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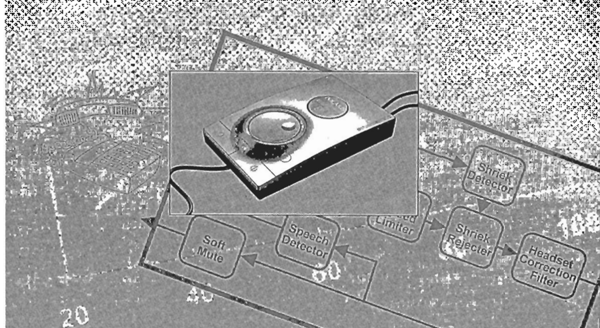

- Sound level meter standards
- Valuing noise impacts
- The virtual Boehm flute
- Acoustic Shock
- Scattering in the ocean

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From the Past President

Past presidents generally lose the opportunity to express their views in this column once their term has expired unless the incumbent President has taken a long vacation or is otherwise indisposed. Our President, Charles Don is at present in Kenya on safari before returning to oversee the arrangements for the upcoming Wespac-8 Conference – 'Acoustics on the Move' to be held in Melbourne 7 – 9 April 2003

This Wespac-8 Conference in drawing acousticians from throughout the Asian and Pacific regions to Australia indeed provides a forum for influence and in a positive way may assist in reversing the negative trend in acoustics as highlighted by our President.

With concerted affirmation on the need for ongoing acoustic research and development which can emanate from such a gathering, Governments, Research Establishments and Universities may hopefully be encouraged to maintain acoustic facilities and re-establish and enhance interest in both pure and applied acoustic research, rather than oversee their demise and that of the magnificent acoustical facilities which still exist, although in many cases under utilised.

Those of us working in this field are clearly cognisant that acoustic issues dominate many aspects of science, medicine and the arts as well as impacting on community well-being.

From an Australian perspective, it would seem very desirable for as many of our acoustic fraternity as possible - academics, consultants and practitioners to join in harmony at this upcoming forum with an avalanche of papers and attendees to highlight the scope and importance of our field of acoustics.

Let the music thus generated positively stimulate the tympanic membrane of those who administer our acoustic research facilities who are listening to the beat of another drum — the cacophony of accountancy (two c's) whose tenets so threaten our field of endeavor. See you at Wespac 8 manning the 'acoustic barriers'.

Geoff Barnes
Past President

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SOUND LEVEL METER STANDARDS FOR THE 21ST CENTURY

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This paper is based on the 2001 PRESIDENT'S PRIZE paper. This prize, established in 1990 by the Australian Acoustical Society, is awarded to the best technical paper presented at the Australian Acoustical Society Conference.

Abstract A new Sound Level Meter standard IEC61672-1:2002 has just been published. The IEC working group 4 (Sound Level Meters) of the IEC Technical Committee 29 (Electroacoustics) has been engaged for some years in the task of writing this new standard that will replace, update and combine the sound level meter standards IEC60651–1979 and IEC60804-1985. It is reasonable to expect that in due course this new standard will become accepted as an Australian standard and will replace AS1259-1990 parts 1 & 2 which have their technical basis in the older IEC standards of the 80s. As most new Sound Level Meters now coming onto the market have anticipated the new standard it is timely to investigate the differences.

1. INTRODUCTION

The first International Electrotechnical Commission standard for sound level meters was published in 1961 as IEC123. There has been a number of versions of an Australian standard for sound level meters; the earliest was AS Z37-1967, which, after several revisions, was re-published as AS1259-1976 culminating in AS1259-1990 Parts 1,2 [1,2]. These were to follow closely the standards IEC60651 and IEC60804 [3,4]. However, by the time that IEC60804 was published in 1985, it and IEC60651 were regarded as technically obsolete as the construction of sound level meters had advanced rapidly with the use of digital technology including the use of digital rather than analogue displays. This is even more true today, as modern designs have become completely digital from the preamplifier with functions now built in as "firmware". There is no longer reliance on hardware components and the dynamics of analogue pointer displays, rather the skill of a programmer to emulate a design goal.

The new standard IEC61672-1:2002 [5] to replace 60651 and 60804 was begun in the early 1990's and is to be published in 3 parts. Part 1 (Specifications) was published in May 2002, Part 2 (Pattern Evaluation Tests) is expected to be published in late 2002 and Part 3 (Periodic Verification) is currently at working draft stage. Part 4 will cover detailed format for reporting tests to Part 2, and Part 5 will provide procedures for the estimation of measurement uncertainties during tests due to the presence of the sound level meter in various acoustical environments [6].

2. AUSTRALIAN CONTEXT

The new series of standards embodied in 61672 are significant for the Australian acoustical community which is no longer represented only by equipment users. There is at least one successful Australian manufacturer and exporter of airport noise monitoring equipment who will in future work with this new standard to enable pattern evaluation to be carried out successfully in whatever part of the world market sales are made. There are also several other manufacturers of noise logging equipment for Australian domestic consumption, at least one with limited export experience.

There are a number of changes in design goals in 61672 that will result in different performance and facilities in instruments which must be taken into account when framing local ordinances and statutes.

In the Australian market there is currently a void as regards local pattern evaluation and the National Measurement Act [7] and its regulations do not list equipment for the measurement of sound in Certified Measuring Equipment. Most if not all of the sound level meters imported at the cheaper end of the market (Type 2) may be non-compliant or marginal and there is in general only the manufacturer's assurance that the equipment complies with the standard. Further, it appears that none of the equipment manufactured for domestic consumption in Australia has been subjected to a rigorous pattern evaluation as defined by the OIML in OIML R88-1998 [8]. Australia subscribes to the OIML (Organisationale Internationale Metrology Legale) via the National Standards Commission which is responsible for legal metrology in Australia. There is consequently little protection for the user unless the equipment being sold in Australia has a demonstrated pattern evaluation from a recognized overseas authority.

The new IEC61672 parts 2 and 3 have been formulated in co-operation with the OIML to have regard for the provisions of legal metrology. The coming of the new standard IEC61672 affords an excellent opportunity for the Australian situation to be clarified by encouraging equipment to be pattern approved. With the increased protection afforded by pattern evaluation there will unfortunately be some increased cost to the user and this may make many of the cheaper instruments suitable only for survey purposes.

Some statutory authorities or services engaged in sound level testing, for example motor vehicle muffler testing, are requiring the provision of a "Regulation 13" [7] certificate that verifies proof of traceability to National Standards for veracity during court proceedings. It is not feasible to issue such a certificate for non-type approved equipment; this hiatus knocks out the present Type 2 equipment thus increasing the cost to the authority at least 5 fold.

In the following sections the technical differences between the current and new standards will be explored.

3. CHANGES

3.1 Measurement Uncertainty

In line with accepted metrological practice, the estimated uncertainty of the measurements must be taken into account when making judgments of pass or fail to a design goal with tolerances. Without taking uncertainties into account when framing the tolerances around design goals in standards, this leads to an effective reduction in the tolerances. The new standard has "loaded" the tolerances with "typical" uncertainties and they are tabulated in the standard for guidance to the test house. This effectively removes the effect of the uncertainties during the judgment process providing the actual test uncertainties are no greater than the tabulated uncertainty. For the purposes of comparison between 60651/60804 and 61672 in this paper, the uncertainties are not included in any tolerances quoted. The "loaded" tolerances may be found in the new standard.

3.2 Change from Type to Class

The old standards 60651 and 60804 allowed for 4 performance types from Type 3 to Type 0 with increasingly tighter tolerances. The new standard 61672 [5] will allow 2 performance categories designated as Classes 1 and 2 with the same design goals but with Class 2 having, in general, wider tolerances. The descriptor "Type" has been changed to avoid confusion with types of instrument in the context of facilities fitted. The older Type 0 and Type 3 have not been included. Type 0 represented a laboratory level seldom used and Type 3 is seen to be unnecessary, as modern manufacturing techniques should ensure improved performance. In practice Types 2 and 3 were seldom subjected to type approval so performance could not be substantiated.

The effect of environmental conditions has been rationalised to allow more realistic ranges of environmental effects such as temperature; Class 2 (0°C to 40°C) as distinct from the higher performance expectation of Class 1(-10°C to 50°C). In 60651 all types were required to demonstrate performance from -10°C to 50°C albeit with different tolerances and this prohibited most manufacturers taking the risk of pattern approval for their Type 2 instruments. In addition reference conditions have been changed from 20°C/65% RH to 23°C/50% RH which brings the equipment into line with most electrical metrology.

3.3 Directional Response

The tolerance limits in 61672 have been extended to include an incidence angle of 150° and have been tightened at higher frequencies. These changes are shown in Table 1 below, where the existing 60651 tolerances are shown in parenthesis. The implication of this change will impact equipment with larger diameter microphones which probably will not meet these specifications, Marsh [6].

3.4 Weighting Networks

The design goals for A and C have not changed and a Z (Zero) or "Flat" weighting has been introduced. There is however no specification for unweighted Peak, see below. In line with greater expectations of performance, the tolerances around the design goals (including Z) have been tightened for Class 1 instruments below 80 Hz and above 6.3 kHz. This is intended to ensure a minimum microphone response at 16 Hz and 16 kHz (20 Hz and 8 kHz for Class 2). This limit was previously +3/-∞ dB in IEC60651, that is, no specific requirement for response. These differences were summarized in [6] and are reproduced below in Table 2 for emphasis.

3.5 Display Linearity

In IEC60651 linearity requirements were based on the available technology of the time and included provision for range changing. Display linearity errors arise from the inability of the detector/squaring circuit or the display circuit to provide a linear display of the sound pressure level at the microphone. The requirement in 60651 was for an indicator range of at least 15 dB with at least 10 dB specified as a "primary" display range. Within those ranges 2 sets of tolerances applied, firstly for increments between 1 and 10 dB within the primary range, (±0.2 dB to ±0.4 dB for Type 1) and secondly, outside the primary range for any signal the tolerances were increased (±1.0 dB for Type 1). Where any range changing, automatic or manual occurred, the tolerance was ±0.7dB within the primary range.

Table 1. Directional response tolerance limits for Class 1 and 2 sound level meters as required by 61672 and compared to 60651 (in parentheses)

Frequency kHz	Maximum absolute difference in displayed sound levels at any two sound-incidence angles within ± θ degrees from the reference direction dB					
	θ = 30°		θ = 90°		θ = 150° (not in 60651)	
	Class/Type					
	1	2	1	2	1	2
0.25 to 1 (0.035 to 1)	1 (1)	2 (2)	1.5 (1.5)	3 (3)	2	5
>1 to 2	1 (1)	2 (2)	2 (2)	4 (5)	4	7
>2 to 4	1.5 (1.5)	4 (4)	4 (4)	7 (8)	6	12
>4 to 8	2.5 (2.5)	6 (8)	7 (8)	12 (14)	10	16
>8 to 12,5	4 (4)	...	10 (16)	...	14	...

Table 2. Frequency weightings and tolerance limits, IEC60651 compared to IEC 61672

Nominal frequency a) Hz	Tolerance limits (dB)					
	Class 1 (Type 1)			Class 2 (Type 2)		
	60651	61672-1	Change	60651	61672-1	Change
10	+3;-∞	+3; -∞		+5; -∞	+5; -∞	
12,5	+3;-∞	+2.5; -∞	*	+5; -∞	+5; -∞	
16	+3;-∞	+2; -4.5	*	+5; -∞	+5; -∞	
20	±3	±2	*	±3	±3	
25	±2	+2; -1.5	*	±3	±3	
31,5	±1.5	±1.5		±3	±3	
40	±1.5	±1	*	±2	±2	
50	±1.5	±1	*	±2	±2	
63	±1.5	±1	*	±2	±2	
80	±1.5	±1	*	±2	±2	
100	±1	±1		±1.5	±1.5	
125	±1	±1		±1.5	±1.5	
800	±1	±1		±1.5	±1.5	
1 000	0 b)	±0.7 c)	*	0 b)	±1 c)	*
1 250	±1	±1		±1.5	±1.5	
4 000	±1	±1		±3	±3	
5 000	±1.5	±1.5		±3.5	±3.5	
6 300	+1.5; -2	+1.5; -2		±4.5	±4.5	
8 000	+1.5; -3	+1.5; -2.5	*	±5	±5	
10 000	+2; -4	+2; -3	*	+5; -∞	+5; -∞	
12 500	+3; -6	+2; -5	*	+5; -∞	+5; -∞	
16 000	+3;-∞	+2.5; -16	*	+5; -∞	+5; -∞	
20 000	+3;-∞	+3;-∞		+5; -∞	+5; -∞	

a) The tolerances from 160 Hz to 630 Hz and from 1600 Hz to 3150 Hz have not changed from 60651 to 61672.

b) Tolerance limits were 0 dB at the reference frequency as the design goal was in terms of sound levels relative to the sound level at the reference frequency, assumed to be 1 kHz for this purpose.

c) In 61672 the tolerance limits are nonzero as the design goal frequency weightings are relative to the unweighted sound pressure level at the position of the microphone on the sound level meter, but in the absence of the meter.

In IEC 61672 these requirements have been clarified by a requirement for a defined reference range with linear operating span of at least 60 dB at 1 kHz for either class of instrument. These requirements are intended to apply from 16 Hz to 16 kHz for Class 1 sound level meters and from 20 Hz to 8 kHz for Class 2. A maximum error of ±0.8 dB (±1.1 dB for Class 2) applies to any range and includes errors introduced by range controls. On a linear operating range, errors for changes in input signal of from 1 dB to 10 dB must not exceed ±0.3 dB for Class 1 or ±0.5 dB for Class 2.

3.6 Time Weighting and Tone Burst Response

There was a clear separation between Time Weighting and Integrating/Averaging functions in IEC 60651 and IEC 60804 with L_{Aeq} (equivalent continuous) as the prime metric and S_{EL} (dose) derived from L_{Aeq} in terms of time. Specifications for Time Weighting and Integrating have been brought together in IEC61672 under the title "Toneburst Response" and the Table 3 is reproduced below. The terminology has been clarified and L_{AE} (S_{EL}) has now become the prime metric.

The quantity L_{AT} (L_{Aeq}) is specified under the heading "Response to repeated tonebursts" in terms of the difference δ_{ref} between the theoretical time-average sound level of a sequence of N tonebursts extracted from a steady signal and the time-average sound level of the steady signal as:

$\delta_{ref} = 10\lg(NT_b/T_m)$ where

T_b is the toneburst duration and

T_m is the total measurement duration, both in seconds.

For L_{AT} the tolerances from Table 3 are used. Thus the emphasis has changed to be time independent for L_{AE}. This does not, as has been feared, remove $L_{AT}(L_{Aeq})$ from the specifications in 61672 which apply for an electrical signal at toneburst durations from 0.25 ms to 1 s. IEC 60804 as amended required a minimum toneburst duration of 1 ms.

