



# Institute of Acoustics

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## **Technical Contributions**

Digital Recording Techniques in Acoustics

*John Watkinson*

A New Beampattern Design Method for Sonar Arrays

*Peter F Dobbins MIOA & Gary J Heald MIOA*

A Practical Guide to the Selection of Glazing for

Acoustic Performance in Buildings

*Cliff Inman FIOA*

## **The Acoustics World**

Physics and Techniques of Ultrasound in Moscow

*N N Shibanova*

## **Technical Note**

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**BULLETIN**

Volume 19 No 5  
September - October 1994

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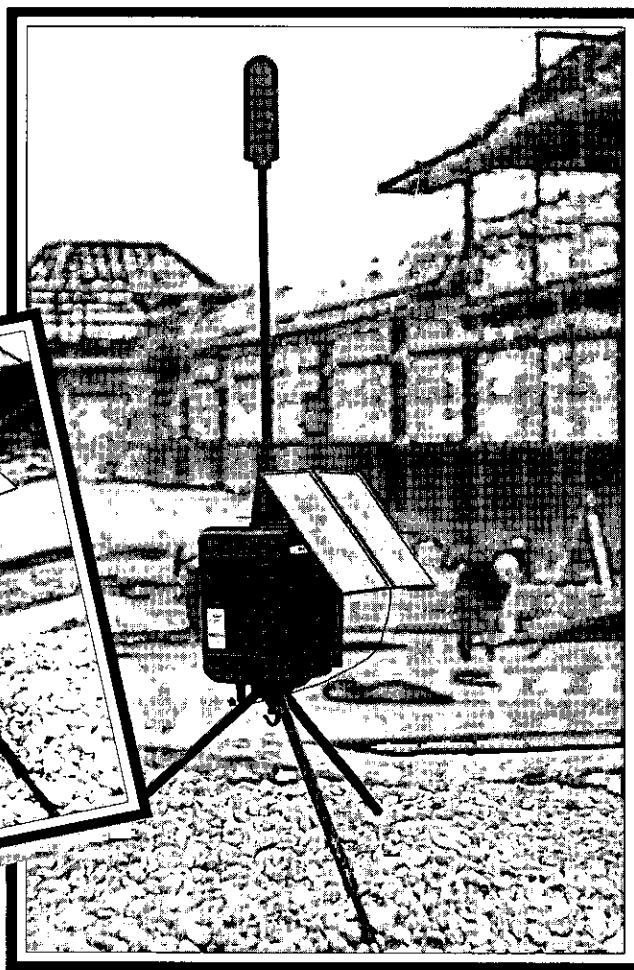
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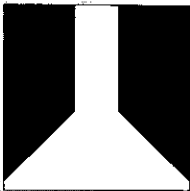


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The Institute of Acoustics was formed in 1974 through the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is the premier organisation in the United Kingdom concerned with acoustics. The present 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.

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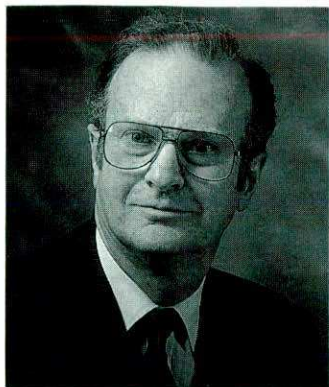
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*Dear Fellow Member*

*This is an opportunity for me to welcome three new Sponsoring Organisations who were elected at the last Council meeting. These are Ecomax Acoustics, Industrial Acoustics Company and the National Physical Laboratory.*

*You may know that during 1994 a Hong Kong Institute of Acoustics was formed along lines similar to our Institute and with equivalent membership standards. Council welcomes this new body and wishes it well in the run up to 1997. Our branch in Hong Kong is expected to hand over the reins to the new Institute which will come of age in 1997 when it will host the next WESTPRAC.*

*Interviews for Chartered Engineers took place in June and July and more recently interviews for Incorporated Engineers and I congratulate the successful candidates for the latter whose details are contained in this issue. The next round of interviews takes place in November and I would encourage interested members to keep the applications flowing in.*

*You may recall that Peter Wheeler first raised the subject of Continuing Professional Development (CPD) in the Bulletin not long ago. Well, a CPD working Party has met twice this year and I attended their last meeting. A discussion document should be published in the new year; we hope there will be a lively debate about the subject over the first half of 1995 and where possible it is hoped that branches will arrange meetings to stimulate discussion of the subject. It is generally expected that an Institute CPD scheme will be started on a voluntary basis in 1996. Comments on CPD in general and the scheme for the IOA in particular are always welcome.*

*Donning my bat as Chairman of Medals and Awards Committee, I would ask for further nominations for the Simon Alport Prize. You will remember that this prize is awarded to a young acoustician who, in the opinion of the judges has published the best recent paper describing work that involves the application of computers to any branch of acoustics.*

*For many years my conference attendances have been strictly limited; for the two years of my term as President this is all going to change. Reproduced Sound 10, the Autumn Conference, the Underwater Acoustic Scattering Conference in Weymouth, the Opera and Concert Hall Conference in February, Sonar Transducers '95 in Birmingham and Acoustics '95 in Liverpool all feature in my diary for the next eight months. I look forward to meeting many of you at these events.*

*Sincerely yours*

A handwritten signature in cursive script that reads "Alex Burd". The ink is dark and the signature is fluid.

**Alex Burd**

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# DIGITAL RECORDING TECHNIQUES IN ACOUSTICS

John Watkinson

## Introduction

One of the most challenging aspects of acoustics is the extremely wide range of applications which it embraces. Sound is used for entertainment, dramatic effect, communication, warnings and echo location and we prize these applications highly and research ways of making them more effective. Unwanted sound is also a by-product of industry, means of transport or simply bad plumbing and we then strive in the opposite direction to eliminate it or the unsuppressed vibrations which often cause it. There is possibly no other discipline in which as much effort is devoted to eliminating the product as to creating it.

By definition sound is a transient phenomenon, and except in rare cases such as airframe fatigue, sound does not leave any evidence. Our understanding of acoustics was enhanced dramatically by the development of means to record sound and vibration waveforms so that they could be repeated at will for study. Very few branches of acoustics have escaped the requirement to record such waveforms and as our analysis techniques have become more sophisticated this has placed greater demands on the quality of reproduction of our recording technology.

Whilst modern analog recording equipment may look sleeker than its ancestors, the principles employed remain the same, but it is now a mature technology. All of the great breakthroughs have been made, and the state of the art advances ever more slowly following a law of diminishing returns.

The main weakness of analog recording is that within the allowable bandwidth, any waveform is valid. If the speed of the medium is not constant, one valid waveform is changed into another valid waveform; a timebase error cannot be detected in an analog system. In addition, a voltage error simply changes one valid voltage into another; noise cannot be detected in an analog system. It is a characteristic of analog systems that degradations cannot be separated from the original signal, so nothing can be done about them. Conventional biased analog recording has poor performance at low frequencies, and frequency modulation (FM) was developed to allow a response down to DC. However, the speed instabilities of the tape are demodulated and restrict the signal to noise ratio achievable.

## What is Digital Recording?

For the digital recording of analog waveforms there is one system, known as Pulse Code Modulation (PCM) which is in virtually universal use. Figure 1 shows how PCM works. The time axis is represented in a discrete, or stepwise manner and the waveform is carried by measurement at regular intervals. This process is called sampling and the frequency with which samples are taken is called the sampling rate or sampling frequency  $F_s$ . The sampling rate is generally fixed and every effort is made to rid the sampling clock of jitter so that every sample will be made at an exactly even time step. If there is any subsequent timebase error, the instants at which samples arrive will be changed but the effect can be eliminated by

storing the samples temporarily in a memory and reading them out using a stable, locally generated clock. This process is called timebase correction and all properly engineered digital systems must use it. Clearly timebase error is not reduced; it is totally eliminated. As a result there is little point measuring the wow and flutter of a digital recorder; it doesn't have any.

All analog signal sources from microphones, hydrophones, accelerometers and so on have a frequency response limit, as indeed do our ears. When a signal has finite bandwidth, the rate at which it can change is limited, and the way in which it changes becomes predictable. When a waveform can only change between samples in one way, it is then only necessary to carry the samples and the original waveform

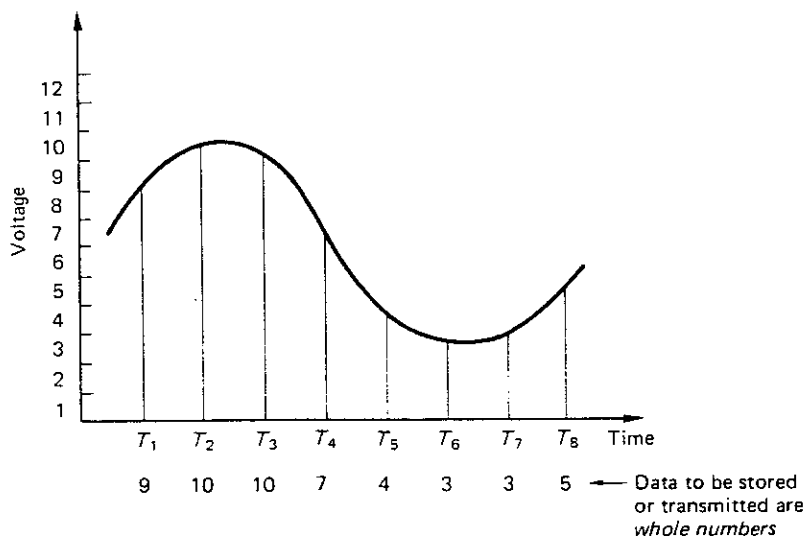


Fig. 1. In pulse code modulation (PCM) the analog waveform is measured periodically at the sampling rate. The voltage (represented here by the height) of each sample is then described by a whole number. The whole numbers are stored or transmitted rather than the waveform itself.

can be perfectly reconstructed from them.

Figure 1 also shows that each sample is also discrete, or represented in a stepwise manner. The length of the sample, which will be proportional to the voltage of the input waveform, is represented by a whole number. This process is known as quantizing and results in an approximation, but the size of the error can be controlled until it is negligible. The advantage of using whole numbers is that they are not prone to drift. If a whole number can be carried from one place to another without numerical error, it has not changed at all. By describing instrumentation waveforms numerically, the original information has been expressed in a way which is better able to resist unwanted changes.

Essentially, digital recording carries the original waveform numerically. The number of the sample is an analog of time, and the magnitude of the sample is an analog of the signal voltage. As both axes of the digitally represented waveform are discrete, the waveform can be accurately restored from numbers as if it were being drawn on graph paper. If we require greater accuracy, we simply choose paper with smaller squares. Clearly more numbers are then required and each one could change over a larger range.

## The Advantages of Digital Recording

There are two key advantages offered by digital instrumentation recording, but it is not possible to say which is the most important, as it will depend on one's standpoint:

- a) The quality of reproduction of a well engineered digital recording system is independent of the medium and depends only on the quality of the conversion processes.
- b) The conversion of waveforms to the digital domain allows tremendous opportunities which were denied to analog signals.

Someone who is only interested in technical quality will judge the former the most relevant. If good quality converters can be obtained, all of the shortcomings of analog recording can be eliminated to great advantage. One's greatest effort is expended in the design of converters, whereas those parts of the system which handle data need only be workmanlike. Wow, flutter, particulate noise, print-through, dropouts, modulation noise, HF squashing, azimuth error, inter-channel phase errors are all eliminated. When a digital recording is copied, the same numbers appear on the copy: it is not a dub, it is a clone. If the copy is indistinguishable from the original, there has been no generation loss. Digital recordings can be copied indefinitely without loss of quality.

Once a waveform is expressed in the digital domain, it becomes data, and as such is indistinguishable from any other type of data. Systems and techniques developed in other industries for other purposes can be used

for audio. Computer equipment is available at low cost because the volume of production is far greater than that of instrumentation recorders. Disk drives and memories developed for computers can be put to use in new applications. A word processor adapted to handle samples of a sound or vibration waveform becomes a workstation. There seems to be little point in waiting for a tape to wind when a disk head can access data in milliseconds. The difficulty of locating a significant event by spooling tape is eliminated when it can be located by viewing the waveform on a screen or, in the case of audio, by listening at any speed to samples retrieved from a memory.

## Uses of RAM

Figure 2 shows the outline of a RAM (Random Access Memory) recorder. What the device does is determined by the way in which the RAM address is controlled. If the RAM address increases by one every time a sample from the ADC is stored in the RAM, a recording can be made for a short period until the RAM is full. The recording can be played back by repeating the address sequence at the same clock rate but reading the memory into the DAC. The result is generally called a sampler. By running the replay clock at various rates, the pitch and duration of the reproduced sound can be altered. Samplers will be restricted to a fairly short playing time, although this can be extended using data reduction where appropriate. Certain oscilloscopes have waveform samplers incorporated which allows a conventional CRT to act like a storage oscilloscope.

If the RAM is used in a different way, it can be written and read at the same time. The device then becomes a delay. Controlling the relationship between the addresses then changes the delay. The addresses are generated by counters which overflow to zero after they have reached a maximum count. As a result the memory space appears to be circular as shown in Figure 3. The read and write addresses are driven by a common clock and chase one another around the circle. If the read address follows close behind the write address, the delay is short. If it just stays ahead of the write address, the maximum delay is

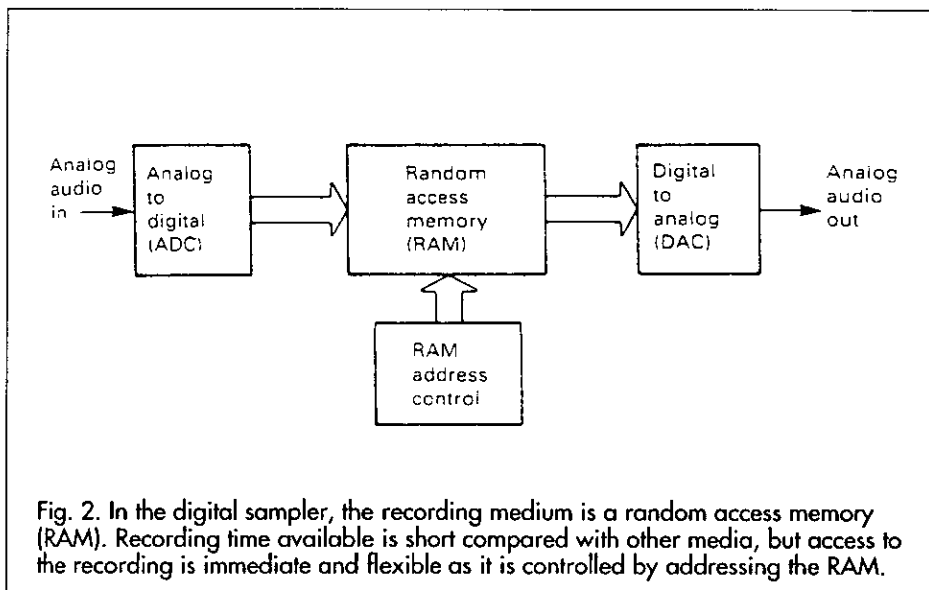


Fig. 2. In the digital sampler, the recording medium is a random access memory (RAM). Recording time available is short compared with other media, but access to the recording is immediate and flexible as it is controlled by addressing the RAM.

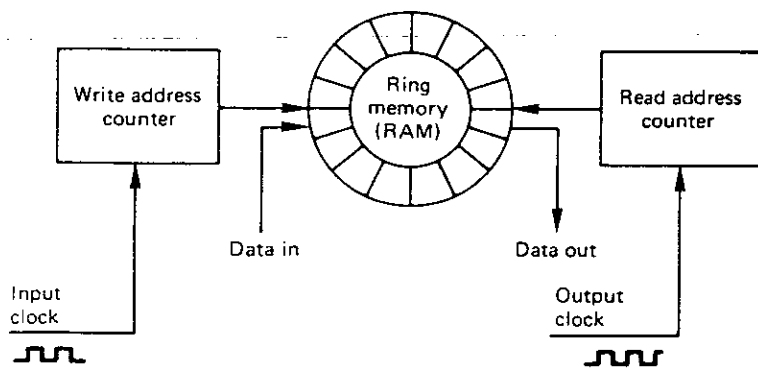


Fig. 3. If the memory address is arranged to come from a counter which overflows the memory can be made to appear circular. The write address then rotates endlessly, overwriting previous data once per revolution. The read address can follow the write address by a variable distance (not exceeding one revolution) and so a variable delay takes place between reading and writing.

reached. Programmable delays are useful in auditoria to align the sound from various loudspeakers.

When samples are converted, the ADC must run at a constant clock rate and it outputs an unbroken stream of samples. Time compression allows the sample stream to be broken into blocks for convenient handling. Figure 4 shows an ADC feeding a pair of RAMs. When one is being written by the ADC, the other can be read, and vice-versa. As soon as the first RAM is full, the ADC output switched to the input of the other RAM so that there is no loss of samples. The first RAM can then be read at a higher clock rate than the sampling rate. As a result the RAM is read in less time than it took to write it, and the output from the system then pauses until the second RAM is full. The samples are now time compressed. Instead of being an unbroken stream which is difficult to handle, the samples are now arranged in blocks with convenient pauses in between them. In these pauses numerous processes can take place. A rotary head recorder might

switch heads; a hard disk might move to another track. In all types of recording, the time compression of the signal allows space for synchronising patterns, subcode and error correction words to be recorded.

Subsequently, any time compression can be reversed by time expansion. Samples are written intermittently into a RAM at the incoming clock rate, but read out continuously at the standard sampling rate. The time expansion stage can be combined with the timebase correction stage so that speed variations in the medium can be eliminated at the same time. The use of time compression is universal in digital instrumentation recording. In general the *instantaneous* data rate at

the medium is not the same as the rate at the converters, although clearly the average rate must be the same. In practical recorders some RAM will always be present for the purposes of time compression and also to provide delay on replay to allow the error correction circuits time to operate. In logging recorders used to measure noise levels over extended periods, only the low-powered RAM need be active most of the time. When the RAM is nearly full of data, these can be transferred to a disk drive which is only powered for the duration of the transfer.

## Synchronisation

It is frequently necessary for a digital recorder to be able to play back locked to an external sampling rate reference so that the data rate can be determined by the capabilities of the analysis system.

Figure 5 shows how this mechanism works. The timebase expansion is controlled by the external reference

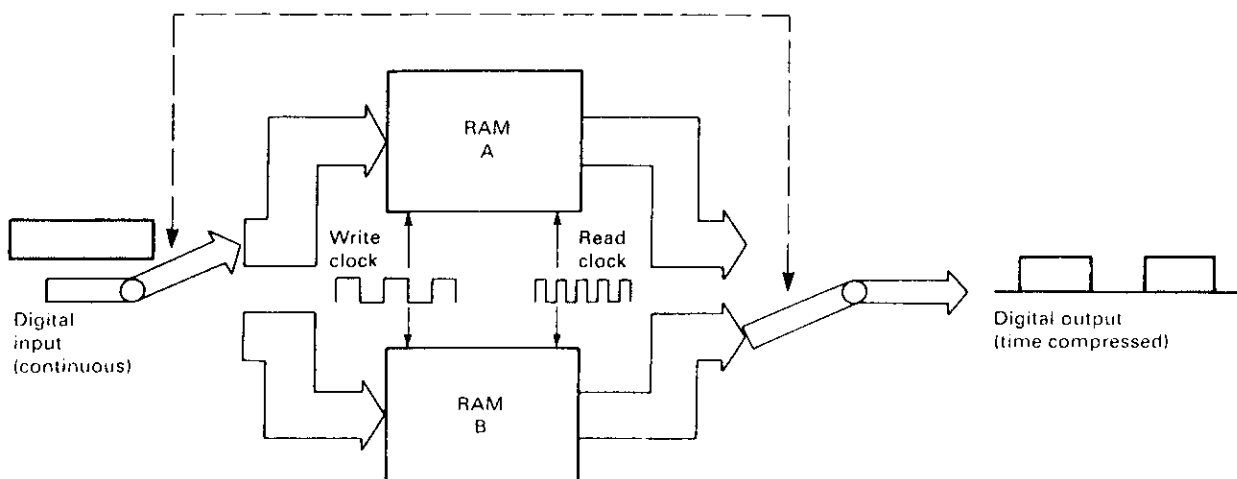


Fig. 4. In time compression, the unbroken real-time stream of samples from an ADC is broken up into discrete blocks. This is accomplished by the configuration shown here. Samples are written into one RAM at the sampling rate by the write clock. When the first RAM is full, the switches change over, and writing continues into the second RAM whilst the first is read using a higher-frequency clock. The RAM is read faster than it was written and so all the data will be output before the other RAM is full. This opens spaces in the data flow which are used as described in the text.

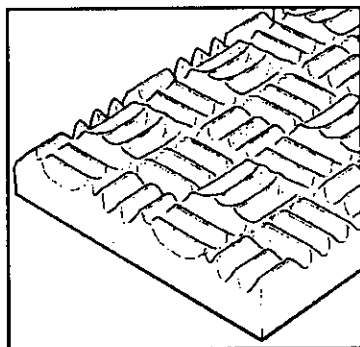
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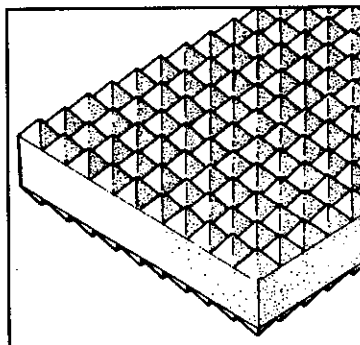
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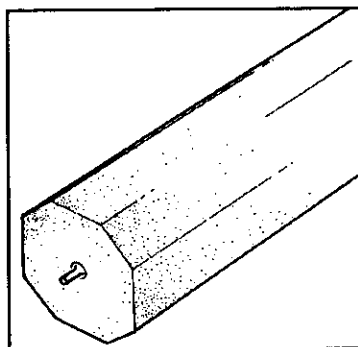
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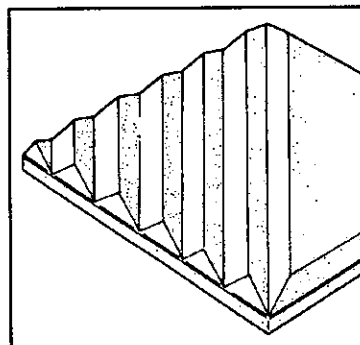
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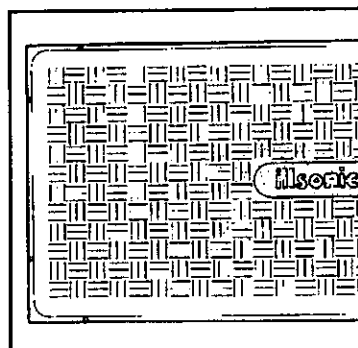
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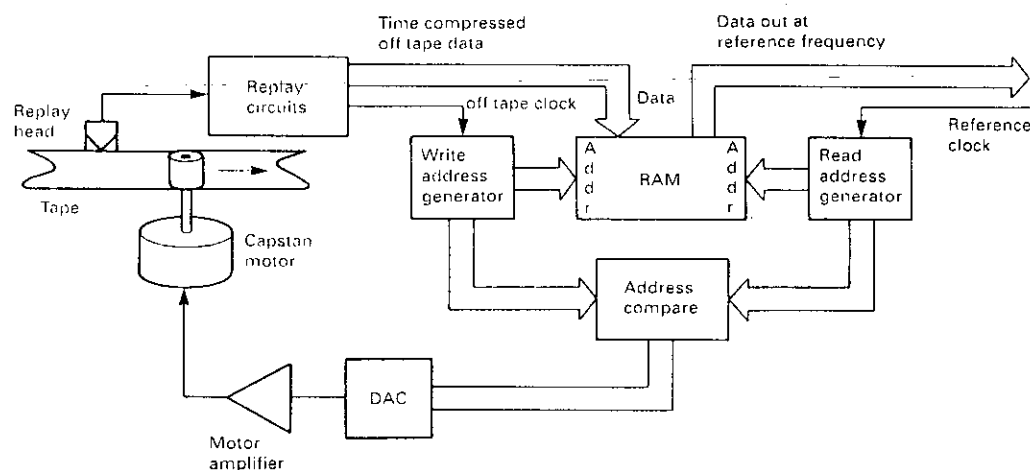


Fig. 5. In a recorder using time compression, the samples can be returned to a continuous stream using RAM as a timebase corrector (TBC). The long-term data rate has to be the same on the input and output of the TBC or it will lose data. This is accomplished by comparing the read and write addresses and using the difference to control the tape speed. In this way the tape speed will automatically adjust to provide data as fast as the reference clock takes it from the TBC.

which becomes the read clock for the RAM and so determines the rate at which the RAM address changes. In the case of a digital tape deck, the write clock for the RAM would be proportional to the tape speed. If the tape is going too fast, the write address will catch up with the read address in the memory, whereas if the tape is going too slow the read address will catch up with the write address. The tape speed is controlled by subtracting the read address from the write address. The address difference is used to control the tape speed. Thus if the tape speed is too high, the memory will fill faster than it is being emptied, and the address difference will grow larger than normal. This slows down the tape.

In multitrack recorders, the various tracks can be synchronised to sample accuracy so that no timing or phase errors can exist between the tracks. This is particularly advantageous in the case of recordings from, for example, hydrophone arrays. Extra transports can be slaved to the first to the same degree of accuracy if more tracks are required. In stereo audio recorders image shift due to phase errors is eliminated.

In order to replay without a reference, perhaps to provide an analog output, a digital recorder generates a sampling clock locally by means of a crystal oscillator. Provision will be made on professional machines to switch between internal and external references.

## Error Correction and Concealment

In a recording of binary data, a bit is either correct or wrong, with no intermediate stage. Small amounts of noise are rejected but, inevitably, infrequent noise impulses cause some individual bits to be in error. Drop-outs cause a larger number of bits in one place to be in error. An error of this kind is called a burst error. Whatever the medium and whatever the nature of the mechanism responsible, data are either recovered correctly, or suffer some combination of bit errors and burst errors. The severity of a bit error depends upon which bit of the sample is involved. If the LSB of one sample was in error in a high amplitude waveform, the effect would be totally

masked and of no consequence. Conversely, if the MSB of one sample was in error in a quiet passage, the resulting transient would be unacceptable. Clearly a means is needed to correct errors from the recording medium.

In binary, a bit has only two states. If it is wrong, it is only necessary to reverse the state and it must be right. Thus the correction process is trivial and perfect. The main difficulty is in identifying the bits which are in error. This is done by coding the data by adding redundant bits. Adding redundancy is not confined to digital technology, airliners have several engines and cars have twin braking systems. Clearly the more failures which have to be handled, the more redundancy is needed. If a four engined airliner is designed to fly normally with one engine failed, three of the engines have enough power to reach cruise speed, and the fourth one is redundant. The amount of redundancy is equal to the amount of failure which can be handled. In the case of the failure of two engines, the plane can still fly, but it must slow down; this is graceful degradation. Clearly the chances of a two-engine failure on the same flight are remote.

The amount of error which can be corrected is proportional to the amount of redundancy. Within this limit, the samples are returned to exactly their original value. Consequently *corrected* samples are inaudible. If the amount of error exceeds the amount of redundancy, correction is not possible, and, in order to allow graceful degradation, concealment will be used. Concealment is a process where the value of a missing sample is estimated from those nearby. The estimated sample value is not necessarily exactly the same as the original, and so under some circumstances concealment can be audible, especially if it is frequent. However, in a well designed system, concealments occur with negligible frequency unless there is an actual fault or problem.

