahim

Low Frequency Sound Transmission Between Dwellings
It is recognised that low frequency sound transmission into and between dwellings is an increasing contribution to nuisance. The objective of this project is to investigate low frequency sound transmission between rooms with dimensions representative of dwellings in the UK and the rest of Europe. The influence of room and wall characteristics will be quantified,

including the likely variance in sound level difference, in the frequency range 40-200 Hz. The project will employ a relatively inexpensive experimentally validated FEM model. It also will allow the effects of low frequency room absorption to be included and circumvents the problems of field measurement, where standard procedures are not available.
Principal Investigator: Professor B M Gibbs
Co-investigator: S Maluski

Application of Virtual Reflectors in Auditoria
Conventional acoustic reflecting surfaces are not always a practical solution to the problem of poor acoustics because of difficulties in location and orientating them correctly and the requirements of stage lighting. Virtual Reflectors, consisting of a microphone, amplifier and loudspeaker are a possible solution to this problem. One application being studied in this work is the modification of the acoustics of domes.
Supervisor: Professor D J Oldham
Research Student: S Felmban

Propagation of Noise from an Overhead Source in City Streets
The aim of the study is to investigate the modulation effect of city streets on the sound field emitted by the various noise sources. Part of the work will involve a parametric study of the effect of the street geometry on propagation as well as speech transmission index.
Supervisor: Professor D J Oldham
Research Student: M R Ismail

Characterisation of Vibrating Machines as Structure-borne Sound Sources
Machines import vibrational energy into connected structures through multiple contacts and by up to six components of excitation at each contact. In addition, the structural dynamics of the connected structure must be known for a full analysis. A characteristic power is proposed which is a measure of the ability of a machine to emit energy, independent of receiving structures.
Supervisors: Dr A T Moorhouse and Professor B M Gibbs
Research Student: Su Jianxin

University of Southampton

Institute of Sound and Vibration Research

Prediction of the Noise of Co-axial Jets
Supervisor: M J Fisher

Fan Noise Prediction and Control
Supervisor: M J Fisher
Researcher: E Fruteau

Multimode Acoustic Radiation from a Circular Unflanged Duct
Supervisors: P F Joseph and C L Morfey

Propagating Acoustic Mode Count in Hard-Walled Axi-symmetric Ducts
Supervisors: C L Morfey and M C M Wright

Parametric Study of Optimised Silencer Acoustic Design
Supervisor: P O A L Davies
Researcher: D C Van der Walt

Aeroacoustic Modelling of Intake/Exhaust Noise Sources
Supervisors: P O A L Davies, K R Holland

Low-Frequency Noise in Ventilation Systems
Supervisor: P A Nelson
Researcher: P Brandstatt

Novel Control Techniques for Ducted Fan Noise
Supervisor: P A Nelson
Researcher: E Fruteau

Nonlinear Propagation of Fan Tones in the Presence of Acoustic Liners
Supervisor: M J Fisher
(in collaboration with Rolls Royce plc)

Active Control of Fan Tones Radiated from Ducted Turbofan Jet Engines
Supervisors: P F Joseph, P A Nelson and M J Fisher

Optimal Control of Laminar Flow
Supervisors: M C M Wright and P A Nelson

Duct Acoustics and Radiation (DUCAT)
Supervisor: M J Fisher
Researchers: A McAlpine and R Self

Prediction of the Noise of Supersonic Tip Speed Fans
Supervisor: M J Fisher
Researchers: A McAlpine and R Self

The Influence of Acoustic Liners on Low-frequency Buzz-saw Noise
Supervisor: M J Fisher
Researcher: A McAlpine

Models for Combustion Noise
Supervisor: M J Fisher
Researcher: A McAlpine

Inverse Filtering in Multichannel Sound Reproduction Systems
Supervisor: P A Nelson
(in collaboration with Tokyo Denki University)

Investigation of the Properties of 'Stereo Dipole' Sound Reproduction
Supervisor: P A Nelson
Researcher: T Takeuchi

Room Acoustic Models for Auralisation
Supervisor: P A Nelson

Determination of a Practical HRTF for the Synthesis of Virtual Acoustic Images
Supervisor: P A Nelson

Numerical Modelling of Head-Related Transfer Functions
Supervisors: P A Nelson and M Petyt
Researcher: Y Kahana