3.7 Peak C Sound Level

In 60651 the performance specification was for a test of the onset time (charging time) of the peak detector (unweighted)

Table 3. Reference 4 kHz toneburst responses and tolerance limits including maximum expanded uncertainty of measurement

Toneburst duration, T_b ms	Reference 4 kHz toneburst response, δ_{ref}, relative to the steady sound level dB		Tolerance limits dB	
			Class	
	$L_{AFmax} - L_A$ $L_{CFmax} - L_C$ and $L_{ZFmax} - L_Z$; Eq. (15)	$L_{AE} - L_A$ $L_{CE} - L_C$ and $L_{ZE} - L_Z$; Eq. (16)	1	2
1 000	0.0	0.0	±0,5	±1.0
500	-0.1	-3.0	±0.5	±1.0
200	-1.0	-7.0	±0.5	±1.0
100	-2.6	-10.0	±1.0	±1.0
50	-4.8	-13.0	±1.0	+1.0-1.5
20	-8.3	-17.0	±1.0	+1.0-2.0
10	-11.1	-20.0	±1.0	+1.0-2.0
5	-14.1	-23.0	±1.0	+1.0-2.0
2	-18.0	-27.0	+1.0-1.5	+1.0-2.5
1	-21.0	-30.0	+1.0-2.0	+1.0-3.0
0,5	-24.0	-33.0	+1.0-2.5	+1.0-4.0
0,25	-27.0	-36.0	+1.0-3.0	+1.5-5.0
	$L_{ASmax} - L_A$ $L_{CSmax} - L_C$ and $L_{ZSmax} - L_Z$; Eq. (15)			
1 000	-2.0		±0.5	±1.0
500	-4.1		±0.5	±1.0
200	-7.4		±0.5	±1.0
100	-10.2		±1.0	±1.0
50	-13.1		±1.0	+1.0-1.0
20	-17.0		+1.0-1.5	+1.0-2.0
10	-20.0		+1.0-2.0	+1.0-3.0
5	-23.0		+1.0-2.5	+1.0-4.0
2	-27.0		+1.0-3.0	+1.0-5.0

NOTE 1 For the purpose of this standard and for conventional sound level meters, reference 4 kHz toneburst response δ_{ref} for maximum time-weighted sound levels shall be determined from the following approximation

$$\delta_{ref} = 10 \lg\left(1 - e^{-T_b/\tau}\right) \quad (15)$$

where T_b is a specified duration of a toneburst in seconds,
τ is a standard exponential time constant specified in 5.7.1, and
e is the base of the natural logarithm.
Equation (15) applies for isolated 4 kHz tonebursts.

NOTE 2 For the purpose of this standard and for integrating and integrating-averaging sound level meters, reference 4 kHz toneburst response δ_{ref} for frequency-weighted sound exposure levels is determined from the following approximation

$$\delta_{ref} = 10 \lg(T_b / T_0) \quad (16)$$

where T_b is a specified duration of a toneburst in seconds, and
T_0 = 1 s is the sound-exposure reference duration.

NOTE 3 Reference 4 kHz toneburst responses in table 3 are valid for the A, C, and Z weightings. Other frequency weightings may have other reference toneburst responses.

and which was specified to be less than 100 μs for Type 1. In practice the actual onset time varies from meter to meter from 10 μs to over 50 μs and the unweighted peak response to an acoustic event using unweighted Peak (Flat) may vary widely between individual sound level meters meeting Type 1 specifications in the presence of infrasound or high audio frequencies. IEC 61672 has adopted C weighting for the Peak design goal which is demonstrated by response to a single cycle input signal at 31.5 Hz, 500Hz and 8 kHz with additional tests using positive and negative $^1/_2$ cycles of 500 Hz. The response in these cases is compared to the steady signal from which the single or $^1/_2$ cycle signals are extracted. This approach will lead to consistent measurement of common events with individual instruments meeting the design goal.

Concerns have been expressed that the use of C weighting for Peak measurement of a noise event may bring about lower indications where there are impulsive signals at the extremes of both very short and very long time constants. The alternative is to have the much greater probability of inconsistent measurements from the use of Peak (flat) unweighted under the specification in 60651. The high frequency roll off at the lower limit of the old 60651 tolerances is essentially the same as the design response of the C weighting network where both are – 3dB at 8 kHz. Thus a marginal Type 1 meter under 60651 may well have had by default a C weighting response when operating unweighted.

Measurements at low frequencies will still present problems and are ultimately limited by microphone response which varies widely amongst SLMs, even those that would comply with 61672. It would seem logical to consider standards for the measurement of blasting events using Peak outside the SLM standard as this is a special case and requires specialist equipment.

3.8 Time weighting I (impulse)

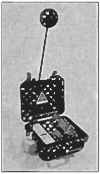
It has been found by the working group that time weighting I is not suitable for rating impulsive sound with respect to loudness hence it is not recommended for use in assessing the risk of hearing impairment. The design goal for time weighting I has been placed in the standard as an informative Annex since I weighting is still referenced in many documents.

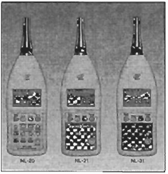
4. CONCLUSION

The new IEC61672 standard will ensure that sound level meters built to its design goals will have enhanced and more consistent performance than under the older standards. If the Australian community adopts IEC61672 [5] as an Australian standard then an ideal opportunity will arise to resolve the present hiatus involving pattern approval of noise measuring equipment.

REFERENCES

1. Australian Standard AS1259.1-1990. "Sound level meters Part 1: non-integrating.
2. Australian Standard AS1259.2-1990. "Sound level meters Part 2: Integrating-averaging.
3. International Electrotechnical Commission Standard IEC61651-1979."Sound level meters.
4. International Electrotechnical Commission Standard IEC61804-1985. "Sound level meters integrating-averaging.
5. International Electrotechnical Commission Standard IEC61672-1:2002. "Electroacoustics - Sound level meters Part 1.
6. Alan H. Marsh, IEC 61672, "The new international standard for sound level meters", Proceedings of the 2001 International Congress and Exhibition on Noise Control Engineering, The Hague, The Netherlands, 2001 August 27-30.
7. National Measurement Act of the Parliament of Australia, Regulation 13.
8. Organisationale Internationale de Metrology Legale recommendation R88-1999.





VALUING NOISE IMPACTS USING HEDONIC PRICING AND STATED PREFERENCE METHODS: WHAT DOES THE EVIDENCE TELL US?[1]

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Abstract: Estimates are presented from both Australia and overseas of the value of traffic noise reductions. These estimates were sourced from both hedonic price and stated preference applications. A similar range of estimates was found using both techniques. However, the number of studies available is relatively limited given the importance of noise impacts within the economy, and there is substantial variability in the estimates generated using both techniques. The variability appears to be primarily an artefact of methodological differences rather than differences in cultural perspectives regarding the cost of noise.

1. INTRODUCTION

One of the main negative externalities arising from road traffic is noise impacts. Noise impacts arise from a vehicle's power train, from rolling noise and from electronic equipment. Actual traffic noise is a function of quite a few different factors. These include traffic volume, the type of vehicles using the road, the road surface, the distance of properties from the road and geography (ie the existence of natural mounds, bluffs and vegetation).

Traffic noise is measured using several indexes. The most common of these is the $L_{Aeq,T}$ index. $L_{Aeq,T}$ stands for "Equivalent Continuous A-Weighted Sound Pressure Level". This is the average (logarithmic) noise level (expressed in dB) that would occur if traffic flow were uniform, within a specified time interval T.

Noise is considered to be a negative externality because it is unwanted, and affects people other than those directly involved in the use of the motor vehicles. Some of the most apparent impacts are on sleeping patterns and general amenity. But there are other impacts. Noise can affect stress levels and people's ability to communicate [1].

The existence of negative externalities is a cause of market failure, and provides a rationale for government intervention within the market. This intervention typically takes one of two forms. The first is modifications to roads to minimise noise impacts. This might involve the construction of barricades to block noise, or modifications to road surfaces. Alternatively compensation may be required, particularly if property prices are affected by road widening and subsequent increases in traffic. The critical question for policy makers in either of these circumstances is "what value should be given to noise impacts?" Answers to this question are needed to determine when the control of noise is warranted, and/or the appropriate level of compensation that should be paid.

Some information about the value of noise can be derived from existing market data. This typically involves looking at changes in damage costs or preventative expenditures [2]. For example, information about expenditure on double glazing windows or other modifications to the design of houses provides an indication of the benefits of reduced noise. However, the benefits of noise reductions are more typically deduced by using related or hypothetical market data. Using these techniques, it may be possible to estimate the 'non-market' value associated with changes in noise levels.

The purpose of this paper is to review the existing literature pertaining to the valuation of road traffic noise. Specifically, the results from hedonic price studies and stated preference studies conducted both in Australia and overseas are reviewed and compared. In Section 2, these two approaches are briefly described. Then, in Section 3, the results from applications of the hedonic price method are reviewed and, in Section 4, the results from the stated preference applications are reviewed. Conclusions are offered in Section 5.

2. METHODS FOR VALUING NOISE IMPACTS

The most commonly used method for valuing noise impacts is the hedonic price method, which in the economics literature is described as a "revealed preference technique". Revealed preference techniques use information from related markets to impute a value for non-market goods [3]. A related market is one that indirectly reveals values for environmental goods.

The hedonic price method uses differences in property prices to impute a value for changes in environmental quality such as noise, air quality, water quality or river health. In most (single stage) hedonic price studies a regression equation is estimated where property prices are a function of all of the attributes of the property, including environmental quality. The effect of marginal changes in environmental quality on property prices can then be quantified. However, to estimate demand (which is required for valuing non-marginal changes) for an externality such as noise is more complicated. Estimating demand requires data from multiple, distinct mar-

1. An earlier version of this paper was presented at the Bureau of Transport Economics Transport Colloquium, Canberra, 27-29 November 2000.

kets, as well as information on the individual purchasers of the differentiated commodity [4, 5]. With distinct markets, the value of noise can then be calculated at different levels of supply, thus identifying the demand curve. This is known as a second stage hedonic function.

Economists tend to have greater trust in the results from revealed preference studies because they are based on existing market data. However, the results from the non-market valuation literature indicate that the variation associated with estimates derived using revealed preference techniques is often very great (and typically larger than the other class of techniques, which will be described shortly) [6]. Moreover, value estimates are subject to the judgement of the researcher. Value estimates can be affected by the attributes selected, the accuracy of measurement of the pollutants involved and the functional form used [7, 8].

Uncertainty about the capacity of the hedonic price method to accurately value noise provides a rationale for using other non-market valuation techniques. The other main class of non-market valuation techniques are those based on the stated preferences of individuals. Stated preference techniques involve the use of surveys from which estimates are derived of the non-market benefits of different resource use alternatives.

The most widely used stated preference technique for estimating non-market values is the contingent valuation method (CVM) [9]. CVM questionnaires contain several well-defined elements including a description of the study site, details of the proposed changes (including a method of payment), an elicitation question and a series of socioeconomic and attitudinal debrief questions. State-of-the-art applications of the CVM generally utilise the 'referenda' format for the elicitation question, an example of which is shown in Table 1.

Under this format, respondents are asked whether they support a project given that they are required to pay a certain amount towards it, with the payment amounts being varied between respondents. The responses to the elicitation question are then regressed against several variables including the payment amount, respondents' attitudes, and socioeconomic characteristics such as income, age, education etc.. This equation is then used to estimate mean and median willingness to pay.

The CVM has the advantage of being recognised by respondents as a standard public choice instrument (as it is similar to a referendum). However, despite its wide usage, the CVM has several limitations. It is relatively costly to use, provides limited information about people's preferences and is arguably prone to various biases [10, 11]. In Australia, it has become controversial since its use by the Resource Assessment Commission to estimate the environmental costs of mining at Coronation Hill [12]. Similar controversy was experienced in the USA where contingent valuation was used in the Exxon-Valdez oil spill case [13].

Table 1: The dichotomous choice CVM format

Do you support the proposal to reduce noise at a cost of $50 per household, or do you oppose the proposal? (*tick one box*)	
I support the proposal at a cost of $50	☐
I oppose the proposal at a cost of $50	☐

A second stated preference technique that has been used to estimate the value of improved water quality and could be applied to valuing the improved environmental quality resulting from the control of noise is conjoint analysis. Conjoint analysis has been widely used in transport economics in predicting market share for transportation options and valuing travel-time savings [14, 15].

Conjoint questionnaires are similar to CVM questionnaires in that they contain background information about the non-market good, an elicitation question, and debrief questions. The main difference between the two methods is in the form of the elicitation question. In conjoint questionnaires, respondents are presented with a series of alternatives that they are asked to evaluate. This evaluation could involve rating, ranking or choosing one of the alternatives. An example of the choice version of conjoint analysis is shown in Table 2. From each choice set, respondents are asked to choose their preferred alternative. The alternatives in the choice sets are defined using a common set of attributes (ie effective speed limit, reduced noise level from road traffic, reduced length of waiting time for pedestrians to cross road, annual cost per household in terms of increased local taxation etc.), the levels of which vary from one alternative to another.

Table 2: Example of one choice set in a choice modelling questionnaire

Please indicate the alternatives you prefer most by ticking one of the boxes below:

	Alternative 1	**Alternative 2**	**Alternative 3** (the status quo)
Speed limit	50 km/h	60 km/h	60 km/h
Noise level	60 dB	70 dB	80 dB
Waiting time to cross road	1 minute	3 minutes	3 minutes
Increased rates	$90	$30	$0
	☐	☐	☐

In conjoint applications goods are decomposed into a set of 'attributes' or characteristics. For example, a car could be considered to be simply the sum of its component parts ie 4 wheels, a chassis, an engine etc. The trade-offs respondents make when choosing between alternatives are quantified using statistical techniques. Where one of the attributes involves a monetary payment, the resulting trade-offs can be used to estimate the value of each of the environmental quality attributes. This can be conceptualised in the case of purchasing a car. Existing market data might show that on average people may be willing to pay $1000 extra for air conditioning — this implies that air conditioning is worth this amount of money.

Conjoint analysis has several advantages over contingent valuation. It provides much greater information about people's preferences for noise reductions. This extra information is particularly useful for benefit cost analysis where multiple alternatives are typically evaluated. Often the full range of policy alternatives may not have been identified before the non-market valuation exercise has taken place. With contingent valuation it may be necessary to undertake a new exercise if a new policy option is identified. In contrast, the results from a CM application can be used to value any alternative within the space of attributes used in the exercise. This provides the decision maker with much greater flexibility. However, conjoint applications do involve a greater level of complexity than is involved with contingent valuation. In subsequent sections, estimates are provided of the value of noise generated using both revealed preference and stated preference techniques.

3. HEDONIC PRICE ESTIMATES

Hedonic price studies have primarily been used as a basis for deriving estimates of the value of noise impacts in Australia. For instance, the Roads and Traffic Authority (p.8.2) "estimated that property values depreciate on average by a rate within the range of 0.8% to 1.28% for every decibel over 50 dB(A)" [16]. This finding was based on report commissioned by the Resource Assessment Commission [5], who in turn primarily based their findings on a review by Pearce and Markandya [17], who primarily based their findings on a review by Nelson [18] which was published in the Journal of Transport Economics and Policy. In Nelson's study, he reviewed nine studies published between 1974 and 1980, and identified a range of adjusted NDSI's[2] of 0.08-1.05%, with a weighted mean of 0.40%.

The use of all of these nine studies in calculating this mean estimates has been questioned by NSW EPA [1]. They comment that:

> *The sample size appears inadequate in some estimates such as Hall et al. (1978) who have a final sample size of 21; and Bailey (1977), who have a sample size of 90. The environmental good is not carefully measured in several estimates...who do not measure noise levels. Bailey (1977) uses the natural log of distance to highways which Nelson (1982) suggests is an 'excellent alternative' but it ignores the potential effect of topography on noise levels...Also, many of the noise measurements cover a very short time period. In Vaughan and Huckins (1975), noise measurements were taken for only 5 minutes at each site...*

Further criticisms could also be made of these studies. Apart from being fairly old, they used only single stage regression analysis and have specification problems such as from collinearities [19]. They also only examined the impacts of highway noise. NSW EPA [1] reported that when the studies that are seen to have less reliability are excluded, the mean of the more reliable estimates is approximately 0.25% per dB.

Several hedonic price studies of road traffic noise have been conducted in Australia. The first two were rudimentary single stage hedonic price models with relatively few regressors. McCalden and Jarvie [20] in a study in Newcastle estimated that the NDSI was 0.20%. In another study conducted in Sydney, Holsman and Bradley [21] estimated that the NDSI was 1.80% for main roads where noise levels were generally higher, and 0.70% for parallel streets.

A third study was conducted by Williams [22], who examined the effect of noise impacts on property prices along the South East Freeway in Brisbane. While using only a single stage hedonic model, the study was more robust than the previous ones. The study was based on a sample of 218 houses within one kilometre of the freeway. The initial model included 13 regressors that were subsequently factor analysed to produce a set of five uncorrelated regressors. This is a fairly novel approach, in the non-market valuation literature, for dealing with problems due to multicollinearity. Williams [22] found that the cost of proximity to the freeway was $4.48 per metre ($872 for an average house or 3% of average house price) in A$1978. Williams [22] suggests that this impact is primarily due to noise impacts, however noise levels were not measured at each of the housing sites. Hence it is not possible to determine the impact on house prices for changes in noise levels.