Concealment is made possible by re-arranging or shuffling the sample sequence prior to recording. This is shown in Figure 6 where odd-numbered samples are separated from even-numbered samples prior to recording. The odd and even sets of samples may be recorded

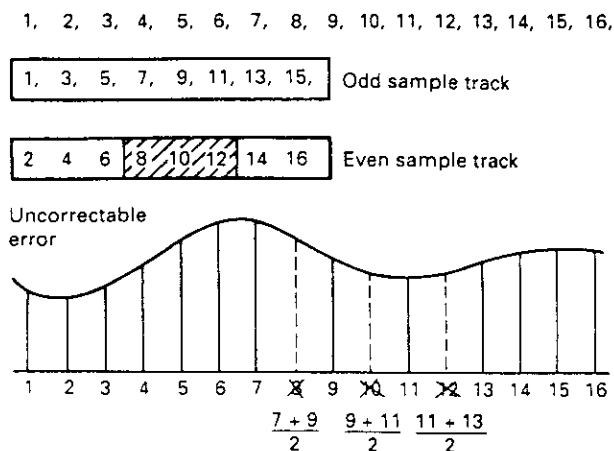


Fig. 6. In cases where the error correction is inadequate, concealment can be used provided that the samples have been ordered appropriately in the recording. Odd and even samples are recorded in different places as shown here. As a result an uncorrectable error causes incorrect samples to occur singly between correct samples. In the example shown, sample 8 is incorrect, but samples 7 and 9 are unaffected and an approximation to the value of sample 8 can be had by taking the average value of the two. This interpolated value is substituted for the incorrect value.

in different places, so that an uncorrectable burst error only affects one set. On replay, the samples are recombined into their natural sequence, and the error is now split up so that it results in every other sample being lost. The waveform is now described half as often, but can still be reproduced with some loss of accuracy. This is better than not being reproduced at all even if it is not perfect. Almost all digital waveform recorders use such an odd/even shuffle for concealment. Clearly if any errors are fully correctable, the shuffle is a waste of time; it is only needed if correction is not possible.

In high density recorders, more data are lost in a given sized dropout. Adding redundancy equal to the size of a dropout to every code is inefficient. Figure 7 shows that the efficiency of the system can be raised

a number of small errors whose size is exactly equal to the correcting power of the codes and the correction is performed with maximum efficiency.

The interleave, de-interleave, time compression and timebase correction processes cause delay and this is evident in the time taken before audio emerges after starting a digital machine.

The presence of an error correction system means that the audio quality is independent of the recording medium/head quality within limits. There is no point in trying to assess the health of a machine by listening to it, as this will not reveal whether the error rate is normal or within a whisker of failure. The only useful procedure is to monitor the frequency with which errors are being corrected, and to compare it with normal figures. Pro-

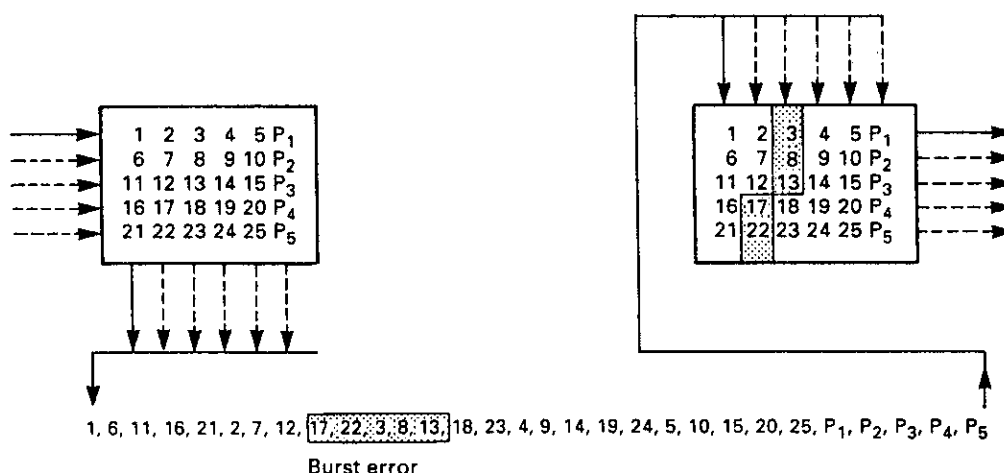


Fig. 7. Interleaving is essential to make error-correction schemes more efficient. Samples written sequentially in rows into a memory have redundancy P added to each row. The memory is then read in columns and the data sent to the recording medium. On replay the non-sequential samples from the medium are de-interleaved to return them to their normal sequence. This breaks up the burst error (shaded) into one error symbol per row in the memory, which can be corrected by the redundancy P.

fessional digital recording equipment should have an error rate display.

## Channel Coding

In most recorders used for storing digital information, the medium carries a track which reproduces a single waveform. Clearly data words representing audio samples contain many bits and so they have to be recorded serially, a bit at a time. Some media, such as hard disks only have one track active at a time, so it must be totally self contained. Other media have many parallel tracks. At high recording densities, physical tolerances cause phase shifts, or timing errors, between parallel tracks and so each track must still be self contained until the replayed signal has been timebase corrected.

Recording data serially is not as simple as connecting the serial output of a shift register to the head. In the two's complement scheme used for bipolar waveform coding, a common sample value is all zeros, as this corresponds to silence. If a shift register is loaded with all zeros and shifted out serially, the output stays at a constant low level, and constant magnetisation is recorded on the track. On replay there is nothing to indicate how many zeros were present, or even how fast to move the medium. Clearly serialised raw data cannot be recorded directly, they have to be modulated in to a waveform which contains an embedded clock irrespective of the values of the bits in the samples. On replay a circuit called a data separator can lock to the embedded clock and use it to separate strings of identical bits.

The process of modulating serial data to make it self-clocking is called channel coding. Channel coding also shapes the spectrum of the serialised waveform to make it more efficient. With a good channel code, more data can be stored on a given medium. Spectrum shaping is used in DAT to allow re-recording without erase heads.

## Hard Disk Recorders

The hard disk recorder stores data on concentric tracks which it accesses by moving the head radially. Clearly while the head is moving it cannot transfer data. Using

ADCs and RAM for time compression, a hard disk drive can be made into a waveform recorder.

Figure 8 shows the principle. The instantaneous data rate of the disk drive is far in excess of the sampling rate at the convertor, and so a large time compression factor can be used. The disk drive can read a block of data from disk, and place it in the timebase corrector in a fraction of the real time it represents in the audio waveform. As the timebase corrector steadily advances through the memory, the disk drive has time to move the heads to another track before the memory runs out of data. When there is sufficient space in the memory for another block, the drive is commanded to read, and fills up the space. Although the data transfer at the medium is highly discontinuous, the buffer memory provides an unbroken stream of samples to the DAC and so a continuous output waveform is obtained.

Recording is performed by using the memory to assemble samples until the contents of one disk block is available. This is then transferred to disk at high data rate. The drive can then reposition the head before the next block is available in memory.

An advantage of hard disks is that access to the recorded material is much quicker than with tape, as all of the data are available within the time taken to move the head.

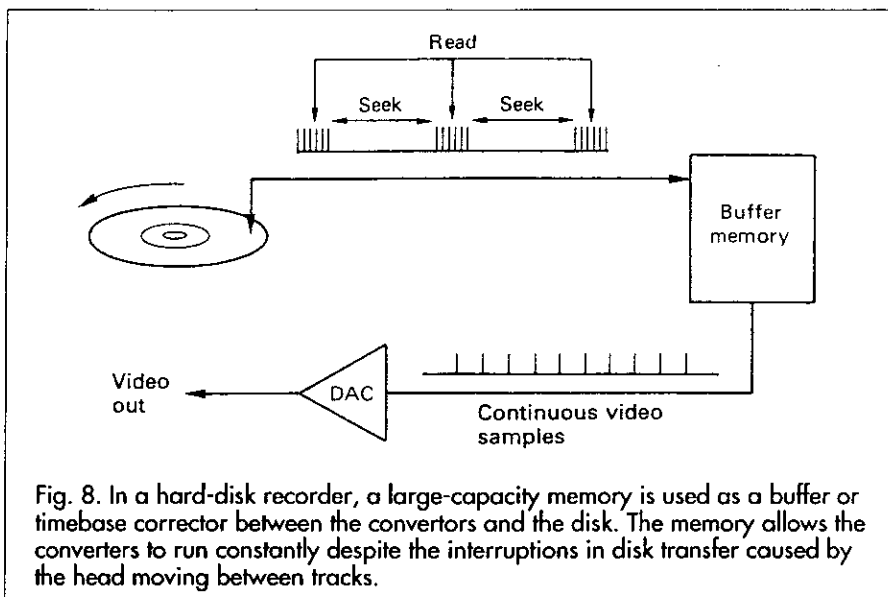
## Rotary Head Digital Recorders

The rotary head recorder borrows technology from video-recorders. Rotary heads have extremely high packing density: the number of data bits which can be recorded in a given space. In a digital recorder packing density directly translates into the playing time available for a given size of the medium.

In a rotary head recorder, the heads are mounted in a revolving drum and the tape is wrapped around the surface of the drum in a helix as can be seen in Figure 9. The helical tape path results in the heads traversing the tape in a series of diagonal or slanting tracks. The space between the tracks is controlled not by head design but by the speed of the tape and in modern recorders this space is reduced to zero with corresponding improvement in packing density.

The added complexity of the rotating heads and the circuitry necessary to control them is offset by the improvement in density. The discontinuous tracks of the rotary head recorder are naturally compatible with time compressed data. As Figure 9 illustrates, the audio samples are time compressed into blocks each of which can be contained in one slant track.

In a machine such as DAT (Rotary-head Digital Audio Tape) there are two heads mounted on opposite sides of the drum. One rotation of the drum lays down two tracks. Effective concealment can be had by recording odd numbered samples on one track of the pair and even numbered



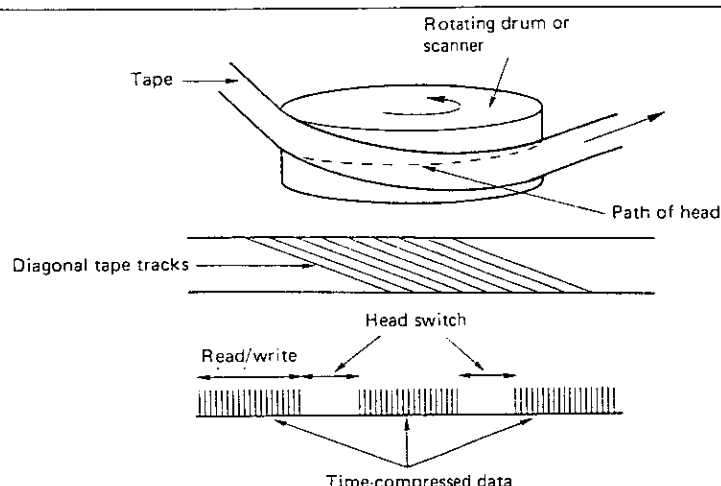


Fig. 9. In a rotary-head recorder, the helical tape path around a rotating head results in a series of diagonal or slanting tracks across the tape. Time compression is used to create gaps in the recorded data which coincide with the switching between tracks.

samples on the other.

A rotary head recorder contains the same basic steps as any digital audio recorder. The record side needs ADCs, time compression, the addition of redundancy for error correction, and channel coding. On replay the channel coding is reversed by the data separator, errors are broken up by the de-interleave process and corrected or concealed, and the time compression and any fluctuations from the transport are removed by timebase correction. The corrected, time stable, samples are then fed to

the DAC.

Digital recording has considerable advantages in a large number of acoustics related applications and it naturally complements the widespread use of signal analysis in computers. With the exception of some specialist applications, digital recording will eventually become universal.

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# A NEW BEAMPATTERN DESIGN METHOD FOR SONAR ARRAYS

Peter F Dobbins MIOA & Gary J Heald MIOA

## Introduction

When arrays of transducers were first employed to form directional beams for transmission and reception in sonar (as well as radar, radio and astronomy) it was realised there was a need for improvement in certain features of the beampatterns obtained. In particular, noise rejection could be enhanced by reducing the level of sidelobes, and it was soon discovered that this could be achieved by varying the sensitivities of individual sensors in the array: a process known as shading in the beamforming context and directly analogous to windowing in spectral analysis.

The earliest shading distributions for sonar and radar arrays, such as the Hann ( $\cos \alpha$ ) and Hamming functions [1], were effectively arbitrary functions chosen for ease of calculation, but attempts were soon made to develop distributions based on physical principles. These were applied to continuous apertures by Taylor [2], to discrete line arrays by Dolph [3] in the familiar Chebychev distribution, and to planar arrays by, eg, Hansen [4]. Such analytical approaches to array pattern synthesis are effective, but limited by the complexity of the equations or the restrictions imposed by simplifying approximations.

The use of computers to carry out the calculations began in the 1960s, and an early approach was simply to solve the simultaneous equations derived from the array geometry and the required number of field points [5]. This method carries no restrictions on geometry, but requires that the desired pattern be specified exactly at a fixed number of points. A more general optimisation procedure was adopted by Wilson [6], who applied a linear programming technique, but the utility of the method was limited by the requirement that the array be symmetrical about a centre point and by the heavy computing load associated with mathematical programming.

Another approach, combining the advantages of computer optimisation with the simplicity of matrix inversion, is to use the least-squares method to find the best approximation to the solution of the beampattern equations for an arbitrary number of points. Although the equations must be linearised, this can be achieved by various means, such as representing each element as independent in-phase and quadrature components. The result is a completely general method that is not computer intensive, and which has been described previously for a ring of directional elements [7] and line array [8]. This article demonstrates its application to planar arrays.

## The Least-squares Algorithm

The theory and mathematical formulation of the least-squares array shading algorithm were explained in detail in [7] and [8]. Given a beampattern specified at an arbitrary

number of points, the procedure leads to a system of  $N$  equations for the  $N$  shading coefficients, known as the normal equations for the approximation, and these may be solved, for example, by straightforward elimination or matrix inversion. This method, as described, will successfully find shading coefficients for line arrays or 2-dimensional arrays that lie in the same plane as the observation point.

With a multi-dimensional array lying outside this plane, the matrix representing the set of equations may become singular, so that no solution can be found. Such a situation arises if the array geometry is symmetrical in any way. Symmetries in the element locations lead to symmetries in the beampattern, and situations arise where the beampatterns along different lines of spatial symmetry can be independently determined from the sums of the shading coefficients along different lines of array symmetry. Because of this no unique solution for the individual coefficients is possible.

One way to overcome this problem is by introducing conditions coupling the patterns along the lines of symmetry. There are various ways to achieve this, but the simplest is to force symmetry in the shading coefficients. This symmetry may be made part of the array geometry definition, or it may be included in the formulation of the least-squares equations. The latter approach is less restrictive, but either technique requires the algorithm to be individually tailored for a specific geometry as will be explained in the examples that follow.

## A Plane Array Application

Example results will be presented for the USRD type F27A acoustic calibration standard (described in [9]). This is a 55 element array on a hexagonal grid, as shown schematically in Figure 1, which has symmetry or anti-symmetry every  $30^\circ$ . This particular array is chosen partly because, although a hexagonal geometry is common for arrays required to approximate a circular aperture, it is difficult to derive shading schemes by analytical methods, and partly because this array was employed as an example by Wilson [6], so his findings may be used for comparison with those obtained with the least-squares method. For consistency with Wilson's results, the inter-element spacing is taken as  $\sqrt{3} \times \lambda/2$  and the directivity of the individual transducers is neglected; they are assumed omnidirectional.

Radial symmetry may be obtained by requiring all elements at the same radial distance from the array centre to have the same coefficient; then only eight different values are required, as seen in Figure 1. As suggested above, this symmetry could be included in the basic

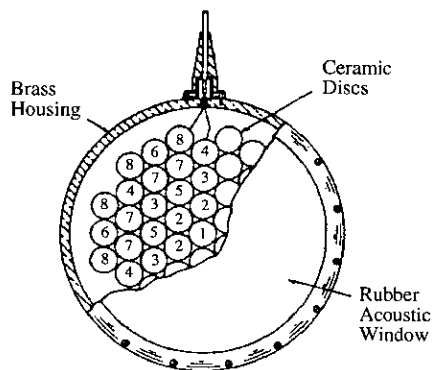


Fig. 1. Sketch of USRD F27A array (from [9]).

array definition, but for the examples presented here additional equations were added to the least-squares formulation equating similar coefficients. Because these conditions are included before the least-squares approximation, circular symmetry in the coefficients will be maintained if a circularly symmetric beam pattern is specified, but only approximated if the required pattern is not symmetrical, so this condition is not unduly restrictive.

The procedure for applying the least-squares algorithm is straightforward and follows a manual iterative process, although this could be automated. The first step is to specify the required beam pattern, and for these examples this is just a statement of desired sidelobe levels and, possibly, null directions.

The second step is to identify a feasible solution as a point of departure; the algorithm cannot find coefficients for a beam pattern that is not realisable with the given array geometry. If shading for a pattern close to the requirement is known then this can be used to initiate the process, otherwise uniform shading is as good a starting point as any. The bearings of the sidelobes in this pattern must be located, and their signs noted. A specification table is then prepared applying the required level at a sufficient number of these locations, along with a zero level at the desired null locations. The 'sufficient number' can only be found by trial and error, but is generally of the same order as  $N$ , the number of elements. It is also noted that best results are obtained if sidelobe locations are specified in pairs symmetrical about the origin (but only if a symmetrical pattern is wanted of course).

The algorithm is then applied to this specification table to obtain a new set of coefficients and a corresponding beam pattern. This new pattern will be closer to the requirement than the original, but sidelobes will move as their level is lowered, and the result may not be exact. In this case the new sidelobe positions should be located and the process repeated until the desired result is obtained.

## Uniform Sidelobes

Wilson's results with the F27A array were based on a requirement for a  $12^\circ$  beamwidth, and resulted in an approximately uniform  $-41$  dB sidelobe level with a DI of  $24.3$  dB and a sensitivity of  $-9.6$  dB relative to an

unshaded array. This beam pattern is easy to reproduce with the least-squares method simply by specifying a level of  $-41$  dB at the location of each sidelobe in Wilson's pattern. The resulting azimuth beam pattern (the array is taken to be vertical and its major axes referred to here as azimuth and elevation) is shown in Figure 2, along with the unshaded pattern. Figure 3 gives a 3-dimensional representation (the vertical range is  $50$  dB). It is clearly seen that the desired uniform sidelobe level has been achieved. The DI for this pattern is  $24.4$  dB, the beamwidth is  $12^\circ$ , and the overall sensitivity is  $-9.5$  dB, giving a marginal improvement on Wilson's result because of a smaller variation in sidelobe levels. For comparison, Table 1 lists the shading coefficients for the Wilson design, the least-squares  $-41$  dB design and the  $-30$  dB design described below.

To demonstrate a beam pattern achieved without such a convenient starting point results obtained with a requirement for a uniform  $-30$  dB sidelobe level are shown as the azimuth pattern in Figure 4, and the 3D plot in Figure 5. This shading scheme was found with just three iterations of the least-squares algorithm, and it can again be seen that the uniform sidelobe criterion has been met. The beamwidth is  $10.9^\circ$ , the DI  $24.8$  dB, and the sensitivity is  $-6.8$  dB relative to uniform shading.

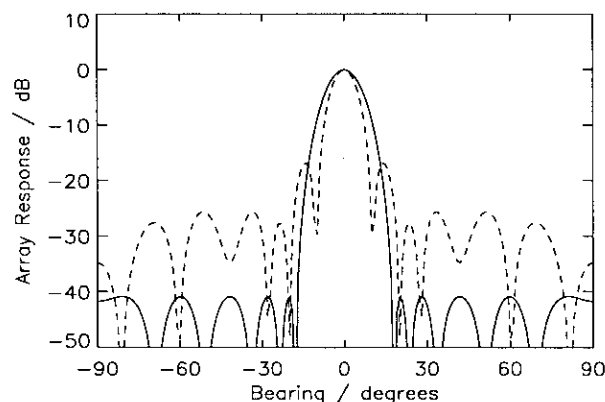


Fig. 2. Azimuth beam pattern for F27A with shading for  $-41$  dB uniform sidelobes (solid line) compared with unshaded pattern (dashed line).

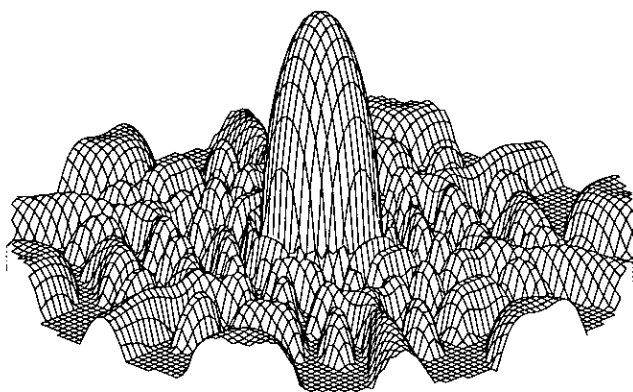


Fig. 3. 3D representation of F27A beam pattern with shading for  $-41$  dB uniform sidelobes.

|   | Wilson<br>Design | - 41 dB<br>Shading | - 30 dB<br>Shading |
|---|------------------|--------------------|--------------------|
| 1 | 1.0000           | 1.0000             | 0.8934             |
| 2 | 0.8277           | 0.8290             | 1.0000             |
| 3 | 0.4981           | 0.5012             | 0.6206             |
| 4 | 0.1925           | 0.1958             | 0.4261             |
| 5 | 0.5967           | 0.5998             | 0.7244             |
| 6 | 0.0763           | 0.0775             | 0.1767             |
| 7 | 0.2761           | 0.2789             | 0.4352             |
| 8 | 0.0667           | 0.0682             | 0.0996             |

Table 1. Shading coefficients for uniform sidelobes.

## Null Steering

The ability to generate nulls in the beam pattern without degrading either the beamwidth or the sidelobe level is illustrated in Figures 6 and 7. These show respectively the azimuth and 3D patterns obtained with a definition identical to that used for the - 41 dB sidelobe example in Figures 2 and 3, except that a null has been specified at  $\pm 42^\circ$  in the azimuth plane. This has had the effect of suppressing the sidelobe at that location, but otherwise the pattern is unchanged. The coefficients for this result are listed in Table 2. No constraint was placed on the symmetry of this pattern, so the shading function can still

be defined with just 8 coefficients.

A more demanding example is presented in Figures 8 and 9, and these results demonstrate that coupling the shading coefficients for elements at the same radial distance from the array centre does not necessarily force equality. Starting with the - 30 dB shading, the requirement was to make the beamwidth in the azimuth plane the same as that of the unshaded pattern by forcing the first nulls to  $\pm 11^\circ$ . It would, of course, be impossible to do this without some increase in the sidelobe level, and it can be seen in Figure 8 that the algorithm has allowed the sidelobes to rise to - 25 dB. However, Figure 9 shows that the pattern in the elevation plane has maintained the - 30 dB sidelobe level. Because the symmetry in the directivity pattern has been disturbed the shading

|   |        |
|---|--------|
| 1 | 1.0000 |
| 2 | 0.8135 |
| 3 | 0.4990 |
| 4 | 0.1828 |
| 5 | 0.5839 |
| 6 | 0.0746 |
| 7 | 0.2639 |
| 8 | 0.0608 |

Table 2. Shading coefficients for - 41dB sidelobes with  $\pm 42^\circ$  sidelobe suppressed.

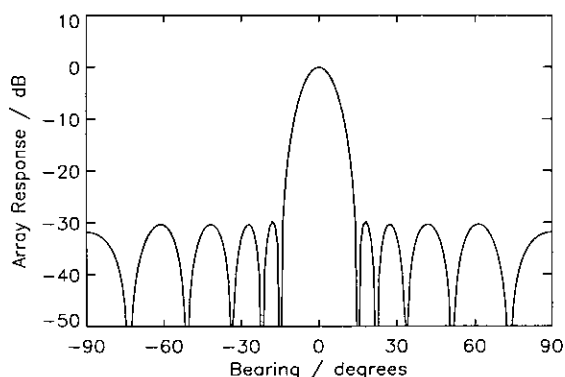


Fig. 4. Azimuth beam pattern for F27A with shading for - 30 dB uniform sidelobes.

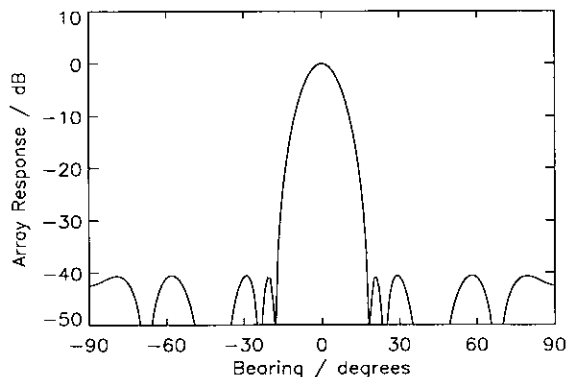


Fig. 6. Azimuth beam pattern for F27A with - 41 dB shading and  $42^\circ$  sidelobes suppressed.

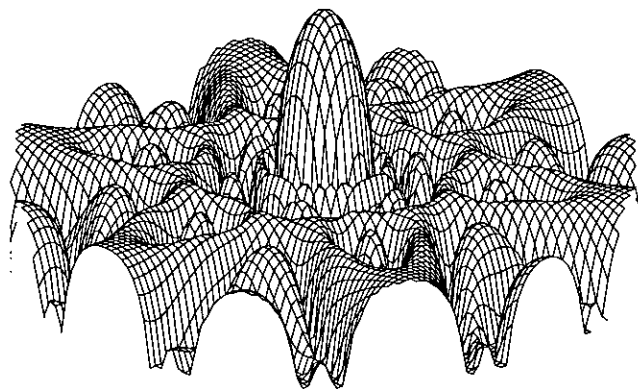


Fig. 5. 3D representation of F27A beam pattern with shading for - 30 dB uniform sidelobes.