Vibroacoustic Coupling Using FE and SEA Models
Supervisor: F J Fahy

A New Form of Volume Acceleration Transducer (VAT)
Supervisor: F J Fahy

Discrete Time LQG Feedback Control of Vibrations
Supervisors: P A Nelson and M C M Wright

Reconstruction of Acoustic Source Strength Distributions and Their Interactions by Inverse Techniques
Supervisor: P A Nelson

FE Modelling of Head Injury Mechanisms
Supervisor: C L Morfey
Researcher: D R S Bradshaw (Dept of Electronics and Computer Science)

The Enhancement of Sonar Detection in Bubbly Environments
Supervisor: T G Leighton
Researcher: J W L Clarke

Acoustic Modelling of Flow Control Valves
Supervisor: C L Morfey
Researcher: B Olsen

Geoacoustic Inversion in Shallow-water Acoustics
Supervisor: P F Joseph
Researcher: B T Cox

Development of Robust Experimental Techniques for Bottom Characterisation in Shallow Water
Supervisors: P F Joseph, P A Nelson and C L Morfey
Researcher: B T Cox

Study of the Bubble-mediated Component of Atmosphere/Ocean Gas Flux Through Active and Passive Techniques: A Comprehensive Bubble Sizing System
Supervisor: T G Leighton
Researcher: M D Simpson

Ultrasonic Propagation in Cancellous Bone
Supervisors: P R White and T G Leighton
Researcher: E Hughes
(in collaboration with Southampton General Hospital)

Acoustic Properties of Water Containing Suspended Sediments
Supervisor: T G Leighton
(in collaboration with DERA Winfrith)

Acoustic Penetration of the Seabed with Particular Application to the Detection of Non-metallic Cables
Supervisor: T G Leighton
Researcher: R Evans

Subjective Acoustics and Environmental Noise
Supervisor: I H Flindell

This continues the list published in the January/February 1999 issue of Acoustics Bulletin.

New Products

CIRRUS RESEARCH PLC

Noise Nuisance Recorder

With the increase in neighbourhood noise complaints it is proving more and more necessary to have the ability to accurately measure noise levels and store an audio record of the actual noise. As the majority of problems occur at night it is also necessary to be able to leave a system unattended with the complainant. The Cirrus CR:281A Noise Nuisance Recorder is a complete package which contains a DAT Recorder together with a CR:703B Type 1 Data Logging Sound Level Meter in a secure enclosure.

The Sound Level Meter provides and stores an accurate measurement of the noise climate which can be later downloaded and analysed to give many different acoustic parameters. The DAT Recorder stores an audio record of the actual noise heard by the complainant which can then be replayed through loudspeakers or headphones.

It features a quick setup procedure along with a simple, two button remote control, battery or mains operation and all of the accessories required including download and analysis software, remote microphone and acoustic calibrator.

Mobile Noise Monitoring CR:245/3 Portable Environmental Noise Analyser from Cirrus Research is a versatile instrument, which when fitted with the optional GSM Cellular Modem, can be used for noise monitoring in almost any location where a mobile telephone can be used.

The instrument provides a wide range of precision acoustic measurements including environmental periods, recognised noise events and noise profile data. The standard version of the instrument can operate for up to 7 days with the internal battery, and for longer periods if extra power is provided. The instrument has a single 120 dB dynamic span to Type 1, has PTB Approval and is supplied with a 10 m microphone extension cable as standard. In addition to the GSM Cellular Modem, the CR:245/3 can be fitted with a wide range of options and accessories including automatic calibration, as well as external power options such as solar power or additional batteries.