A final and more recent Australian study identified by Renew [23], that was conducted in streets throughout Brisbane, estimated a NDSI (L_{eq}) of 1.00%. The data set included 350 houses (across 36 streets) with sales occurring over a three year period. Noise levels were measured for 24 hours at a representative site in each street. A linear regression model was estimated, and ten attributes (including noise levels) were used to explain variations in house prices.

Thus the Australian evidence shows considerable variance, with the NDSI ranging from 0.20% to 1.80%. It is possible that the divergence could reflect the different nature of the towns (Newcastle being a rural centre). However, there may be other explanations such as the differences in when the studies were conducted (ie changing tastes), or differences in methodology.

Given the lack of convergence of the Australian estimates, it is appropriate to consider other estimates derived in North America and Europe. Since Nelson's [18] study, several other studies have been conducted to value the impacts of traffic noise, some of which are reported in Table 3. Overall, there appear to be relatively few studies conducted on the value of traffic noise compared to the relatively broad literature where the hedonic price method has been used to value aircraft noise

2. Noise Depreciation Sensitivity Index. This gives the average percentage change in property prices per decibel.

Table 3: Overseas estimates of the value of traffic noise impacts

Study	Location	NSDI
Grue et al [27]	Oslo, Norway	0.21-0.54%
Hall et al [28]	Toronto, Canada	0.42-0.52%
Iten and Maggi [29]	Zurich, Switzerland	0.9%
Pommerehne [30]	Basel, Switzerland	1.26%
Hidano et al [31]	Tokyo, Japan	0.7%
Sougel [32]	Neuchatel, Switzerland	0.91%
Vainio [19]	Helsinki, Finland	0.36%
Wilhelmsson [33]	Stockholm, Sweden	0.6%
Bateman et al [34]	Glasgow, United Kingdom	0.2%

and air pollution. The studies reported in this table show a similar variation in estimates to the Australian studies, with the NDSI ranging from 0.21% to 1.26%, with a mean of 0.71%.

The similarity in the spread of values to the Australian studies is somewhat surprising, given the differences in cultural context and time periods over which the various studies were conducted. This implies either that (1) noise is valued similarly across cultures or (2) that differences in methodology are part of the reason for the convergence. Given what is known about how sensitive hedonic price estimates are to methodological variations, the latter explanation is likely to be important. This suggests that it would be prudent to conduct a meta-analysis to determine the value of noise, once allowance has been made for differences in methodology and culture.

4. STATED PREFERENCE ESTIMATES

Several stated preference studies have been conducted in Europe to value traffic noise. This includes the use of both contingent valuation and conjoint analysis. The first two of these studies by Vainio [19] and Barreiro, Sanchez and Viladrich-Grau [25] used the contingent valuation method. The latter application, by Garrod, Scarpa and Willis [26] used conjoint analysis. Given that only a few stated preference applications have been conducted to value traffic noise impacts, they will be reviewed in greater detail.

The study by Vainio [19] paralleled an application of the hedonic price method that was reported in the previous section. Vainio [19] sent a survey to 700 households in Helsinki, Finland and received back 421 valid responses (60%). In the survey they asked the following question to estimate respondents' willingness to pay to reduce noise in a street where they felt noise was a particular nuisance:

The purpose of this equation is to estimate how much people would be willing to pay for the elimination or considerable reduction of traffic nuisance.

Let's consider the idea that the road/street that is causing the harm could be calmed be eg diverting the traffic elsewhere or into a tunnel so that the street would be converted to a "residential street". The residents of the street could still use it but the through passage would be prohibited. This would incur costs which need to be distributed in some way.

How much would you be willing to pay for the traffic volume to diminish considerably ... [the noise] nuisance?

Thus Vainio [19] used an open-ended elicitation format for estimating willingness to pay. This type of format is no longer regarded as state of the art. The referenda format, which is used by Barreiro, Sanchez and Viladrich-Grau [25], is now preferred because it is less susceptible to strategic behaviour.

The data from this study were analysed using ordinary least squares (linear) regression. The coefficients of several important explanatory variables were significant, including noise, income and work status, which provides some confidence in the validity of the results generated. However the explanatory power of the regressions was relatively low (adjusted R^2 ranging from 0.05 to 0.27). Willingness to pay for a change in noise levels from Leq 65 to Leq 55 was estimated to be $1032 ($US) per year or $10,320 (annualised using a 10% discount rate). This contrasts with an estimate made using the hedonic price method of $2662. At first glance it appears that the contingent valuation estimates are substantially greater than the hedonic price estimates, which is suggestive of yea-saying behaviour. However, the arbitrary selection of a 10% discount rate has probably affected the comparability. Empirical evidence indicates that discount rates in contingent valuation studies are typically far higher than this, often being 30% or higher. If a more appropriate discount rate were selected, then there would most likely be greater convergence between the estimates.

The second study, by Barreiro, Sanchez and Viladrich-Grau [25], was another application of the contingent valuation method to value reductions in traffic noise in the city of Pamplona in northern Spain. Pamplona is a moderately sized city with a population of about 200,000 inhabitants. Pamplona is a relatively noisy city, with 59% of measurements throughout the city being about 65 dB(A) and an average noise level of 67.1 dB(A).

Barreiro, Sanchez and Viladrich-Grau [25] described to respondents three projects that the local government could implement to reduce traffic noise. These included: (1) a noise control campaign, (2) a program of surveillance that would include fines for infringements and (3) modifications to road surfaces. A double bounded dichotomous choice format was used to determine willingness to pay. With this format, respondents were first asked if they were willing to pay a given amount. If they answered positively they were asked if they were willing to pay a higher amount, and if they answered negatively they were asked if they were willing to pay a lower amount. The sample size for this study was 600 respondents.

The data in Barreiro, Sanchez and Viladrich-Grau's study were analysed using a binary logit model with a very simple model specification that included no socio-demographic or attitudinal regressors. While this basic model appeared to be relatively robust, and generated fairly tight confidence intervals, the lack of detail reported makes it difficult to assess the validity of the estimate. Mean willingness to pay was estimated to be about 39 euros per year. This represents about 0.19% of total annual income, which is much lower than the results of the previous contingent valuation study where willingness to pay was 4.84% of total annual income[3].

The final study is a conjoint application by Garrod, Scarpa and Willis [26]. The objective of their study was to estimate the benefits of traffic calming procedures, such as warnings about speed restrictions, road humps, chicanes and visual warnings. They used the choice version of conjoint analysis, where respondents were presented with three alternatives (one of which represented the status quo) and asked to choose their preferred alternative. The alternatives presented to respondents were described using the following attributes:

- Effective speed limit (20 or 30 mph)
- Reduced noise level from road traffic (60, 70 or 80 dB)
- Reduced length of waiting time for pedestrians to cross the road (1 minute or 3 minutes)
- Overall appearance of the traffic calming scheme ("basic" or "improved")
- Annual cost per household of the traffic calming scheme in terms of increased local taxation (£10, £20, £30).

About 400 surveys were conducted at three locations in England where noise from main roads was a problem. The data from the choice experiments were analysed using conditional logit and other model specifications. Note that in the basic model specification, the coefficient for appearance was not significant. However, it did become significant when variable interactions were included in the model. Hence no willingness to pay figure has been reported for appearance. Results from the basic model specification indicate that respondents are willing to pay:

- £0.45 per mile per hour for reductions in the effective speed limit
- £1.95 per dB per annum for reduced noise
- £3.75 per minute per annum for reduced waiting time

Household income in Britain in 1997/98 was £9405 per year. Willingness to pay of £19.50 for a 10 dB decrease in noise is equivalent to 0.21% of annual household income. Thus the results from the conjoint analysis indicate a comparable willingness to pay to the contingent valuation study by Barreiro, Sanchez and Viladrich-Grau [25]. One possible explanation for the much lower value estimate compared to the study by Vainio [19] is that the elements of the traffic reduction programme have been decomposed into attributes in this study, of which noise is just one attribute. In hedonic price studies, noise would most likely be a proxy for changes in several attributes including noise.

The next relevant question is how well do the stated preference generated estimates compare with the hedonic price estimates? This is perhaps easiest understood in the Australian context. Given the previously reported NDSI's that ranged from 0.20-1.26%, a 10 dB(A) decrease in noise would imply a 2.0-12.6% increase in prices. Assuming a median house price in Australia of $145,200 [24], this is equivalent to an increase in price of $2904-$18,295.

Now let's compare this with the stated preference estimate. Household individual income in Australia was found to be $47,326 in the 1996 census. Willingness to pay, based on the results of the stated preference studies, was 0.19-4.84% of annual household income, which is equal to about $79-$2004 per year for a 10 dB decrease in noise levels. Assuming a discount rate of 10% over 25 years, the present value of willingness to pay is equal to $714–$18,187. Thus there is a fairly similar range of estimates generated using both the stated preference and hedonic price techniques.

This result is similar to the findings of Button [2]. Button conducted a rudimentary meta-analysis of noise valuation studies and included a variable that represented the use of willingness to pay techniques (as opposed to property value techniques). The coefficient for this variable was not found to be significant, indicating that stated preference and hedonic price generated value estimates converge.

5. CONCLUSION

The results from this review indicate that there is considerable uncertainty regarding the value for noise. Both hedonic price and stated preference generated estimates differ by up to an order of magnitude. The wide range in these estimates appears to be driven primarily by methodological differences, however cultural differences may also be contributing.

Noise is particularly important economically. Button [2] reported estimates of the cost of noise ranging from 0.02 to 11.18% of GDP. Given the importance of noise to policy decisions, it is surprising that such little attention has been given to establishing the value of this negative externality, in Australia and elsewhere. For more accurate and informed decision making, there is a case for undertaking further studies to establish the value of traffic noise in Australia.

REFERENCES

[1] NSW EPA. *ENVALUE: NSW EPA Environmental Data Base.* NSW Environment Protection Authority, Chatswood (1995).

[2] K. Button, "What Can Meta-Analysis Tell Us About the Implications of Transport?" *Reg. Stud.* 29, 507-517 (1995).

[3] K.G. Mäler, *Environmental Economics: A Theoretical Inquiry.* The Johns Hopkins University Press, Baltimore (1974).

[4] R.B. Palmquist, "Welfare Measurement for Environmental Improvements Using the Hedonic Model: The Case of Nonparametric Marginal Prices." *J. Environ. Econom. Manag.* 15, 297-312 (1988).

[5] M.C. Streeting, *A Survey of the Hedonic Price Technique.* Research Paper No.1. Resource Assessment Commission, Canberra (1990).

3 The lower figure for willingness to pay could be a function of the choice of the bid vector. The bid vector was based on the actual costs of the noise mitigation projects rather than on likely willingness to pay. There may also be a cultural explanation, as about a third of the sample indicated a zero willingness to pay for the noise reduction schemes.

[6] R.T. Carson, N.E., Flores, K.M Martin, J.L. and Wright, "Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-Public Goods". *Land Econom.*, 72, 80-99 (1996).

[7] P. Graves, J.C., Murdoch, M.A., Thayer, M.A. and D. Waldman, "The Robustness of Hedonic Price Estimation: Urban Air Quality". *Land Econom.*, 64, 220-233 (1988).

[8] V.K. Smith and J.C. Huang, "Can Markets Value Air Quality? A Meta-Analysis of Hedonic Property Value Models". *J Pol. Econom.*, 103, 209-227 (1995).

[9] R.C. Mitchell and R.T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Resources for the Future, Washington DC (1989).

[10] D. Kahneman and J.L. Knetsch, "Valuing Public Goods: The Purchase of Moral Satisfaction". *J. Environ. Econom. Manag.*, 22, 57-70 (1992).

[11] P.A. Diamond and J.A. Hausman, "Contingent Valuation: Is Some Number Better than No Number?". *J. Econom. Persp.*, 8, 45-64 (1994).

[12] RAC, *A Contingent Valuation Survey of the Kakadu Conservation Zone*. Research Paper Number 3. Resource Assessment Commission, Canberra (1991).

[13] J.W. Bennett, "The Contingent Valuation Method: A Post-Kakadu Assessment". *Agenda*. 5: 185-194 (1996).

[14] M. Ben-Akiva and S.R. Lerman,. *Discrete Choice Analysis: Theory and Application to Travel Demand*. MIT Press, Cambridge (1985).

[15] J.J. Louviere, "Conjoint Analysis Modelling of Stated Preferences: A Review of Theory, Methods, Recent Developments and External Validity". *J. Transp. Econom. Pol.*, 22, 93-119 (1988).

[16] Roads and Traffic Authority. *Economic Analysis Manual*. Roads and Traffic Authority, Sydney (1995).

[17] D. Pearce and A. Markandya, *Environmental Policy Benefits: Monetary Valuation*. OECD, Paris (1989).

[18] J. Nelson, "Highway Noise and Property Values". *J. Transp. Econom. and Pol.*, 16, 117-138 (1982).

[19] M. Vainio, *Traffic Noise and Air Pollution. Valuation of Externalities with Hedonic Price and Contingent Valuation Methods*. Helsinki School of Economics and Business Administration (1995).

[20] G. McCalden and W. Jarvie, *Trucks in Suburbs: the Social and Economic Impacts of Bulk Road Haulage on Urban Communities*. Report Prepared by DATEC Cooperative Ltd, Newcastle (1977).

[21] A.J. Holsman and R. Bradley, *The Economic and Social Impact of Main Road Traffic Noise in Sydney*. Report Prepared for the NSW State Pollution Control Commission, Sydney (1982).

[22] A.W. Williams, A Guide to Valuing Transport Externalities by Hedonic Means, *Transp. Rev.* 11, 311-324 (1991).

[23] W.D. Renew, *The Relationship Between Traffic Noise and House Price*. Conference of the Australian Acoustical Society, Brisbane (1996).

[24] ABS. *1996 Census Data*. Austats (www.abs.gov.au). Australian Bureau of Statistics (1996).

[25] J. Barreiro, M. Sanchez and M. Viladrich-Grau. *How Much are People Willing to Pay for Silence? A One and One-Half-Bound DC CV Estimate*. Universidad Publica de Empresas, Spain (2000).

[26] G.D. Garrod, R. Scarpa and K.G. Willis, *Estimating the Benefits of Traffic Calming Routes: A Choice Experiment Approach. Draft*. University of Newcastle Upon Tyne, UK (2000).

[27] B. Grue, J. L. Langeland and O. I. Larsen, *Housing Prices – Impacts of Exposure to Road Traffic and Location*. TOI Report 351/1997, Oslo (1997).

[28] F.L. Hall, B.E. Breston and S.M. Taylor, Effects of Highway Noise on Residential Property Values. *Trans. Res. Rec.* 686, 38-43. (1978).

[29] R. Iten and R. Maggi, *The Economic Value of Traffic Noise Abatement In an Urban Area: Empirical Evidence from a Hedonic and Discrete Choice Approach*. Paper presented at the Fifth World Conference on Transportation Research, Yokohama (1990).

[30] W. Pommerehne, Offre et Financement des Services Publics Locaux, in Gurgat, P and Jeanrenauds, C (eds). *Economica*, Paris (1986).

[31] N. Hidano, Y. Hayashiyama and M. Inoue, "Measuring the external effects of noise and vibration of urban transportation by the hedonic approach", *Environ. Sci.* 9, 401-409 (1992).

[32] N. Sougel, *Evaluation Monetaire des Atteinties a L'environment: Une etude Hedoniste et Contingente sur L'impact des Transport*. Imprimerie de L'Evolve SA Neuchatel (1994).

[33] M. Wilhelmsson, The Impact of Traffic Noise on the Values of Single-family Houses. *J. Environ. Plan. Manag.* 43, 799-815 (2000).