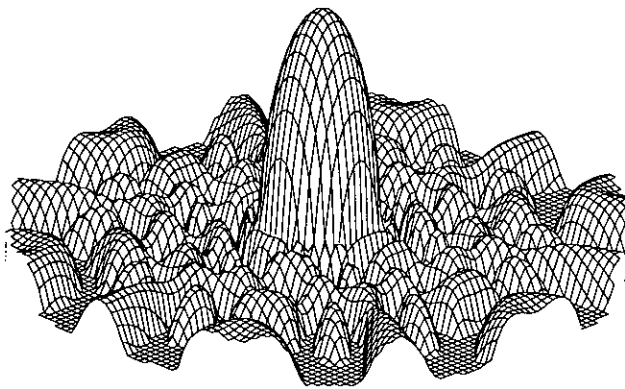
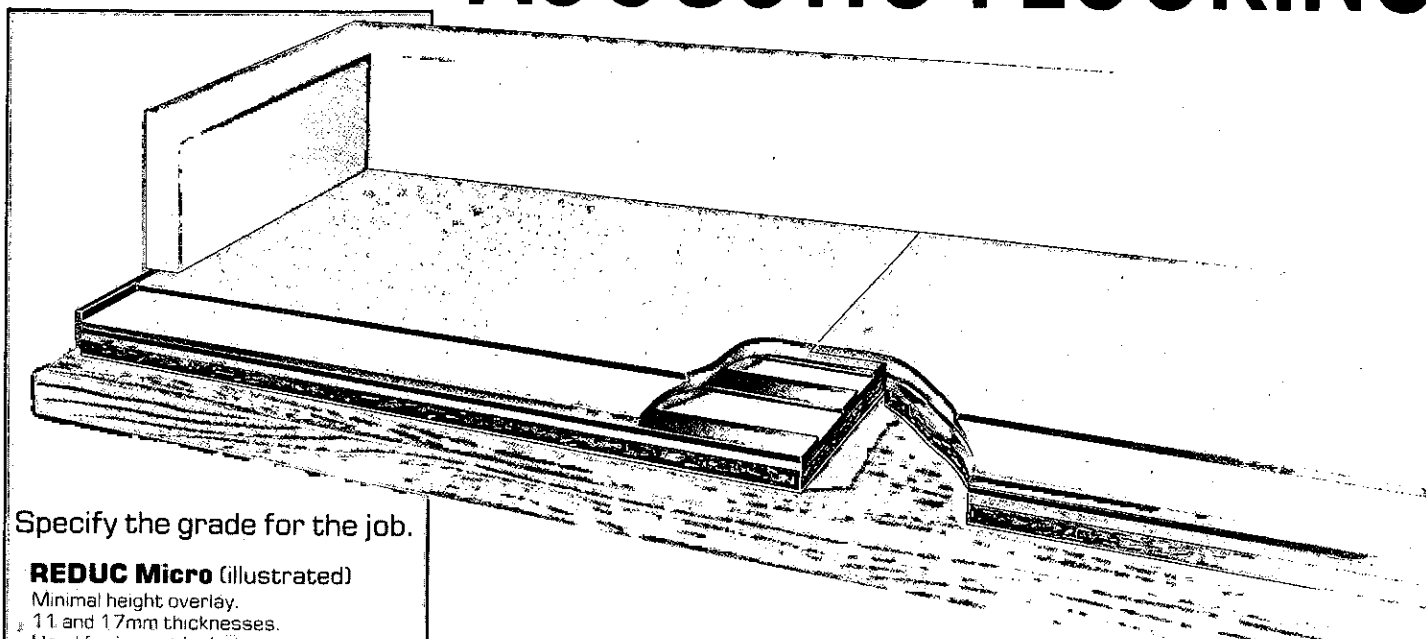


Fig. 7. 3D representation of F27A beam pattern with - 41 dB shading and  $42^\circ$  sidelobes suppressed.

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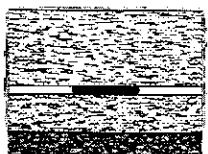
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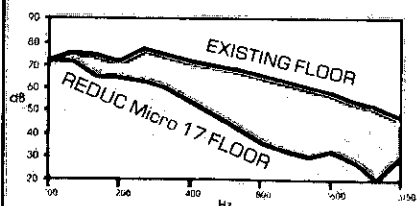
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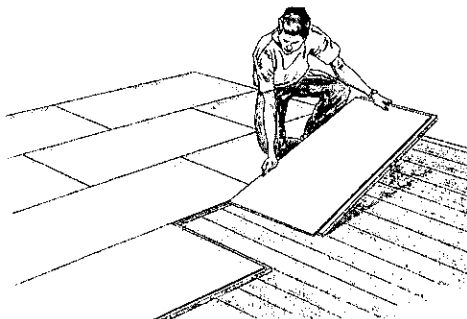
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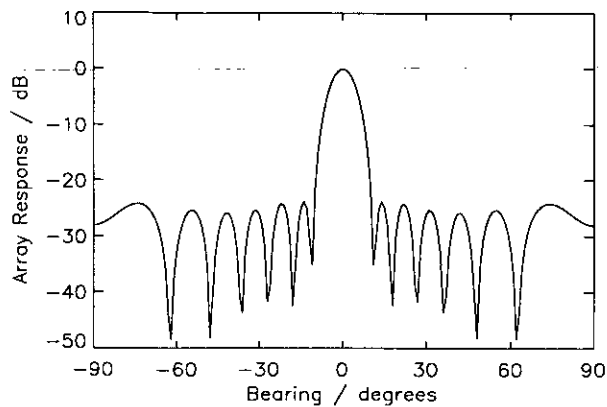


Fig. 8. Azimuth beampattern for F27A with - 30 dB shading and nulls at  $\pm 11^\circ$ .

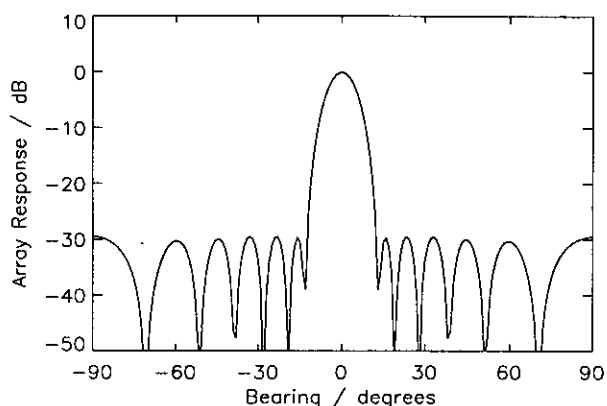


Fig. 9. Elevation beampattern for F27A with - 30 dB shading and nulls at  $\pm 11^\circ$ .

|        |        |        |        |
|--------|--------|--------|--------|
|        | 0.3786 |        |        |
| 0.3350 |        | 0.4572 |        |
|        | 0.3253 |        | 0.3645 |
| 1.0000 |        | 0.6101 |        |
|        | 0.7675 |        | 0.4015 |
| 0.7900 |        | 0.6059 | 0.6622 |
|        | 0.8665 |        | 0.6214 |
| 0.7872 |        | 0.7072 | 0.6443 |

Table 3. Shading coefficients for - 30 dB sidelobes with  $\pm 11^\circ$  nulls in azimuth plane (upper right quadrant only).

can no longer be described with only 8 coefficients, but there is still mirror symmetry about both the azimuth and elevation axes, so coefficients for just one quadrant of the array are needed, and these are listed in Table 3 for the upper right quadrant, including the centre rows (thus the centre element is bottom right in the table).

## In Conclusion

The algorithm described here is easily implemented as a computer program, either in conventional programming languages or the more recent 'mathematical' packages

such as Mathcad, Mathematica and IDL. The examples discussed in [7] and [8] were obtained with a BASIC program, whilst most of the results presented in this article were produced using Mathcad or IDL. Compared with earlier numerical optimisation approaches (eg [5] and [6]) this method is not computer intensive and arrays of several hundreds of elements are easily handled by a PC.

The examples given here do not represent any specific beamforming application, but are intended to show the sort of problems that can be tackled using the least-squares technique, and to demonstrate that reasonable solutions can be obtained quickly and easily. Work is currently in hand to demonstrate the application to 3-dimensional arrays and to automate the process.

Details of the way the algorithm is used are very much problem dependent, but the approach described has proved successful in a number of applications. However, the procedure does not always find a useful answer, or indeed any answer, if the requirements are not physically realisable with the specified array geometry. The algorithm cannot, for example, suppress diffraction secondary lobes if the element spacing is too wide. Nevertheless, like other CAD techniques, if it is used intelligently and with an understanding of the behaviour of arrays and beamforming, the method provides an efficient tool for finding the best possible shading for a particular array geometry and a given set of beampattern requirements.

## Acknowledgements

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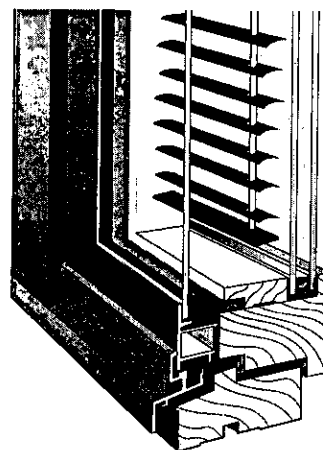
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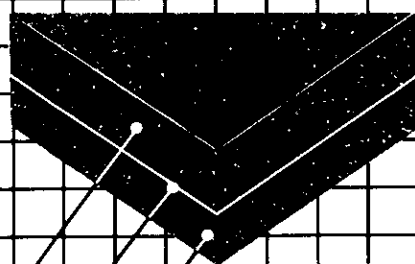
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# A PRACTICAL GUIDE TO THE SELECTION OF GLAZING FOR ACOUSTIC PERFORMANCE IN BUILDINGS

Cliff Inman FIOA

## Introduction

Glazing and windows play an important role in attenuating outside noises so that building occupants are not unduly disturbed. Achieving this may involve thick glass, double or multiple glazing, laminated glass, and their combinations. The appropriate strategy selected depends on a number of factors, including the nature of the noise, when, and for how long, it occurs, and the tasks or activities of the people inside the building.

This Guide attempts to highlight the basic principles involved in the selection of glazing for effective acoustic control.

## Major Noise Sources

Noise transfer problems rarely involve a single frequency, but usually a fairly wide range of frequencies. Examples of exceptions to this are noises that arise from sawmills and helicopters.

### Road Traffic Noise

This is predominantly of low frequencies, its level and spectrum being influenced by vehicle speed, engine type, road surface, local topography, etc.

However, in rainy weather there may be a significant increase in some higher frequency levels owing to tyre 'hiss' and the window designer should be mindful that such conditions have the potential of provoking additional complaints of noise intrusion. Compatible design measures are possible to reduce, or even eliminate, this risk.

### Railway Noise

This involves a broadly similar spectrum to that from road traffic except that it contains more middle frequency tones and, apart from really fast trains, there is a relatively more rapid fall off at the higher frequencies. Dominant influences here include speed, type of rail (ie jointed lengths or continuous welded), type of sleeper (ie timber or concrete), mix of rolling stock, and whether the train is progressing through sections of the track which include bridges, embankments or cuttings.

Though noise levels adjacent to railways can be very high indeed, people's tolerance to railway noise is also greater because the rise and decay of each train passby follows a predictable pattern and the corresponding peaks are of short duration. It is widely accepted that railway noise can exceed road traffic noise by more than 10 dB, whilst generating only the same degree of annoyance or disturbance.

### Aircraft Noise

As heard on the ground aircraft noise changes sig-

nificantly with the altitude of the aircraft, climatic conditions, the type and load utilisation of the aircraft and on whether the aircraft is landing, taking off, overflying, or manoeuvring on the ground. Take off noise is dominated by low frequencies whereas landing noise contains strong high frequency components, characteristic of the engines being operated in reverse thrust mode. Stationary aircraft may also emit significant high frequency components from the auxiliary power units (APUs) in their tails, which generate all the necessary electrical power. This noise usually has strong tonal components at around 2 kHz and 4 kHz, in particular.

### For Speech

The most important frequencies here lie between 500–2000 Hz, female and children's speech being approximately an octave above male speech. It is the suppression of the higher frequencies which is most important in providing privacy of conversation because these contain the essential aural clues of intelligibility, called the sibilants (ie the 'hissing' sounds of language, like s, sh).

## Some Relevant Acoustic Indices

The sound transmission properties of partitions are inherently frequency and hence source spectrum dependent. Road traffic noise, for example, is relatively rich in low frequency energy and the selection of a partition to control that form of noise needs to be particularly effective in that region.

However, as with most sectors of acoustic activity and study, confusion may arise because of the profusion of diverse acoustic indices some of which are, or should be, reserved only for particular application under well-prescribed circumstances. In order to attempt to unravel the perceived mystique in this respect, a review is included here of the most commonly used indices appropriate to glazing and to building acoustics in general.

### $R_m$ (Mean Reduction)

The complete way of specifying the acoustic performance of glazing – or any other building element – is to establish its sound insulation over a wide range of frequencies. The British and European preferred range is 100–3150 Hz and for a complete description the sound insulation value (properly termed the Sound Reduction Index, SRI) should be determined at all sixteen  $1/3$  octave bands.

The arithmetic mean of these values is a simple indicator of acoustic performance, designated  $R_m$  or Mean Sound Reduction Index, and is expressed in dB.

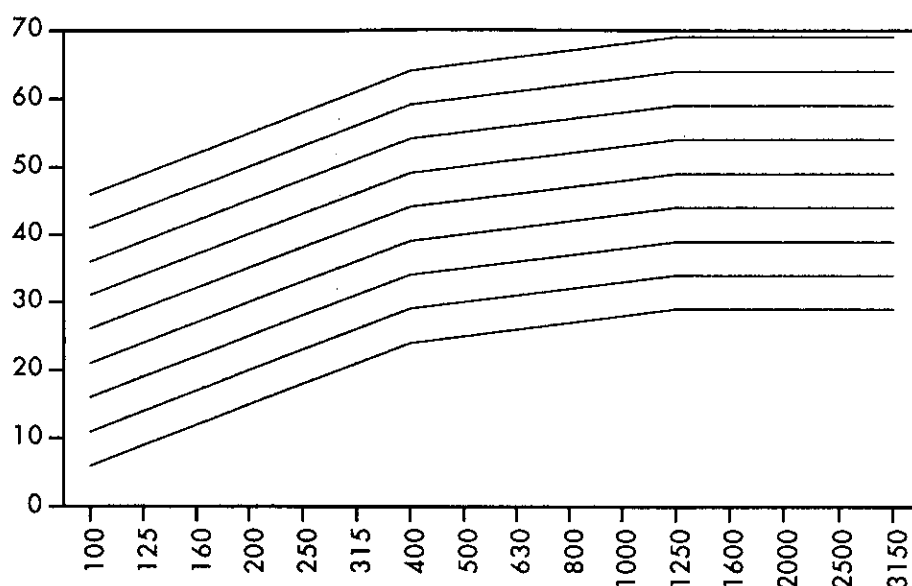


Fig. 1. Reference curves for  $R_w$  at  $1/3$  octave frequencies (Hz) see text.

## $R_w$ (Weighted Reduction)

Since the publication of BS 5821 in which  $R_w$  is defined,  $R_m$  has been phased out although it still surfaces occasionally to cause confusion since both indices are expressed in the same units. The numerical values differ by up to 5 dB for the same window ( $R_w$  is the greater).

The procedure for determining the  $R_w$  value for a partition allows for the frequency selective response of the

ear and is based on a comparison of the measured SRI vs frequency curve with a family of reference curves as in Figure 1. The  $R_w$  value for a partition is the Sound Reduction Index at 500 Hz on the lowest reference curve for which the aggregated adverse deviations over the sixteen  $1/3$  octave bands is more than 32 dB. An adverse deviation is the difference between a measured SRI value and the corresponding quantity on the selected reference curve provided the SRI value is the lower. Deviations where the SRI value is correspondingly greater are not considered.

## Using $R_m$ and $R_w$

The procedure for determining the sound level inside a room

resulting from airborne propagation through a partition would involve a knowledge of

- (i) the area and SRI values over the frequency range of the various components that contribute areas to the partition;
- (ii) the full specification of the external sound spectrum;
- (iii) the acoustic properties of the receiving room.

This means that neither  $R_m$  nor  $R_w$ , although useful for



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| $t$ (mm) \ $f$ (Hz) | 4  | 6  | 10 | 19 | 6.4* | 7** | 17** |
|---------------------|----|----|----|----|------|-----|------|
| 100                 | 17 | 18 | 24 | 25 | 18   | 22  | 26   |
| 125                 | 23 | 22 | 26 | 29 | 22   | 23  | 28   |
| 160                 | 22 | 22 | 28 | 31 | 22   | 28  | 32   |
| 200                 | 21 | 22 | 26 | 31 | 22   | 25  | 31   |
| 250                 | 21 | 26 | 28 | 32 | 26   | 27  | 33   |
| 315                 | 24 | 26 | 29 | 35 | 26   | 29  | 34   |
| 400                 | 26 | 29 | 32 | 36 | 29   | 31  | 37   |
| 500                 | 29 | 31 | 34 | 38 | 31   | 33  | 39   |
| 630                 | 30 | 33 | 36 | 36 | 33   | 35  | 41   |
| 800                 | 32 | 34 | 37 | 35 | 34   | 37  | 42   |
| 1000                | 34 | 36 | 36 | 38 | 36   | 38  | 44   |
| 1250                | 34 | 36 | 33 | 40 | 36   | 39  | 45   |
| 1600                | 36 | 32 | 33 | 44 | 36   | 41  | 46   |
| 2000                | 36 | 26 | 38 | 47 | 34   | 42  | 44   |
| 2500                | 31 | 30 | 41 | 50 | 31   | 43  | 38   |
| 3150                | 25 | 34 | 43 | 52 | 35   | 41  | 42   |
| 4000                | 31 | 37 | 44 | 55 | 39   | 37  | 46   |
| $R_m$ (dB)          | 28 | 29 | 33 | 37 | 30   | 33  | 38   |
| $R_w$ (dB)          | 31 | 32 | 36 | 40 | 33   | 37  | 41   |
| $R_{tra}$ (dB)      | 27 | 28 | 32 | 35 | 29   | 31  | 36   |

Table 1. Sound Reduction Index at  $1/3$  octave frequencies for glass of thickness  $t$ . (\*= pvb, \*\*= Audioscreen)

rank ordering materials, can be used directly to estimate interior noise levels.

It is important to appreciate that  $R_m$  and  $R_w$  relate to the material from which a partition is constructed rather than to a sample of a particular size.

## STC (Sound Transmission Class)

Occasionally, requirements may be stated in terms of Sound Transmission Class (STC) values as found in the American Standard ASTM E413. Its derivation follows the  $R_w$  Index procedure, except that the relevant frequency range is 125 – 4000 Hz (ie it is shifted upwards by  $1/3$  octave from the British Standard range). For this reason, STC is typically around 1 dB higher than its  $R_w$  equivalent because materials generally perform better at higher frequencies.

## R<sub>tra</sub> (Traffic Noise Reduction)

A useful way around the issue outlined above in the case of urban road traffic noise is to derive an additional single figure index  $R_{tra}$  for the purpose. This is obtained by assuming an idealised road traffic sound spectrum to derive the external to internal attenuation in dB(A) which a particular window offers.

To benefit from the simplicity of this procedure it is necessary that the glazed part of the facade in question is the determining part as far as the overall sound insulation is concerned.

This of course would normally be the case and in such situations it gives a very useful indication of in-service performance. It is currently a proposed European (CEN) Standard.

## The Insulation of Glazing Configurations

### Homogeneous (Ordinary) Glass

Theoretical Mass Law analysis indicates that a 6 dB increase in sound insulation should accrue from doubling the glass thickness. However, resonances interfere with this trend and, in practice, the incremental increase is reduced to around 4 dB. Measured values are tabulated in Table 1. These data show a systematic impairment of expected sound insulation at a frequency which is inversely proportional to the glass thickness. This frequency is called the Critical Frequency is determined from the formula:  $f_c = 12000/d$  where  $d$  is the glass thickness in millimetres and  $f_c$  is in Hz. This pattern of acoustic behaviour is illustrated in Figure 2.

### Toughened (Tempered), Coated and Wired Glass

This behaves, acoustically, the same as the standard product of the same thickness.

### Patterned (Texture) Glass

This yields an acoustic performance which corresponds with that of standard flat glass of the same average thickness. For example, a patterned glass whose thickness varies between 4 mm and 6 mm is likely to exhibit the acoustic characteristics of 5 mm thick ordinary flat glass.

### Laminated Glass

Instead of using ordinary solid (or homogeneous or monolithic) window glass, the thickness may be a composite of a number of thinner components, bonded together by a softer interlayer material. This is a common strategy in

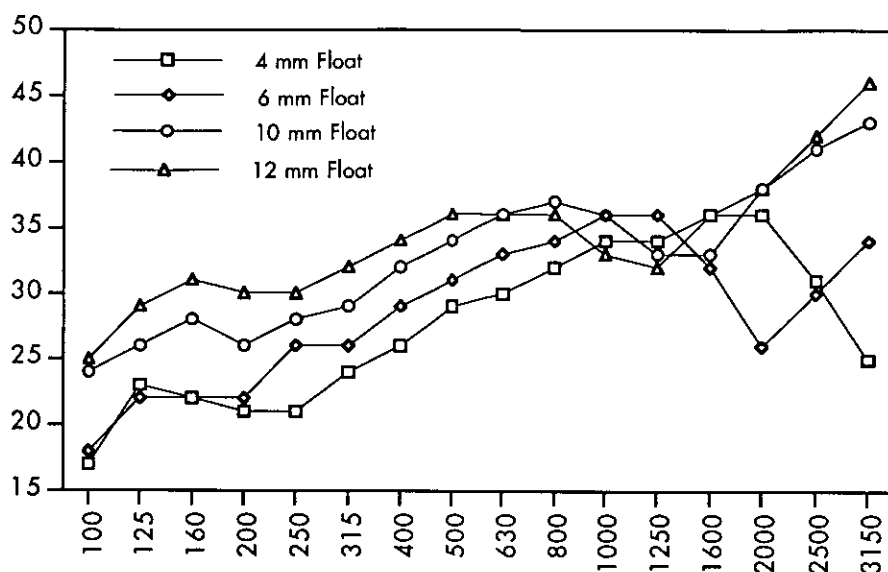


Fig. 2. Sound insulation of single glasses. Sound Reduction Index (dB) vs  $1/3$  octave band frequency (Hz).

safety and security applications, and such laminations may also demonstrate acoustic benefits, particularly in the suppression of the resonance at the Critical Frequency.

Two main types of interlayer material are used, (i) polyvinyl butyral (pvb) and (ii) polymethyl methacrylate (pmma). Each has its own particular merits, according to the application.

pmma being softer than pvb. Laminates of pvb exhibit the basic acoustic behaviour of the corresponding solid glass, except that at frequencies around the Critical Frequency the usual dip in sound insulation is somewhat less prominent. With the more resilient pmma laminates, however, the component glasses are able to vibrate almost independently so that the residual resonances correspond

Laminates of pvb require special ovens called autoclaves where bonding is made at very high temperature and pressure. The more recent technique with pmma involves pouring it, immediately after exposure to other chemicals to promote the necessary reaction, between the component glasses which have been held apart by spacers at the periphery of the pane. Typically, spacers of 1–2 mm are employed. When the 'cell' is full, the edges are then fully sealed, and the pmma cures into a resilient solid after a few hours.

There are significant differences in the acoustic characteristics of these two generic laminates, due mainly to

| $f$ (Hz) \ $t$ (mm) | 4/12/4 | 6/12/6 | 10/12/4 | 10/12/6 | 10/12/6.4* | 10/12/17** |
|---------------------|--------|--------|---------|---------|------------|------------|
| 100                 | 25     | 17     | 23      | 27      | 27         | 26         |
| 125                 | 24     | 26     | 28      | 27      | 28         | 32         |
| 160                 | 23     | 22     | 26      | 24      | 26         | 29         |
| 200                 | 21     | 18     | 19      | 24      | 26         | 29         |
| 250                 | 21     | 18     | 23      | 29      | 30         | 35         |
| 315                 | 19     | 24     | 26      | 31      | 32         | 35         |
| 400                 | 22     | 27     | 31      | 33      | 34         | 40         |
| 500                 | 25     | 29     | 33      | 34      | 36         | 45         |
| 630                 | 30     | 33     | 36      | 37      | 40         | 47         |
| 800                 | 33     | 37     | 39      | 39      | 41         | 47         |
| 1000                | 36     | 39     | 41      | 41      | 42         | 46         |
| 1250                | 38     | 39     | 41      | 41      | 41         | 45         |
| 1600                | 40     | 39     | 41      | 39      | 41         | 48         |
| 2000                | 41     | 34     | 45      | 37      | 42         | 49         |
| 2500                | 35     | 37     | 45      | 40      | 44         | 48         |
| 3150                | 31     | 42     | 42      | 43      | 49         | 52         |
| 4000                | 40     | 47     | 44      | 47      | 53         | 57         |
| $R_m$ (dB)          | 29     | 30     | 34      | 34      | 36         | 41         |
| $R_w$ (dB)          | 31     | 33     | 36      | 38      | 40         | 45         |
| $R_{tra}$ (dB)      | 25     | 26     | 29      | 32      | 34         | 37         |

Table 2. Sound Reduction Index at  $1/3$  octave frequencies for double glazing units. (\* = pvb, \*\* = Audioscreen)

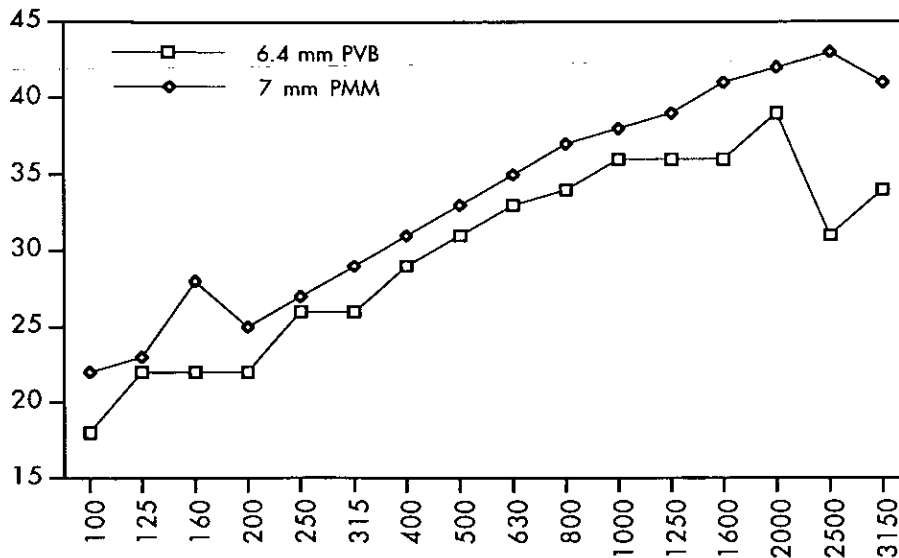


Fig. 3. Comparison of laminate performance. Sound Reduction Index (dB) vs  $1/3$  octave band frequency (Hz).

more with those of thinner glasses and this causes them to shift towards the higher frequencies where the dip can be more readily tolerated in terms of overall acoustic performance.

Figure 3 contrasts these sound insulation characteristics for laminates of comparable thickness.

## Double Glazing

The principle of using two sheets of glass separated by an air space was originally introduced to reduce heat loss through windows. However, by careful design it is possible to achieve moderately high acoustic insulation in this way. The general design procedure to be followed starts with selecting one pane of thick glass which is better able to cope with the low frequency noise components. The second pane should differ in thickness from the first by at least 30 per cent in order to separate the resonance frequencies associated with the two panes. In other words, sympathetic resonance effects are suppressed. Common examples of a choice of thicknesses that satisfy this requirement are 10 mm + 6 mm and 6 mm + 4 mm.

An improvement is found if one of the panes is laminated; a further small improvement is achieved if the second one is also laminated. Identical sound insulation is obtained irrespective of which way round the double glazing units are installed.

## Effect of Cavity Width

Over the usual cavity width range of 6 mm to 20 mm for double glazing unit

include low emissivity coatings in order to upgrade their thermal performance to match that of triple glazing units. To supplement this enhancement the cavity may be filled with argon instead of air. Such units exhibit exactly the

construction there is little variation in acoustic performance although there is a more significant change in thermal insulation. This acoustic plateau is due mainly to relatively strong coupling of the component glasses via the spacer bar around the periphery of the units.

The sound insulation data presented in Table 2 were specifically derived from tests on double glazing units which featured standard dry air-filled cavities; negligible error is introduced if these values are also adopted for all cavities in the 6–20 mm range.

## Effect of Gas Filling

Occasionally, double glazing units are specified which



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# RAYNOISE



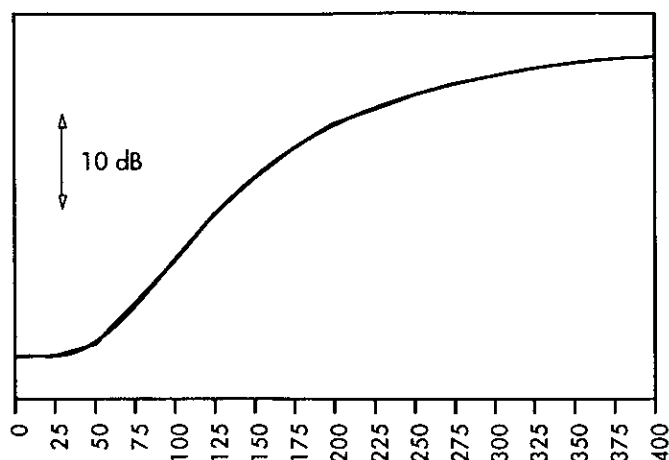


Fig. 4. Typical relative variation of sound insulation (in dB) with cavity width (in mm) between two glasses.

same acoustic performance as standard air-filled units of the same glass combination.