Further information: James Tingay, Cirrus Research plc, Acoustic House, Bridlington Road, Hunmanby, North Yorks YO14 0PH Tel: 01723 891655 Fax: 01723 891742 email: sales@cirrus research.co.uk

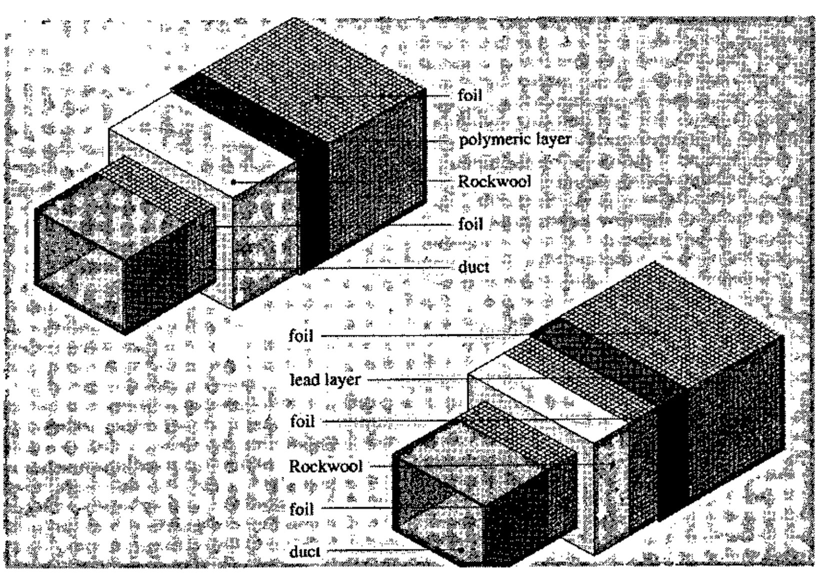
Cirrus Research is a Key Sponsor of the Institute.

ROCKWOOL FIRESAFE INSULATION

Techwrap

The solution to noisy ducts and equipment could be an installation of Rockwool Techwrap, a new high performance acoustic controller. Techwrap is a single application composite product suitable for the acoustic and thermal insulation of ducts and equipment operating from 0 degrees C to 230 degrees C. The multi-layered protection comprises a flexible panel of rockwool laminate, polymeric sheet facing and aluminium foil. Techwrap has been independently tested at AIRO [Acoustical Investigation & Research Organisation] laboratory and the Rockwool base material is rated non-combustible in accordance with BS 476: Part 4.

For further information contact Rockwool Ltd, Pencoed, Bridgend CF35 6NY Tel: 01656 862621 or Fax: 01656 868353.



HHB COMMUNICATIONS LTD

New HHB CD Recorders and Monitor Speakers

The new CDR850 is claimed to be the most comprehensively equipped professional audio CD recorder in its class, combining exceptional sound quality with a full set of functions designed to make CD recording a simple process. Features include four one-touch recording modes, auto copying of CD, DAT, MD, DCC and DVD track starts and an on-board sample rate converter which can be switched out of the signal chain when not required. Accessible via a straightforward front panel menu are full control over SCMS, Auto Stop Delay, Fade In/Out, Auto Threshold Track Increment, Auto Pause and Output Level. Audio connectivity is equally comprehensive and includes balanced XLR and RCA phono line inputs and outputs, coaxial and optical SPDIF digital I/O, plus an AES/EBU digital input.

HHB is expanding the Circle range with a new compact desktop monitor, the Circle 3, and a new powered sub-woofer, the Circle 1.

Available in both active and passive versions, the Circle 3 shares the same controlled order crossover management as the Circle 5, resulting in an untiring sound in long mixing sessions, and a familiar 'house sound' across the Circle range.

The Circle 1 powered sub-woofer combines a 12" fast transient attack speaker with a 100 watt amp module and on-board five channel active filtering to form the perfect basis for a 5.1 Circle surround sound monitoring system capable of exceptional detail and accuracy in the most demanding applications.

Also new is the Genex GX8500 professional multi format recorder. The GX8500 is the first and only commercially available digital audio recorder capable of recording in DSD (Direct Stream Digital), the new audio encoding format developed for use with DVD and Super Audio CD. In addition, the GX8500 can record in conventional PCM formats up to 24 bit/192 kHz. Multiple disc and file formats ensure wide compatibility and either internal MO or hard drives can be specified, and other external storage devices connected via SCSI.

For more information contact: Martin Westwood, Export Director, HHB Communications Ltd, 73-75, Scrubs Lane, London NW10 6QU Tel: 0181 962 5000 Fax: 0181 962 5050 e-mail: sales@hhb.co.uk

KEMO LTD

CardMaster 2

CardMaster2 from Kemo is a two-channel carrier card designed to provide versatile anti-aliasing and noise filtering and signal conditioning in data-acquisition and condition-monitoring Systems.