[34] I. Bateman, B. Day, I. Lake and A. Lovett. *The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study*. Report Prepared for the Scottish Executive Development Department, Edinburgh (2001).

THE VIRTUAL BOEHM FLUTE — A WEB SERVICE THAT PREDICTS MULTIPHONICS, MICROTONES AND ALTERNATIVE FINGERINGS

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ABSTRACT. We report a web service for flute players, 'The Virtual Boehm Flute', that provides alternative fingerings which may be easier to play, less awkward to finger and/or more in tune for different circumstances. It also provides possible fingerings for multiphonics (chords). It uses an expert system that predicts the playability of notes from features in the input impedance spectra, based on the playability of 957 impedance minima as determined by an expert flutist. Used in conjunction with a theoretical model, developed from detailed experimental measurements, it can predict the acoustic impedance spectrum for 39,744 different acoustic configurations of the flute. The resulting database provides, via a musician-friendly interface, the predicted possible notes and multiphonics for any selected fingering, and all the possible fingerings predicted to play a desired note or multiphonic. The service is at http://www.phys.unsw.edu.au/music/flute

1. INTRODUCTION

A particular combination of keys pressed on a woodwind instrument is called a fingering and corresponds to an acoustic configuration with specific tone holes closed or open. One might expect that a flute with 17 tone holes would have 2^{17} possible configurations, but the number is smaller because of linkages and clutches. In this paper we describe a database and web service that allow flute players to search all 39,744 acoustic configurations of the modern flute, both C and B foot. We begin by explaining why it is interesting to look at so many.

A few dozen fingerings are 'standard': beginners on the instrument learn one or perhaps two 'standard' fingerings for each of the few dozen notes in the normal playing range. More advanced players learn dozens of alternative fingerings that have different properties of pitch, stability and timbre at different playing loudness, or that may be used to facilitate awkward, fast passages and trills (rapid alternations between notes). Players of contemporary flute music are required to use many more fingerings. Some of these produce multiphonics, or chords, in which two or more notes are sounded simultaneously. Others produce microtones: notes with pitch intermediate between those of the equal tempered scale. Yet others are used to produce notes with unusual or contrasting timbres. The composer Berio [1] was one of the early users of these techniques.

Of the 39,744 possible fingerings, only a fraction are given in advanced texts for flutists or for composers writing for the instrument [2,3], so presumably many playable chords and other possibilities remain unknown. Further, searches cannot be conducted easily. A composer wishing to use multiphonics or interesting effects of contrasting timbres (or a player required to play them) has hitherto had no easy way of finding out which chords are possible and how they may be played. The Virtual Boehm Flute aims to overcome these problems.

2. FLUTE ACOUSTICS

Much information about the acoustical properties of the flute for a given fingering may be determined from the spectrum of the acoustical impedance $Z(f)$, the ratio of acoustic pressure to volume flow of air, measured at the embouchure hole (the 'input') of the flute. For any fingering, the flute plays notes whose frequencies are close to those of the resonances or standing waves in the tube of the instrument for that fingering. The flute is played with the embouchure hole open to the atmosphere, and so its resonances correspond closely to the minima of the acoustic impedance at the embouchure. The acoustical principles of the flute are reviewed by Fletcher and Rossing [4].

Standard fingerings

In many standard fingerings, all the holes are closed down to a certain point, and (nearly) all open beyond that. In a crude approximation, the flute with such a fingering acts like a tube, open at both ends, whose length L is approximately that between the embouchure hole and the first open tone hole. The minima in $Z(f)$ correspond to standing waves with wavelengths of $2L/n$, where n is an integer. These resonances give rise to a harmonic series. Thus the flute can operate using one of these resonances as the fundamental, and producing harmonics that are supported by the higher resonances. Vibrations with frequencies in harmonic ratios together produce a periodic wave and are usually recognised as a single note. In practice, the standing waves propagate a little past the first open hole, and the geometry near the embouchure is complicated, so accurate calculations of each resonance frequency are rather more involved.

Cross fingerings and multiphonics

Cross fingerings are fingerings in which one or more tone holes are closed downstream from the first open hole. An open hole acts like a low impedance shunt (actually an inertance, the acoustic analogue of an inductance). Some of the travelling wave is reflected at the first open hole, and some is transmitted, only to be reflected at the next open hole or series of open holes. These two reflections can give rise to two different standing waves, which the player may be able to excite simultaneously in superposition. As the lengths involved are not in general simple harmonic ratios, these two different resonances sound together as a chord or multiphonic (see Fig 1).

There are several constraints on producing them. First, the jet becomes increasingly non-linear as one blows harder, so mode locking occurs [5]. Consequently, multiphonics can usually be produced only at relatively low dynamic levels. Further, the impedance of a single, large, open hole is so low at low frequencies that little power in the wave is transmitted beyond it. Consequently, there are few multiphonics in the low range of the instrument, and those that occur at the lowest frequencies are usually those that use the smallest holes in the instrument as the first reflection. Multiphonics have been studied acoustically by several authors who have examined the relationship between the spectra of the notes produced and the input impedance spectrum of the instrument [6,7], the relationship among the fundamental frequencies of the notes produced [8], and the behaviour of the sound spectra in phase space [9,10]. Backus [7] studied multiphonics by relating the sound spectrum to the instrument's impedance spectrum. He reported heterodyne components from the interaction, indicating a non-linear superposition of the two notes.

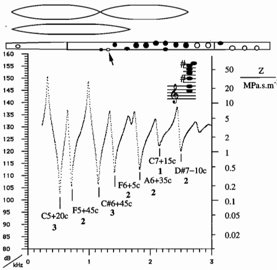

Figure 1. A sketch of the configuration of a flute that will play a multiphonic with notes close to C5 and F5, among others. On the flute schematic, black and white indicate closed and open holes respectively. When the small hole arrowed is closed, this fingering plays F5, whose standing wave is sketched at the top of the figure. When open, this hole produces a reflection whose standing wave is approximately that of C5 (the second standing wave sketched). The wave has a substantial end effect: the inertance of the small hole behaves like an extra length of bore, as indicated. The graph is the measured impedance spectrum for this fingering in MΩ, or MPa.s.m^{-3}. (The dB scale is 20 $\log_{10}$(Z/MΩ).) The playabilities predicted by the expert system are shown for each of the identified minima (bold numbers: 3 is easiest, 0 is impossible).

3. A THEORETICAL MODEL FOR *Z(f)*

Waveguide models have been used to calculate ***Z(f)*** for a range of orchestral wind instruments: e.g. [11-15]. These models take advantage of the fact that the wavelengths of the sounds of interest are rather longer than the diameter of the instrument. Consequently, the important waves in the bore are predominantly planar.

To perform such a calculation, one starts from the downstream end of the flute and works back towards the embouchure. The acoustic impedance spectrum at the end of a pipe is that of the radiation field, which is known [16]. This is then used as the load impedance for a section of waveguide leading to the first tone hole. The input impedance of the waveguide is calculated using a transfer matrix. The tone hole is also a (very short) section of waveguide whose load is either another radiation load (if open) or open circuit (if closed). These two waveguides in parallel form the load for the next segment of the bore. The process continues to the embouchure.

This approximation has limitations, of course, because the instrument is clearly not one dimensional, particularly at the junctions between the bore and a tone hole or the embouchure. However, the effects of these complications can be included by adding extra elements, such as an end correction to account for the junction between pipes of different cross sectional areas. We have measured the parameters describing these effects independently, using progressively more complex geometrical systems (a single cylinder, open or closed, simple branched tubes of varying lengths in which the single side branch had the same diameter, a cylindrical flute head, a cylindrical head with a small number of holes, a real head joint, a real flute). The components were then combined into a complete model for the whole flute [17,18] and tested against the fingerings in our database of experimental measurements [19,20]. The average rms difference between $\log_{10}$ of the calculated ***Z(f)*** and $\log_{10}$ of the measured ***Z(f)***, averaged over 40 standard fingerings each covering the frequency range from approx. 200 Hz to 4 kHz in 1402 steps, was ±0.073. The model could thus predict ***Z(f)*** for any fingering with sufficient accuracy for our purposes.

4. FROM *Z(f)* TO PLAYING FREQUENCIES

There are several reasons why playing frequencies in a flute do not coincide with those of the measured minima in *Z(f)*. Although these differences are 'only' a few percent or less, this means that they may be a substantial fraction of a semitone. Flutists raise the temperature and humidity of the air in the instruments, and thus raise the pitch overall. They can also vary the pitch by varying the extent to which the lower lip covers the embouchure hole. They also vary the speed of the jet.

We elected to include all these factors in a single, empirical function. Two flutists were asked to play the flute used in the experimental study. They were asked to use their normal embouchure and to avoid correcting the pitch when and if the instrument was out of tune. They played each note over the range from B3 to E7 using standard fingerings and maintaining the note for several seconds while a pitch measurement was made using a commercial tuning meter. The use of only the impedance minimum of the fundamental to estimate playing frequency is a crude approximation for notes at the bottom of the range, for which several harmonic minima may all contribute to the playing régime [5, 20]. However, this approximation should be valid for quietly played notes, where the jet behaviour is least non-linear. Flutists are used to correcting for the variation of pitch with loudness, so this approximation should not greatly reduce the utility of the model. The difference between the measured frequency f of the note played, and the frequency f_m of the minimum that corresponded to the fundamental of the note played, was calculated using the following relationship, which corresponds to three straight line segments in a plot of pitch correction vs pitch.

$$f = \beta f_m^{\alpha}$$

where $\alpha = 1.0293, \beta = 0.8588$ if $f_m < 350$ Hz;

$$\alpha = 0.9769, \beta = 1.1674 \text{ if } 350 \le f_m < 1700 \text{ Hz}; \quad (1)$$

$\alpha = 1.026, \quad \beta = 0.8074$ if $f_m \ge 1700$ Hz.

The correction never exceeded 35 cents.

We neglect variation among flutes: the measurements were made on a standard, production model, prepared in a standard way [20], so this is the flute being modelled. Different flutes and different players will give different results, but in this context it is worth noting that players vary frequency by more than 10 cents (a tenth of a semitone) in different circumstances.

5. PREDICTING PLAYABILITY FROM *Z(f)*.

*Quantifying extrema in **Z(f)**.*

The frequency range studied was 0.2 to 4.0kHz. This covers the range of all playable notes on the instrument and furthermore, ***Z****(f)* has very little structure above about 3 kHz. A set of parameters $(Z_m, f_m, \Delta f_m)$ was calculated for each extremum (maximum or minimum) and stored. f_m denotes the frequency corresponding to that extremum, Z_m denotes the magnitude of $\boldsymbol{Z}(f)$ at frequency f_m and Δf_m denotes the bandwidth. $Q \equiv f_m/\Delta f_m$ was also evaluated as a variable that might influence playability.

Measured 'playability' of notes

The presence of a minimum in $\boldsymbol{Z}(f)$ does not necessarily mean that a note can be played at that pitch. The 'playability' of minima was measured as follows. An experienced flutist ranked the notes corresponding to each of the 957 minima present in measured $\boldsymbol{Z}(f)$ data for 76 selected fingerings on one flute into four levels of playability, from 3 (most readily playable) to 0 (impossible). Some playabilities are indicated in Fig. 1.

*Predicting playability from parameters of **Z(f)**.*

What features in $\boldsymbol{Z}(f)$ are related to playability? As well as the sets $(Z_m, f_m, \Delta f_m)$ corresponding to each minimum, the influence of other parameters was also examined, particularly the presence of higher minima that are harmonics of the minimum studied, the impedance at these minima, and the proximity and magnitude of nearby minima and maxima.

Three methods were tried to relate playability to these parameters. Linear regression yielded little insight because many of the parameters are strongly correlated. The neural net method was unacceptably slow for these data, even when only subsets of the parameters were used.

The successful method used decision trees, developed using the C5.0 algorithm suite. Decision trees are an artificial intelligence technique described by Quinlan [21,22] The set of expert decisions was used to train a two-tiered system; the first decision tree predicts whether a given impedance minimum is playable or unplayable based on its physical parameters (using C5.0), and the second decision tree ranks playable minima on a continuous scale of 0 to 3 via a conditional set of linear equations (using Cubist, the continuous form of C5.0).

When presented with the discrete expert data (i.e. whether each of the 957 impedance minima are simply playable or unplayable), C5.0 evaluates a decision tree relating physical minima parameters to a decision of playability. Cross-validation was used to test the performance of the decision tree with unseen data. In this process the expert data are randomly divided into ten subsets, and in each iteration a single subset is withheld from the C5.0 algorithm and used as a test set. Using this technique, a decision tree may be pruned to remove spurious dependence on any of the minima parameters that do not improve the error rate of the tree. The decision tree which demonstrated the least error rate (5.2% during cross-validation) is shown in Fig. 2.

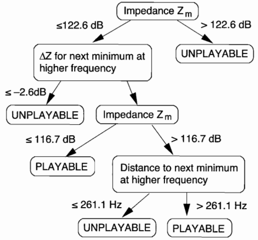

Figure 2. A schematic diagram of the C5.0 decision tree.

Similarly, playable expert data were presented to Cubist to evaluate a set of linear equations relating minima parameters to a degree of playability P ($0 \le P \le 3$). Whereas the parameter dependence and error rate of the discrete decision tree are well-behaved, the composition of Cubist's output is somewhat fuzzy. This is for two reasons: (i) the physical minima parameters have a wide range of correlations with the expert flutist's discrete scale of playability (P = 1, 2 or 3), and (ii) the minima parameters themselves are strongly correlated, and can therefore appear interchangeably in relationships. Nevertheless a rough estimate of playability is useful to a musician, and we found it possible to rank the playability of a minimum with frequency f_m on this continuum scale using only the following rule.

$$P = 3.0 \quad \text{if } Z_m < 103.2\ \text{dB} \quad \text{else}$$

$$P = 0.6 + 0.77 \log \frac{Z(f_-^+)}{Z_m} - 0.57 \log \frac{Z(f_-^-)}{Z_m} + 1.6\times10^{-3}\ (f_+^+ - f_m) \tag{2}$$

$$- 2\times10^{-4}\ (f_m - f_-^+) + 8\times10^{-5}\ (f_m - f_-^-) + 0.005\ N + 0.018\ H$$

where f_+^+ and f_-^+ denote the frequencies of the nearest maxima above and below f_m respectively. f_-^- denotes the frequency of the closest minimum below f_m.

The harmonicity of higher minima was included in the study because of their possible involvement in 'mode locking' of the non-linear oscillation régime of the jet [5]. Minima at frequencies above f_m were deemed to be harmonic if their frequency was in the range $n(1\pm0.05)f_m$, where n is a positive integer. The harmonic number N was the total of such harmonic mimima. The harmonicity function H was the average of $\log(Z)/n$ for the harmonic minima. The small coefficients of N and H in equation (2) seem at first glance to suggest that harmonicity was not very important in determining playability. However because of the various correlations among the input variables, including those in equation (2), one should be cautious in regarding any of these coefficients as simple weighting factors.

6. THE VIRTUAL BOEHM FLUTE

The following process is performed to predict the playable notes of any fingering: (i) calculate an impedance spectrum for a given fingering using the developed physical model, (ii) extract the physical parameters of each minimum from the spectrum, (iii) use the developed expert system to determine which minima are playable and their degree of playability, and (iv) correct the pitch of playable minima for playing conditions. For any fingering, pairs and triplets of playable notes that are not harmonically related are predicted as possible multiphonics. These steps are repeated for each of the 39,744 B foot and C foot fingerings, the entire process requiring approximately 12 hours to compute on an Intel Pentium III PC. The resulting data are stored in a substantially sized relational database (there are in the order of 150,000 possible notes). To access these data in a manner which is useful and intuitive for a musician, a web interface was developed following the principles of Greenspun [23] and Nielsen [24]. This web service, titled 'The Virtual Boehm Flute', provides three tools for flutists and composers. These are shown, as they appear on the screen, in Fig. 3.