For applications where middle frequency acoustic performance is the most critical (eg speech) double glazing units may be filled with gases or gas mixtures, among them sulphur hexafluoride (SF<sub>6</sub>). By this means both the middle frequency performance and the corresponding  $R_w$  index is elevated but, accompanying this improvement, SF<sub>6</sub> introduces a significant resonance at 200 – 250 Hz, which could be a problem for transportation noises that are often dominated by low frequency components.

## Wide Airspaced Double Windows (Secondary Sashes)

Where high sound insulation of windows is required, airspace widths of greater than 100 mm may be worth consideration; the above ideas on dissimilar thicknesses are still valid.

Lining the window reveals with acoustic absorbent material (eg fibreboard) is beneficial because it can reduce reverberation in the cavity, giving an attenuation improvement of 2 – 6 dB, according to its area and absorption characteristics.

Increasing the width of the cavity produces an increase in sound insulation but benefit accrues slowly at greater than 200 mm as illustrated in Figure 4.

This type of window can only achieve its high sound insulation potential, if all the airgaps are sealed. Ideally this requires that the frames carrying the glasses must be fixed and sealed. If the windows are to be openable they should for preference be of the casement type incorporating multiple seals all round and a multipoint locking mechanism to avoid twisting.

Sliding sashes are not able to achieve the required airtightness, and their acoustic performance is most often no better than a well-designed sealed double glazing unit.

Data on some examples of this type of window – fully sealed – are included in Table 3 and Figure 4.

### Effect of Window Area

If the sound insulation of the masonry component of a facade is at least 10 dB higher than that of the glazing, propagation through the solid part is negligible; this applies in most practical circumstances unless the window area happens to be particularly small or the masonry part insubstantial. So it can be taken that doubling or halving the window area produces an aggregate corresponding noise level change of 3 dB which is just on the threshold of being noticeable.

### Influence of Frame Material

Nowadays there is a wide range of window frame types available, the principal ones being of timber, aluminium, and PVC-u. In spite of hollow box sections being an integral feature of modern aluminium and PVC-u framing, laboratory and field measurements indicate that, up to a glazing rating of about  $R_w$ 38 the window frame is unlikely to offer a serious leakage path. The sound insulation of the glazing can therefore be adopted as representative of the window as a whole. For glazing of ratings higher than  $R_w$ 38 the actual acoustic performance of the framing should be considered.

## Window Sound Insulation Data

In order to be able to implement the principles of effective window design outlined earlier, reliable sound insulation data is of paramount importance. For proper consideration of glazing acoustic performances, it is logical that comparisons should only be made of values derived from measurements made under near-identical experimental conditions. The data in this paper satisfies this ideal. *Audioscreen is an acoustic laminate, based on a polymethyl methacrylate variant.*

Cliff Inman FIOA is with Pilkington Glass, St Helens. ❖

| $f$ (Hz) \ $t$ (mm) | 6/100/4 | 6/150/4 | 10/200/6 |
|---------------------|---------|---------|----------|
| 100                 | 25      | 27      | 32       |
| 125                 | 27      | 30      | 37       |
| 160                 | 27      | 30      | 39       |
| 200                 | 33      | 34      | 45       |
| 250                 | 33      | 34      | 46       |
| 315                 | 37      | 39      | 46       |
| 400                 | 41      | 42      | 47       |
| 500                 | 46      | 46      | 45       |
| 630                 | 50      | 50      | 45       |
| 800                 | 54      | 54      | 44       |
| 1000                | 57      | 57      | 45       |
| 1250                | 59      | 58      | 50       |
| 1600                | 58      | 58      | 53       |
| 2000                | 52      | 52      | 58       |
| 2500                | 51      | 49      | 58       |
| 3150                | 48      | 47      | 64       |
| 4000                | 57      | 52      | 64       |
| $R_m$ (dB)          | 44      | 44      | 47       |
| $R_w$ (dB)          | 46      | 47      | 49       |
| $R_{tra}$ (dB)      | 37      | 39      | 45       |

Table 3. Sound Reduction Index at 1/3 octave frequencies for double windows (secondary sashes).

# PHYSICS AND TECHNIQUES OF ULTRASOUND IN MOSCOW

N N Shibanova

## Introduction

Research in ultrasonics in Russia is mainly concentrated in the Moscow region and is generally carried out in special research centres, universities and industrial companies. The aim of this article is to provide a review of the wide range of scientific and technical activity in the field, and to identify the principal scientists and institutes involved.

The history of the field is closely connected with the activities of N N Andreyev, L M Brekhovskikh, I A Viktorov, Yu V Gulyaev, V A Krasil'nikov, V E Lyamov, V I Pustovoyt, and R V Khokhlov. The principal areas of activity are Physical Acoustics, Acoustoelectronics, Acoustooptics and Ultrasound Technology.

There are three major research centres involved in these fields: The department of Acoustics of Moscow State University was set up in 1943 by Professor S N Rzhoevkin, and pursues research on a broad front. For around forty years members of the N N Andreyev Acoustical Institute have been active in physical acoustics, general ultrasound technology and medical ultrasonics. The Institute of Radioengineering and Electronics, Russian Academy of Sciences, under the direction of Academician Yu V Gulyaev has been active since 1962 in the fields of physical acoustics, acoustoelectronics and acoustooptics. Whilst all of these institutions retain much expertise in the 'basics' of ultrasonic science and technology, there have been many exciting modern developments in medicine and biology, nondestructive testing (NDT), underwater acoustics, the acoustics of liquid crystals, sonochemistry and acoustooptics.

This review will discuss some of these developments to provide the reader with a 'flavour' of these many diverse and often intense activities. Most of the review will be organised on the basis of the activities of particular institutions involved. For the sake of clarity, activities in the field of biology and medicine will be grouped together at the end.

## Moscow State University

The contribution of the Moscow State University roughly divides into four activity-centred groups, although, as might be expected, there is much overlap between them. The first group includes Professors O V Rudenko, V A Krasil'nikov and L K Zarembo, and Dr P S Landa and Dr D A Sapozhnikov.

Their fields include nonlinear phenomena such as acoustic shockwaves and damage mechanisms, laser optoacoustics, nondestructive testing and medical scanning, and much basic work, both theoretical and experimental, in wave interactions with materials, and in the

stochastic behaviour of dynamical systems.

The second main grouping centres around the physical acoustics of solids, and the principal scientists in the area are Professors Krasil'nikov and V E Lyamov, and Dr I Yu Solodov, all of course are supported by able research students and assistants. Their work covers many applications of surface, interface and bulk waves, including nonlinear propagation, wave propagation in high temperature superconductors, novel nondestructive testing methods, and a most exciting development in acoustic microscopy.

There is much activity in the field of underwater acoustics, the principal interest of Professor V A Burov, Dr O S Tonakanov and Dr V A Gordienko. There is similarly large scale activity in the field of aeroacoustics, principally on the part of Drs K A Velizhanina and I V Lebedeva whose interests cover resonant-type absorbers for low frequency and high frequency sound, acoustic interferometry and intensity measurement, and sound source identification, all using a modern suite of anechoic and reverberation chambers.

There is also an active group directed by Professor V N Parygin in the area of physics of oscillations, with key interests in acoustooptical interactions in anisotropic media, with applications to modulation processes, and scanning and spectral filtration of radiation in the visible, IR and UV regions.

## The N N Andreyev Acoustical Institute

This institute, presently under the directorship of Professor N A Dubrovsky, is active in a broad range of acoustics problems and applications. Ultrasonics research mainly supervised by Professor V Kazantsev covers solids, liquids and gases with many new technologies emerging. These include high amplitude ultrasonic cleaning, atomization of liquids, hardening processes for solids, and novel applications to NDT, surface ultrasonic holography, impedance measurements, and the technology of ultrasonic array transducers, a principal interest of Yu B Somennikov.

Professor I A Victorov, one of the founders of acoustoelectronics and who for many years pioneered developments of surface acoustic waves (SAWs) applied to many classes of solids, including semiconductors and ferroelectrics. His thorough theoretical and experimental investigations of SAW propagation and scattering on complex surfaces have greatly influenced much international effort to develop this technology, and are likely to continue to do so for some considerable time to come.

Dr A A Chaban was the first to investigate acoustic wave parametric interaction with AC electric fields in

piezoelectric semiconductors. He explained the new phenomenon of electroacoustic memory in piezoelectric semiconductors, and simultaneously with Dr K L Meecher and N S Shiren, discovered the long-time storage echo in piezoelectric powders. He also developed a theory of acoustooptical interactions in photoconducting piezoelectrics with light gratings, and proposed a new way to explain the acousto-photorefracting effect. In related work Dr P A Pyatakov and his group are investigating optoacoustic interactions in semiconducting and photo-refractive crystals, and a most important outcome has been the generation of acoustic wave patterns that could be recorded and erased using a photorefractive grating – that is, a photoacoustic effect with memory.

In addition, much novel science has been developed in the field of piezoelectric materials. Dr E A Grishchenko works on second order piezoelectric interactions in solids and Dr I P Golyamina and colleagues are involved in the investigation of piezoelectric films, based on PVDF, and piezoelectric composite devices.

On a much larger physical scale the institute supports important activities in underwater acoustics applied to oceanography and related fields. High power acoustics, nonlinear and long range parametric signal propagation have been the research domain of Professor L M Lyamshev, Dr K A Naugolnickh and Dr I A Esipov. Propagation in shallow channels and ducts in deep ocean is studied by Dr O P Galkin and co-workers. In the field of devices Dr O A Kapustina's group is developing new acoustic and hydroacoustic seismic devices, and nematic sensors for environmental monitoring.

## The Institute of Radio Engineering (IRE); Russian Academy of Sciences (RAS)

The RAS is the largest multidisciplinary research body in Russia, and among its functions are the planning and pursuit of scientific programmes designed to support national priorities in science and technology.

At present there are more than fifty RAS institutes in Moscow alone. The Institute of Radio Engineering and Electronics is one of these, and enjoys a certain autonomy and its own legal status. Its present director is Academician Yu V Gulyaev who many years ago founded its activity in acoustooptics and acoustoelectronics, and since the 1970s the institute has led the field in these areas.

Indeed, it was Academician Gulyaev, in collaboration with corresponding RAS member V I Pustovoyt, who first suggested the application of SAWs in electronics and developed a theory of SAW amplification by supersonic drift of electrons in piezoelectric semiconductors and layered structures. He discovered a new type of SAW, the Bleustein-Gulyaev wave, and developed the theory of nonlinear acoustoelectronic interaction. Together with Professor E M Epstein he discovered the acoustomagneto-electric effect and other acoustoelectronic drag effects. In collaboration with Professor V P Plessky he predicted the so-called 'gap waves', and a type of SAW, on a corrugated surface. He also created the theory of nonlinear acoustooptic interaction with Professor G N Shkerdin and Professor V V Proklov.

Much pioneering experimental work in field of SAW excitation, and propagation in piezoelectric materials and layered structures, has been contributed by a group of four investigators of the institute – Drs A V Medved, A M Kmita, V N Fedoretz and V I Grigor'evsky. Many exploitable innovations have come out of this work, such as capacitive anodising of transducers for electronic filters for TV and telecommunications, and acoustoelectric amplifiers. SAWs in periodic structures, and SAW devices for gas and chemical sensing, including some based on Langmuir-Blodgett films, have been developed by Professor V P Plessky's group.

Among the original investigations carried out in the IRE are the application of acoustic waves at frequencies up to 9.4 GHz in piezosemiconductors, and nonlinear and parametric phenomena in sound propagation in semiconductors in alternating electric fields, including the prediction and observation of nonlinear Landau type absorption and gain, the principal investigators being Professors S N Ivanov, G D Mansfield and M E Zilberman.

There has also been the discovery of giant oscillations in absorption coefficient under the influence of alternating electric fields, nonlinear interactions of acoustoelectronic fluctuations, and the discovery and supporting theory of the sharp decrease in lattice absorption coefficient in heavily doped crystals, principally by Dr V V Medved, Professor S N Ivanov, and A G Kozorezov. At the present time these groups are working in nonlinear magnetoacoustics, including investigations of acoustomagnetic recording in polycrystalline ferrites, and special effects in new materials with high acoustic transparency.

Photoelasticity is well represented at the IRE by, for example Dr G N Shkerdin, who has carried out extensive work on photoelasticity in solids, and has studied characteristic resonances of the photoelastic tensor at microwave frequencies near exciton resonances that characterise quantum well structures. He is also responsible for many novel acoustic devices for the control of optical emission.

This work is complemented by the activities of Professor V Y Proklov who combines studies of acousto-infrared phenomena with a number of projects in the visible such as acoustooptic nonreciprocity, light stimulated nonlinear acoustooptic processes, and some important pioneering studies of anisotropic collinear acoustooptic interactions in integrated optical devices. Recent moves to the IRE by corresponding RAS member V I Pustovoyt and Dr L A Chernozatonsky (a world expert on fullerenes) have greatly strengthened both the experimental and theoretical aspects of acoustoelectronic and acoustooptic research. The future of the IRE seems reasonably secure and its research will continue to retain a balance between world class fundamental work and new techniques and technologies.

## Other Institutes

So far this article has concentrated on the activities of three main players in ultrasonics research and technology – Moscow State University, the Acoustical Institute, and the Institute of Radioengineering and Electronics. However

no article on ultrasonic science in Moscow would be complete without mention of the many significant contributions to the field from institutes that do not focus on acoustics to the same extent as those above but who, nevertheless, maintain an appreciable presence. As an example, the Moscow Institute of Physics and Technology, has hosted studies by Professor A S Bugaev and Academician Yu V Gulyaev on the interaction of magnetostatic and elastic waves in ferrite films and layered microstructures, including magnostriptive generation of hypersonic waves, and spinwave instability in phase synchronism, acoustoelectronic interactions in semiconductors in AC electric fields, and nonlinear acoustoelectronic phenomena.

The Moscow Power Engineering Institute supports a department of Radioengineering in which many advanced devices for radio frequency filtering and nonlinear convolution operations have been developed, particularly in the context of satellite communications technology. The Moscow Institute of Radiocommunication offers many advanced devices on a commercial basis to support civil radio, TV and general communications, and special military systems.

The Institute of Oceanology has seen major contributions by Academician L M Brekhovskikh, who was instrumental in the 1950s in developing the field of undersea acoustics. His output in general underwater wave problems was significant, culminating in the 1970s with one of the most important discoveries of twentieth century earth sciences – the discovery of synoptic vortices in the ocean. Brekhovskikh, a world authority in acoustics, and particularly in the physics of scattering, has also made significant contributions to geophysics, particularly in the field of SAW propagation as a function of the physical properties of the earth's crust. His results contribute to the solution of many seismic problems, and, on a much reduced physical scale, to nondestructive testing of layered structures. Finally, a large effort in the peaceful applications of acoustics to underwater studies, mention must be made of significant developments by Professor N A Dubrovsky, the Institute's director, on the acoustic location of dolphins in their natural environment.

Sono-chemistry is of growing importance in the Russian scientific and technological effort, much of the effort being centred in the All-Russia Institute of Organic Synthesis. Here, Dr M A Margulis has developed a new electrical theory on the basis of sonochemical reactions and sonoluminescence. On the theoretical side fundamental studies have led to theories of diffusion, sonoluminescence and quenching, as well as to new sonochemical processes such as the initiation of chain reactions and stereoisomerisation with high energy fields. In the All-Russia Institute of Light Alloys much effort over the past 25 years has gone into the synthesis of new composites using aluminium alloys, as well as ultrathin filtering methods for melts, using sound capillary effects.

## Ultrasonic Research in Biology and Medicine

Under this heading the main areas of investigation are

studies of the biological action of ultrasound and ultrasonic safety in medicine, acoustic spectroscopy of solutions of biological media, and acoustic characterisation of tissues and biological objects, acoustic visualization and microscopy, and clinical ultrasonics.

Most of these fields have been developed by Professor A P Saravazyan's group in the Institute of Theoretical and Experimental Biophysics of the Russian Academy of Sciences, situated at Pushchino in the Moscow region. This group's more important recent investigations are the recording of tissue mechanical response to describe internal anatomical structures in terms of their viscoelastic properties for cancer detection, combined with model experiments with tissue phantoms to illustrate the basic principles and possibilities for clinical applications. They have shown that the mechanical characteristics of internal tissues obtained from changes in geometric or dynamic features of a scanned image could be used in various types of medical acoustic imaging instruments. Another field is the application of ultrasonic studies in molecular biophysics.

This work has included studies of conformational transitions in proteins and hydration of biological molecules, the energetics of molecular processes, and the P-V-T thermodynamic state of liquid systems. The group has developed instrumentation for precision acoustic measurements in small volume samples over a wide range of temperatures and pressures, and have investigated the nonlinear acoustic properties of aqueous solutions, including contributions of various molecular interactions to the acoustical nonlinearity of these mixtures.

In the professorial unit for biophysics of the Moscow Veterinary Academy the group of Dr Akopyan has studied the mechanisms of the biological effects of ultrasound, ie ultrasonic cavitation, effects on cell suspensions and tissues, and sonoluminescence by formation of hydrogen peroxide free radicals and other chemically active compounds. Besides clinical medicine his group is also involved in veterinary medicine. In particular they have managed with the aid of ultrasound to introduce medication into the foetus in an incubator. Ultrasound techniques have also been used to stimulate organisms to get effects similar to those generated by autothermotherapy. Some work is also in progress in the field of cryobiology.

In the Institute of Chemical Physics, Russian Academy of Sciences, Dr R I Bragynskaya and coworkers study the effects of ultrasound on biological media of different levels of organization, ie proteins, nucleic acids, membranes, whole cells, etc; they have developed the basic principles of ultrasound spectroscopy for nucleic acids and their derivatives, and determined the relaxation mechanisms and the basic properties of chemical and structural transitions of molecules in aqueous solutions.

They studied the comparative contribution of chemical and physical factors associated with ultrasonic cavitation to damage in biopolymers and cells, and found effects such as changes in erythrocytes, and membrane bound enzymes in pathological transformations of tissues. They also studied the effects of physiologically active compounds on cell structures using acoustic methods.

In the field of medical applications special reference must be made to the use of focused ultrasound in medicine. In the Laboratory of Medical Acoustics of the N N Andreyev Acoustical Institute Dr L R Gavrilov and others study the application of high power ultrasound to tissue transformation. The work concerns the possible use of focused ultrasound in the MHz frequency range for local irradiation of superficial and deep biological tissues. The main application was to bring about ultrasonic hyperthermia of tumours.

In addition, many new ultrasonic methods and devices for medical applications have been developed, a most interesting group for the diagnosis of neurological and skin diseases by measurements of various sensitivity thresholds in skin and deep structures, and also for the diagnosis of various hearing disorders by means of amplitude-modulated ultrasound for stimulating labyrinth neural structures ('the Ultrasonic Audiometer'). Methods based on focusing transducers for remote noninvasive measurements of various acoustical and thermal parameters of biological tissues have also been developed. Recently Dr I P Golyamina's group at the Acoustical Institute has developed surgical instruments for use in ophthalmology, neurosurgery, otolaryngology and general surgery.

Among recent scientific and practical developments related to acoustic visualization a most important one is that of acoustic microscopy. The developments of microscopic methods have involved biological applications of a scanning acoustic microscope in both a two-lens and a

one-lens arrangement. The acoustic microscope, suggested by Professor S Ya Sokholov, was developed in Moscow State University by Professor V E Lyamov, in the IRE by Dr A I Morozov, and in Chemical Physics Institute by Dr R G Mayev, whose group studied acoustic properties of live tissues and bones with acoustic microscopy. High acoustic resolution gave the opportunity for an integrated understanding of acoustic images of various biological tissues, including pathological ones.

## Concluding Remark

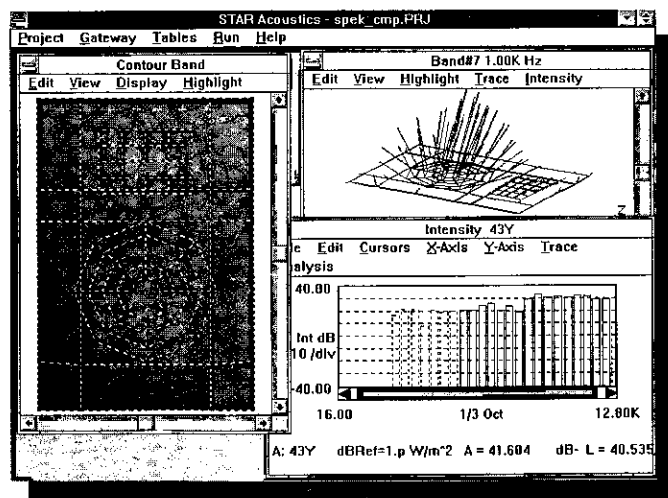
In order to constrain this article to a reasonable length it has been necessary to limit my discussion to little more than a list of the many and varied activities of a significant group of Russian scientists working in the field of Ultrasonics and Physical Acoustics. Over the years their contributions have shown great ability and imagination and have been truly significant on a world scale. I hope that I have demonstrated the depth, breath and intellectual vibrancy of these special people.

## Acknowledgements

I would like to thank Academician Yu V Gulyaev and Professor G D Mansfield for their most helpful collaboration and discussion in the production of this article. I also thank Professor R E Challis for editorial assistance.

Professor N N Shibanova is at the Moscow Institute of Physics and Technology, Institutsky per Dolgoprudny, Moscow Region. ♦

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# CALL FOR PAPERS

1995 Spring Conference

**ACOUSTICS '95**

## **Environmental Noise and Vibration**

(Organised by the Environmental Noise Group)

Britannia Adelphi Hotel, Liverpool

9-11 May 1995

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

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

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

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

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

Offers of contributed papers should be sent with a 100-word abstract to the Institute office before 12 December 1994. Written papers will appear in Volume 17 of the Proceedings of the Institute of Acoustics (1995) which will be available to delegates upon arrival. Completed manuscripts, normally no more than 8 pages long and typed on the camera ready paper provided, must be with the Institute before 20 March 1995. Intending authors should indicate if it is their intention to have their paper refereed under the new procedure.

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

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

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# MEETING NOTICE

One Day Meeting  
**Sound Power Measurement**  
 (Organised by the Industrial Noise Group)  
 Commonwealth Conference Centre, London  
 30 November 1994

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

## Programme

|       |                                                                     |
|-------|---------------------------------------------------------------------|
| 10.00 | Registration                                                        |
| 10.30 | Introduction, <i>Alistair Mackinnon</i>                             |
| 10.40 | Sound Power Measurement, <i>a speaker from NEL</i>                  |
| 11.10 | Sound Power Instrumentation, <i>Andrew Small, Bruel &amp; Kjaer</i> |
| 11.40 | Standards, <i>Roger Higginson, Consultant</i>                       |
| 12.10 | Legislation, <i>Harry Lester, HSE</i>                               |
| 12.45 | Lunch                                                               |
| 14.00 | A User's Perspective, <i>Martin Williams, Kent County Council</i>   |
| 14.30 | A Manufacturer's Perspective, <i>Paul Guckian, AT&amp;T</i>         |
| 15.00 | Sound Intensity Case Studies, <i>Dick Whitson, NEL</i>              |
| 15.30 | Coffee                                                              |
| 16.00 | Discussion Forum to include a contribution from the DTI             |
| 16.45 | AGM of the Industrial Noise Group                                   |
| 17.30 | Close                                                               |

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

☐ I wish to attend the Meeting on **Sound Power Measurement**

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☐ I cannot attend the meeting. Please send me a copy of the proceedings £18 (members) £25 (non-members)

Please return this form or a photocopy before 21 November 1994 to

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# SECOND CALL FOR PAPERS

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## Sonar Transducers '95

(Organised by the Underwater Acoustics Group)

3-5 April 1995  
University of Birmingham, UK

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

Here are some suggestions for topics:

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

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

Prospective authors are invited to submit a 200 word synopsis not later than 14 November 1994, and successful authors will be notified by the end of November. Arrangements will be made for papers to be refereed if authors would prefer.