Designed for use with Kemo's 1200 Series of resistor-set filter modules or 1600 Series of programmable filter modules, CardMaster2 features switchable pre-filter input gain, a wide-range power input, a configurable input stage, and variable post-filter gain and offset.

The card measures 220/160 x 112 x 20 mm, and is equally suited to stand-alone use or mounted in a 3U rack or a PC/ISA slot. BNC connectors are provided for inputs and outputs.

Inputs can be differential or single-ended, with AC or DC coupling. A 4 mA ICP transducer input is also provided. Input gain is set by switches, in steps of 20 dB, up to 60 dB. The post-filter gain and offset stage provides variable gain from 0.1 to 12x and ±6 V offset. Input power can be 10-30 V ±15 V or 5 V DC, and power consumption is typically 5 W.

For further information contact Kemo Ltd, 3 Brook Court, Blakeney Road, Beckenham, Kent BR3 1HG Tel: 0181 658 3838 Fax: 0181 658 4084 www.kemo.com.

VIPAC ENGINEERS & SCIENTISTS

Vipac launches AutoSEA2

Vipac Engineers & Scientists Ltd and its software engineering arm Vibro-Acoustic Sciences Ltd have announced the release of AutoSEA2, the latest software program in noise and vibration prediction.

AutoSEA2 is the second generation of AutoSEA, a high quality software program introduced in the early 90s using Statistical Energy Analysis (SEA) to approach noise and vibration problems in a variety of industries. Prior to the introduction of AutoSEA, NVH problems were frequently left until physical prototypes were built and tested, often causing extensive redesign and increasing overall project costs. AutoSEA was the first fast and easy-to-use SEA tool with a simple graphical interface to model noise and vibration problems earlier in the design process, eliminating costly mistakes well before prototypes are built or tooling begins. The software can be run effectively on a laptop computer so that it is now possible for the noise and vibration engineer to sit in a design meeting and provide immediate feedback on the spot. This is what Vibro-Acoustic Sciences calls the new Design Evaluation process, responding to the criticism of current CAE methods, such as Finite Element Analysis, where the results of analysis are said to be too late and too complex to aid the designer.

AutoSEA2 uses the probabilistic engineering methods of SEA and room acoustics. The statistical approach has – in comparison to the conventional *deterministic* SAE software – the major advantage of much simpler model substructuring, making the process very fast. Furthermore, the statistical analysis method predicts the expected mean noise and vibration behaviour efficiently averaged over uncertainty in the as-built system dynamics/design details at the concept stage.

AutoSEA software is already widely used in the aerospace, automotive, marine and railway industries – with many successful validation studies published in the open literature.

Further enquiries can be directed to Anton Molnar, Vipac Instrumentation Division, Vipac Engineers & Scientists Ltd, 275 Normanby Road, Port Melbourne, Victoria 3207, Australia Tel: (03) 9647 9700 Fax: (03) 9646 3427 www.vipac.com.au

CEL INSTRUMENTS LTD

Meters for Hazardous Atmospheres

CEL Instruments Ltd, a member of the Casella Group, announces the availability of hand-held and bodily-worn noise monitoring instruments with intrinsic Safety Certification. The instruments are classified to Eex ia IIC T4 under Certificate Number Ex97E2110X. This CENELEC approval for use in hazardous atmospheres is recognised throughout the European Union and is accepted in many other parts of the world.

Equipment which is certified to this level can be used in atmospheres that normally contain gas as well as at locations where gas is only intermittently present. The level of safety protection provided in the design will allow measurements to be made in atmospheres containing hydrogen and acetylene which are the most dangerous gases, in addition to other less flammable hydrocarbons.

There are four model types available; two Integrating Sound Level Meter types and two Personal Noise Dosimeters. The instruments use the same rugged protected body which can be fitted with two different microphone types that configure the instrument either for bodily-worn or hand-held use. Two different memory programs are available to satisfy the requirements of the quick survey application as well as the more detailed data recording use.

The instruments use an icon-based keypad for easy-to-understand operation. Measured as parameters for all meters include the Daily Personal Exposure Level, Maximum Level, Time-Average Sound Level and Peak Noise Level together with calendar date and time.