The first tool allows the user to input a fingering, using a graphical interface that represents the keys on a flute in a way that is obvious to flutists. The Virtual Boehm Flute returns a prediction of all possible notes, with predicted pitches and playabilities, and a list of multiphonic possibilities.

The second tool is used for alternative fingerings and microtones. The user enters the desired note, and some details about the flute s/he is using. The database is then searched for all possible fingerings that predict notes within half a semitone of the note sought. These may be ranked by playability or pitch.

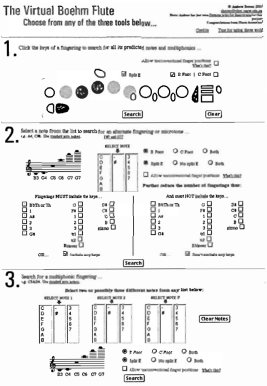

Figure 3. The entry page for The Virtual Boehm Flute, showing the three available tools.

Ranking them by pitch allows the user to seek microtone fingerings for a desired pitch.

Alternative fingerings are very useful to musicians: players often practise a single phrase many times because of the awkwardness or poor intonation of the standard fingerings for a particular series of notes. Combinations of fingerings are often particularly awkward in the higher registers. The alternative fingering tool allows players to include certain keys (that might be already used in the preceding or succeeding note) or to exclude keys, so that all fingers move in the same direction. For example, the rapid alternation (trill) between the notes F6 and A6 is awkward using standard fingerings. A search for an alternative fingering for F6 in which the standard keys closed for A6 were included yields the fingering (known in text to a flute player as (Th 1 2 3 | 1 – tr2 D#) which yields a comfortable, easy trill.

This tool can also find fingerings that are easier to play, or have better intonation than those given as standard, particularly in the fourth octave. One of the authors (a player of reed instruments who rarely plays flute) is unable to play F7 with the standard fingering (– 2 – | – – 3 tr2 D# C#). The Virtual Boehm Flute suggests a fingering (1 2 – | – 2 tr2) with which he can play it either softly or loudly.

The third tool searches the database of multiphonic combinations that are input by the user. It may be used, for example, by a composer who wishes to include a chord for the flute, but who needs to know if the chord is possible. Traditionally, composers are expected to supply the fingering when multiphonics or other peculiar effects are required.

All tools allow the user the possibility of running the theoretical model for the selected fingering to produce $Z(f)$, whose minima may be identified with notes using the mouse.

The Virtual Boehm Flute is widely used by flutists around the world, whose comments have been highly favourable. It is located on our music acoustics site at

<http://www.phys.unsw.edu.au/music/flute/virtual>.

ACKNOWLEDGEMENTS

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REFERENCES

1. L. Berio, *Sequenza,* Suvini Zerboni, Milan 1958
2. B. Bartolozzi, *New Sounds for Woodwind,* Oxford Univ. Press, London 1967
3. R. Dick, *The Other Flute,* Multiple Breath Music Co. 1989
4. N. H. Fletcher and T. D. Rossing, *The Physics of Musical Instruments,* (second edition) Springer-Verlag. New York 1998 pp 503 - 551
5. N. H. Fletcher, 'Mode locking in nonlinearly excited inharmonic musical oscillators', *J. Acoust. Soc. Am.* **64**, 1566-1569 (1978)
6. A. H. Benade, *Fundamentals of Musical Acoustics*, Oxford Univ. Press 1976
7. J. Backus, 'Multiphonic tones in the woodwind instruments', *J. Acoust. Soc. Am.* **63**, 591-599 (1978)
8. D. H. Keefe and B. Laden, 'Correlation dimension of woodwind multiphonic tones', *J. Acoust. Soc. Am.* **90**, 1754-1765 (1991)
9. V. Gibiat, 'Phase space representations of acoustical musical signals', *Journal of Sound and Vibration*, **123**, 529-536 (1988)
10. T. Idogawa, T. Kobata, K. Komuro and M. Iwaki, 'Nonlinear vibrations in the air column of a clarinet artificially blown,', *J. Acoust. Soc. Am.* **93**, 540-5515 (1993)
11. G. R. Plitnik and W. J. Strong, Numerical method for calculating input impedance of an oboe', *J. Acoust. Soc. Am.* **65**, 816-825 (1979)
12. J. W. Coltman, 'Acoustical analysis of the Boehm flute', *J. Acoust. Soc. Am.* **65**, 499-506 (1979)
13. R. Caussé, J. Kergomard, and X. Lurton, 'Input impedance of brass musical instruments - comparison between experiment and numerical models', *J. Acoust. Soc. Am.* **75**, 241-254 (1984)
14. W. J. Strong, N. H. Fletcher, and R. K. Silk, 'Numerical calculation of flute impedances and standing waves', *J. Acoust. Soc. Am.* **77**, 2166-2172 (1985)
15. C. J. Nedeveen, *Acoustical aspects of woodwind instruments*, (revised edition) Northern Illinois University Press, DeKalb 1998
16. H. Levine, and J. Schwinger, 'On the radiation of sound from an unflanged pipe', *Phys. Rev.* **73**, 383-406 (1948)
17. A. Botros, J. Smith, and J. Wolfe, 'Alternative fingerings and multiphonics: measurements, analyses and databases', Proc. International Symposium on Musical Acoustics, Perugia. D.Bonsi, D.Gonzalez, D.Stanzial, eds, pp 509-512. (2001)
18. A. Botros, J. Smith, and J. Wolfe, 'A wave guide model for all fingerings of the Boehm flute', submitted to *Journal of Sound and Vibration*
19. J. Wolfe, J. Smith, J. Tann and N. H. Fletcher, 'Acoustic impedance of classical and modern flutes: a compendium of impedance spectra, sound spectra, sounds and fingerings' *JSV+*, (2001) Electronic publication at http://journals.harcourt-international.com/journals/jsv/supplementary/suppindex.htm
20. J. Wolfe, J. Smith, J. Tann and N. H. Fletcher, 'Acoustic impedance of classical and modern flutes', *Journal of Sound and Vibration*, **243**, 127-144 (2001)
21. J. R. Quinlan, *C4.5: Programs for Machine Learning*, Morgan Kaufman, San Mateo 1993
22. J. R. Quinlan, "C5.0: An Informal Tutorial', Rulequest Research. http://www.rulequest.com/see5-unix.html 2002
23. P. Greenspun, *Philip and Alex's Guide to Web Publishing*, Morgan Kaufman, San Francisco 1999
24. J. Nielsen, *Designing Web Usability,* New Riders, Indianopolis 2000

ACOUSTIC SHOCK*

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ABSTRACT: Acoustic shock can be a problem to people, such as call-centre operators, who use headsets to make or receive a large number of telephone calls. A device is described that significantly reduces the likelihood of receiving an acoustic shock.

1. BACKGROUND

The problem: Occasionally, intense, unwanted signals accidentally occur within the telephone network. These signals are variously called acoustic shocks, audio shocks, acoustic shrieks, or high-pitched tones. The exact source of an individual acoustic shock is usually unknown, but various sources are possible, such as alarm signals, signalling tones, whistles, or feedback oscillation.

The last may be the most common and can easily occur, such as when a cordless telephone is brought too close to its base station while the base station has its hands-free loudspeaker operating. A high-pitched tone then results in just the same way that a public address system squeals when the amplification is increased too much.

Although these high-pitched tones can affect anyone, people using a regular hand-held telephone can quickly move the phone away from their ear, thus limiting their sound exposure to a fraction of a second.

Call-centre operators, however, usually use a head-set, which takes considerably longer to remove from the ear were an intense sound to occur. They thus receive a greater noise exposure than for people using hand-held phones. The problem may be exacerbated if call centres are so noisy that the operators need to have the volume controls on their telephones turned up higher than would be necessary in a quieter place.

The effects: Unexpected high-level sounds have been reported to cause a variety of symptoms. Symptoms that have been reported, in diminishing frequency of occurrence, include pain, tinnitus, vertigo/nausea, altered sensations (blocked, hollow, echoing, fullness in ear, burning or tingling), hypersensitivity to loud sounds, headaches, hearing loss, altered psychological state (shock, anxiety, depression, or tiredness), and numbness (Milhinch, 2001). In some cases, symptoms are reported to continue for years after the incident, although more commonly the symptoms are short-lived.

Some operators who experience an acoustic shock understandably feel apprehensive about using the phone or about loud sounds in general. Measurements of loudness perception, based on the Contour test (Cox et al., 1997), performed on 24 telephone operators at a call centre at which several cases of acoustic shock had occurred, indicated significantly abnormal loudness perception. Although loudness perception was normal at low presentation levels, loudness growth was steeper than normal, leading to a loudness of "loud but OK" being achieved at levels 12 dB less than normally occurs.

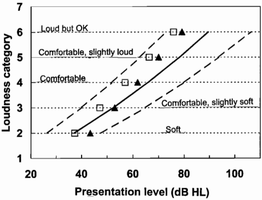

Figure 1. Average loudness growth perception for 24 telephone operators working in a call centre in which acoustic shocks had been experienced. Squares are for 500 Hz, and triangles for 3 kHz. Data for left and right ears have been combined. The solid line shows the mean for normal-hearing listeners, and the dashed lines show the range that takes in 80% of normal-hearing listeners.

The damage mechanism: The mechanism causing the adverse symptoms is not known with certainty. It seems highly likely, however, that the sound exposure elicits an acoustic startle reflex (Patuzzi, personal communication). (The same startle reflex can also be elicited by an unexpected touch or puff of air to the eyes). When startle occurs, numerous muscles in the upper limbs, shoulders, neck, eye and ear (the stapedius muscle and the tensor tympani muscle) are activated. If the noise exposure is loud, or if the person is in an aroused state (e.g. anxious, fearful) prior to the startle, the magnitude of the muscular response is heightened. It seems possible that the ongoing symptoms are the after-effects on the muscles and ligaments caused by the muscles being tensed to an unusual degree.

It is well established that the emotional state of a person affects the startle response (Butler et al., 1990; Cook et al., 1991, Grillon et al., 1993). A fearful state, for instance, lowers the threshold of sound at which the startle reflex occurs, and increases the magnitude of the response when it does occur (Cook et al., 1992). It thus seems possible that call-centre operators who fear that they will be injured by an acoustic

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shock may truly be at greater risk of injury than those who are not apprehensive about the likelihood of an incident. If this is true, then incidents are more likely to occur in call centres in which incidents have previously occurred than in call centres in which there have been no previous incidents.

The link between startle response and emotional state opens the possibility that the after-effects of an incident have a self-perpetuating element even without further headset use: Loud sounds normally elicit the stapedius muscle, either with or without a startle response. If such muscle action causes further pain or discomfort soon after an incident, the person affected may become more apprehensive about loud sounds in general, thus increasing the likelihood of further startle reactions. Furthermore, repeated application of the stapedius muscle may even tone and strengthen it, thus enabling it to exert even more force on the structures around it (Patuzzi, personal communication.)

Note that while NAL has extensively researched means to minimize the incidence of acoustic shock (see below), it has not directly investigated the underlying physiological and/or psychological damage mechanisms. The statements regarding damage mechanisms in this report are inferences based on reported symptoms and the known properties of the startle response.

It may be of interest to note that one of the authors once experienced an acoustic shock while wearing headphones connected to some (faulty) laboratory equipment. In this case the symptoms during the exposure (of approximately one-second duration) were a high level of pain and felt similar to being hit about the head. Symptoms in the 30 or so minutes after the exposure included nausea and disorientation. The physical sensations during and after exposure were similar to that caused by an electric shock (which the same author has also experienced).

2. SOLUTIONS

The potential solutions to the problem listed below were identified. Digital signal processing code that implemented the first two aspects was devised by NAL/CRC (see Figure 2). This code carried out the operations of automatic volume control, limiting, and shriek rejection. The code included digital filters that were the inverse of response characteristics of particular headphones, so that the code could control the SPL generated by the headphone at the eardrum of the average user. The digital code was installed in a prototype device developed by Telstra that was designed to be inserted between the telephone console and the headset. Over 1000 units of this version, which was specifically designed for Telstra call centres, were constructed by Telstra and installed by them. A general-purpose version, known commercially as the *SoundShield*, has been produced under licence by Polaris Communications for application in any call centre. The device, shown in Figure 3, was designed after considering the following potential contributions to a solution:

Sound limiting. Simple headset amplifiers that limit the amount of sound produced by the headsets have not solved the problem. This is understandable; output levels cannot be limited to too low a level, or the clarity and quality of speech is adversely affected, particularly in noisy call centres. Limiting is, however, an important part of the solution so that all sounds, including high-pitched tones, are no louder than they need be. Limiting should be carried out in such a way that it introduces the minimum possible distortion of speech. This requires limiting to be accomplished in several stages, comprising instantaneous, very fast-acting and somewhat slower compression amplifiers. The instantaneous and very fast-acting limiters also minimise the impact of brief "spikes" (clicks, pops and impact sounds). The effectiveness of limiting is enhanced if it is combined with very slow-acting compression to keep the overall level near the comfort level of the operator. Limiting should allow for the frequency response of the headset on the average listener. Such frequency-dependent limiting is necessary if the optimal amount of limiting is to be provided at each frequency.

Shriek rejection. As a startle response can occur at levels as low as 60 dB SPL (Blumenthal et al, 1991), it is not possible to prevent startle by limiting alone while still preserving speech clarity. More sophisticated processing differentiates between wanted sounds (such as speech) and unwanted high-frequency sounds, so that each can be processed differently.

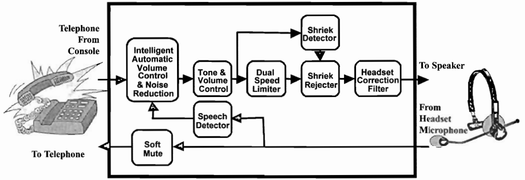

Figure 2: Block diagram of the signal processing devised to minimise the chance of acoustic shock occuring.

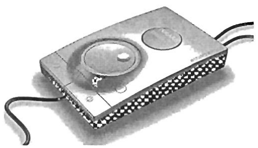

Figure 3: The SoundShield implementation by Polaris Communications of the NAL/CRC signal processing designed to reduce the risk of acoustic shock.

When a high-pitched tone occurs, its frequency can be measured, and of any sound at this frequency blocked. In the implementation devised by NAL/CRC, the tone is typically detected and blocked within a few hundredths of a second. Consequently, the duration and loudness of the acoustic shriek is greatly diminished without speech being much affected.

Call centre design. The design of the call centre will greatly affect the level of ambient noise experienced by the operators. Achieving low noise levels enables the average level and limiting level of the headset amplifier to be reduced, which minimises the level at which any unwanted sound occurs. More information about the design of call centres and specifically tailored call-centre services, such as audiological testing, hearing rehabilitation, and acoustic measurements, can be obtained from NAL Consulting.

Confidence building. To the extent that the problem has a psychological component, the solution also requires a psychological aspect. If apprehensive operators are more likely to be adversely affected by high-pitched tones, then demonstrating the protective qualities of a headset amplifier to operators may increase their confidence in their equipment and thus decrease the likelihood of incidents. (This assumes that the headset amplifiers are sufficiently sophisticated to provide a high level of protection.)

3. OUTCOMES

Tests with a variety of real and synthesised high-intensity, high-frequency sounds revealed that the signal processing was well able to detect and attenuate unwanted narrow-band sounds in the presence of speech. Human acceptance tests on the prototype protection devices were carried out in a call-centre that had previously experienced a high incidence of shrieks. Operators reported that they preferred the sound quality, clarity and comfort of the prototypes, and felt increased confidence that the device protected them from harmful sounds. (The high level of protection provided by the device is easily demonstrated to operators, and developing this confidence by the operators may be an important element in providing a comprehensive solution to the problem.)

The new device, in both the form of the Telstra prototype, and more especially in the commercial SoundShield version, is expected to play a leading part in protecting hearing by reducing the incidence of acoustic shock, especially in call centres. There is considerable interest in take-up of the device, both within and outside Australia.