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

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

All communications should be sent to the Conference Secretary:

*Mr J R Dunn MIOA, School of Electronic and Electrical Engineering,  
University of Birmingham, Edgbaston, Birmingham B15 2TT.  
Tel: 021 414 4312 Fax: 021 414 4291  
email: JDUNN@EE-ADMN.BHAM.AC.UK  
Compuserve: 100111,3610*

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# CONFERENCE NOTICE

## 1995 International Auditoria Conference

# Opera and Concert Hall Acoustics

(Organised by the Building Acoustics Group)

**Forte Crest Hotel, Gatwick Airport, UK**

**10-12 February 1995**

### Friday, 10 February 1995

#### Technical Session 1:

ACOUSTICS OF THE CONCERT HALL (WITH SPECIAL REFERENCE TO ST DAVID'S HALL, CARDIFF & THE GLASGOW ROYAL CONCERT HALL) *A Burd, Sandy Brown Associates* • INVESTIGATIONS INTO PROBLEMS OF AUDITORIUM ACOUSTICS *P Mapp (Consultant)* • SPATIAL INFORMATION OF SOUND FIELDS FOR AUDITORIA DIAGNOSTICS *Professor R Guy & A Abdou, Centre for Building Studies, Montreal* • THE IMPORTANCE OF DIFFUSE REFLECTION IN COMPUTERISED ROOM ACOUSTIC PREDICTION & AURALIZATION *B-I Dalenback, Chalmers University of Technology, Sweden* • FURTHER INVESTIGATION INTO THE SUBJECTIVE LOUDNESS OF RUNNING REVERBERATION *D Griesinger, Lexicon, USA*

#### Technical Session 2:

THE ACOUSTIC DESIGN OF THE EDINBURGH FESTIVAL THEATRE *L Haslam, Sandy Brown Associates* • THE ACOUSTIC DESIGN OF THE ANVIL CONCERT HALL, BASINGSTOKE *R Cowell, Arup Acoustics* • ACOUSTIC PROBLEMS OF THE SALLE PLEYEL (PARIS) & THE MODIFICATIONS IN 1994 *A Y Xu, Xu-Acoustique, France* • THE ACOUSTIC DESIGN OF THE YORK BARBICAN *N Spring, Sandy Brown Associates* • THE WOODEN CONCERT HALL FOR THE MUSIC FESTIVAL OF EVIAN, "LA GRANGE AU LAC" *A Y Xu, Xu-Acoustique, France* • STUDIES OF OPERA HOUSE ACOUSTICS *M Barron, University of Bath*

### Saturday, 11 February 1995

#### VISIT TO GLYNDEBOURNE OPERA HOUSE

(Welcome speech by Sir George Christie)

THE ORIGIN & ANTECEDENTS OF THE GLYNDEBOURNE AUDITORIUM

*I Mackintosh, Theatre Projects Consultants*

THE ACOUSTIC DESIGN OF GLYNDEBOURNE OPERA HOUSE

*D Sugden & R Harris, Arup Acoustics*

TOUR OF THE GLYNDEBOURNE OPERA HOUSE

### Sunday, 12 February 1995

#### Technical Session 3:

OPERA HOUSE DESIGN - TO HEAR, TO SEE OR TO BE SEEN? *Anne Minors, Theatre Projects Consultants* • ACOUSTICS CONDITIONS IN ORCHESTRA PITS & PROSCENIUM ARCH THEATRES *J O'Keefe, Aercoustics Engineering Ltd, Toronto* • QUANTIFYING THE SENSITIVITY OF MODERN STAGE ACOUSTICS MEASUREMENTS *J O'Keefe, Aercoustics Engineering Ltd, Toronto* • THE SOUND OF LIGHT *A Russell, Theatre Projects Consultants* • ACOUSTIC RECOVERY OF A 200 YEARS OLD NATIONAL OPERA HOUSE: THE TEATRO S CARLOS IN LISBON *D Commins, Commins Acoustics Workshop, France* • THE NEW OPERA HOUSE IN CAGLIARI *P Fausti, University of Ferrara*

#### Technical Session 4:

ACOUSTIC CHARACTERISATION & RESTORATION OF THE GOLDONI THEATRE IN LIVORNO *Dr G Licitra, G Giusti, M Cerchiai, P Paoli, B Pisani & C Rini, Unita Sanitaria Locale, Livorno, Italy* • THE ACOUSTIC CONDITIONS OF THE SAN FRANCISCO OPERA HOUSE & REHEARSAL & WORKSHOP FACILITIES *D Paoletti, K Graffy & L Tedford, Paoletti Associates Inc, USA* • THE ACOUSTICAL DESIGN OF THE NEW PRINCESS OF WALES THEATRE IN TORONTO, CANADA *J O'Keefe, Aercoustics Engineering Ltd, Toronto* • STUDY OF OPERA & CONCERT HALL ACOUSTICS *D Sugden, Arup Acoustics*

**Conference Organiser: Jeff Charles FIOA, Bickerdike Allen Partners**

*To register an interest in this conference and to receive an early copy of the full programme and an application form to attend as a delegate, please fax the Institute office on +44 (0)1727 850553.*

# CONFERENCE NOTICE

International Conference

## UNDERWATER ACOUSTIC SCATTERING

(organised by the Underwater Acoustics Group sponsored by the Defence Research Agency)

Weymouth, 20-22 December 1994

### Provisional Programme

#### Tuesday 20 December 1994

**Surface Scattering and Losses** Sea Surface Scattering (Invited paper) *P Crowther (GEC-Marconi)* • Near surface backscatter: its modelling and use as a mixing marker *A Graham (University of Southampton)* • Meteorological effects on sound attenuation in the oceans *G P Singh and A G Holt (University of Newcastle)* • Experimental studies of acoustic scattering from surface roughness in a water tank *S Sun and L Bjorno (Technical University of Denmark)* **Techniques in Underwater Acoustic Scattering** Histogram variation with range in side-scan records, and shade compensation by histogram matching *G Shippey, A Bolinder, R Finndin (Chalmers University of Technology, Gothenburg, Sweden)* • Direct path fluctuations observed in the Mediterranean Sea *A H Alkhalidi, B V Smith, R F W Coates and R H Owen (University of Birmingham)* • Surface reflected fluctuations observed in the Mediterranean Sea *R H Owen, B V Smith and R F W Coates (University of Birmingham)* **Scattering from Underwater Structures and Objects** Experimental studies of acoustic scattering by cylindrical objects *V F Humphrey (University of Bath)* and *C Beckett (BAeSEMA)* • Resonances in acoustic scattering by cylindrical objects *V F Humphrey and P A Chinnery (University of Bath)* • Transmission and scattering by doubly periodic structures *P C Macey (PAFEC, Nottingham)* and *D J W Hardie (DRA, Portland)* • Oblique incidence diffraction by axisymmetric structures *P C Macey (PAFEC, Nottingham)* and *R A Hazelwood (Sonardyne Ltd)*

#### Wednesday 21 December 1994

**Scattering by Suspended Sediments and Biologics** Volume scattering by marine suspensions (Invited paper) *P D Thorne (Proudman Oceanographic Laboratory)* • Resonance scattering from fish schools *C Feuillade and R H Love (NRL, Stennis Space Center, USA)* • Acoustic spectroscopy of suspended sediments *A S Schaafsma (Delft Hydraulics, Netherlands)* **Modelling of Reverberation and Scattering** Reverberation modelling with INSIGHT *M A Ainsley and C H Harrison (BAeSEMA Ltd)* • Rough surface scattering and the inverse problem at low grazing angles *M Spivak (University of Cambridge)* and *D Waymont (Smith System Engineering)* • Parabolic equation techniques in ocean acoustics (AB Wood Memorial Lecture) *M D Collins (NRL Washington, USA)* **Bubble and Ship-Wake Scattering** Acoustic Scattering from surface ship wakes *P H Pidsley (GEC-Marconi)* • Acoustic properties of bubble distributions: comparison between theory and experiments • *D Bucknell, P R Atkins, B V Smith, S Otto (University of Birmingham)*, and *F Riordan (University College, Cork, Eire)* • Interferometric synthetic aperture sonar for high-resolution 3-D imaging *H D Griffiths (UCL London)*, *J W R Griffiths, S Meng, C F N Cowan, T A Rafik (University of Technology, Loughborough)* and *I Shafeeu (UCL, London)* **Seabed Scattering** Scattering from the sea bed (Invited paper) *D R Jackson (APL-University of Washington, Seattle, USA)* • A simple model for estimating the backscattering strength of the ocean floor *J W Caruthers and J C Novarini (NRL, Stennis Space Center, USA)* • Analyses of the direct path, low frequency monostatic reverberations from exposed rocks and sediment covered areas of the ARSRP fine-scale experiment *A K Kalra and J K Fulford (NRL, Stennis Space Center, USA)*

#### Thursday 22 December 1994

**Sediment Acoustics** Sediment volume scattering (Invited paper) *N G Pace (University of Bath)* • A model for bistatic scattering from trapped gas bubbles in sandy sediments *F A Boyle and N P Chotiros (ARL, University of Texas at Austin, USA)* • Shallow water bottom scattering strength at low frequencies *P Cable, J O'Connor and M Steele (BBN Systems and Technologies, USA)* **Seabed Classification** Gain invariant sea bed classification *T M Edgecock (GEC-Marconi)* • Seabed classification using angular dependence of backscattering strength and textural analysis *M A Pinto and E Faure (Thomson Sintra ASM, Brest, France)* • Bottom reverberation measurements in deep and shallow water *G Searing, K R Williams, G B Wood (DRA Portland)*

### Information

For further information concerning the conference programme contact the Conference Organisers: G J Heald MIOA, Tel: 0305 863105 or S A S Jones MIOA, Tel: 0305 863461 DRA, Southwell, Portland, Dorset DT5 2JS, UK Fax: 0305 863446.

Registration fees for the conference are £100 (For authors who are members of the Institute), £120 (Authors who are not members of the Institute & members who are not authors), £65 (students supported by a letter from the head of department confirming status) and £160 (non-members). VAT must be added to each of these amounts. Registration forms and information regarding hotel accommodation are available from the Institute office. A commercial exhibition will be staged where equipment may be demonstrated or services advertised; information on this from the organisers or the Institute office.

# ANNOUNCEMENT and CALL FOR PAPERS

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International Conference

## Sonar Signal Processing

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

University of Technology Loughborough Leicestershire UK

18-20 December 1995

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

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

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

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

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

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

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

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# INSTITUTE DIARY 1994/5

## 1994

**3 NOV**  
**Reproduced Sound 10,**  
**4 days**  
**Windermere**

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

**9 NOV**  
Miniature Microphone  
Workshop  
*University of Salford*

**10 NOV**  
IOA Education  
Committee  
*St Albans*

**10 NOV**  
Environmental Noise  
Group Committee  
*St Albans*

**10 NOV**  
South-west Branch  
meeting: Underwater  
Acoustics  
*Bristol*

**11 NOV**  
Workshop: Current  
Issues in  
Standardisation  
*London*

**18 NOV**  
Acoustics '95  
Committee meeting  
*Liverpool*

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

**16 NOV**  
London Branch Annual  
Dinner

**23 NOV**  
Chartered Engineer  
Interviews  
*St Albans*

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

**29 NOV**  
Southern Branch  
meeting  
*Basingstoke*

**30 NOV**  
Workshop: Sound  
Power Measurement  
*London*

**1 DEC**  
IOA Meetings  
Committee  
*St Albans*

**1 DEC**  
Inter-noise '96  
Committee meeting  
*St Albans*

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

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

**14 DEC**  
London Branch mtg:  
Loudspeaker Design  
*London*

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

## 1995

**2 FEB**  
IOA  
Publications, Meetings  
Committee  
*St Albans*

**10 FEB**  
IOA CofC in  
Workplace Noise  
Assessment exam  
*Accredited Centres*

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

**16 FEB**  
IOA Membership,  
Education Committee  
*St Albans*

**2 MAR**  
IOA Medals & Awards,  
Council  
*St Albans*

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

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

**15 MAR**  
London Branch mtg:  
Building Services Noise  
*London*

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

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

**26 APR**  
London Branch mtg:  
Acoustic Intensity  
*St Albans*

**27 APR**  
IOA Publications,  
Meetings Committee  
*St Albans*

**4 MAY**  
IOA Membership,  
Education Committee  
*St Albans*

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

**10 MAY**  
IOA 1995 AGM and  
Annual Dinner  
*Liverpool*

**19 MAY**  
IOA CofC in  
Workplace Noise  
Assessment exam  
*Accredited Centres*

**25 MAY**  
IOA Medals & Awards,  
Council  
*St Albans*

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

**15-16 JUN**  
IOA Diploma  
Examinations  
*Accredited Centres*

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

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

**21 SEP**  
IOA Publications,  
Meetings Committee  
*St Albans*

**28 SEP**  
IOA Membership,  
Education Committee  
*St Albans*

**5 OCT**  
IOA Medals & Awards,  
Council  
*St Albans*

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

## MEMBERSHIP

The following were elected at the Council Meeting held on 6 October 1994

|                |                         |                |                  |                  |
|----------------|-------------------------|----------------|------------------|------------------|
| <b>Fellow</b>  | Stinson, A B G          | Dubet, M A E   | McCaffrey, C A   | Walker, H G      |
| Goodchild, J C | Tate, J D               | Duffy, G       | Moule, A P       | Wallace, J E     |
| Griffiths, H D | Thomas, K E             | Ellis, P R     | Mowforth, J      | Ward, J A        |
|                | Woodger, A N            | Faragher, I    | Muggleworth, S D | Wastell, K       |
| <b>Member</b>  | <b>Associate Member</b> | Francis, D J   | Netherton, A M   | Waters-Fuller, T |
| Allen, W G     | Abbey, C S              | Freeman, P     | Officer, A G     | Whittington, R A |
| Anakwue, P M   | Atkins, N D             | Fritsch, H B   | Omar-Ali, F F    | Wilkins, S L     |
| Benson, I M    | Atkins, P               | Garthwaite, K  | Peers, R P       | Williams, E A    |
| Chan, K O      | Bird, A L               | Gray, J        | Poon, W Y        | Woodan, M J      |
| Cheepen, C     | Boase, S A              | Grimley, A P   | Richards, J K    | Zeolla, F N      |
| Forni, M S     | Brown, D W              | Halliday, D W  | Roberts, M J     |                  |
| Gough, R G     | Bryan, R J              | Harker, R J    | Roberts, R L     | <b>Associate</b> |
| Legerton, M L  | Budd, R W S             | Haynes, D R    | Scourfield, P M  | Jones, A P       |
| Manley, D M    | Clift, P J              | Jamieson, H S  | Smith, D J       | Palmer, B A      |
| Moran, J C     | Cooper, J               | Johnson, F M   | Speich, N J      |                  |
| Moys, P J      | Cox, S A                | Johnston, E    | Taylor, N        | <b>Student</b>   |
| Norman, G      | Day, C                  | Lavender, D A  | Thompson, P      | Boegli, S K      |
| O'Neil, L      | Deacon, M               | Laws, E J      | Thurgood, D W    | Cox, B T         |
| Shaw, K        | Doamekpor, A A          | Lee, H E       | Tingay, J D      | Goutas, P        |
| Shilton, S J   | Dobson, C J             | Mackenzie, R G | Towse, K M       | Papaker, F M     |
| Smith, M A     |                         | McCabe, J F    | Treby, N D       |                  |

## Conferences organised by member societies of the European Acoustical Association (GEIE)

### 21-23 March 1995

euro-noise '95  
Software for noise control,  
Lyon, France  
Contact: euro-noise '95  
Secretariat, CETIM Acoustical  
Dept, 52 av. Felix Louat, 60300  
Senlis, France

### 5-8 June 1995

30th International Conference  
on Acoustics, Noise and  
Environment, High Tatras,  
Slovakia  
Contact: EDUCO-CENTRUM,  
N Bajova, Hurbanova 329,  
P O Box 39, 01008 Zilina,  
Slovakia.

### 12-16 June 1995

Symposium on Fisheries and  
Plankton Acoustics,  
Aberdeen, UK  
Contact: Mr E John Simmonds,  
Marine Laboratory, P O Box  
101, Victoria Road, Aberdeen  
Scotland

### 26-30 June 1995

15th ICA Congress,  
Trondheim Norway Contact:  
ICA'95, N-7034 Trondheim

### 2-6 July 1995

International Symposium on  
Musical Acoustics, Dourdan,  
France Contact: ISMA'95  
Secretariat c/o Agnes Couailler  
IRCAM, 1 place Igor-Stravinsky,  
75004 Paris, France

### 3-7 September 1995

1995 World Congress on  
Ultrasound, Berlin Contact: J  
Herbertz, WCU'95 Secretariat  
Gerhard-Mercator-Universitat,  
4708 Duisburg, Germany

### 23-26 Sept 1995

32nd Conference on  
Psychology Acoustics,  
Acoustics of Speech and Music,  
Prague, Czechia Contact: CAS  
Technicka 2, 16627 Prague 6,  
Czechia

### 10-12 Oct 1995

2nd Int Conference on  
Acoustics and Vibratory  
Surveillance - Method and  
Diagnostic Techniques,  
Clamart, France Contact: SFM  
Maison de la Macanique 39-41  
rue Louis Blanc, 92400  
Courbevoie France

### 1-4 April 1996

European Congress on  
Acoustics, Antwerp Belgium.  
Contact: Convention Secretariat  
Technological Institute, K VIV  
Desguinlei 214, 2018  
Antwerpen, Belgium

### 24-28 June 1996

3rd European Conference on  
Underwater Acoustics,  
Heraklion Greece Contact: J S  
Papadakis Foundation for  
Research and Technology  
Hellas Institute and Computer  
Mathematics, POB 1527, 71110  
Heraklion, Crete, Greece

# WINDFARM DEVELOPMENTS

K Ratcliffe FIOA

## Introduction

During the last few years there has been a rapid increase in the number of planning applications for the development of windfarms. The Government has encouraged this with financial incentives to developers and land owners via the Non Fossil Fuel Obligation. By the deadline of 9 March 1994 over 650 renewable energy projects had been submitted for the new round of contracts and 230 of these were for wind energy proposals. Tim Eggar, Energy Minister, said recently that he would expect to see no more than twenty or so windfarms result from this round (NFFO 3). As a consequence there will no doubt continue to be planning applications submitted to local authorities, to some of whom, the technicalities will be unfamiliar. During the last few years, ISVR Consultancy Services (ICS) has carried out work in the fields of the generation and propagation of noise from wind turbine generators (WTGs) and since 1991 have assisted a number of local planning authorities in dealing with the noise aspects of planning applications for windfarms. Three of these have resulted in the preparation and presentation of evidence at planning appeals. Some of the basic matters considered are described and the general approach is given.

The IOA has informed members of windfarm developments by means of meetings and references in Acoustics Bulletin. For example at the Windermere Conference in November 1993 a visit to Haverigg Windfarm was arranged and this was followed by a workshop session and an open discussion. On 17 February 1994 a one day meeting, 'Windfarm Noise' was held at the Society of Chemical Industry at Belgrave Square, London. There has also been correspondence from members in Acoustics Bulletin including one from NEL, East Kilbride.

## Some Initial Considerations

Perhaps noise is not the first thing that springs to mind when wind turbine generators are mentioned. Particularly when viewed singly, they can appear to be elegant structures, at least in an engineering context. In groups, as in windfarms, they are sometimes regarded as visually obtrusive especially when on hills in country areas. The casual observer will be limited to a day-time viewing and might not consider effects which might arise due to noise from the wind turbines occurring during the night. Since their operation is dependent on the natural occurrence of wind, the turbines commence to generate electric power when the wind speed exceeds a certain value – the 'cut-in' speed. Clearly this can occur at any time of the day or night. WTGs are therefore unusual sources of noise in that the occurrence of possible intrusion cannot be forecast as it often can with many industrial activities which operate on a known time schedule.

## The Noise Source

The noise is produced aerodynamically from the blades, and mechanically from the gearbox and hydraulic pumps in the nacelle. Although the noise levels are not high in absolute terms, the random nature of their occurrence can be a cause of complaint. This is exacerbated by the fact that background noise levels during the night can be relatively low, even in urban and suburban areas. Windfarms are more usually planned for rural areas where this problem is even greater.

In addition WTGs are unusual because the noise generated is from sources well above local ground level, typically 30 to 50m. This leads to unusual behaviour in terms of the propagation of noise compared with the more common cases of industrial noise sources which are often close to the ground.

## Standards and Guidance

There are many sources of information relating to the technical and other aspects which provide guidance to developers, local authorities and other interested parties. Some of these are specific to WTGs or windfarms but there are others which deal with environmental noise more generally and are of value when considering the environmental impact due to noise.

### PPG 22. 'Renewable Energy' (Dept of the Environment Feb 1993)

The Annex on Wind Energy deals with noise in paras 13 and 39–51. This document must be read with care since some of the statements made are debateable. For example it states in para 13 that under most operating conditions, it is likely that turbine noise would be completely masked by wind-generated background noise. Whilst this is possible at high wind speeds it is not generally the case at the cut-in speed which can be the most critical condition. A further misleading statement, given in para 1, is that aerodynamic noise from wind turbines is generally unobtrusive, is broadband in nature and in this respect is similar to the noise of wind in trees. In fact the aerodynamic noise is quite unlike the noise of wind in trees and has been the cause of many complaints from people living in the vicinity of windfarms.

The only other matter which will be dealt with here is the reference in PPG 22 to the use of BS 4142 in assessing the likelihood of complaints due to noise from windfarms. This occurs in para 44 where reference is made to cases where background noise levels are below 30 dB(A) and for which the Standard is not applicable. This has led to considerable argument at planning appeals resulting in some Inspectors agreeing with what is said in PPG 22 whilst others have accepted that BS 4142 is applicable. It should be noted that the BSI Working Group dealing with the revision of BS 4142 : 1990 has included this matter

of the minimum background noise level in its considerations. Paragraph 44 also draws attention to the reference to wind speeds of 5 m/s average above which noise measurements should not be taken. It is stated that wind-farms are likely to be situated in windy areas where the BS 4142 conditions may not be satisfied. It appears that the authors of PPG 22 did not consider that wind speeds at the location where background noise measurements would normally be taken would almost certainly be lower than those at the hub height of the WTGs. Hence a wind speed of below 5 m/s at a receiver location would allow the use of BS 4142 and the corresponding higher wind speed at the hub height could cause the WTGs to be on load.

## **BSI Draft No 93/215391 (September 1993)**

Draft IEC Standard: Acoustic Noise Measurement Techniques for Wind Turbine Generator Systems. This draft standard has much in common with the methods developed over the last ten years by the International Energy Agency (IEA). It deals with the method of noise and wind measurements required to establish the reference sound pressure level and the apparent sound power level of the WTG. A method of quantifying the tonality of the noise is included.

## **Some Controversial Matters**

Inevitably there are differences of opinion between expert witnesses who present technical evidence at planning appeals on behalf of the developers, local authorities and third party objectors. In the case of noise from windfarms the areas where disagreement exists includes the following:

- (i) the fact that in the case of most manufacturers there is an on-going programme of development and it is not always possible to quote the basic sound power level of the WTG to be used to an acceptable degree of accuracy;
- (ii) the prediction of noise levels at receiver locations at distances of the order of 300 m to 1 km is still the subject of research into the patterns of sound propagation from WTGs especially in hilly areas;
- (iii) the question of the subjective effect of noise from WTGs in terms of both aerodynamic noise and mechanical (tonal) noise;
- (iv) the applicability of BS 4142 as a means of assessing complaints due to noise from windfarms;
- (v) the relevance of sleep disturbance criteria, based on absolute levels of noise rather than the exceedence over the background levels;
- (vi) assessments based on the loss of amenity including the enjoyment of gardens and other areas outside residential property.

## **Example: Planning Appeals in North Devon**

An appeal against the refusal of an application to develop a windfarm at Fullabrook Barton in North Devon was heard in January 1992 when ISVR Consultancy Services gave noise evidence on behalf of the North Devon District Council.

The original proposal was for the erection of twelve WEG M5-3 type 300 wind turbines with an alternative of eleven Vestas Windane 400 kW machines. Several dwellings would have been affected by noise and visual intrusion in the rural area concerned and these were in an area of low lying land adjacent to the hill where the wind turbines would have been sited. Wind speeds and background noise levels were significantly lower near those dwellings than on the hillside. The evidence on noise took this into account and it was argued that on the basis of an assessment by BS 4142 or by using a sleep interference criterion, the windfarm would have an adverse effect on the amenity of local residents.

The Secretary of State considered the evidence on planning, visual and noise effects in coming to his decision to dismiss the appeal.

In March 1994 a further appeal was heard into a second application by the same developer for windfarms of both Fullabrook Barton and the adjoining Crackaway Barton. The applications were for nine and seventeen Vestas 500 kW wind turbines at these two sites respectively.

The technical evidence presented by ICS was similar to that used for the first appeal but it was necessary to counter the view of the consultant acting for the developer that the propagation of noise from wind turbines should be based on spherical rather than hemispherical divergence. The major issues, as before, were planning, visual intrusion and noise and after considering all of these the Planning Inspectorate dismissed both appeals.

The outcome of an appeal held in January 1994 into the refusal of an application into the development of a windfarm at Shoreham Harbour in Sussex is still awaited.

## **Conclusion**

Clearly the use of wind energy as a means of generating electrical power is basically attractive but there can be concomitant penalties in terms of the environmental impact. Wind turbines are not universally accepted and it is becoming evident that windfarm developments can cause justifiable complaints due to noise and other effects. There is pressure on the designers and manufacturers of WTG to mitigate the noise problem and this is no doubt a direct result of public complaint in relation to some developments.

**Ken Ratcliffe FIOA is with ISVR Consultancy Services. ♦**

## **Advertising in Acoustics Bulletin**

contact

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# SINGLE PURPOSE AND MULTI-FORM: A TALE OF TWO AUDITORIA

Rob Harris FIOA

## Introduction

In May of this year batons were raised for the opening performances in two major new UK music auditoria of similar capacity: the new Glyndebourne Opera House (1256 seats plus standing) and The Anvil concert hall, Basingstoke (1400 seats). There the similarities end.

This article contrasts the acoustic designs for the two halls in the context of the nature and expectations of the clients and architects, the resultant acoustic challenges, the modelling techniques adopted, the developed designs and subsequent acoustic reputations.

More detailed technical analysis will be included within papers to be presented at the IOA Opera and Concert Hall Acoustics conference in February 1995.

## Briefs and Opportunities

Glyndebourne was a rare delight for an acoustician – the opportunity to design an auditorium solely for one clearly defined purpose, namely excellence in opera performance. Conversely The Anvil presented the more common challenge of use for a wide range of events, but with a clear agreement with the client that the acoustic would be designed primarily for classical and symphonic music, with adaptation to other performance types and formats, including light entertainment, rock concerts, dance and cinema.

The funding for Glyndebourne was private, with a number of key individuals representing the client body. At Basingstoke the money was public, administered by elected committees and council officers. At Glyndebourne, Sir George Christie had a clear idea of the sound he wanted, this could be summarised as 'resonance (ie reverberation) with clarity'. At The Anvil it was for the acoustic consultants to set the basic aims. These

were not dissimilar – a warm, reverberant orchestral sound, but with high clarity. Acoustical intimacy and adequate loudness were prerequisites of both designs.

## The Architects

Again, differences. Michael and Patti Hopkins (Glyndebourne) had never before designed a major performance venue; Renton Howard Wood Levin (The Anvil) have a long track record of auditorium design. It is Arup Acoustics' philosophy to integrate acoustic requirements within the architecture and this has been achieved – to those familiar with their work, Glyndebourne is clearly a Hopkins' building, The Anvil equally clearly a Renton Howard Wood Levin design.

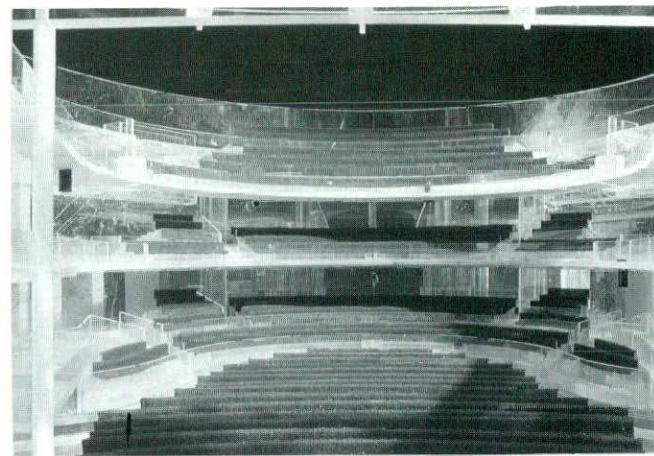
## Form and Precedents

Glyndebourne follows a classical opera house form, the horseshoe, but within an overall circular drum geometry. This form ensures intimacy by bringing the audience as close as possible to the stage. Further, the balustrades of the circles reduce the effective width of the auditorium, providing early reflections to the stalls which enhance clarity and vocal intelligibility. At the same time, a concave plan form introduces obvious dangers of undesirable sound focusing, or even echoes. In traditional houses extensive areas of drapes, carpet, etc absorb sound and mitigate these dangers, but neither the client nor the architect at Glyndebourne (nor indeed the acoustician) were interested in a 'plush and velour' house. The challenge, therefore, was to provide an unfocused acoustic within a visually circular geometry.

The Anvil is an ideal size for a concert hall with excellent acoustics. It has the fan out/parallel side wall/reverse fan form which ensures a good distribution of useful early sound reflections to all of the main seating



Glyndebourne - interior of auditorium



Glyndebourne - same view into acoustic scale model



The Anvil - audience at acoustic test concert

source ODEON computer model, supported by laser tracing of early reflections using card models. The distribution of height (ie volume) within the auditorium was optimised at an early stage using deliberately simplified ODEON models of the possible geometries.

### Acoustic Challenges

The Glyndebourne auditorium contains a family of acoustic elements to provide a good distribution of sound, enhancing clarity and avoiding image shifts or perceptible late reflections caused by concave form focusing. These are principally diffusive:

- semi-exposed structural ribs and fins
- convex pre-cast concrete panels within the roof zone
- convex timber diffusers and backs to seating areas
- exposed large radius circular ducts

Sound absorptive panels are used only where the tight geometry prevented the installation of (deeper) diffusion, for example at exit ways.

Acoustic transparency is also used – many concave balustrades are acoustically-transparent, both to avoid focusing and maximise the sound level at overhung seats.

Conventional acoustic wisdom is that the low frequency reverberation time in opera houses should not rise at low frequency, as vocal intelligibility might be lost. This results in many houses having a dry, thin sound, with a weak bass line. At Glyndebourne it was decided that the low frequency reverberation time should rise, ensuring a full, warm orchestral sound, with the orchestral/singer balance being maintained by powerful early reflections, particularly in the singers upper formant ranges.