The CEL-462 and 466 instruments also store extensive time-history information which can be downloaded to a PC using the supplied dB12 SoundTrack program which includes graphing utilities.

All four instruments have Configuration File memories which will store a user-defined set-up, additional to the pre-configured set-ups for data collection to both ISO and OSHA noise exposure standards.

For further information contact: CEL Instruments Ltd, 35-37 Bury Mead Road, Hitchin, Herts SG5 1RT Tel: 01462 422411 Fax: 01462 422511 e-mail: sales@cel.ltd.uk

CEL Instruments is a Key Sponsor of the Institute.

THE NOISE CONTROL CENTRE

Melatech

Melatech, the low density, semi-rigid foam sound absorbent material available from The Noise Control Centre is now available in a range of colours.

Since Melatech is easy to cut and mould into any shape or dimension, it is suitable for a multitude of acoustic applications. It now can be provided in a range of colours infused into the body of the material to provide solid and consistent colour throughout. Additionally it can be treated to have hydrophobic properties to control moisture intake and it comes in a range of pre-machined profiled faces for aesthetic or application specific situations.

For further information contact: The Noise Control Centre, Toutley Road, Wokingham, Berkshire RG41 5QN Tel: 0118 977 4212 Fax: 0118 977 2536.

The Noise Control Centre is a Sponsor Member of the Institute.

News

CEP ACOUSTICS LTD

Coustone Acoustic Solutions

The CEP Group have recently acquired the assets and intellectual property rights of Sound Absorption Ltd and formed a new company, CEP Acoustics Limited, to further develop Coustone, the specialist durable acoustic cladding, and expand into new market sectors where the acoustic performance of Coustone provides a unique solution to control the increasingly serious environmental problem of noise. Coustone unites high sound absorption of up to 0.95 NRC and sound insulation properties up to 46.1 dB in a product which is highly durable and impact resistant, making it suitable for a whole range of applications.

Constructed from resin bonded flint with scientifically designed air cavities, Coustone is available in 3 base colours and 8 architectural colours (most RAL colours can be provided to special order), and in two panel sizes, standard 500 x 500 x 28 mm and light 600 x 600 x 14 mm. In addition Coustone is manufactured under ISO 9002 quality assurance, and meets the requirement for Class 1 spread of flame, and also the requirements for part 6 Fire Propagation, and is designated by the Building Regulations as Class 0.

CEP Acoustics offer a free technical service and using specialist software are able to provide budget proposals based on specified reverberation times, ensuring the desired solution whatever the problem.

Further information from CEP Acoustics Ltd, Falcon Court, Clayton Business Park, Clayton-Le-Moors, Accrington BB5 5JD Tel: 01254 391111 Fax: 01254 232020.

HOWICK JOINERY (REDHILL) Ltd

Multifold Folding Sliding Partitions

As a result of recent sound insulation tests carried out by Sound Research Laboratories at their Suffolk testing centre in Sudbury, Howick can now certify their acoustic value on the 3 types of M70 Multifold Folding Sliding Partitions, with specified dB ratings of 35, 39 and 42 dB.

The M70 is the most popular model of their range, and is suitable for schools, offices, hotels and conference rooms, in fact anywhere where multiple usage and fast changing of room layouts is required.

For more information about the Multifold M70 contact: Howick Joinery (Redhill) Ltd, 3 Ormside Way, Holmethorpe Industrial Estate, Redhill, Surrey RH1 2LW Tel: 01737 778665 Fax: 01737 780733.

FIRESPRAY INTERNATIONAL LTD

New Audex Brochure

Following the acquisition of Mandoval Coatings Ltd's specialist coatings and OEM business interests in November 1998, Firespray International Ltd have now launched the first of what is to become a range of comprehensive product data guides.

The inaugural publication describes the Firespray Audex range of decorative acoustic coatings.

In addition to reflecting the thirty-year pedigree that the product range has earned with many specifiers around the world, the brochure also introduces some all-new system formulations originally developed in 1997, but until now not available.

Audex acoustic coatings enable effective levels of sound absorption to be achieved across the entire frequency range, on almost every conceivable type of commonly used building material – from plaster and plasterboard to sand/cement renders, concrete, brickwork and blockwork.