ACKNOWLEDGMENT

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REFERENCES

Blumenthal, T & Goode, C (1991). The startle eyeblink response to low intensity acoustic stimuli. *Psychophysiology*, 28(3), 296-306.

Butler, R., Braff, D., Rausch, J., Jenkins, M., Sprock, J., & Geyer, M. (1991). Psychological evidence of exaggerated startle response in a subgroup of Vietnam veterans with combat-related PTSD. *Am J Psychiatry*, 147(10), 1308-1312.

Cook, E., Hawk, L., Davis, T., & Stevenson, V. (1991). Affective individual differences and startle reflex modulation. *J Abnorm Psychol*, 100(1), 5-13.

Cook, E., Davis, T., Hawk, L., Spence, E., & Gautier, C. (1992). Fearfulness and startle potentiation during aversive visual stimulation. *Psychophysiology*, 29(6), 633-645.

Cox, R.M., Alexander, G.C., Taylor, I.M., & Gray, G.A. (1997). The contour test of loudness perception. *Ear & Hear* 18(5):388-400.

Grillon, C., Ameli, R., Foot, M. & Davis, M. (1993). Fear-potentiated startle: relationship to the level of state/trait anxiety in healthy subjects. *Biol Psychiatry*, 33(8-9), 566-574.

Milhinch, J.C. (2001). Acoustic shock injury – A report on injury following acoustic incidents in call centres. Melbourne.

SCATTERING IN THE OCEAN*

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ABSTRACT Acoustic scattering in the ocean can arise naturally from interactions of sound with suspended particles, volume inhomogeneities, bubbles, the moving random sea surface, the seabed, and organisms, either in resonant or nonresonant processes. Measurements of backscatter stimulated via these processes by active sonar are becoming increasingly useful as remote sensing tools in highly diverse applications. These include assessments of fish stocks and fish migration, seabed and habitat characterization, inferences of turbidity, measurements of waves and currents, and detection of objects. Some of these applications are broadly described, together with the physical scattering mechanisms involved.

1. INTRODUCTION

Scattering from the ocean environment causes reverberation, a major part of the unwanted background noise level that hinders military active sonars seeking to detect sound scattered by ships, submarines, and mines. Military sonar designs have previously sought to suppress environmental scattering to enhance their target-seeking ability. However, environmentally backscattered[1] sound now finds a surprisingly large number of applications in underwater acoustics. It is used as a means of remote sensing, and as such can be used to quickly examine large oceanic volumes, or large areas of the air/sea or sea/bottom interfaces. Optical devices experience high attenuation, but direct sound transmission and acoustic backscatter can be used to probe oceanic processes over a very wide frequency range (Hz to MHz). Many interesting physical problems arise in marine acoustic scattering, since it involves interactions with physical, chemical, biological, geometrical, and geological properties of the environment. One of the more interesting applications can be found in sidescan sonars, which provide high-resolution pictures of the seabed similar to video imagery. Other backscatter devices can infer concentrations of suspended solids at high levels where optical measures are defeated.

2. SCATTERING THEORY AND HIGH FREQUENCY SONARS (S. Anstee)

High-frequency sonars are the acoustic equivalent of vision systems, and work in much the same way. If something radiates sound, a sonar can use the phase and amplitude information in the radiated waves to estimate the location and nature of the source. However, most of the underwater environment does not spontaneously radiate sound, so many sonars rely on *scattered* sound, that is, sound bounced from objects and interfaces. Optical vision systems can often rely on intense external sources of radiation – the sun, room lighting and so on – to provide a radiation source. Natural sources of acoustic radiation are much weaker, although the technology for sonars relying on scattering of environmental noise, so called "acoustic daylight", is in development [26]. Most sonars relying on scattered sound are *active*, that is, they provide their own intense acoustic radiation source, most often adjacent to the receiver. The sound they emit is usually *pulsed* and *coherent*, more like a laser beam than a torch, with the energy centred on a relatively narrow band of frequencies[2].

When there is no change in sound speed, a sound wave propagates away from the source indefinitely, never returning. However, when a travelling wave encounters an abrupt change or interface between two media with different physical properties, only part of the wave is transmitted across the interface, with the rest returning to the original medium. The transmitted and returned waves contain additional information about the interface they encountered, encoded as phase and amplitude changes.

The field after the wave hits an interface can be expressed as

$$p(\mathbf{r},t) = p_{inc}(\mathbf{r},t) + p_s(\mathbf{r},t) \quad (1)$$

the sum of the original, *incident* field and a new *scattered* field. Scattering is a reradiation of incident acoustic energy. *Reflection* is a special case of scattering where the scattered field retains most of the information in the incident field. If the interface is completely flat, the reflected field is (to within a scale factor) just the incident field that would have originated from a source placed at the reflected position of the true source. *Scattering* is usually taken to mean the more general case where most of the original phase information is lost and the bulk of the information carried by the scattered field describes the interface it scattered from.

Scattering is a function of frequency, being stronger for higher frequency components of a signal, and also of the size, compressibility, shape, and density of the scatterer, which can be one or more discrete objects, or roughness elements on a continuous surface. At low frequencies (wavelength λ much greater than scatterer size, the Rayleigh criterion) scattering is omnidirectional, while at high frequencies the scattering becomes directional (and the object will cast a shadow).

* The publication of this paper in the April 2002 issue was unfortunately marred by a software error during the printing process. The whole article is therefore reprinted here.

[1] Backscattered sound is that part of the total scattered sound that goes back towards the source.

[2] Some active sonars are "broad-band", with bandwidths of one or more octaves. Such sonars emit pulses that can appear incoherent or "noisy", but knowledge of the exact waveform allows the sonar processor to select only echoes with exactly matching waveforms, thereby greatly increasing the signal to noise ratio.

In general ocean water is turbid for light, but transparent for sound, even at several hundreds of kHz, because suspended particles[3] are typically 1 to 10 microns in size, which makes them larger than optical wavelengths, but smaller than acoustical wavelengths (a 1-MHz sound wave has a wavelength of 1.5 mm). The optical cross section of a typical particle (but not a bubble) is similar to its geometrical cross-section, but its acoustic cross section is much smaller than its geometrical cross-section [6]. Acoustic backscattering can therefore carry more energy over longer distances than optical wavelengths.

Discrete scatterers

The simplest scattering object is a sphere of gas immersed in a liquid, e.g., an air bubble in water. When a mono-frequency plane wave with frequency ω radians per second travels through the liquid and strikes the sphere, the total field thereafter includes a second, scattered field, p_s. For Rayleigh scattering the scattered pressure takes the form

$$p_s(r,t) \approx a_0 k^2 \frac{e^{i(kr-\omega t)}}{r} \quad (2)$$

Here, r is the radial distance; $k = 2\pi / \lambda$ is the wavenumber; and a_0 is a complex constant. This is simply a travelling wave radiating outward from the scatterer, which functions like an elementary source. The wave contains no information about the source of the incident radiation, except for amplitude. A very small liquid or solid sphere also has this form of scattered pressure, but with an additional dipole term that preferentially forward- and back-scatters sound along the direction of propagation. An arbitrarily shaped small object also generates the same form of scattered field as a small sphere. Hence, when a sonar pings at water containing suspended sediments and plankton, each particle acts as a spherical scatterer and some of the energy is backscattered to the sonar as *volume reverberation*. Although the incoming sound is coherent, the particles are randomly distributed and the backscattered sound is an *incoherent* sum of waves with random phases and amplitudes.

Larger objects and surfaces

Scattering by larger objects and surfaces is more complicated, with a combination of reflection and random scattering contributing to the total pressure field. The field scattered by an arbitrary closed surface can be entirely described by the pressures and pressure gradients at the surface. The surface can be considered as a collection of elemental sources and dipoles, each radiating in all directions. When the surface is perfectly flat, the individual contributions all add in phase (coherently), and the form of the scattered pressure is similar to the form of the incident pressure, but appearing to come from a different source — "specular" scattering.

Both the seabed and sea surface can be approximated as flat surfaces perturbed by roughness, and the scattered field can then be predicted. However, the resulting equation is generally difficult to solve.

If we assume that each surface element acts like an infinite plane and ignore any interactions between elements, then $p(\mathbf{r}') \approx (1+R)p_{inc}(\mathbf{r}')$ and, $\nabla' p(\mathbf{r}') = (1-R)\nabla' p_{inc}(\mathbf{r}')$, where R is the plane-wave reflection coefficient the surface would have if it were uniform and flat. Then the solution for the scattered pressure equation collapses to a function of the incident pressure and is easy to evaluate. This is the *Kirchhoff* or *physical acoustics* approximation. Experimentally it is a good fit for backscatter when the sonar looks steeply down at the seabed or up at the sea surface, and for forward scatter, as long as the surface is not too rough. It is a poor approximation when the sound approaches the surface from a shallow angle, but in such cases, another approximation, the *small roughness* approximation, may be used. In this approximation, seabed roughness is treated as a vertical perturbation away from a flat surface and the surface pressure is perturbed by an amount $p_1(\mathbf{r}') \approx -h(\partial p_{inc}/\partial z + \partial p_s^{(0)}/\partial z)$, where z is vertical direction, h the vertical roughness scale and $p_s^{(0)}$ the pressure field that would be scattered from a perfectly flat surface. It turns out that the first-order *coherent* field is zero – the roughness makes no difference to the energy reflected from the underlying flat surface, but the first order *diffuse* or *incoherent* field is non-zero. The diffuse field is sensitive to the proportion of points on the surface that happen to be correctly separated to scatter sound at the observing direction, as though the surface were a random ensemble of Bragg diffraction gratings. In between steep and shallow incident angles, it is possible to interpolate between the small roughness and Kirchhoff regimes, or use other, more general approximations. In situations of extreme roughness, all of these approximations break down and an empirical approach is taken.

3. ACOUSTICAL SEABED IMAGING (P.B. Chapple)

Acoustic backscatter from the seabed can be used to image the seabed, enabling active sonar systems to provide valuable information about seabed properties. Acoustics is particularly important in this role, because ocean waters are usually too deep and turbid for optical imaging to be effective. Information obtainable includes bathymetry (depth), seabed hardness, clutter, slope and the presence of objects on the seafloor. At frequencies less than about 50 kHz, significant energy can penetrate the seabed, particularly for soft sediments, and some sub-bottom information can be obtained using suitably designed systems. At higher frequencies, there is very little seabed penetration, and information obtained from seabed backscatter essentially indicates the properties of the seabed surface. Using frequencies as high as 500 kHz, it is possible to image the seabed with 10 to 20 cm horizontal resolution, although range is often limited to about 100 m.

The most popular method of acoustically imaging the seabed is using sidescan sonar (Figure 1). Acoustic energy is emitted from either side of a moving vessel, or from a towfish pulled by the vessel, from horizontal linear arrays of transducers on the port and starboard sides which point slightly downwards. The beamwidth is narrow in the along-track direction, but broad in elevation or across-track direction, enabling a thin strip or narrow swathe to be ensonified perpendicular to the array with each sonar ping

[3] Grains of clay.

(Figure 1). Backscattered energy from the seabed is used to build an image of the seabed, strip by strip, as the vessel moves along. The timing of the return signal from each acoustic pulse is used for estimating the range of the patch of seabed contributing to the signal. A "waterfall" display of the seabed is formed as the vessel moves along (Figure 2(a)).

The depth of a sloping seabed cannot be reliably estimated from sidescan sonar. A flat-bottom assumption is made in order to estimate the location of each part of the imaged seabed, which is calculated from a combination of range, estimated position of the towfish relative to the towing vessel and the differential GPS position acquired at the boat. Utilising this information, a mosaic image of the seabed can be formed (Figure 2(b)) from numerous boat tracks.

The texture of sidescan sonar images can be used to characterise the seabed, by segmentation into regions with different textural statistics, indicating the presence of mud or sand, scattered rock and other bottom types. Several difficulties arise in this approach: (i) The appearance of the seabed in a sidescan image depends on the distance from the nadir. There is generally poor horizontal resolution in the nadir region. (ii) The appearance of features such as sand waves depends strongly on the direction of ensonification. (iii) Seabed slope significantly affects the appearance of sidescan imagery, complicating attempts to determine seabed type.

Multibeam echosounder systems allow seabed imaging with bathymetric information. While the feature detection capabilities are not usually as good as for sidescan sonar, some modern systems such as the Reson 8125 have very high spatial resolution. Bathymetric relief images can be segmented to delineate different broad-scale texture regions, with the seabed characterisation independent of the direction of ensonification. Further seabed information can be obtained by measuring the backscatter magnitude as a function of the angle of incidence of the acoustic wave on the seabed.

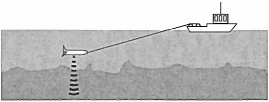

Figure 1: (a) Towed sidescan sonar.

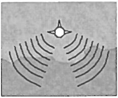

Figure 1: (b) End view of towfish

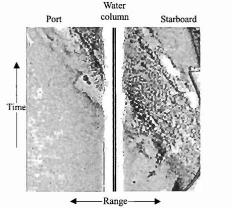

Figure 2: (a) Waterfall image, that scrolls downwards during data acquisition (from the Klein 5500 sidescan sonar). Smooth seabed on the lower left is disrupted by the rough surface of the Sydney Harbour tunnel.

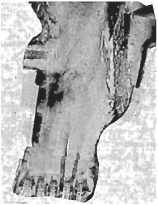

Figure 2: (b) Mosaic image of the seabed of Sydney Cove, including Circular Quay wharves and the rough surface above the Harbour Tunnel.

4. SEABED PROPERTIES MODELLING AND INVERSION TECHNIQUES (P.J. Mulhearn)

The shapes and energies of echoes received by echosounders depend on bottom acoustic hardness and roughness. The first part of the echo shape is a peak dominantly from specular return, and the second part is a decaying tail principally from incoherent backscatter contributions. Rougher sediment surfaces provide more backscattered energy than smoother surfaces (which simply reflect the energy away from the direction of the transducer), so their echoes are expected to have lower peaks and longer tails than smoother surfaces of the same composition. Echo shape is also affected by sub-bottom volume reverberation including contributions from gas bubbles, and echosounder characteristics such as frequency, ping length, ping shape, and beam width.

A number of acoustic seabed classification systems are commercially available which can be used to estimate seabed properties from echo characteristics [14] using one of two empirical methods: (i) echo statistics are obtained at a number of sites with known seabed type, to calibrate the system. The whole area is then surveyed, and the seabed classified as belonging to one of these types; or (ii) an area is surveyed and the echoes are grouped by some statistical technique into a number of classes, which are subsequently ground-truthed. At times the first approach may reveal seabed types for which calibrations were not obtained, so that some post calibration is required.

The oldest commercial system is RoxAnn, which uses the first and second echoes from the seabed [4,16]. The first echo simply travels from the transducer to the seabed and back to the transducer. The second goes from the transducer to the seabed back to the sea surface (including part of the ship's hull), back to the seabed and finally back to the transducer. RoxAnn uses the energy in the tail of the first echo as a measure of sea floor roughness and the total energy in the second echo as a measure of sea floor "hardness". These two parameters are really indices of seabed acoustic backscatter and acoustic impedance, respectively.

The second most used commercial system is QTC-View, from Quester Tangent Corporation (QTC) [25,15]. QTC uses only the first echo, calculating 166 statistical parameters from it. Principal Component Analysis is used to derive three "Q-factors", which are linear combinations of the 166 parameters. These three Q-factors are the three major Principal Components specifying the shape of the waveforms. The system then clusters seabed types in either a supervised or unsupervised classification mode, much like methods (i) and (ii) above, respectively.

It is important to better understand what these empirical seabed classification systems are really measuring, and to determine how well they can be expected to work. To these ends existing models of seabed acoustic backscatter are being utilised to examine the characteristics of acoustic returns from the seabed at steep grazing angles (e.g. 65° to 90°) for frequencies between 10 and 100 kHz [22]. A widely used model is that of Jackson [2], in which seabed backscatter is modelled as the sum of both a surface and a volume term. The model provides backscatter as a function of grazing angle, but no information on backscatter versus time, so that it provides no information about the shape of a return pulse. Examination of the model indicates that for the above range of grazing angles, and all but the very roughest of surfaces, the Kirchhoff approximation provides a good model of the surface scattering contribution. It can also be concluded, for realistic ranges of input parameters, that the dominant factors influencing backscatter are: roughness size; the ratio of sediment to water acoustic impedance; and a volume backscattering parameter, σ_V, the dimensionless backscattering cross section per unit solid angle per unit area due to volume scattering below the sediment surface.