The main challenge at The Anvil was not geometry – which was strongly influenced by the acoustician at the start of the project – but money. The entire building (including two smaller performance and meeting spaces)

areas. Its precedents might be considered the concert hall at the University of Warwick and, on a larger scale, the new Manchester Concert Hall (also a RHWL/Arup Acoustics design) which is currently under construction and due to open in February 1996. Of particular interest is the rigid proscenium frame which rises out of the concert platform to provide an end-stage format for theatrical events. In addition to the desired reduction in volume (and hence reverberation time) when the proscenium is in place, 400 m<sup>2</sup> of motor-driven acoustic banners and drapes are provided, to reduce reverberation for amplified and sound reinforced events. At Glyndebourne there is no need for acoustically variable elements – here is a rare theatre which is always 100% full! Of course there are rehearsals and recording sessions, but the seating design ensures that the mid-frequency RT change is limited to 0.2s between full occupancy and unoccupied.

### Acoustic Modelling

The curved geometry of Glyndebourne was not well suited to computer modelling. Accordingly, the main modelling tool employed was a 1:50 scale acoustic model, constructed by the Arup model shop and controlled by MIDAS software. The model proved to be invaluable in demonstrating to the architect that the original proposal for a domed roof was Not A Good Idea – the late reflections were auralised within the model. The scale model was also particularly valuable for developing the geometry of acoustic elements.

The limited budget available for design at The Anvil precluded even the modest costs of a 1:50 scale acoustic model. Predictions of response used the hybrid ray trace/image



Derek Sugden at the first Glyndebourne acoustic tests, December 1993  
Photo courtesy of Richard Davies

| Parameter                | Glyndebourne                 |                    | The Anvil                    |                   |
|--------------------------|------------------------------|--------------------|------------------------------|-------------------|
|                          | criterion                    | achieved           | criterion                    | achieved          |
| Mid-frequency RT         | 1.45 s                       | 1.25 s             | 1.8 s                        | 1.85 s            |
| Low-frequency RT(125 Hz) | $\leq 1.75$ s                | 1.65 s             | 2.1 s                        | 2.2 s             |
| Volume per seat          | (7 m <sup>3</sup> )          | 6.2 m <sup>3</sup> | 10 m <sup>3</sup>            | 10 m <sup>3</sup> |
| Furthest seat to stage   | 30 m                         | 29 m               | 30 m                         | 28.5 m            |
| Clarity C <sub>80</sub>  | > 0 dB                       | 3.3 dB             | ~ 0 dB                       | - 1 dB            |
| Loudness L <sub>T</sub>  | 0 dB < L <sub>T</sub> < 5 dB | 1.25 dB - 4.6 dB   | 2 dB < L <sub>T</sub> < 5 dB | -                 |
| Background Noise Level   | PNC 15                       | PNC 15             | PNC 20                       | PNC 17            |

Table 1 Comparison of key acoustic data, occupied condition (average of 500 Hz and 1 kHz octave band values)

was built for £11.4M, around half of the Glyndebourne budget (itself modest by opera house standards). Hence a particular feature of The Anvil is the multiple function of simple building elements.

For example the roof construction, in precast double T concrete panels, is arranged to produce randomised separation of the ribs and is directly painted to form the internal finish. It therefore acts structurally, for thermal capacitance, for sound insulation and for diffusion of sound. The large supply and extract ducts play an important part in reducing the width of the hall at the front, providing for quiet air supply and extract. The undersides work with the walls to supply corner reflections to the audience and back to the performers.

## Building Services Noise

Stringent background noise levels are recognised as being essential to allow the full dynamic range and ensure that the performer/listener bond is not broken at moments of dramatic or orchestral tension.

A limit of Preferred Noise Criterion (PNC) 15 was set for Glyndebourne, PNC 20 (max) for The Anvil. In both buildings the central plant (chillers, boilers) is structurally separate. At Glyndebourne it is within a converted stable block, at The Anvil it is within a visually-striking plant tower which appears to be part of the main building but is actually structurally separate with vibration isolation at all crossing points.

The auditorium at Glyndebourne is ventilated and cooled by individual air supply units which form the seat pedestals. This is an elegant solution in that it makes use of the natural buoyancy of warm air which is extracted at high level. Acoustic testing proved interesting, as all 1200 units together had to meet PNC 15 - 3 dB, ie each could only contribute PNC 15 - (3 + 10 log 1200) dB.

Air supply at The Anvil is more conventional, being low noise Jetflo supply units and large extract grilles.

Until recently, auditorium house lighting has tended to be with low wattage, high voltage (240V) lamps, which produced negligible noise. Today lighting designers want to use stage luminaires, including Par lamps, low voltage fittings and discharge lighting. On both of the projects this necessitated careful electrical design and extensive acoustic testing of luminaires.

## The Results

Table 1 summarises key acoustic criteria and achieved values. In the words of the general administrator at Glyndebourne, however, 'the acoustic experts told us that it all measures correctly, but until we heard the test concert we did not know whether we would like the sound'.

By all accounts musicians, conductors, audiences and (nearly all!) the critics have praised the sound in both auditoria, though it is still early days in the musical histories of these buildings.

Rob Harris FIOA is with Arup Acoustics, Parkin House, 8 St Thomas Street, Winchester, Hants SO23 9HE. ♦

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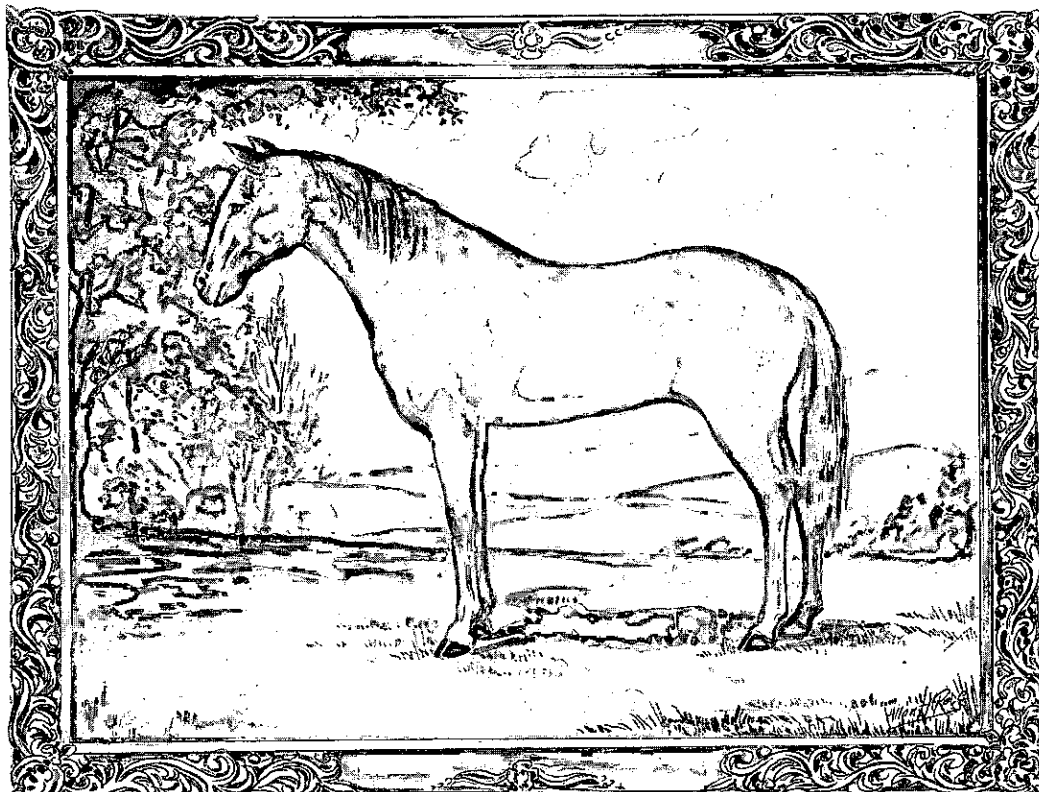
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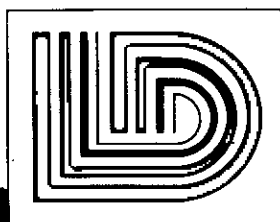
So, just in case we need to change our approach to advertising I have decided to display a rather nice picture of a horse so that the next time you require noise and vibration instrumentation you'll remember the horse and hopefully Larson\*Davis.



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## Engineering Council

In 1993, the Institute of Acoustics as a Nominated Body of the Engineering Council, established a scheme for the registration of Incorporated Engineers. Following Professional Reviews by a panel of the Engineering Division the first three members (featured below) to attain this status were registered in August and an announcement appeared in *The Times* and *Daily Telegraph*.

A further series of Chartered Engineer interviews will take place in November. Revised guidelines for members seeking registration as Incorporated Engineer or Chartered Engineer have recently been prepared and are available from the Institute office. Enquiries should be sent to the Engineering Division Manager, Dennis Playle, at the Institute office.

### New Incorporated Engineers

#### Howard Gwatkin

Howard Gwatkin started his career in the construction industry studying civil engineering. This was followed by a period during which he graduated from Hatfield Polytechnic, Hertfordshire in 1980 with a BSc in Mechanical Engineering.



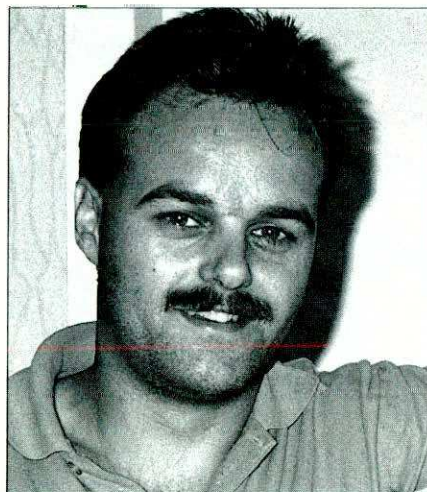
He has been involved in acoustics since 1985 when he began studying for his MSc and joined Bickerdike Allen Partners. There he became involved in all aspects of the consultancy's work: environ-

mental impact assessment and noise control; building and room acoustics; mechanical plant, and services noise and vibration control; and providing evidence as expert witness. In 1986 he obtained his MSc in Environmental Acoustics from the Polytechnic of the South Bank, London.

Howard has recently joined the world-wide organisation of Arup Acoustics working in Hong Kong, where besides other work he takes over the day to day running of Arup's role as adviser to the mass transit authority on the acoustics of the new rail link to Hong Kong's new airport, all currently under construction.

#### Dean Kettlewell

Following successful completion in 1983 of an OND in Electrical and Electronic Engineering, he joined Vibac Noise Control (latterly LBJ Fabrications) as Trainee Technical Sales Engineer. During his training period he continued with his studies attaining a merit award on the HNC course.



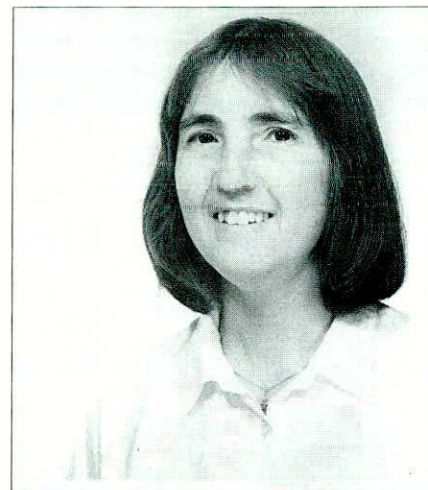
Working initially on industrial noise control he became increasingly involved in project development, noise surveying and the progress of projects from design through to commissioning.

In 1988 he completed (with merits) his Diploma in Acoustics and Noise Control and during the company's expansion in 1989 he was promoted to Technical Sales Manager. Over the last five years he has been increasingly involved with consultancy work designing noise control systems and training sales engineers.

#### Penny Moys

Penny Moys joined the Suffolk County Council in 1973 as a draughtswoman in the design office of the Highways Department. In 1977 she became involved in the assessment of road traffic noise, and over the next seven years was engaged in all aspects of the administration of the Noise Insulation Regulations, including calculation and measurement work together with contract organisation of the installations.

In 1984 a specialist Noise Team was formed and Penny became the Technical Assistant supporting the Noise Control Manager. Also in 1984 she was awarded a BA Honours degree by the Open University, and in 1988 obtained an HNC in Civil Engineering for which she received the Society of Civil Engineering Technician's award for the best examination results in East Anglia.



In 1991 she was awarded the Institute's Diploma in Acoustics and Noise Control and also the Certificate of Competence in Workplace Noise Assessment after studying for both at the Colchester Institute.

Her current work in the noise Control Section as Senior Noise Control Technician embraces the environmental appraisal of major road proposals, the preparation of specifications to control noise from road and bridge construction sites, and the administration of all aspects of the Noise Insulations Regulations. Another important aspect is the preparation of conditions of consent, with regard to noise, on behalf

of the County Planning Officer in respect of proposed development such as waste disposal and land forming sites, mineral extraction sites and associated miscellaneous proposals.

## Events

### Environment Event 1994

The 1994 Environmental Event, was held on 1st September at the Institution of Civil Engineers in Great George Street, London. There were two main features, the launch of the Engineering Council's Guidelines on Environmental Issues and the Environmental Award for Engineers.

#### Guidelines on Environmental Issues

This document, which follows on from the Code of Professional Practice published last year, was introduced by Ms Sara Parkin, an environmentalist. Its stated aims are to help engineers towards (i) a fuller understanding of the Code and how it may be implemented (ii) an increased understanding of environmental issues (iii) an ability to identify possible future trends (iv) a

clearer picture of the principles and the main techniques involved in various aspects of good practice (v) an appreciation of the importance of partnership and cooperation with other interested groups and organisations and (vi) an awareness of the many examples of good practice currently available.

Included in the Guidelines are definitions of some of the more commonly used terms in Environmental Management and in the environmental legislation that can apply in engineering. There are also outlines of some of the techniques which engineers will find useful. Both the Code and the Guidelines are sponsored jointly by Lloyd's Register and the Department of the Environment.

Gratitude was expressed to the Engineering Institutions who provided expert advice during the preparation of the Guidelines.

#### The Environment Award for Engineers

This award, sponsored this year by Lloyd's Register, is designed to encourage engineers to demonstrate their skill and versatility in giving pri-

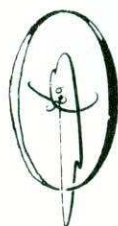
ority to environmental issues when planning projects.

The award ceremony was opened with an address by the Director General of the Engineering Council, Denis E Filer. He said 'The Engineering Council launched this award for two main reasons, to publicise and encourage good practice in protecting the environment and to demonstrate that environmental awareness can mean good business.'

'These projects maintain the long tradition of excellent work which engineers have undertaken to protect the environment. This comes as no surprise to engineers but those outside our profession are often unaware of the role played by engineers in safeguarding the environment. Each of the projects selected as finalists have devised cost effective solutions to existing problems and have, in some cases, generated substantial savings for their company.'

The prizes were presented by Judith Hann of BBC's 'Tomorrow's World'

The first prize was awarded to John Lindley, a Chartered Engineer



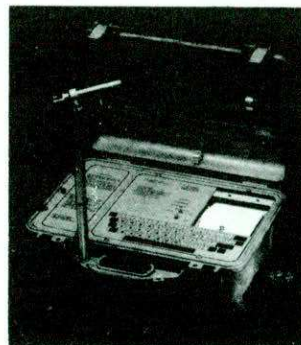
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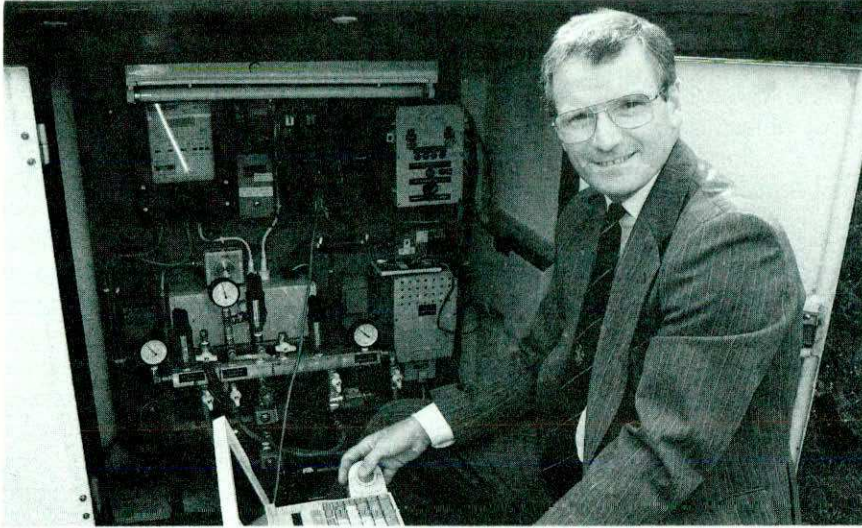
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John Lindley working on his a mains water pressure management system

of Staffordshire Water, Walsall, who devised a mains water pressure management system which has already saved 526 million litres of water in a monitored area by reducing the chances of burst water mains and leaking pipes. His prize was £3000 and the Lloyd's Register Trophy.

In second place with a prize of £2000 was the project of John Warlock, Kevin Linsley, Kenneth Cuthbert CEng and Philip Roberts of British Steel Technical, Teeside Laboratories, Middlesbrough. Their project is concerned with the recycling of the majority of the slurry generated by the waste gas cleaning system of a blast furnace and has significantly reduced the amount of material taken to landfill. The water content of the slurry can also be reused.

Third place with a prize of £1000 was awarded to Dr Panos Papavergos CEng of the BP Research Centre, Sunbury on Thames who developed a fine water spray fire suppression system which replaces halon firefighting technology and puts out a fire faster than other conventional water based systems.

## 'Young Engineers for Britain 1994'

Four 17 year-old youngsters from Plymouth became the 'Young Engineers for Britain' on Wednesday 21st September, beating nearly

1000 other young inventors. Christopher Cooper, Paul Brenton, Stuart Newsham and Eve Richards, all from Plymstock School won the coveted trophy, £1000 to share and £1500 for their school, by inventing 'Flexi-valve', an automatic flow control system for a waste water treatment works.

They were among 61 finalists, aged 11 to 19, competing in the national final of the Young Engineers for Britain competition organised by The Engineering Council and held at the National Westminster Hall in the City of London. They had been selected at 12 regional events from young people who had competed for prizes totalling £20,000.

The winning projects also included powered secateurs, a shuttlecock for the visually impaired, a new sling to rescue a person fallen overboard from a boat and a portable device to detect high voltage earth leakage.

Among several group prizes awarded were two under the WISE (Women Into Science and Engineering) scheme initiated by the Engineering Council. £800 from the Engineering Council for the best project by a girl or team of girls was awarded to Sarah Freese (17), Chinenyi Iwuji (16), Kanako Minami (18) and Helen Wilson (17), from St Felix School, Southwold, Suffolk, for their new device to remove shives from beer casks. (This was the only project noted by the editor as having any acoustic content; the reason for undertaking this project was the high noise level, requiring the use of ear defenders, produced by the traditional method of removing the shives which involved hitting the shives and the metal cask hard with a special hammer.) The new method used an extractor operated by air pressure and was faster, much quieter and caused less damage to the beer casks.

The second WISE award of £400, sponsored by Thames Water, went to Elizabeth Bulleyment (11), from Dronfield, Yorkshire, for her electrical flex cable 'tidy'.

John Tyler FIOA ❖



Winners of the Young Engineers for Britain 1994 competition

## Environmental Noise Assessment

Workshop at UWE, Bristol, 20 September 1994

The Environmental Noise Group's first workshop was attended by 35 delegates drawn primarily from consultancies and local authorities. The major purpose of the workshop was to shape up the Institute's response to the recent DOE consultation paper on Environmental Assessment. Although opinion was quite diverse, some common strands emerged and these formed the basis of our response to the paper which is set out below.

The afternoon commenced with two presentations. The first was from Martin Slater of the Institute of Environmental Assessment who set out the context in which the noise assessments have to be carried out for environmental statements. He also gave a helpful insight into the content of some noise assessments the IEA have reviewed. Fortunately he was able to be fairly complimentary about them! This was followed by a joint presentation from Ken Collins of Ashdown and Stephen Turner of TBV indentifying the issues raised when faced with carrying out a noise assessment. The presentation concluded by giving the delegates five questions to consider.

The workshop divided into six groups for discussion. After an hour or so we reassembled and the group leaders gave the delegates the outcome of their deliberations. *Plans are now being considered for a similar workshop in Scotland, possibly around Easter 1995.*

### Response to the DOE document: Environmental Assessment & Planning: Consultation draft guide on the preparation of Environmental Statements

'The Institute of Acoustics welcomes the opportunity to respond to this draft document and we set out below our comments.

The Institute covers a wide range of acoustic interests and has within its organisation several special interest groups. The Environmental Noise Group, comprising experts who are very experienced in the assessment of the noise and vibration impact from new developments, were asked to consider the document and they have compiled this response on the Institute's behalf.

Despite the consultation period covering the summer break, we were able to hold a half day workshop on this subject and draw on the view of our membership. We have confined our attention to the relevant specialist appendix, Appendix 11- Noise & Vibration, and make no comment on the general sections of the guide.

We agree that some form of discipline specific advice is required to support the general guidance given but we feel that Appendix 11 does not meet the need. The specific advice given, especially in paragraph 12, is imprecise and for some circumstances incorrect. The reference to guidelines and standards is also imprecise, eg there is nothing in the Environmental Protection Act that would assist in the evaluation of the noise impact of a proposal.

We feel that the advice should be non-prescriptive, describing the overall process that should be followed. The nature of our subject is such that there is no precisely correct way of approaching the assessment procedure. The extent and duration of the baseline survey, the

parameters measured, the selection of the monitoring sites and the prediction methods used are all project specific. The detail included will vary from project to project, as will the various guidelines and standards used in the assessment. Given this inevitable flexibility of approach, we feel it is important that whatever methodology is adopted it should be clearly justified within the environmental statement. This situation also means that the noise and vibration assessment should be undertaken by a competent person who understands the subtleties of the subject and we would recommend that this requirement is included in the advice.

The timescale for the production of the DOE guide is not known, but it may be of interest to know that following our workshop, which was attended by an officer of the Institute of Environmental Assessment, the two organisations are now working together to produce a guidance note on the noise and vibration aspect of an environmental assessment. It is very early days and because of the complexity of the issue such guidance is not likely to be forthcoming quickly. Therefore, as an interim measure we would recommend that an appendix on noise and vibration along the lines we've suggested would be appropriate.

We would of course be happy to comment on any re-drafting of the Appendix prior to final publication. These comments are not confidential.'

Stephen Turner ❖

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## Contributions

### DOE Press Release on New Neighbour Noise Initiatives

A new initiative to identify quicker and simpler remedies for resolving neighbour noise problems was announced today by Environment Minister Robert Atkins. The Minister also launched comprehensive new guidance to local authority planners and developers and others in England on how the planning system can help to minimise the adverse impact of noise without placing unreasonable restrictions on development.

Announcing the initiatives, Robert Atkins said:

'Noise pollution is a growing menace for many people which can totally destroy their quality of life. We need to minimise the impact of noise pollution whether it occurs from anti-social behaviour by inconsiderate and selfish neighbours, or inappropriately sited new development.

'The increase in neighbour noise complaints is a particularly worrying trend. The evidence is that only a small minority complain because of the belief that nothing can be done. Of those complaints which are received by local authorities, only 3 per cent result in formal enforcement action, and the existing procedures can place a heavy burden on the complainant, on local authority officers and the police.

'We need to look urgently at how these procedures could be simplified and made more effective and at whether there are alternative approaches which make better use of scarce local authority and police resources, while offering the citizen a more certain and reliable remedy for problems which, if not resolved, can lead to violence. To this end I am setting up a working party, which will include representatives of the Home Office, the Lord Chancellor's Department and other interested Departments to look at options for improving the effectiveness of the legislation in this area. I shall be inviting representatives of the police,

and of local authorities to take part and I hope to have the conclusions of the working party early in the New Year.

'We also need to take action through the planning system to minimise noise, and I am therefore today launching a Policy Planning Guidance Note on how to do this.

'The new guidance has two main messages - firstly, wherever practicable, noise sensitive developments should be separated from major sources of noise; and secondly, where this is not possible, local planning authorities should consider measures to control or reduce noise levels, or to mitigate its impact through the use of planning conditions or planning obligations.

'The planning system can do much to prevent noise developing and can complement other controls, including the Building Regulations, which set standards for sound proofing dwellings, and nuisance control which provide remedies for existing noise pollution.'

#### Notes to the Press Release

*Planning Policy Guidance note (PPG) 24 fulfils a commitment in the Environment White Paper 'This Common Inheritance' that the Government would issue guidance on the siting of developments to avoid noise nuisance.*

*It also acts upon one of the recommendations in the Report of the Noise Review Working Party 1990 to update DOE Circular 10/73 'Planning and Noise', which is now cancelled.*

*This guidance aims to give local planning authorities advice on how the planning system can help to minimise the adverse impact of noise.*

*Planning Policy Guidance note (PPG) 24 'Planning and Noise' published by the Department of the Environment introduces the concept of noise exposure categories for residential development, encouraging their use and recommending appropriate levels for exposure to different sources of noise.*

*PPG 24 'Planning and Noise' is published by HMSO Price £6.90, ISBN 0 11 752924 9.*

### Digital Radio

The BBC expects to start digital broadcasting in London next autumn providing CD quality audio for car radios and portable radios able to process the signals. The aim is to encourage the spread of the new broadcasting technology and the manufacture and marketing of new, low cost, receivers. The BBC hopes to extend the network service to cover most urban areas and motorways by 1998.

### One Glove Clapping

The audience attending a recent concert at the Hong Kong Stadium were provided with one glove each so that the sound of applause would not unnecessarily disturb occupants of tower blocks that overlook the stadium.

### Cardiff Bay Opera House

Ove Arup & Partners and Arup Acoustics led by architectural designer Saha Hadid, have won a competition to design Wales' national opera house, the third largest in the UK, on the waterfront at Cardiff Bay.

It will provide a focus for Cardiff's urban regeneration as well as a superb new musical venue for Wales and a home for the Welsh National Opera. Arups also provided acoustics and engineering input to seven of the eight finalists, including the Sir Norman Foster's and Itsuko Hasegawa's schemes, both of which received commendations.

The opera house scheme forms part of a plan for industrial and economic regeneration based upon the construction of a barrage to create a freshwater lake in Cardiff Bay. In late 1993, design teams were invited to submit designs in the two-stage competition. It is intended that the £43M (1993 prices) opera house will open on St David's Day - 1 March - in the year 2000 and that it will attract a substantial contribution from the National Lottery Millennium Fund.

Ove Arup & Partners and Arup Acoustics provided structural, building services and acoustical design

for the winning scheme, which comprises an 1800-seat auditorium, rehearsal rooms, catering facilities and carparking for 600 cars.

A four-storey 'necklace' encloses the site above the first floor. This draws people inside the necklace either over a raised ground level, or into the foyers below, as well as providing an intimate connection between the heart of the building and the waterfront. This necklace houses the Theatre Administration, the Welsh National Opera, carparking and the flytower for the main stage which is accommodated within the general roof level and is therefore not a visible protrusion. Several 'jewels' project inwards from the necklace, the largest of which is the auditorium.

The strongly expressed architectural form has been developed to provide a space which enhances the dramatic experience with an excellent acoustic for opera and the flexibility to accommodate ballet, music and the spoken word.

The acoustic design uses and develops the benefits of asymmetry

and heavy modelling in the auditorium and the necklace concept is used positively for acoustics separation.

Ove Arup & Partners developed a services design which not only reduces the running costs, but also contributes to minimizing environmental pollution.

## DOE Noise Forum

The Institute of Acoustics is now represented formally, rather than through common membership, on the Department of the Environment's Noise Forum which convenes on several occasions each year to advise the Department on matters related to environmental noise.