The Audex System now incorporates a range of products sufficiently versatile to be applied to ceilings and walls in most interior and semi-exposed locations, even within environments with fluctuating high humidity levels and where high thermal conductivity and acoustic control are prerequisites.

For further details contact: Stephen Bush, Firespray International Ltd, Douglas Drive, Catteshall Lane, Godalming, Surrey GU7 1JX Tel: 01483 424712 Fax: 01483 413914.

Firespray International Ltd is a Sponsor Member of the Institute.

EUREMICA LTD

Larson Davis Modified Noisebadges for DERA

DERA, Systems Integration Department at Farnborough have purchased eight more Larson Davis Model 705 Noisebadges which are then modified by adding 'Knowles' miniature microphones. The model 705 is a profiling dosimeter and has proved ideal for DERA's work with the military for aspects of personal monitoring within the RAF. Royal Navy and Army, measuring pilots of fast jets, helicopters and transport aircraft. More interestingly, DERA have modified these instruments with miniature microphones so that they can be fitted into the headsets of pilots to more accurately measure actual noise exposure during flights. Each person is fitted with two model 705's – one inserted into the head,set and the other with a standard 3/8" microphone fitted onto the collar as normal. This in turn allows the two readings to show the differing noise levels of the aircraft as well as actual noise to personnel during flights.

The Model 705 weighs 3oz and is complete with 'Windows' software for setting up, downloading collected data and then presenting colour graphs of Time History and showing L_{eq}, L_{max} and Peak. The very small size and light-weight of the 705 are stated to be perfect for these conditions.

For further information on this and other Larson Davis products, please contact David Neil at EUREMICA Ltd, Instrument House, Morgan Drive, Guisborough, Cleveland TS14 7DG Tel: 01287 204020 Fax: 01287 204021 email Sales@Euremica.Com

IAC LTD

Acoustic Louvres and Chiller Plant

IAC Ltd was commissioned to supply an unusual three-sided enclosure around a chiller in a new development at Basingstoke in order to restrict the noise levels inside nearby offices to NR37.

An enclosure, constructed of special elliptical louvre blades formed in galvanised steel and measuring 9 m x 5.5 m x 3 m, was designed and erected in five weeks. Noise readings confirmed that the target had been achieved.

Further information from Simon White, IAC, Tel: 01962 873000 Fax: 01962 873102.

IAC Ltd is a Sponsor Member of the Institute.

CEL LTD

Noise Monitoring at a Tunnel Site

A tunnel is being built under the Thames to extend the Docklands Light Railway towards the Millennium Dome at Greenwich. The current project reroutes the DLR track at Island Gardens.

Noise levels are reported daily to officers of Tower hamlets Council. A CEL500 series Real-Time Sound Level Analyser measures 5 minute L_{eq}s in one-hour blocks.

The instrument is connected via a 63 m cable to an adjacent office block. A consultant downloads a day's data and processes it with CEL's dB1 Windows™ software for onward transmission.

For further information contact: CEL Instruments Ltd, 35-37 Bury Mead Road, Hitchin, Herts SG5 1RT Tel: 01462 422411 Fax: 01462 422511 e-mail: sales@cel.ltd.uk

CEL Instruments is a Key Sponsor of the Institute.

LOCHARD PTY LTD

Airport Monitoring System

Lochard Pty Ltd has won the BAA contract for replacement of the Noise and Track Keeping Systems for London's Heathrow, Gatwick and Stansted Airports.

The system to be installed will use the industry's standard Global Environment Management System. A fourth system at National Air Traffic Services will provide a high speed data collection facility.

For further information contact Phil Stollery, Lochard Pty Ltd, Queen Street, Leeds LS10 1SL Tel: 0113 277 0973 Fax: 0113 276 0452 e-mail info@lochard.com.au web www.lochard.com.au.

Items for inclusion in this section should be sent to John Sargent MIOA, Oak Tree House, 26 Stratford Way, Watford WD1 3DJ ❖

Responses to Ian Watson's letter on Inaudibility in Acoustics Bulletin November/December 1998

From S A Williamson MIOA and others
The Editor
Dear Sir,

We refer to the letter regarding Inaudibility in the November/December 1998 issue of the Institutes Journal and offer the following response.

When properly applied inaudibility is not a flawed criteria but the argument proposed against it by the author of the letter is.