It should be possible, from real data of acoustic backscatter versus grazing angle, to estimate these three parameters, because of their different influences on the shape of the backscatter versus grazing angle curve. From these three parameters it would then be possible to infer sediment type. Curves for typical sediments are shown in Figure 3. However echosounders obtain backscatter versus time over a range of grazing angles, not backscatter versus grazing angle.

To examine the time evolution of the return pulse from a seabed surface a model, called BORIS-3D (Bottom Response from Inhomogeneities and Surface) was recently developed at NATO's SACLANT Undersea Research Centre in La Spezia, Italy [24,3]. This model uses the Kirchhoff approximation for the surface scattering and Small Perturbation theory for volume scattering. For a given transmitted impulse shape, surface and volume backscattered time-series are computed and summed. Figure 4 shows the geometry of the set-up. Surface and volume responses will generally overlap in time. Modelling of responses from various realistic sea floors is currently in progress.

5. VOLUME BACKSCATTER (M.V. Hall)

Volume backscattering from within the water column gives rise to reverberation at any frequency, but the results discussed here are confined to frequencies between 2 and 20 kHz (λ from 75 to 7.5 cm). At these frequencies the major scattering objects are fish swim bladders, which contain air. Many species of fish have a swim bladder, with general function to keep the fish neutrally buoyant. Large shallow water fish have muscles attached to their bladder, and use it as their vocal chord. Small deep-sea (mesopelagic) fish do not make sounds with it, but can pump dissolved air in, and back out, to maintain the bladder at a constant volume as they make diurnal depth migrations. Although only around 5% by volume of the fish body, the bladder dominates the scattering at all wavelengths greater than the fish dimensions because it contains air. In addition there is also a low resonance frequency, which is determined by the elasticity of the air and the mass of the surrounding tissue and seawater.

Simple bubble resonance theory

For a free spherical bubble of radius a in water of density ρ, the resonance frequency f_0 is given by [21]:

$$f_0 = \sqrt{(3\,\gamma\,P_0/\rho)}\,/2\,\pi\,a \qquad (4)$$

where γ is the ratio of specific heats, and P_0 is the local hydrostatic pressure: $P_0 = \rho\,g\,(z + 10)$, in which z is depth in metres. For a radius of 2 mm for example, the resonance frequency at the surface ($z = 0$) is 1.6 kHz ($\lambda = 94$ cm), whereas at a depth of 500 m it would be 12 kHz ($\lambda = 13$ cm). These wavelengths are much greater than the bubble size, so the scattering is omnidirectional. The resonance wavelength being orders of magnitude larger than the size of the object is an unusual phenomenon. For a conventional Helmholtz resonator such as the milk bottle, the elasticity and mass are both those of the internal fluid, and the resonance wavelength is comparable to its length. For a bubble however, the properties come from different media: the elasticity is that of the gas, while the mass is that of the water. For a bubble encased in solid tissue, the shear modulus also has an effect on

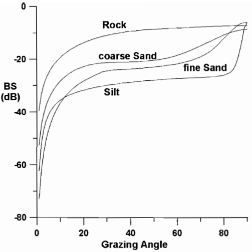

Figure 3. Modelled backscatter versus Grazing Angle Curves for different bottom types, using typical sediment parameters for each type. BS = Backscatter Strength.

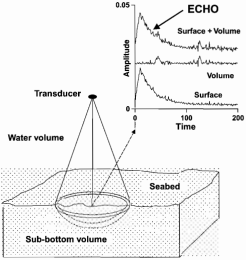

Figure 4. Construction of a simulated time series for reconstruction of bottom echoes. The echo starts on the first vertical contact of the ping with the seabed, and for subsequent sampling intervals is the sum of a surface contribution from annuli whose radii increase with time, coupled with volume contributions.

the resonance frequency [1]. By modelling the bladder as a shell, the following approximate expression has been derived [11]:

$$f_0 = \sqrt{\{3\, m\, \gamma\, P_0 / [4\, \pi^2 a^2 \rho / \phi - 4(m-1)d]\}} \qquad (5)$$

where m is the ratio of the external to internal volumes of the shell ($m \approx 2$), ϕ is the shape correction factor to allow for the bladder being non-spherical ($\phi \approx 1.1$), and d is the constant of proportionality in the relation between tissue shear modulus and frequency-squared ($d \approx 0.001$ kg/m).

Scattering cross-section

The scattering cross section (σ) of an object is 4π times its scattering or target strength, since σ gives the power scattered in all directions, while the scattering strength gives the power scattered per unit solid angle. At high frequencies ($\lambda < a$) the scattering cross section approximately equals the cross-sectional area of the object ($\sigma \approx \pi a^2$ for a sphere). At low frequencies the general behaviour is that $\sigma \propto f^4$ (Rayleigh scattering), and any resonance will appear as a perturbation. The scattering cross section at frequency f of an object resonant at frequency f_0 is given by [5]:

$$\sigma(f) = 4\,\pi\, a^2 / [(f_0^2/f^2 - 1)^2 + \delta^2] \qquad (6)$$

where δ is the acoustic damping term. An expression for δ for a free bubble was discussed by [8], and an adaptation to a swimbladder was given in [11]. In general its order of magnitude is 0.1.

At resonance the scattering cross section is

$$\sigma(f_0) = 4\,\pi\, a^2 / \delta^2. \qquad (7)$$

As $f/f_0 \to 0$, $\sigma(f) \to 4\pi\, a^2\, (f/f_0)^4$. Equation (7) is not valid for high frequencies, since its derivation assumes the pressure to be uniform over the surface of the bubble, which is equivalent to assuming $\lambda >> a$. As $f/f_0 \to \infty$, Eq. (6) yields $\sigma(f) \to 4\pi a^2$ for small δ, whereas the correct asymptote is $\pi\, a^2$.

Bio-mass estimates

Volume backscattering has been used by several institutions world-wide to estimate biomass. In Australasia the most active have been the New Zealand Ministry of Agriculture & Fisheries [9,7], and the CSIRO Division of Marine Research [10,18]. These surveys used narrow-band ultrasonic projectors as the sound source, and made use of the beam pattern of the emitted signal. A study involving one of the authors [12] used small explosive charges as the sound source. These are omnidirectional but contain useful energy over frequencies up to 20 kHz. Midwater trawls were conducted concurrently with an 8-square-metre net. The fish caught were weighed and sorted into classes based on mass. For each class the swimbladder size was estimated and the corresponding resonance frequency, for the known trawl depth, was determined using Eq. (6). From the population density of each class, the reverberation in each third-octave band from 2.5 to 20 kHz was computed using Eq. (7), and the results were compared with the measured reverberation. There was generally good agreement at frequencies above 8 kHz. The main difference was that although the trawls did not catch any fish heavier than 3 g, the acoustic results indicated that many heavier fish were in fact present. This difference was attributed to the ability of these larger fish to escape capture.

Effect on sonar

It is important for active sonars to have a narrow beam pattern, for both localising a target, and also to reduce the level of reverberation. Because of the large volumes of water ensonified by a sonar beam at long ranges, volume reverberation is generally the environmental parameter that limits the performance of long range active sonar. By having a database or model of the dependence of backscattering on frequency, geographic location, time of day, and depth, a sonar operator can adjust the carrier frequency of a sonar to obtain the optimum performance for a given location and time of day.

6. TURBIDITY (L.J. Hamilton)

Measurements of suspended sediment concentration (SSC) profiles in aquatic environments are used for diverse purposes e.g. examination of turbidity or water clarity, pollution studies, underwater visibility, sediment transport rates, and knowledge of the dynamics affecting turbidity e.g. wave processes. It is possible to estimate SSC at high temporal (0.1–1 s) and spatial (1–10 cm) resolutions with Acoustic BackScatter (ABS) instruments, and to remotely and non-intrusively monitor and image suspension processes in real-time. ABS instruments infer SSC profiles by emitting bursts of MHz frequency pulses, and time gating the return. Narrow beamwidths are used e.g. 1.5°. Ranges of 10–20 m may be obtained at 0.5 MHz, and about 1 m for 3 MHz. After allowance for transmission losses, and by making some simple assumptions about suspended sediment properties, the backscatter can be directly related to SSC.

The backscatter processes may be described by single scattering theory [30]. Negligible grain shielding and negligible multiple scattering are assumed, with allowance for near and far-field transducer beam patterns, beam spreading, and absorption due to water and the suspended sediment itself. Absorption by suspended sediment is assumed to be proportional to SSC, a simple assumption yielding good results [30]. Attenuation constant for a particular sediment particle size may be calculated from formulae [27,28], and absorption due to water is calculated from temperature and salinity measurements. The backscattered pressure or voltage signals received by the transducer from scatterers in a particular range bin are treated as incoherent [29] (also see Section 2), allowing them to be squared and summed without phase considerations.

If backscatter were sensitive to particle volume, then for constant particle density, changes in size distribution during measurements would not affect inferences of SSC [20]. However, in the Rayleigh region the size, shape, and density of irregularly shaped particles chiefly determine the backscatter [28,27]. To overcome this it is commonly assumed particle size distribution and particle backscatter function at a site are invariant during measurements, and that only total concentration varies at any depth in the column, a necessary but weak link in the calibration [20]. To reduce variability in the Rayleigh distributed backscatter from a particular range bin, backscatter values are averages for pulse trains. With the stated assumptions, backscatter is linearly proportional only to concentration, and SSC can be obtained to within 20–30%.

Calibration is usually performed after laboratory determinations of SSC have been obtained from water samples, but useful field calibrations can be made in conjunction with optical devices [13]. In the latest developments in this field, multifrequency devices are used to infer both SSC and particle diameter [19,31], although inversions are subject to noise, and only short ranges of about 1 metre are obtained. ABS instruments provide a highly versatile means of routinely obtaining information on dynamic turbidity events and suspension profiles.

7. CONCLUSION

Acoustical backscattering is an extremely useful means of probing the oceanic environment which finds application over a wide range of technology and physical processes. In usefulness and scope it may be compared to satellite based remote sensing techniques, although having a more limited scale, with both technologies being able to probe large areas in short times in a repeatable fashion. Other applications of acoustic backscatter employing very different principles than those discussed here also exist e.g. use of Doppler shift from scatterers to infer current profiles; characterisation of vegetation by classifying the jagged pattern obtained when transiting the vegetation; and estimates of fish populations by echo counting. From being merely a hindrance to sonar applications, backscatter is now a fully realized tool for diverse oceanic investigations.

REFERENCES

1. I.B. Andreeva, Scattering of sound by air bladders of fish in deep sound-scattering layers (English translation). *Soviet Physics Acoustics* **10**, 17–20 (1964)

2. *Applied Physics Laboratory,* APL-UW High Frequency Ocean Environmental Acoustic Models Handbook, *Technical Report APL-UW TR-9407, October 1994, Applied Physics Laboratory, University of Washington, Seattle.*

3. O. Bergem, E. Pouliquen, G. Canepa and N.G. Pace, "Time-evolution modelling of seafloor scatter. II. Numerical and experimental evaluation". *J. Acoust. Soc. Am.* **105**, 3142–3150 (1999)

4. D.R. Burns, C.B. Queen, H. Sisk, W. Mullarkey and R.C. Chivers, Rapid and convenient acoustic sea-bed discrimination for fisheries applications". *Proceedings of the Institute of Acoustics* **11**, Part 3, 169–178 (1989)

5. E.L. Carstensen and L.L. Foldy, Propagation of sound through a liquid containing bubbles. *J. Acoust. Soc. Am.* **19**, 481–501 (1947)

6. S. Clay S. and H. Medwin, Acoustical oceanography: principles and applications. John Wiley and Sons. New York (1977)

7. R.F. Coombs and P.L. Cordue, Evolution of a stock assessment tool: acoustic surveys of spawning hoki (Macruronus novaezelandiae) off the west coast of South Island, New Zealand, 1985-91. *New Zealand Journal of Marine & Freshwater Research* **29**, 175–194 (1995)

8. C. Devin, Survey of thermal, radiation and viscous damping of pulsating air bubbles in water. *J. Acoust. Soc. Am.* **31**, 1654–1667 (1959)

9. M.A. Do and R.F. Coombs, Acoustic measurements of the population of Orange Roughy (*Hoplostethus atlanticus*) on the North Chatham Rise (N.Z.) in 1986. *New Zealand Journal of Marine & Freshwater Research* **23**, 225–237 (1989)

10. N.G. Elliott and R.J. Kloser, Use of acoustics to assess a small aggregation of orange roughy, *Hoplostethus atlanticus* (Collett), off the east coast of Tasmania. *Australian Journal of Marine & Freshwater Research* **44**, 473–482 (1993)

11. M. Hall, Measurements of acoustic volume backscattering in the Indian and Southern Oceans. *Australian Journal of Marine & Freshwater Research* **32**, 855–876 (1981)

12. M. Hall and A.F. Quill, Biological sound scattering in an ocean eddy. *Australian Journal of Marine & Freshwater Research* **34**, 563–572 (1983)

13. L.J. Hamilton, Calibration and interpretation of acoustic backscatter measurements of suspended sediment concentration profiles in Sydney Harbour. *Acoustics Australia* **26**(3), 87–93 (1998)

14. L.J. Hamilton, P.J. Mulhearn and R. Poeckert, A Comparison Of *RoxAnn* And *QTC-View* Acoustic Bottom Classification System Performance For The Cairns Area, Great Barrier Reef, Australia. *Continental Shelf Research* **19**(12), 1577–1597 (1999)

15. http://marine.questertangent.com/m_sitemap.html

16. http://www.seabed.co.uk/NewFiles/ROXANN/hydrogr.html

17. R. Kloser, T. Koslow, T. Ryan, and P. Sakov, Species identification in deep water using multiple frequencies. Program and Abstracts, 13th National Congress of the Australian Institute of Physics (page 159) (1998)

18. R.J. Kloser, J.A. Koslow, and A. Williams, Acoustic assessment of a spawning aggregation of Orange Roughy (*Hoplostethus atlanticus,* Collett) off South-eastern Australia, 1990-93. *Marine & Freshwater Research* **47**, 1015–1024 (1996)

19. T. H. Lee and D.M. Hanes, Direct inversion method to measure the concentration profile of suspended particles using backscattered sound. *J. Geophysical Research* **100**, C2, 2649–2657

20. C. Libicki, K.W. Bedford and J.F. Lynch, The interpretation and evaluation of a 3-MHz acoustic backscatter device for measuring benthic boundary layer sediment dynamics. *J. Acoust. Soc. Am.* **85**(4), 1501–1511 (1989)

21. M. Minnaert, On musical air-bubbles and the sounds of running water. *Philosophical Magazine* **16**, 235–248 (1933)

22. P. J. Mulhearn, Modelling Acoustic Backscatter from Near-Normal Incidence Echosounders — Sensitivity Analysis of the Jackson Model, *DSTO Technical Note DSTO-TN-0304, September 2000*

23. P.D. Osborne, C.E. Vincent and B. Greenwood, Measurements of suspended sand concentrations in the nearshore: field intercomparison of optical and acoustic backscatter sensors. *Continental Shelf Research* **14**, 159–174 (1994)

24. E. Pouliquen, O. Bergem and N.G. Pace, Time-evolution modelling of seafloor scatter. I. Concept, *J. Acoust. Soc. Am.* **105**, 3136–3141 (1999)

25. B.T. Prager, D.A. Caughey and R.H. Poeckert, "Bottom classification: operational results from QTC View" *OCEANS '95 — Challenges of Our Changing Global Environment Conference*, San Diego, CA, USA, October 1995

26. M. Readhead, Acoustic daylight — using ambient noise to see underwater, *Acoustics Australia* **29**(2), 63–68 (2001)

27. A.S. Schaafsma and A.E. Hay, Attenuation in suspensions of irregularly shaped sediment particles: A two-parameter equivalent spherical scatterer model. *J. Acoust. Soc. Am.* **102**(3), 1485–1502 (1997)

28. J. Sheng J. and A.E. Hay, An examination of the spherical scatterer approximation in aqueous suspensions of sand. *J. Acoust. Soc. Am.* **83**(2), 598–610 (1988)

29. P.D. Thorne and P.J. Hardcastle, Acoustic measurements of suspended sediments in turbulent currents and comparison with in-situ samples. *J. Acoust. Soc. Am.***101**(5), Pt 1, 2603–2614 (1997)

30. P.D. Thorne, C.E. Vincent, P.J. Hardcastle, S. Rehman and N. Pearson, Measuring suspended sediment concentration using acoustic backscatter devices. *Marine Geology* **98**, 7–16 (1991)

31. E.D. Thosteson and D.M. Hanes, A simplified method for determining sediment size and concentration from multiple frequency acoustic backscatter measurements. *J. Acoust. Soc. Am.* **104**(2), Pt 1, 820–830.