The rest of the membership is drawn mainly from what might be termed campaigning organisations such as The Right to Peace and Quiet Campaign, the Noise Abatement Society, the National Society for Clean Air and the National Society for Deaf People. The Chartered Institute for Environmental Health, the UK Environmental Law Association and the Noise Council (through

which the Institute has previously had a voice) also participate.

At a meeting of the Forum on Wednesday 12 October 1994, John Sargent from BRE gave a presentation on the progress of the BRE/Sound Research Laboratories study on low frequency noise sources in the UK. In attendance by invitation were two leading members of the Low Frequency Noise Sufferers Association who took the opportunity to question aspects of the methodology of the study and to request that greater attention be paid to what they termed the plight of their members. Their plea for more wide ranging research was noted.

The members of the Forum are expected to seek the views of those they represent on such matters as the effective implementation of existing statutory controls on neighbour noise.

*Contributors: DOE 3 October 1994, John Tyler FIOA, BBC Radio 4's Today programme, 16 October 1994, Nigel Cogger MIOA, Roy Lawrence FIOA* ♦

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# Hansard

15 June 1994

## Noise Legislation

**Mr Simon Hughes:** To ask the Secretary of State for the Environment what plans he has to review current noise disturbance legislation.

**Mr Atkins:** In 1990 an independent noise review was established by my Department to consider all forms of control over noise pollution. It made several useful recommendations relating to improvement of the legislation which were considered carefully. As a result provisions were introduced into the Environmental Protection Act 1990 to strengthen the existing statutory nuisance duties and powers to control noise from domestic, industrial and commercial premises. These powers have been further extended by the Noise and Statutory Nuisance Act 1993 to control noise from vehicles, machinery and equipment in the street. We continue to monitor the effectiveness of existing environmental noise legislation and are keen to ensure that it is used to their full effect. My Department continues to discuss all aspects of noise pollution and disturbance, including the scope for further improving the operation of the relevant legislation, with other Departments, and a wide range of professional and voluntary organisations concerned with these issues.

14 July 1994

## M25 (Noise Pollution)

**Sir George Gardiner (Reigate):** I have been a Member of Parliament long enough to remember when between junctions 8 and 10 there was no M25 at all. When its opening was delayed because the concrete surface cracked, there was considerable impatience among my constituents, so the partial opening in 1985 was greatly welcomed. It linked up with the further section to junction 7, and so took a great deal of heavy traffic from the A25, weaving its way – to the detriment of our environment – through the towns of Reigate and Redhill and the villages in the constituency of my hon Friend the Member for Surrey, East (Mr Ainsworth).

However, no sooner was this section of the motorway in use than complaints rolled in about the noise generated by its brushed concrete surface. They came not only from those living within a 300 m band on either side, such as the populous Merstham estate and the relatively rural area of Mogador to the south and the nearer reaches of Walton-on-the-Hill to the north, but from whole communities beyond, which complained of the constant whine, or hum, from the motorway.

Their case is well documented in letters to me from Tadworth's local councillor, John Chiles. As the volume of traffic using the motorway has increased over the years, so too has the constant background whine, day and night.

There were public demands for the concrete to be replaced by tarmac, which everyone judged to be quieter. At first, the Department of Transport claimed

that there was no appreciable noise difference – brushed concrete just seemed louder to those driving over it, officials claimed. But that argument did not hold water for long, and it is now generally recognised that porous asphalt produces less noise than hot rolled asphalt, and far less noise than a brushed concrete surface.

At the risk of using technical language, I must get this point on record. The use of porous asphalt, as compared with brushed concrete, achieves a reduction of 6 decibels in dry road conditions and a reduction of 10 decibels in wet road conditions. In human subjective hearing terms, a 10 decibel reduction would be perceived as being half as loud. That is the penalty that those living nearby have to pay for the use of a brushed concrete surface. Small wonder that the call to switch to porous asphalt is growing all the time.

In this debate, I am concerned with noise pollution, but there are other advantages in using porous asphalt. For drivers using the motorway, it decreases spray production in wet weather, cuts down glare, and decreases the risk of aquaplaning. All these are road safety factors, which I know loom large in the mind of my hon Friend the Minister for Roads and Traffic. Porous asphalt is also increasingly being used in a wide range of climates in continental Europe. Yet in Britain its considerable advantages seem not yet to have been accepted.

So what is the argument against using porous asphalt? The principal argument over the years has been that it is much more expensive than brushed concrete. . . The case that porous asphalt is quieter has already been accepted by my hon Friend's Department, yet, because of the mythical 'high cost' factor, its use has been authorised only for sections of the motorway that pass through highly populated areas. Thus, the use of porous asphalt has been agreed near the more densely populated Ashted in Mole Valley, and a short stretch alongside Merstham in my own constituency. Unless a change is announced by my hon Friend tonight, those living within audible reach of the remaining sections will continue to suffer from the brushed concrete surface.

Yet all that section will shortly be expanded from three lanes in each direction to four. That will be with the blessing of Surrey County Council, and indeed, with my blessing too. What a marvellous opportunity the widening presents to scrap the concrete surface altogether and replace it with quieter – and cheaper – porous asphalt.

The Highways Agency recently announced its proposal to widen the M25 between Sevenoaks – junction 5 – and junction 7, with the M23. I understand that no concrete at all is to be used on that section. The Department has also decided to replace concrete with porous asphalt on a 12 km section of the M23 south of its interchange with the M25. I welcome that decision, but ask how it can be squared with a decision not to lay porous asphalt over the sections of the M25 with which I am concerned.

The total number of houses within the 300 m band over that 12 km section of the M23 is 271, which works out at a density of 23 houses per km. Let us compare that with the sections of the M25 between junctions 8 and 10, which under present plans are not to have porous

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FLAME RETARDANT

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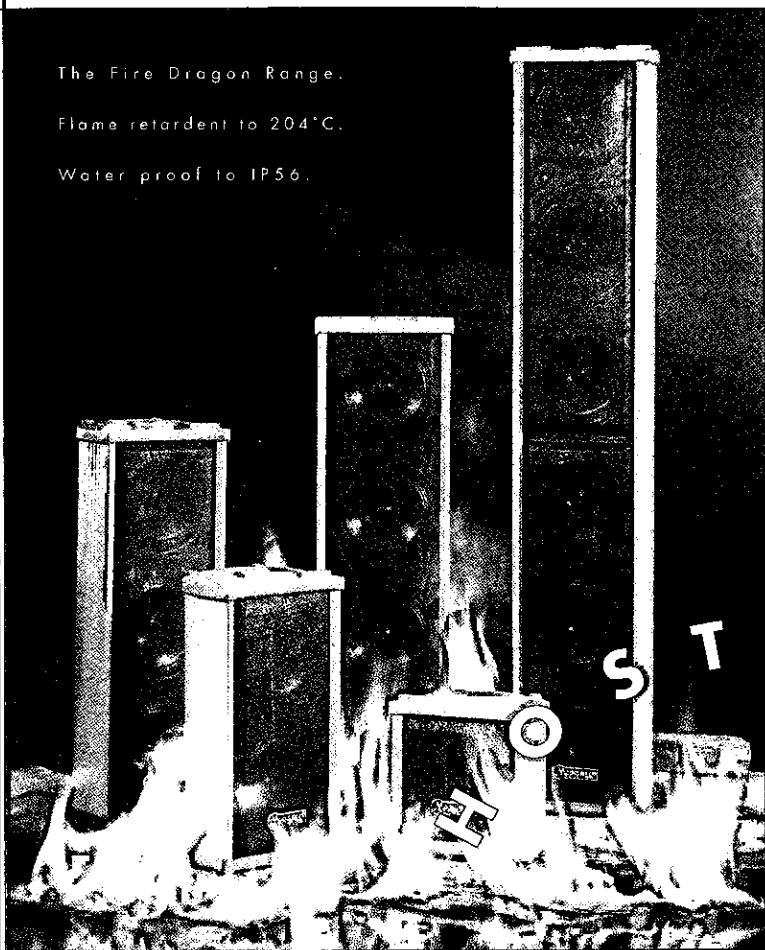
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asphalt. We find that the density of houses per kilometre is identical – 23. Thus, the rationale for providing porous asphalt is the same for the M25 as it is for that section of the M23.

Even more telling is the fact that, when that density of houses along the section of the M23 which is to be given a porous asphalt surface is compared with the density of homes which are not benefiting, so far, from porous asphalt between junctions 7 and 8, we find that the density of homes in the 300 m band is 80 properties per kilometre as compared with 23. Thus, the case for giving the noise benefit deriving from porous asphalt to that stretch is overwhelming.

I can understand my hon Friend setting his face against the logic of the case if there was no immediate question of rebuilding the highway, but that is not the case. The motorway must be reconstructed anyway to provide four lanes. So, in the interests of all those residents, not to mention the thousands who live just beyond the 300 m band, I urge my hon Friend to seize this opportunity and to make a major contribution towards easing the level of noise pollution emanating from that section of the M25.

**Mr Peter Ainsworth (Surrey, East):** First, I congratulate my hon Friend and constituency neighbour the Member for Reigate (Sir G Gardiner) on securing this debate, and also thank him for enabling me to make a brief speech.

He has chosen to focus on the widening proposal for a section of the M25 between junctions 7 and 10. A small part of that stretch falls in my constituency. I have corresponded with my hon Friend the Minister over the concerns raised by the White Hill residents association and others, who have already argued for the use of porous asphalt to protect their homes from the increased noise which will occur as a result of the widening scheme.

A much greater number of my constituents are concerned with the Highway Agency's proposals for the stretch between junctions 5 and 6. My hon Friend will know that a number of local representatives are seeking a meeting with him to discuss their concerns. For these residents, and for those, of course, who live between junctions 7 and 10, there are many anxieties – air pollution, light pollution, the safety implications of narrower lanes, surface water contamination, and the effect on side roads of newly generated traffic. But by far the greatest concern is the prospect of even higher levels of noise intrusion.

When the M25 was first proposed, the Department of Transport said that, if the bunds and noise barriers were not good enough, they would be expanded and extended. Although traffic flows and noise are much higher than originally envisaged, with a daily traffic flow of 110,000 vehicles against a design capacity of 79,000, nothing has been done.

To make matters worse, although local people are already suffering from a level of noise which many find unacceptable, they can expect a further 50 per cent increase in traffic, with seriously inadequate noise protection.

I agree with my hon Friend the Member for Reigate; the widening of the motorway presents an excellent

opportunity for noise levels to be restored to those which were expected when the road was built. Higher bunds and noise barriers, together with porous asphalt, would achieve that, and, in the process, they would restore the faith of my constituents in the Department.

I pay a sincere tribute to my hon Friend the Minister, and to his officials, who worked so closely with local people when dealing with the widening of the M23. As my hon Friend the Member for Reigate has said, it has been found possible to introduce porous asphalt throughout the length of the stretch of that motorway which is being widened.

The M25, of course, is a far busier, much noisier motorway. It affects a far larger number of homes, yet there are no plans at all to lay porous asphalt at present, as I understand it, on any of the stretch of the motorway which runs through my constituency. I urge my hon Friend the Minister to reflect on that and to consider the great concern to and hostility among my constituents.

**The Minister for Roads and Traffic (Mr Robert Key):** . . .

I fully understand the concern of my hon Friend the Member for Reigate, who has spoken so powerfully on behalf of his constituents who are affected by noise from the M25. I recognise fully how distressing traffic noise can be, especially when a new road is built through an otherwise quiet area – the area which my hon Friend represented when he was first elected to the House. Noise can be an abomination. I live in the depths of the Wiltshire countryside and, ironically, the noise from the trunk road that passes my bedroom window is considerably greater than the noise in central London. That is not a common perception.

We must, however, face up to the facts. The M25 is the busiest road in the country. It is essential for both the national and the local economy. It connects all the major radial routes to London, the southern ports, the airports and the channel tunnel. Congestion on parts of the motorway is encouraging traffic back into towns and villages around the motorway, bringing pollution and noise and making the roads more dangerous.

If nothing is done to improve the capacity of the motorway to take the increased traffic, those towns and villages will suffer even more from traffic trying to avoid motorway congestion. That would cause a return to the conditions which the motorway was built to relieve. Of course I understand that my hon Friend's constituents do not see it that way, but when I travel the country I realise that, from a national perspective, the M25 is seen as the London bypass. It is therefore important for the economic well-being of the country that we ensure that the bypass is up to standard and able to support the wealth-creating sectors of our economy. Roads and villages that are quiet now will increasingly become rat runs – which can only be bad for residents, pedestrians, local motorists, businesses, and of course the environment and everyone's health and safety. It is to help to stop that happening that we propose improvements.

The section of the motorway between junctions 7 and 8 which runs through my hon Friend's constituency is currently dual three lanes. It was designed to carry up to

79,000 vehicles per day. Peak-time flows are currently about 110,000 vehicles per day. The case for widening this very busy stretch speaks for itself . . .

As both my hon Friends have vividly described, the main concerns of the residents following the public consultation centred on the existing noise from the motorway and the likelihood of it increasing with the addition of more traffic lanes. Extensive additional acoustic fences were included in the widening proposals, and the residents and the local councils considered that further measures were required, especially in the Merstham area. The proposed level of mitigation was reviewed and enhanced noise mitigation measures were announced in the decision letter issued in July last year. The enhancements include more than 2 kilometres of additional acoustic fences and raising the height of some of the existing ones.

Once upon a time, I was but an innocent motorist. I thought that a road was a road, and that the road surface was the road surface; now I know differently – it is the pavement. I now know that road surfaces matter a great deal. I shall address some of the technical arguments put by my hon Friend the Member for Reigate . . . The costs quoted in the parliamentary question to which my hon Friend referred were right, but the costs for the concrete section related to total reconstruction of the road. The costs for porous asphalt were for resurfacing only. I have had to learn the hard way – by pounding the motorways of this country – about these things. I now understand that the cost per mile of laying different substances for the pavement varies enormously and, there-

fore, I am not at all surprised at the variations which my hon Friend quoted.

There are many engineering and accountancy elephant traps in these matters because the cost of laying certain materials is not the same as the cost of the entire reconstruction work. Furthermore, the life of different surfaces varies. The life of porous asphalt is comparatively short – it may be as short as five to seven years – whereas a concrete surface can last more than 20 years. Those are some of the sums which I invite my hon Friend to consider . . .

It is also important to recognise that my Department cannot simply lay new asphalt if there is still life in the existing concrete pavement. Often, it is true that the existing concrete pavement has been agreed as a noisy road surface, for which substantial payments have been made to those nearby in compensation already, and a double payment would not please the Public Accounts Committee . . .

The scheme includes the reconstruction of the carriage-way around junction 7, which is nearing the end of its life, and provides for the reconstruction of the existing asphalt surface in conventional hot-rolled asphalt. Following requests from residents and local authorities for the use of a quieter road surface, porous asphalt surfacing is being used on a trial basis in the densely populated Merstham area.

Commercial vehicle flows on that section are high. Porous asphalt surfacing has not been used extensively on heavily used roads in this country and evidence of its dur-



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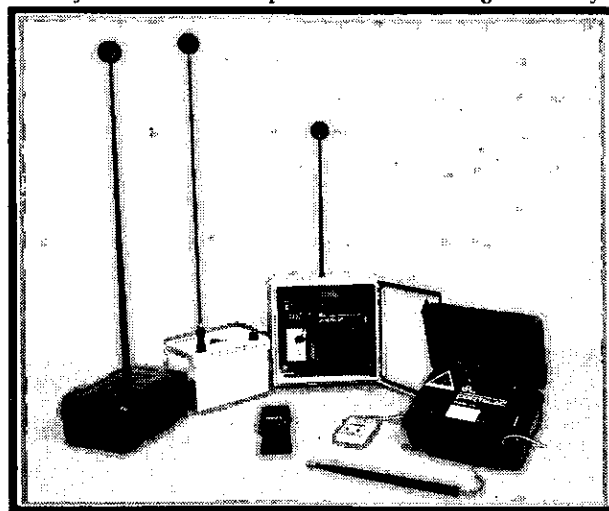
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ability is limited. In addition, it is more expensive than other surfacing materials and has a shorter life, so all the noise and dust of resurfacing would come round sooner . . .

Following the publication of the environmental statement for the widening scheme between junctions 8 and 10 earlier this year, Reigate and Banstead borough council drew attention to discrepancies in the predicted noise levels at the point where the two schemes abut at Mogador, just west of junction 8. The consultants involved have investigated the apparent discrepancies and it has been established that the predicted noise levels at Mogador, which were quoted in the junctions 7 to 10 statement, were too low.

In recognition of the predicted higher noise levels in the Mogador area, higher noise fences will now be incorporated into the current junctions 7 to 8 widening works, to reduce noise further in the area. Residents affected in the Mogador area were informed of those changes last week. As a precaution, noise levels were reassessed for the whole scheme, which has resulted in a slight upward movement in some of the figures. Because of the extensive mitigation measures already included in the scheme, including bunds and noise fences, with one exception, Dell house at Merstham – that does not trigger the offer of further insulation, over and above that already proposed.

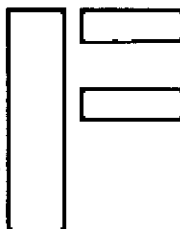
In calculating the noise levels at Merstham, no account has been taken of the porous asphalt surfacing because it is being used on a trial basis only. That surface treatment will, however, reduce the existing and future noise levels by about 4 decibels, which is a substantial improvement; that is in addition to the benefits obtained from the bunds and fences.

Unfortunately, and perhaps inevitably, there have been some complaints about construction noise from the widening works near the main residential areas of Merstham. The contractor has now been told not to operate large plant at night. Strict noise limits are set on the works contractor's operations and agreed with the environmental health officer. Wherever possible, work is carried out behind existing noise fences and earth bunds. Lower speed limits through contraflow systems on the motorway during construction should also lead to a small reduction in traffic noise.

Proposals for widening the section between junctions 8 to 10, to dual four lanes within the existing highway boundary, were published in February. I am pleased to take the opportunity of this debate to announce the results of that public consultation. More than 200 people submitted written comments to the Department and all the opinions expressed were considered carefully. Many issues were raised but, as my hon Friend pointed out, noise was the issue that caused most concern. We have decided to proceed with the widening of the M25 between junctions 8 and 10 generally, as described in the environmental statement. I am pleased to say that we have been able to increase the height of some of the barriers and provide extra barriers in certain areas.

I fully understand the concerns about traffic noise expressed by many of those who live close to that section

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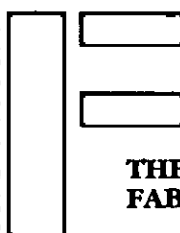
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of the M25. The published proposals accordingly included extensive noise fencing to reduce the noise impact of the scheme and the provision of porous asphalt through the Leatherhead area, where there would be benefits for a considerable number of people.

In addition to noise barriers, the effects of the widening works will be moderated by retaining as much as possible of the existing motorway landscape planting and earthbundings, and by new planting. To complement that planting, the scope for tree and shrub planting on land in private ownership outside the motorway boundary will also be considered. Many of the existing noise barriers will be replaced.

During the construction period, every effort will be made to minimise disruption and disturbance to local people and the local environment. The construction contract will include limits on noise levels and access routes. The length of time between the removal of existing noise fencing and the erection of replacement fencing will be kept to a minimum. Temporary fencing will be erected at the start of works, to protect the existing planting.

As already made clear to the House, the greatest concern expressed during public consultation was about the levels of traffic noise currently experienced by people living close to the motorway and the potential increase in noise from a widened motorway. Many people considered that the proposed provision of a porous asphalt carriageway in the Leatherhead and Ashted gap should be extended elsewhere along that section of the motorway.

I considered carefully all the representations made, but the existing surface is in good condition and, other than in the Leatherhead section, that part of the motorway passes through scattered and sparsely populated areas, with the notable exceptions of some small communities, including Downside and Walton-on-the-Hill. The proposed noise fences will help in those areas, but I am afraid extending the provision of porous asphalt cannot be justified at this time.

However, when the carriageway is in need of major maintenance, the use of porous asphalt or other noise reducing surfaces will be considered. Porous asphalt is a well-known low-noise surfacing, but there are others. My hon Friend the Member for Reigate referred to the noise of ridged concrete on our motorways. We are all familiar with that when driving a car and changing from surface to surface. It can be very noisy for the driver of the car, and it can be even worse for a person who has to sit near it all day and who sometimes has to endure it in the wet, which can be even noisier.

I had to learn about the different tones which emanate from the different kinds of surfaces. I am delighted to report that technology is again on our side, and it marches on. There is a new substance called 'whisper concrete' which we are trialling on the M18 in Humber-side. I visited the trial site, pounded up and down the M18, stood beside it, listened and looked at it from all angles. I listened to the advice of experts, and it is true – it is a very quiet surface. It has been extensively used elsewhere in Europe.

We hope very much that we will be able to use it more widely here. We have a second trial on the A564 in the east midlands under construction at present. Initial signs from the first trial are encouraging and we are carefully monitoring how it performs on noise, skidding and durability. The skidding point is very important. We can build an almost silent surface for a road, but if one then puts a car on it, it will skid all over the place, which is very dangerous. We have to get the balance right. We hope to take decisions on the wider use of 'whisper concrete' very shortly.

It will be of enormous benefit if technology has triumphed, because that surface will have a much longer life than porous asphalt. If we get it right, the surface noise generated will be about as quiet as porous asphalt. Details of the additional mitigation measures are given in the decision letter, which will be published tomorrow. We will now invite tenders for the design and construction of the widening works which are expected to start next spring.

On the proposals for widening westwards between junctions 12 and 15, I would like to assure the House that I am fully aware of the strength of feeling about our proposals for adding three-lane link roads to each side of the motorway between those junctions. That is the busiest stretch of road in the country and additional capacity for this section is needed if the motorway is to continue to function effectively.

Many have said that they would experience considerable difficulty in preparing for the public inquiry before the end of the year, as is currently anticipated. I fully appreciate their concerns. It is a very complex scheme and these are important issues. Therefore, in the light of those representations I have decided that the public inquiry will not now start this year. An announcement on an actual start date will be made as soon as practicably possible.

I have also received representations from my hon Friend the Member for Surrey, North-West (Sir M Grylls) on behalf of his constituents who are seeking an extension to the objection period for the draft compulsory purchase order which ends tomorrow.

Since the public inquiry will not now start this year I will of course be prepared to receive objections after tomorrow.

**Extracts provided by Rupert Taylor FIOA**

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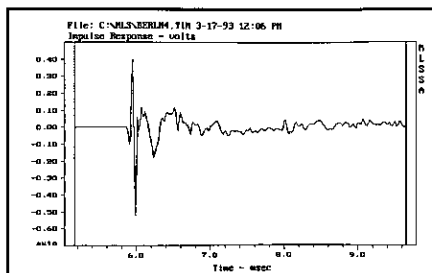
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- ISBN 0 11 885940 4: Code OP: Date 12 Dec 91: Price £20.00  
HSE CRR 14/1989 Effects Upon Hearing of Noise in Combination With Other Agents
- ISBN 0 11 885927 7: Code OP: Date 12 Dec 91: Price £20.00  
HSE CRR 7/1988. A Review of Agricultural Tractor Noise Test Procs. & Measured Lev
- ISBN 0 11 885902 1: Code OP: Date 12 Dec 91: Price £20.00  
HSE CRR 28/1991. Investigation of Machinery Noise Reduction at Source
- ISBN 0 11 885995 1: Code OP: Date 16 Dec 91: Price £20.00  
HSE CRR 35/1991. Survey of Sound Levels at Pop Concerts
- ISBN 0 11 885944 7: Code NH: Date 16 Dec 91: Price £55.00  
HSE CRR 18/89 Exposure to Noise in Agriculture
- ISBN 0 11 885921 8: Code OP: Date 16 Dec 91: Price £25.00  
HSE CRR 2/88 Tables For the Estimation/hearing Impairment/noise/otologically
- ISBN 0 11 752315 1: Code - : Date 10 Jan 92: Price £6.25  
DOE Building Regs.1991 Approved Document E - Sound Insulation
- ISBN 0 11 885997 8: Code OP: Date 10 Feb 92: Price £50.00  
HSE CRR 29: Tables/Estim./Heari.Impairm./Noise/Otologically Normal/Males/Females
- ISBN 0 11 885903 X: Code OP: Date 19 Feb 92: Price £25.00  
HSE CRR 30/1992. Non Auditory Effects of Noise at Work: Review/Literature
- ISBN 0 11 752779 3: Code - : Date 6 May 93: Price £4.00  
DOE; MPG11: Control of Noise at Surface Mineral Workings
- ISBN 0 11 882133 4: Code OP: Date 10 May 93: Price £30.00  
HSE CRR 55/1993 Attitudes Towards Noise as Occupational Hazard Vol.3
- ISBN 0 11 882128 8: Code NH: Date 3 Aug 93: Price £60.00  
HSE CRR 54/1993 Attitudes Towards Noise/Occupational Hazard Vol 1 & 2 (1 Book)
- ISBN 0 11 752884 6: Code - : Date 30 Nov 93: Price £30.00  
DOE UK Environmental Foresight Project Vol 3 Road Transport/Noise Agenda UK
- ISBN 0 11 551360 4: Code - : Date 31 Dec 93: Price £11.00  
DTP Rept of Field Study of Aircraft Noise & Sleep Disturbance
- ISBN 0 11 805858 1: Code - : Date 7 Jan 94: Price £4.45  
SIF:GP 46 SGP 4. Environmental/Pollution Noise & Statutory Nuisance A.1993.Ch.40
- ISBN 0 11 551449 X: Code - : Date 2 Mar 94: Price £2.75  
H 14/76 Dmrb Vol 5 Assess/Prep.Road Schemes Section 2 Noise Barriers

## Book Reviews

**Illegal Raves – A guide for Environmental Health Officers.** 27 pages, published by the Avon, Gloucestershire and Somerset Environmental Monitoring Committee, 1994. Available from Health & Housing, Kingswood Borough Council, Bristol BS15 2TR, Price £15.00

This interesting booklet will be of great value to Environmental Health Officers who have the problem and duty of coping with the noise and health implications of sudden illegal open air musical events (raves), and also for consultants who may get involved in such things.

The document is in three sections. The main body defines the type of event under consideration, the necessity for contingency planning, the types of safety problems which can arise and the need for a measured response. There is an emphasis on co-operation with the police, particularly in the section which follows describing the procedures which can be employed at various stages. These often depend on the degree of prior warning which the authorities have for the event.

The main body is followed by two appendices, the first describing, at some length, the relevant statutes and the powers of the local authority and the police. The second appendix lists the more important aspects of a possible contingency plan and is not only thorough but illuminating. For example, raves are often associated with drug-taking, particularly 'ecstasy' and, as a result, the letter 'E' is often highlighted in any distributed fly sheets. Some of this is quite a revelation for the uninitiated!

My only criticism is that the booklet would be improved by having consecutive page numbering and a contents listing at the front. In addition, the appendices should form sections of the main structure of the work.

If you are likely to be involved with this sort of problem, this booklet will be very useful.

*A J Pretlove*

**Industrial Noise Control: Fundamentals and Applications (2nd Edition)** L H Bell and D H Bell Dekker 1994 ISBN 0-8247-9028-6: Price £98.95

This is the second edition of this popular book from the American publisher Marcel Dekker in their extensive series of books on applied mechanical engineering.

The book is wide-ranging in its coverage of the subject and is, accordingly, split into four sections, as follows: Part I, five chapters on fundamentals, including basic physics, hearing and loudness, levels and spectra, types of noise, scales, propagation and measurement. This occupies 33% of the book: Part II, five chapters on noise control methods including enclosures, silencers, mufflers, active noise control (new, but with only a minimal treatment), reverberation control and vibration control (36%); Part III, four chapters on basic sources of noise including fans, blowers, jets, gears and various machine types (18%); Part IV, four chapters on environmental acoustics including noise in buildings, community noise, regulations and standards (US only) and personal hearing protection (13%).