There are, as the author stated, many forms of noise pollution which affect peoples lives. What he did not say is that there are almost as many criteria used in the attempt to determine nuisance or amenity as there are noise sources. This comes about because of the need to consider all aspects of noise. The selection of appropriate criteria will remain a subject for debate with or without the use of the word inaudible.

So what is in a word? The so-called inaudibility criterion has been used successfully and without significant complaint for years. Indeed the concept of inaudibility has been recommended in both planning advice and in legislation as far back as the Control of Pollution Act in 1974. Of course, it was not called inaudibility at that time; the reference was to the hours of operation. A different use of words but the effect is the same; it does not matter whether we are talking about a construction site, a factory or some other type of operation, if it is not operating its operations will be inaudible.

So why do we speak about the inaudibility criterion? Simple really; without it, it would be necessary to refuse many late licenses and planning applications for certain types of new development ie those involving music. Inaudibility is used, not to inhibit or thwart development but to allow it to take place in circumstances which would otherwise be unacceptable.

The important thing is that the criterion is chosen at the appropriate time and applied correctly for relevant reasons. It is disingenuous of the author to mention motor cars and phones although he does mention planes and there are airports whose hours of operation are restricted which results in no planes so that there is no noise. Music however, is perhaps the most appropriate use of the criterion since it is so easily controlled; all music systems being provided with a volume control. The author seems to suggest that the WHO level of 30 dBA for steady continuous noise would be appropriate, but we cannot agree with this. The bass beat from music cannot be described as steady noise and at levels of 30 dBA the words could be clearly discernible to the affected party. Indeed because the music contains coherent information in the beat, the melody and the words it is impossible to ignore intrusive music even at very low levels.

As for the idea that it causes difficulty, we can only say that if it were easy there would be no need for consultants. Inaudibility can be achieved in most circumstances if the will is there, if it is clearly not achievable then the development should either not happen or its hours should be restricted.

The appropriate use of inaudibility to control music has been successful in many Local Authorities. It has not, so far as we are aware, resulted in any unnecessary court cases, it has protected the public and allowed developments to take place which would not otherwise have been possible. It does require a lot of work by the Environmental Health Officers who deal with noise problems because the intention when levels are set is not just to make sure that the music is inaudible (it is easy to turn down the volume control) but to try and get the maximum possible level for the operator. With this willingness and effort the criterion is fair to all parties and strikes an appropriate balance between the needs of the community and the rights of individuals to enjoy their property.

In Local Government an Environmental Health Officer is employed by the community and serves the needs of all, taking a fair and non-partisan approach to all problems within the framework of a given set of rules. Inaudibility when appropriately applied is a rule that can and has served the community well but as with all criteria there are some for whom the extra effort it requires is perceived as a cost too much. This should not be reason to lose sight of the benefits of Inaudibility.

S A Williamson MIOA
A Somerville MIOA
J Stirling FREHIS
D Paris MIOA
B Friel MIOA
Dr B McKell MIOA
Professor R J M Craik FIOA
D MacKenzie MIOA
A McDiarmid MIOA
T Stirling AMIOA

From Michael Stewart MIOA
The Editor
Dear Sir

In the 1970s and 1980s Environmental Health Officers (EHOs) were trying to deal with a rising tide of complaints from amplified music [1]. The criterion in use at the time was from the Wilson report which stated that a noise level (L_{A10}) of 35 dB should not be exceeded within any noise sensitive property. This is not much higher than an L_{Aeq} of 30 dB (based on the World Health Organisation (WHO) recommendation) which is the criterion Ian Watson thinks should be used for entertainment noise. However, as mentioned in [1], the background noise level is often much lower than this and there was clear evidence that many residents were dissatisfied even when the intrusive noise levels were below an L_{A10} 35 dB. The Wilson report level was clearly not correlating with subjective experience of nuisance. And therefore neither will the WHO levels that Ian Watson recommends. The WHO levels are much better suited to assessing disturbance due to transportation or mechanical services noise. Not to entertainment noise which annoys people more when at the same level as these other sources. There's little comfort in a consultant or

EHO saying to a suffering resident that the noise level is within statutory limits when they are clearly unhappy. That's just salt to the wounds. To deal with this problem, in 1980 Edinburgh District Council Environmental Services re-worded their recommendations to the Planning Department from:

'any amplified music and vocals shall be so controlled as not to exceed 35 dBA when measured in the nearest noise sensitive dwelling house'

to

'any amplified music or vocals shall be so controlled as to be inaudible within the nearest noise sensitive dwelling house'

This was accepted by the Planning Department for all new licensed premises. Was that fair?

There are various opinions on this so I would like to briefly review some of the main arguments for and against. The main advantages of the inaudibility criterion are that it is easier to understand for non acousticians. 'If you can hear it, it's unacceptable' is a lot easier for your Honour to understand than the technicalities of an L_{A10} or an L_{Aeq} which are difficult for non acousticians to get a subjective feel for. Also it gives more clout to Environmental Health Officers who had often found themselves having to tell complainants that the noise they were suffering was within accepted criteria when they themselves considered the situation unacceptable and would have been the first to complain if they lived there.

It accounts for low background noise levels in a way that the fixed level in the Wilson report never did. 35 dBA would be perceived as much more intrusive in a rural area where the background noise level is much lower than the same level in the city centre.

The obvious disadvantage is that it is not an objective criterion and this leaves acousticians – who generally prefer thinking in dBs – uncomfortable as they have to develop their own method of assessing whether a noise is going to be audible in a residence when called in to design the sound insulation of entertainment premises. Some authors have suggested ways of dealing with this by recommending a descriptor to pin down inaudibility to something objective [2]:

'The unweighted L_{90} ambient noise level to be measured in the 16 $^1/_3$ octave bands between 40 Hz and 1.6 kHz at the boundary of the nearest effected property in the absence of the disturbing noise. The unweighted L_{10} noise level to be measured in the same bands at the same measurement position with the disturbing noise present.

Subtraction of the L_{90} from the L_{10} value in each band shall not show a positive value in any $^1/_3$ octave band.'

This seems a perfectly reasonable guideline to work to when designing licensed premises to meet an inaudibility criterion. However, if non-experts found the sound levels in the Wilson report difficult to deal with, the above would be incomprehensible and therefore may not be suitable for use as a criterion. As the author says in earlier part of his paper: *'Courts and licensing committees are increasingly concerned as to whether occupants are actually being disturbed by noise which is directly attributable to the operation of licensed premises – not with some mysterious decibel level which they do not understand and usually do not want to know.'*

Also, some people (particularly owners of night clubs close to complainant's residences) unsurprisingly regard inaudibility as draconian and unreasonable. However, it is important to note that the criterion of inaudibility is vastly more stringent than the criterion it superseded so has the pendulum swung too far the other way? If you choose to live one floor above a pub with live music is it not reasonable to expect some noise? Perhaps you should, but how do you create a clear, simple, enforceable criterion if you try and shade the law so it can be applied in different ways for flats above pubs, suburban flats further away from night spots etc? That would be a nightmare for acousticians, EHOs and solicitors. Yes, perhaps the law can be hard on some places of entertainment close to residences but the boot was definitely on the other foot when the noise level from the Wilson report was the criterion.

Therefore my own recommendation would be that – in the absence of a criterion based on research into what is an acceptable level of non-intrusive noise – the inaudibility criteria is fair. Besides, an acceptable level of non-intrusive noise is unlikely to be much higher than *'barely audible'* at low frequency where the main problems of amplified music tend to be.

References

[1] R J M CRAIK & J R STIRLING, Amplified Music as a Noise Nuisance, Applied Acoustics 19 (1986) 335-356

[2] K DIBBLE, Inaudibility – So What Is New? Proc IOA, Vol 10, Part 4, (1988)

Napier University,
Edinburgh

Corrections

Measurement of an Effective Absorption Coefficient below 100 Hz by X Zha, H V Fuchs, C Nocke & X Han
Acoustics Bulletin vol 24 no1 January / February 1999, pp 5-10.

Page 5 column 2, paragraph 2, after the word *measured* the following should have been added

'This procedure has been vaguely proposed in L Cremer & H Cremer, 'About the theoretical derivation of the reverberation laws – part 2' (in German), Akust Z, 2, 296-302.

Page 7 bottom of column 2, the word 'knot' should have been replaced by 'node".

Apologies for these errors
Editor