There are also nine appendices most of which have little general value but contain occasional useful snippets of information.

Much of the fundamentals of noise is well-described and liberally illustrated with worked examples. There are also copious problems for the student to attempt (with answers). In some places the explanations are a little superficial, to my taste, but perhaps this is compensated for by the volume of material which has been packed into the book.

A significant omission is any analysis or discussion of the effect of source size in relation to wavelength as it relates to radiation efficiency or directionality. The book seems to concentrate much more on the pragmatic or empirical approach so that, for example, directionality is described only in terms of the directivity index and its use, or again, a one-inch microphone is stated as being limited to 10 kHz but without the simple explanation why (in terms of wavelength). For these reasons I have doubts about the claimed suitability of the book for students. It seems to me to be a practitioners book and this then would justify the approach taken in Part I.

In the second and third parts of the book the authors have clearly used their own experiences or case studies to illustrate the general principles involved in the noise control of various specific types of industrial source. This makes for interesting and useful reading, but it has been difficult to provide a well-balanced diet. For example, there is an unduly long section on the use of the impedance tube to measure (normal incidence absorption coefficients) including the use of Smith charts. But, the explanation of how the random incidence absorption coefficient is found is lacking, although a formula is given. On the other hand, the section on barrier materials, in the same chapter, is excellent. All of these parts of the book are copiously illustrated with good diagrams and photographs and provided with much tabular data.

The final part of the book concerns environmental acoustics. The treatment of noise control in buildings is very practical. However the next chapter on community noise reverts to the structure of earlier chapters and commences with a general introduction on how community noise may be described and measured and is then illustrated by some worked examples. This is naturally followed by an account of standards or regulations, but this is unfortunately limited only to the US. The final (new) chapter on ear protection is of limited value.

Summarising, the book contains a wealth of useful and interesting information primarily aimed at the noise control engineer (and not at students). There is some emphasis on US practice but this does not greatly hinder the usefulness of the book to European readers. All of the chapters are well-referenced and the chapter bibliographies are valuable too. The use of many worked examples, and the inclusion of unworked examples for the reader, is an undoubted asset. The book can be strongly recommended to the specialist noise control engineer and also has some value to the general acoustician.

*A J Pretlove* ❖

## New Products

### HARTNELL AND ROSE

#### Soundseal

SOUNDSEAL is a new way of sealing small apertures to stop the passage of sound. It is a high density impregnated polyurethane foam strip supplied in pre-compressed coils, with self adhesive backing.

Once unwound SOUNDSEAL expands to four times its original thickness, sealing the gaps and accommodating irregularities in any surface.

It is ideal for use as a sealant between ceilings and partition heads, where partitions abut structural walls, or around the perimeters of floating floors. Clean and easy to use, it can be applied in any situation where a small gap needs to be filled to maintain acoustic integrity. Further details are available from Hartnell and Rose Ltd, 4 Lever House, Lever Street, Bolton BL3 8NY Tel: 0204 380074 Fax: 0204 380957.

### CASTLE ASSOCIATES

#### Industrial Range Sound Level

##### Meters

Castle Associates have released their new Industrial Range of sound level meters. The GA109 Type 1 sound level meter has three ranges covering 70 to 140 dB with A & C weighting and a choice of 'slow', 'fast' and 'peak' time constants.

The GA206 Type 2 industrial sound level meter has a unique 'noise exposure' ready reckoner for industrial safety applications showing the allowed working time for the measured noise level. By using A & C weightings, suitability of hearing protection using the HML method can also be determined with this instrument.

The GA112 Type 1 octave band sound level meter is a compact instrument with integral filters which work in automatic and manual drive modes.

For further details contact Simon Bull, Castle Associates Ltd, Salter Road, Scarborough, North Yorkshire YO11 3UZ Tel: 0723 584250 Fax: 0723 583728.

### G.R.A.S. SOUND & VIBRATION

#### Outdoor Microphone System 41AM

The outdoor microphone system 41AM from the Danish company G.R.A.S. Sound and Vibration has been designed for trouble-free outdoor acoustic measurements and monitoring. The 41AM is PTB approved as part of an IEC 651 Type 1 system.

A half-inch precision condenser microphone and thick film pre-amplifier ensure maximum stability and performance. The system includes a built-in electrostatic actuator to enable calibration checks at 1000Hz to be carried out in-situ. Also included are anti-bird spikes, a windshield and a rain cap.

Further details are available in the UK from Gracey & Associates, High Street, Chelveston, Northants NN9 6AS Tel: 01933 624212 Fax: 01933 624608.

Gracey & Associates is a Sponsor Member of the Institute.

### LARSON DAVIS

#### Night Nurse

Night Nurse is a portable battery and/or mains operated system from Larson Davis Ltd specially designed for continuous noise level monitoring and DAT recording of noises for source identification. The whole system weighs less than 14 lbs and the case is lockable, airtight and waterproof. The user selects one of five Larson Davis sound level meters which is then incorporated into the Night Nurse system employing the use of a Sony TCD-D7 DAT recorder which is activated and de-activated by the complainant on the press of a button.

In addition to the wide variety of measuring parameters available to all instruments in the range, including short period and overall time history  $L_{eq}$ ,  $L_{10}$ ,  $L_{90}$  plus four other  $L_n$  indices),  $L_{max}$ ,  $L_{peak}$  (unweighted or 'C' weighted), the Larson Davis Models 720 and 820 can measure and store exceedance events above a user defined threshold showing  $L_{eq}$ ,  $L_{max}$ ,  $L_{peak}$ , SEL, duration time and date. An Exceedance Time History is also available for high resolu-

tion storage of noise events on these two instruments.

The Models 720 and 820 can also be used to automatically trigger the DAT recorder above a user defined threshold and the DAT is automatically placed into standby once the level falls below the threshold level.

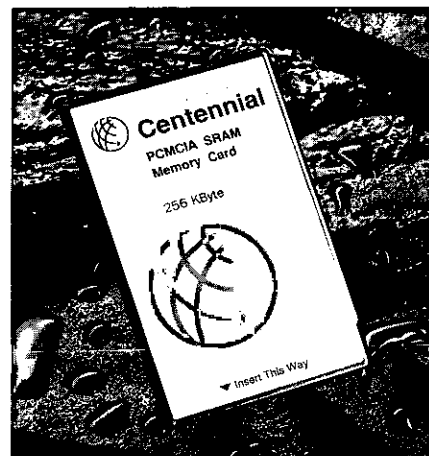
The system is battery powered and a special feature indicates whether or not the case has been moved from its original position enabling the EHO or consultant to determine whether the data is valid.

Other options are available depending on the user's preference. Full details can be obtained from Alan Boyer, Larson Davis Ltd, Redcar Station Business Centre, Station Road, Redcar, Cleveland TS10 2RD Tel: 0642 491565 Fax: 0642 490809.

### HAKUTO

#### Green PCMCIA Cards

A new range of PCMCIA SRAM memory cards, designed with the environment in mind, have been developed to meet demands of industry. These cards are unique in their use of a built in rechargeable battery system rather than the existing technology of disposable batteries. This range is now available from Hakuto.



The use of rechargeable batteries removes the need for the disposal of toxic lithium cells during the cards' ten year life offering a 'greener' solution to this problem. This technology also offers a more rugged sealed package suitable for many field applications. These SRAM cards are available in capacities

# CEL REAL-TIME SOUND LEVEL ANALYSERS

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& Fast Store Options**

CEL Real-Time Sound Level Analysers offer power, speed and choice. Using advanced digital technology this is an unrivalled range of instruments for noise measurement applications in industry, the environment and research.

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### Speed...

An environmental survey taking over six hours with a meter offering only sequential measurements, was completed by a CEL Real-Time analyser in under TWELVE MINUTES!

The reason - simultaneous measurements of two parameters in Real-Time. The operator has complete freedom to choose measurement parameters but a CEL analyser will also make all the standard measurements like SPL, LAeq, Lmax, Lavg etc and store the results automatically in a massive 200,000 value memory.

### Choice...

Whatever your application there is a CEL Real-Time Analyser to suit you.

There are twelve models in the range centred on the CEL-593 and CEL-573.

The CEL-593 adds time history profile information, additional period times and event data to the features found in the CEL-573 to make it the premier instrument for the assessment of noise in the community.

The CEL-573 will soon be the workhorse for acoustic measurements in industry.

Both models offer the same options, these are:

#### • Frequency Measurement

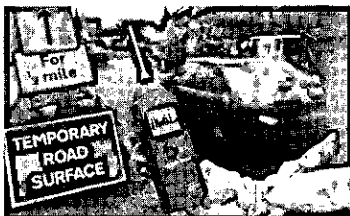
They can be specified to include Octave and Third Octave band analysis, Octave band only, or Broad Band Only.

#### • Instrument Types

Both instruments can also be ordered to Type 1 (Precision Class) or Type 2 (Industrial Class).

### What if my needs change?

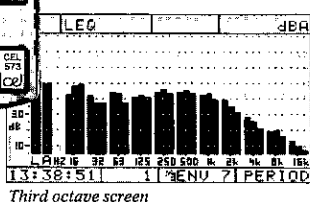
No problem! CEL analysers can be upgraded, in stages, at any time, to contain all the features found in the top of the range instrument. Because the upgrades involve no hardware changes the process is fast, convenient and also enables enhancements to be added without fuss.



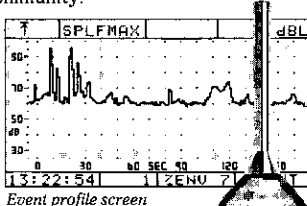
### System Support...

There are lots of uses for such adaptable instruments and these were kept in mind when developing the accessories. For instance, the analysers can be powered by internal dry cell batteries, external battery or AC mains supply. Data can be downloaded to printers and PC's and the instruments can be connected to DAT recorders, a remote microphone or a weatherproof microphone enclosure.

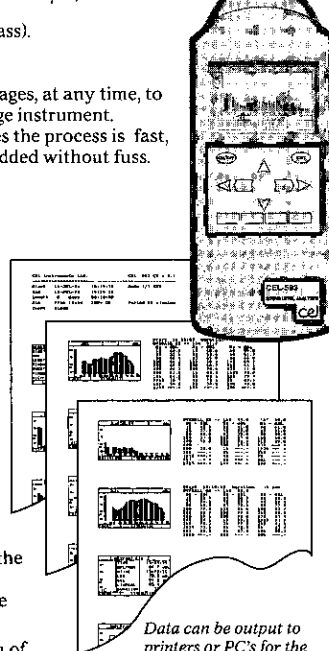
There is, therefore, a very comprehensive selection of accessories that will enable users to tackle almost any short, medium or long term noise monitoring task.



Third octave screen



Event profile screen



Data can be output to printers or PC's for the preparation of hard copy reports.

### Price and Guarantee...

Real-Time Analysis, speed of operation, accuracy, choice, upgrades, system support should all add up to an expensive instrument but CEL Real-Time analysers are highly competitively priced. We are also so confident of the reliability and accuracy provided by the advanced DSP technology used in the new analysers that we have extended the FREE WARRANTY from 1 to 2 years.

### Free Real-Time Guides.

The time-saving benefits of simultaneous measurements are explained in a series of free CEL guides.

The guides are targeted at three important application areas: Environmental Noise Surveys, Product Noise Testing and Occupational Noise Assessments.

A free copy can be obtained by contacting your nearest CEL instrument supplier.

- Provides real-time measurement capability in a hand held sound level meter.
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- Allows simultaneous, real time measurements to be made of two selectable parameters.
- Over 200,000 measurement results can be stored in the memory.
- Retains seven set up conditions in each mode for rapid continuation of measurements.
- Provides all of the important time domain functions found in modern sound level meters. (Leq, Lmax, Lmin, Lpeak, LTM3, LTM5, up to five Ln's).
- Can be powered from dry cell batteries (up to 20 hours continuous operation), car batteries or direct AC supply.
- Clear on screen prompts and cursor control make the instruments very easy to use.
- Large LCD screen (78mm x 54mm)
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- Choice of data download options: directly to printers, or to PC's using the dedicated CEL software program.

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from 64 Kb to 2 Mb in 8 or 16 bit widths and have the advantages of high speed operation with low power consumption. The credit card sized 68 pin package circuitry is protected by stainless steel plates top and bottom to protect the card from electrostatic discharge. Also available in the PCMCIA format are FLASH, MASK and OTP memories.

PCMCIA technology is now the acceptable standard for computer enhancements and many peripheral products are available in this format. Hakuto can also supply FAX/Modems, SCSI, Hard Drives, Lanes, Tokens, GPS systems, Frame Grabber, Sound blasters, Smart PCMCIA cards, Ethernet, etc. Hakuto can offer both software and hardware support to assist users in the implementation of this technology.

For further details please contact: D Coffey MIOA, Hakuto International (UK), 33-35 Eleanor Cross Road, Waltham Cross, Herts EN8 7LF Tel: 0992 787000 Fax: 0992 763300.

## HHB

### Portadat Range

On show to European broadcasters for the first time at the International Broadcast Convention in Amsterdam were production models of the PORTADAT range of portable DAT recorders from HHB who claim to be the world's leading independent suppliers of DAT technology. Designed to be the new standard in location sound recording, both the PORTADAT PDR1000 and the time code equipped PDR1000TC are exceptionally compact and light, featuring 4-heads for confidence monitoring, phantom powering and advanced Nickel Metal Hydride batteries along with many professional facilities.

Also new from HHB and on show at IBC were SERIES 2 versions of the DC-1 De-Clicker and CR-1 De-Crackler from Cambridge based CEDAR Audio, the company dealing in real-time audio restoration, and the new Panasonic SV4100 DAT recorder. The latter is a studio machine developed from the SV3700 with a range of new features making it ideal for use in audio for video applications.

For further information please contact: Brian Binding, Broadcast Sales Manager, HHB Communications Ltd, 73-75 Scrubs Lane, London NW10 6QU. Tel: 0181 960 2144, Fax: 0181 960 1160.

## ROEHM

### Plexiglas XT Soundstop

Plexiglas XT Soundstop is a new product for the manufacture of transparent noise control barriers. It has been successfully installed at a number of locations throughout Europe. It provides effective noise control and is used either to replace or in combination with conventional barriers to improve the natural visibility, thus making the barriers more environmentally acceptable.

Plexiglas XT Soundstop is a specially manufactured, state of the art, extruded transparent thermo-plastic sheet. It satisfies the requirements for noise control barriers as laid down in the German ZTV-Lsw 88 standard and is fully guaranteed against weathering.

Further information is available from Roehm Ltd, Plastics Division, Bradbourne Drive, Tilbrook, Milton Keynes, Bucks MK7 8AU Tel: 0908 274414 Fax: 0908 274588.

## EDERENA CONCEPT

### Aluminium sandwich laminate for loudspeakers

A high performance material which is claimed to give loudspeakers unrivalled clarity has been patented by a French company EDERENA CONCEPT.



The new material, Derenid, is a sandwich laminate; an aluminium honeycomb layer fixed between two thin steel sheets by a special adhesive. When used as a loudspeaker cabinet material the following benefits are claimed; low distortion amplitude, no resonance or vibration from cabinet walls, no tonal colouration, ultrarapid recovery time and lightweight construction (Derenid is claimed to be five times more rigid and three times lighter than wood composites of the same thickness).

To demonstrate the qualities of Derenid, Ederena Concept has developed the Aira loudspeaker. Aira is a two-way bass reflex design in a Derenid cabinet equipped with a 28 cm woofer and a ribbon tweeter, designed by Christian Yvon an acoustic engineer and designer of high fidelity systems.

We are informed that Ederena Concept operates in a wide range of high-tech sectors including space exploration, aeronautics, mechanical engineering and robotics.

For further information contact Christine McCaffrey at the French Technology Press Bureau. Tel 071 235 5330.

## News Items

### ACSOFT

#### A European Alliance

A new alliance has just been announced between three highly respected players in the acoustic instrumentation world, to offer totally compatible systems to tackle all aspects of noise and vibration measurement.

This European alliance, called **Acoustic One**, consists of 01dB from France, Norsonic from Norway, and GRAS Sound & Vibration from Denmark.

01dB supply software based measuring systems on PC and notebook platforms, for many specialised acoustics applications such as environmental noise, building acoustics, sound intensity and frequency analysis, using the popular Microsoft Windows interface. Norsonic brings to the party their range of traditional

## CONSULTANT

Wimpey Environmental Limited, one of the Country's leading acoustics consultancies, has a vacancy for an acoustics consultant. Applicants should have a relevant qualification and a minimum of two years' experience. The post would be based at our Hayes office, although a location in our Cardiff office would be considered for an exceptional candidate. The successful candidate would work on a full range of noise and vibration projects.

Salary will be commensurate with age and experience. Wimpey Environmental offers a full package of benefits, as would be expected from a major employer.

Please apply in writing with CV to Mrs L Snoding, Wimpey Environmental Limited, Beaconsfield Road, Hayes, Middlesex, UB4 0LS.

For further information please ring Richard Clough on 081-573 7744, extension 233.

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sound level meters and analyzers, and GRAS completes the triumvirate with a choice of top specification measuring microphones, intensity probes and front-end hardware.

The three companies will work closely together on development and marketing projects, and will share many of their sales outlets. An example of the co-operation can already be seen with the release of a new noise analysis package, dBSONO, from 01dB which accepts data from Cirrus and Aclan data-logging sound level meters and dosimeters, and now the Norsonic 116 Sound Level Meter has been incorporated, to allow new and existing users access to the powerful data treatment concept pioneered by 01dB. Plans include further compatibility between Norsonic instruments and other 01dB software, giving a one-stop shop approach to buying noise and vibration measurement systems.

In the UK, 01dB systems and software, which include the Concerto and Aria PC-based analyzers, are handled by AcSoft. Norsonic

will continue to be represented by Gracey & Associates and GRAS products and accessories will be available to complete systems from both stables.

A new catalogue describes the range of systems available from Acoustic One.

Contact John Shelton MIOA at AcSoft on 01296 662 852 or fax 01296 661400 for further details.

## A PROCTOR DEVELOPMENTS

### Profloor Micro Deck

Developed and manufactured under licence from Heriot-Watt University, Edinburgh, Profloor Micro Deck is said to cost-effectively deliver 10 – 19 dB improvements in impact sound insulation in newbuild and refurbished timber and concrete flooring.

The bonded foam and board design is the result of a two-year Royal Society/SERC Industrial Fellowship awarded to Professor Robin MacKenzie whilst at the Department of Building Engineering and Surveying at the University. The prod-

uct has been described as a highly successful example of R&D Technology transfer from university to SME.

The research established that 30 kg/m<sup>3</sup> open-cell polyether-urethane foam provides the most suitable resilience for normal domestic loading and is also viable in terms of chemical stability (ageing) and cost.

Incorporation of a 50 mm-wide closed cell foam strip at the edges of very thin MDF boards overcomes the problems of joint fracture previously associated with good impact performance in shallow deck overlay systems.

Further information from Allan Proctor, Managing Director, A Proctor Developments Ltd, The Haugh, Blairgowrie, Perthshire PH10 7ER Tel: 0250 872261 Fax: 0250 872727.

**A Proctor Developments is a Sponsor Member of the Institute.**

*Information on new products should be sent to John Sargent MIOA at the Acoustics Section, Building Research Establishment, Garston, Watford, Herts WD2 7JR.* ♦

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## Letters to the Editor

The Editor  
Acoustics Bulletin

Sir,  
In the recently published Institute Register there is a piece about the history of the Institute on page 3.

It contains a substantial error where it says, in paragraph 1, that the British Acoustical Society sprang in 1966 from the Society of Acoustics Technology. In fact the Society was initiated in 1946 by Alan Pickles, newly appointed as Head of Physics at the Building Research Station, and me, his newly appointed deputy. Under the aegis of the Physical Society we got together an ad hoc group of representative acoustic personalities and launched the Society. It survived and grew vigorously until the merger which became the Institute in 1974.

Interestingly enough our first speaker was my pre-war friend Erwin Meyer; he and Pickles had been war-time opponents, Pickles as Scientific Head for underwater defence and Meyer in the same role for underwater attack.

No one has ever honoured Pickles for the initiative, but the idea was his.

I hope this letter can be published and go into the Institute archives.

Yours truly  
William Allen HonFIOA

The Editor  
Acoustics Bulletin

Sir,  
Earlier this year the Health and Safety Executive published a new guidance document HS(G)88 'Hand-Arm Vibration'. This contains comprehensive and detailed information on how to identify, assess and control the risks of exposure to vibration in industry. To complement it the HSE are preparing a more descriptive book of case studies, similar in format to the existing '100 Practical Applications of Noise Control'.

The book will contain illustrated descriptions of how real vibration problems were solved, the reductions achieved and the costs involved. It is intended as a useful guide to what can be done for managers and those with health and safety responsibility.

AV Technology, who have been appointed to research the cases, are currently looking for interesting examples to include in the book and would be very pleased to speak to anyone who thinks they know of one.

They are looking for examples from as wide a range of industries and using as wide a range of technologies as possible. No case should be considered too big or too small as long as a real vibration exposure problem has been reduced. The cases to be included in the book will

each be investigated by AV Technology and described in an illustrated single page article.

If any readers think they may know of an interesting case it would be appreciated if they would contact Mike Hewitt at AV Technology, AVTECH House, Birdhall Lane, Cheadle Heath, Cheshire SK3 0XU Tel: 061 491 2222. Any organisation involved with each case can either be fully acknowledged or remain anonymous as they wish.

Yours sincerely  
Mike Hewitt

## Obituary

### Bryan Miles

Members will be saddened to hear of the death of Bryan Miles, a Fellow of the Institute and a member for many years.

Bryan started his career with Smiths Industries and later became one of the first Specialist Inspectors appointed by the Health and Safety Executive to work in the field of industrial noise. From those days he was always a leading advocate of improving the acoustic environments to be found in industry.

In the early years with the Health and Safety Executive he was involved in the development of legislation as well as advising industry on the application of the 1972 Code of Practice, which in later years formed the core of the Noise at Work Regulations.

He was one of the architects of the original Article 100 Directives which set noise limits to a range of construction plant and machinery. These Directives have subsequently reduced exposure levels to workers in that sector of industry. He had many inspired ideas, including the publication of a successful HSE book on noise case studies which showed industry how noise control could be practically applied.

Bryan, whilst having a deep knowledge of the subject, would always apply it in a simple and understandable way. This ability to reduce complex solutions into lay terms was a gift and a strength.

He travelled widely during his time with HSE, with secondments to Hong Kong and Turkey making him one of the architects for the requirements there of their national legislation as regards noise at work.

Bryan will be remembered for the many presentations he gave at Institute conferences which always stimulated a healthy debate amongst the delegates.

A great supporter of charities, his enthusiasm shone through in recent years with his support for The Hearing Dogs for the Deaf.

He will be sadly missed not only by his close colleagues and Institute members but also by anyone who had made contact with him over his many years of service to the cause of acoustics.

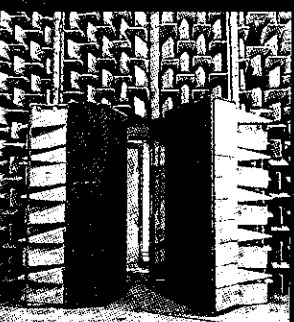
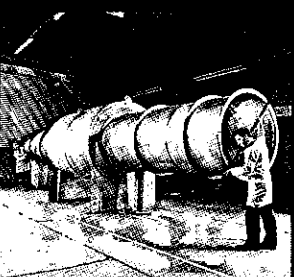
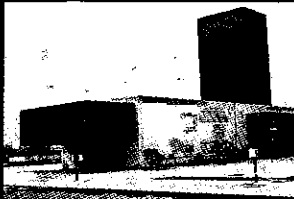
Our thoughts are with his widow Marie and his family at this time.

Keith Broughton MIOA



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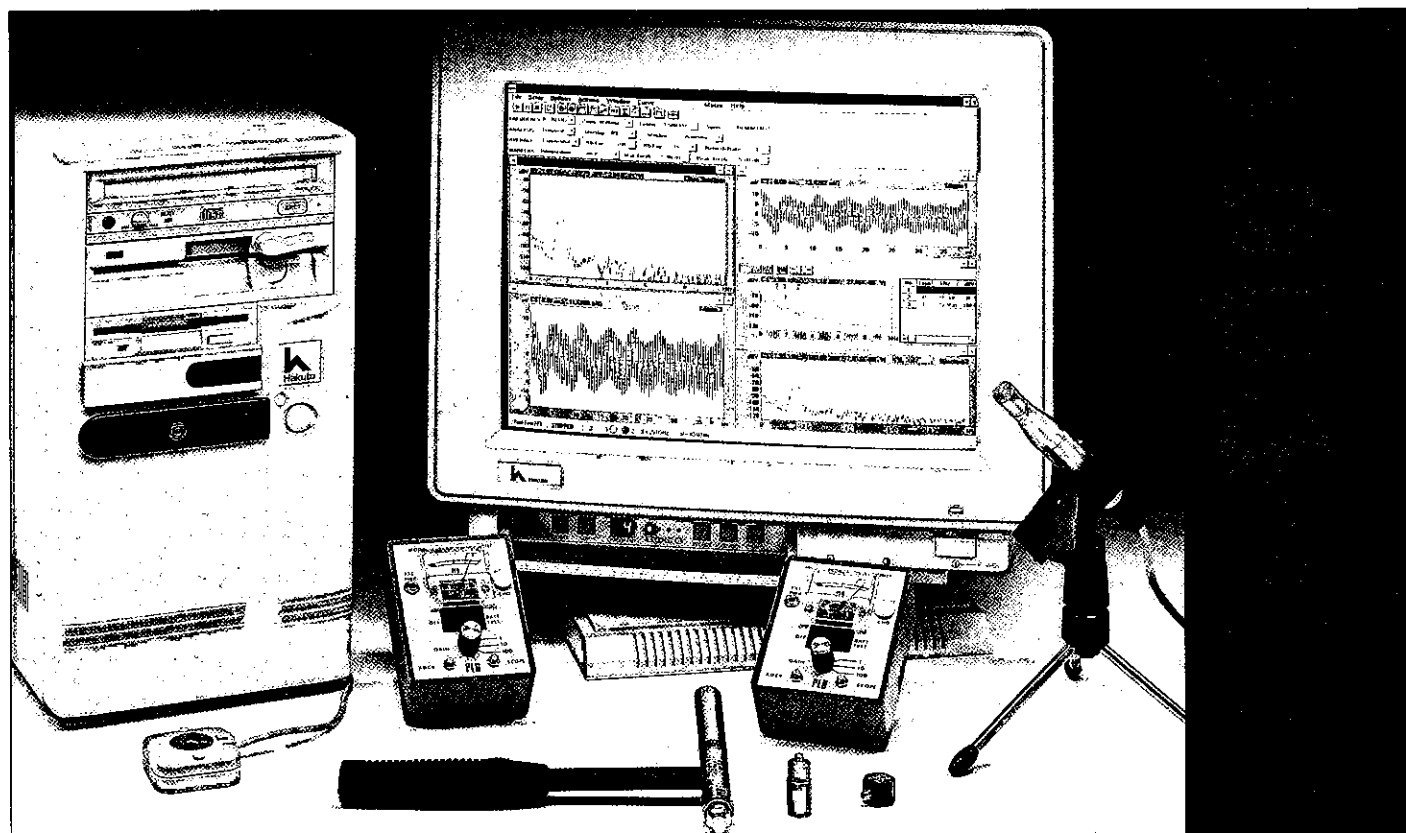
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