Book Reviews

Formulas of Acoustics

F P Mechel (ed)

Springer Verlag, 2002, 1175 pp, ISBN 3 540 42548 9 (hard cover). Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price A$ 375.67 incl GST

In the preface to this book the editor makes the following statements with which I am sure all will agree "Modern acoustics is more and more based on computations, and computations are based on formulas....It consumes much time and effort to search needed formulas during the actual work" This collection of formulae commenced with the editor's own compilation and has additional contributions from M J Munjal, M Vorlander, P Koltzsch, M Ochmann, A Cummings, W Maysenholder, W Arnold and O Rudenko. You can be sure of the comprehensive coverage of this book with such a well respected list of contributors.

The collection should not be considered to be a text book itself but it does give some derivations and, very importantly, source references where more details can be obtained. Long explanations would not be expected in such a compilation but there are many detailed diagrams and graphs which assist the reader to understand the application of the formulae. These figures are adjacent to the relevant section so the need for figure numbers has been removed and captions are rarely necessary.

The 1,117 pages of this book are divided into 19 areas of acoustics commencing with General Linear Fluid Acoustics and concluding with Non Linear Acoustics. The headings for each of the chapters are simple to understand such as Reflection of Sound, Porous Absorbers, Duct Acoustics etc.

With such a large amount of mathematics it is likely there will be some errors within the book. Mechel advises that he takes full responsibility for any printing errors and seeks feedback from readers as well as recommendations for expansion in future editions of the book.

This comprehensive book is highly recommended as a reference book for anyone who has needed to seek a mathematical solution to a particular problem in acoustics. It should be considered as an essential addition to any library collection of reference books on acoustics.

Marion Burgess

Room Acoustics (edition)

Heinrich Kutruff

Spon Press, 2000, 349 pp, ISBN 0 419 24580 4 (hard cover). Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price A$ 291.72 incl GST

The first edition of this book in 1973 aimed to 'present the fundamentals of room acoustics in a systematic and comprehensive way'. The book achieved this goal and became a valued reference for any one trying to understand the acoustics within rooms. Subsequent editions in 1979 and 1991 and this recent edition provided the author with the opportunity to cover the new ideas and methods for room acoustic analysis.

The book commences with facts on sound and hearing as relevant to room acoustics. Then follows sections on sound fields, reflection, scattering, reverberation, energy density and sound absorption. The remaining half of the book covers, subjective effects, measurement techniques, design considerations and electroacoustic installations. It is in these latter chapters that this 4th edition of the book has been considerably updated. In particular the increased application of computers in measurement methods and in modelling has led to revision, expansion and introduction of new sections such as one on auralisation.

This book manages to achieve a balance between in-depth coverage of the necessary theory with clear examples and applications. Each edition has offered the opportunity to the author to revise and refine the text which has led to continued improvement. This book is certainly recommended for anyone working in the area of room acoustic design.

Marion Burgess

Marion Burgess is a Research Officer with the Acoustics and Vibration Unit of the University of New South Wales at the Australian Defence Force Academy. She is involved with research and consulting in a wide range of areas in acoustics.

Meeting Reports

ABCB Sound Insulation

Forum 16th April 2002

The Australian Building Codes Board (ABCB) produces and maintains the Building Code of Australia (the BCA), a regulatory framework standardising a minimum form of construction for buildings in Australia. Of particular interest to AAS members are the sound insulation provisions contained in the BCA that have essentially remained unchanged since its first release in 1990. Since that time, there has been a dramatic increase in the number of people living in high-rise apartments and townhouses and a corresponding venting of displeasure about the poor quality of sound insulation being provided in them. Newspaper headings foretold the grim story – "High-rise crisis looming", "Board exodus adds to apartment tower woes" and "Towers of trouble". Whilst some complaints can be traced to instances of unacceptable building construction practices, the overall impression is that the minimum requirements in the BCA are not relevant to today's standard of living and need to be upgraded.

Indeed, a comparison of our residential sound insulation standards with those of many developed countries indicates that our sound insulation performance requirements are amongst the lowest.

In 1996, the City of Sydney took matters into its own hands and upgraded the sound insulation performance for buildings in its jurisdiction. The Association of Australian Acoustical Consultants (AAAC) also wrote to the ABCB pleading for changes to the BCA. The ABCB recognised that Councils going their own way would result in a proliferation of sound insulation standards having the effects of undermining the intent of the BCA and (potentially) complicating regulation.

In the period January 2001 through to February 2002, the ABCB released three documents entitled "Proposal to Change the Sound Insulation Provisions of the Building Code of Australia" which incorporated recommendations and feedback from various stakeholders including the building industry, building products manufacturers, Councils, the AAAC, acoustic consultants and the Housing Industry Association. It was hoped that the last of these documents would form the regulatory framework for a new updated BCA to apply from July 2002.

However, as we understand it, the building industry and its suppliers were not supportive of the document and this prompted the ABCB to convene a special Forum on the 16th April 2002 to find out why. Forty nine people attended representing the marketplace stakeholders. Kym Burgemeister and Renzo Tonin represented the Australian Acoustical Society. Other AAS members representing interested parties included John Davy, Mark Debevc, Victor Fattoretto, Bob Fitzell and Peter Knowland.

Coincidentally, on the 19th April, Kym Burgemeister and Peter Knowland also made a submission to the NSW Parliament's Joint Select Committee on the Quality of Buildings outlining their views in respect of the poor sound insulation performance achieved in current day residential buildings (this report is now available on www.parliament.nsw.gov.au).

The Forum's common consensus was primarily that the proposed BCA regulations have several inconsistencies and problems that require further investigation. It was apparent that the revision would not achieve its intended goal of "eliminating the complaints". The reasons were many; the proposed new metrics for sound insulation (Rw+Ctr) and for floor impact (Ln,w+C1) were too complicated, the deemed to comply constructions were untested and unproven (and may not be the most cost-effective solutions to the problem), what was being achieved in the laboratory was not being achieved in field tests, the cost impacts are understated, floors would need to be too thick to achieve the ratings and would "wipe out the brickies" and the proposals were aimed at dealing with problems in the luxury end of the market and would incur unnecessary cost at the consumer end.

At the conclusion of a vigorous discussion process chaired by a professional facilitator, the Forum identified that the following actions need to be taken by the ABCB;

1. Performance Standards. It was ultimately agreed that the proposed new metrics represented a sufficiently high standard for the new BCA and should prevail despite their complexity. However, the standards for waste and water supply pipe noise could be simplified.

2. Deemed to Satisfy (DTS) Constructions. The proposed constructions should work in the field not just in the laboratory and should be economically sensible solutions. It was proposed that these solutions should be submitted by industry/manufacturers/associations. A regime was proposed for acceptance of DTS Constructions including laboratory testing, demonstrated field performance and a detailed construction specification to enable the system to be built in the same manner consistently.

3. Code of Practice for Administration. ABCB's role in preparing the BCA is only to produce a building performance standard. It is not ABCB's role to administer certification of building works – this is performed by Councils or other regulatory authorities (in NSW the legal framework for administration and certification is contained in the Environmental Planning & Assessment Act). The Forum recognised that "eliminating the complaints" cannot be accomplished by the BCA alone. Certification of building works is a necessary component of the building cycle to ensure that what is specified is ultimately built.

However, in respect of sound insulation, there is no satisfactory standard of certification. It was therefore recommended that the industry set up a code of practice for the administration of the BCA having the endorsement of the ABCB. The code will be given legal status if the Councils and regulatory authorities include it as a condition of consent in their Development Application. Renzo Tonin has taken on this task on behalf of the AAAC.

4. Community and Industry Education. It was recommended that the following documents – "Guidelines for Designers", "Guidelines for Builders" and "Guidelines for Purchasers" - should be prepared to ensure that all stakeholders involved in the building process are adequately informed of their respective roles. For designers, good practice guidelines: for builders, what to look out for: for purchasers, how to make quality judgements, what to expect and how to do inspections.

5. Cost Analysis. It was considered that the indicative costs of the new regulation prepared by the ABCB were not realistic and should be reviewed.

6. Identify All Noise Issues. The BCA's perspective was considered to be a narrow one and should embrace all noise issues in multi-dwelling living including wall and floor sound and impact transmission, waste plumbing, reticulation water noise, storm-water noise, lifts and plantrooms and external noise intrusion. The ABCB considered that these issues were on its future agenda.

The ABCB expressed its gratitude to the Forum for its constructive input and agreed to convene a committee to move the process forward. A target date of 1 January 2003 was set for the change in regulation. A "Sound Insulation Provisions Directions Report" has recently been circulated by the ABCB incorporating the outcomes of the Forum to provide the industry with sufficient lead-in time to prepare for the 1 January 2003 change.

Kym Burgemeister and Renzo Tonin

Federation Bells

The objects of this 2002 Victoria Division technical meeting held on Apr 10 were twofold: to hear the Federation Bells in Melbourne's Birrarung Marr Park, and to learn something of the details of their design. The meeting was led by Dr Neil McLachlan, Senior Research Associate in Acoustic Ecology and Soundscape Studies at the RMIT School of Architecture and Design.

The Federation Bells were commissioned by the Melbourne Festival of the Arts to celebrate the centenary of Australia's federation. The project was begun in 1999 and is now nearly complete. The instrument comprises 39 bells of different pitches and were designed by Neil McLachlan and manufactured in Victoria by the Australian Bell Co P/L.

The meeting began at the Birrarung Marr bell site with a recital of four specially composed bell pieces by local composers Terry McDermott (2), Ann Boyd and Brenton Broadstock (1 each). After the performance Neil McLachlan explained that this instrument has yet to be finally voiced and tuned.

He also explained that, when sounded, the bells are normally played under computer control, with composed and programmed music. The loudness of each note played can be varied, and is controlled by the time for which each solenoid-driven mallet head is energized. Because the striking of a bell is thus slower or faster, the computer control program has also to include due allowance for this when the particular music being played requires that two bells are intended to be struck so as to sound together. Varying the material of the mallet heads also varies this loudness and, in addition, the tonal character of the bell's sound.

After the recital a more detailed description of the bells' design was given at RMIT by Neil McLachlan. This included aspects of their acoustic and engineering design.

From the acoustical point of view, just tuning of the bells was adopted, with frequency ratios of 9/8 or 10/9 for major or minor tone intervals, and 16/15 for semitones. From the engineering point of view, a number of different experiments were tried in order to produce bells having their overtones in a harmonic series. This aspect was described as shape optimization. The main bell shapes used were cylindrical, conical and cupped. Though bells are more usually conical or cupped, some experiments were carried out on cylindrical bells.

Since with each shape a bell can flex circumferentially or axially, various length/diameter ratios were tried to check the effect on harmonic content. It was found that adjustment of the shape could give desired harmonics to within $\pm$ 2%. Variation of bell thickness was also found to be a controlling variable. A suitable arrangement was found to be with maximum thickness at the closed end and minimum at the open. It was also found that conical bells, if scaled up for the lower notes, would not be loud enough for proper balance, so that for these cupped bells were necessary. For finer tuning, the pitch of a bell could be varied by varying the wall thickness and cone angle. Increasing the percentage of tin was found to sustain the duration of ring. Further experiments were made with "polytone" (European) bells having two fundamental tones and sets of harmonics. A computer program was written to incorporate the effects of these variables.

In general, it was established that the natural frequencies of bells are inversely proportional to the square of the wavelengths for purely circumferential or axial vibrations, and the square root of the mass density. They are directly proportional to the wall thickness and the square root of the elasticity. If a cylindrical object is equally scaled in 3 dimensions the frequency will be inversely proportional to the scale factor.

C Louis Fouvy

Future Meetings

ACOUSTICS 2002

The AAS Annual Conference, Acoustics 2002, will be held in Adelaide, November 13-15. The Theme is Innovation in Acoustics and Vibration. It will provide a forum for the presentation of a wide range of papers in all aspects of fundamental and applied Acoustics and Vibrations. A special stream on underwater acoustics with a guest speaker from Canada is planned. All submitted papers will be peer reviewed under the coordination of a scientific advisory panel.

Two Workshops will run parallel with the Conference. One on Auditorium Acoustics run by Keith Ballard (from Marshall Day NZ) will include historical introduction, room acoustics fundamentals, psychoacoustics, design processes/requirements, design tools, measurements plus a review of one or two flagship projects. The second on Acoustic Noise Models to be run by Norm Broner (from VIPAC Melbourne) will cover an overview of the various packages available, prediction and calibration, usefulness and validity of the packages for prediction of blast and low frequency noise and a "shoot-out' between two or three packages.

The Conference will be held at Hotel Adelaide International in North Adelaide near park lands and adjacent to a promenade of cafes. It is within walking distance of a wide range of accommodation and entertainment/dining. The conference will start with a tour of the Capri Theatre which is rich in history and music, featuring a gigantic organ, containing a total of 2076 pipes. The opening of the Conference will be held on the Wednesday evening at the South Australian Art Gallery. On Thursday night, all conference participants will be treated to dinner (with special entertainment) at the Hotel Adelaide's restaurant, which offers excellent views overlooking the city and park lands. The conference fee will include the Capri tour (and wine tasting), opening, dinner and workshops.

Information: Acoustics 2002, Department of Mechanical Engineering, Adelaide University, SA 5005, AUSTRALIA. Tel: +61-8-8303 5469; Fax:+61-8-8303 4367; aas2002@mecheng.adelaide.edu.au, www.acoustics.asn.au

WESPAC8

The technical program for this international conference to be held in Melbourne 7-9 April 2003, is really starting to look exciting. The excellent Plenary, Distinguished and Keynote Lecturers will cover a broad range of topics, from Ultrasonics to Speech, from Noise Control to Room Acoustics, from Music to Underwater Acoustics and the Environment, and much more. A number of special sessions have also been organised and include: Active Noise Acoustic Imaging, Auditorium Acoustics, Building Acoustics, Codes of Practice, Consultant Acoustics, Electro-Studio Acoustics, Environmental Noise, Instrumentation Musical Acoustics, Noise and Vibration, Psychological and Physiological, Sound Quality Speech, Transport Noise, Ultrasonics, Underwater Acoustics.

In addition, there will be a comprehensive trade display in an area, adjoining the lecture rooms, which overlooks Albert Park Lake. During the conference will be a bush barbecue at the historic homestead of Emu Bottom and a conference banquet

The details of the technical program and some of the abstracts, registration details are all available on www.wespac8.com.

INTERNOISE 2003

The 2003 International Conference and Exposition on Noise Control Engineering will be held at the International Convention Center (ICC) JEJU, Korea from 25 to 28 August 2003. The theme of the conference will be Noise and Vibration Control for Human and Environment. The conference will have distinguished speakers, more than 10 parallel sessions for contributed papers and an extensive technical exhibition. The international conference venue is on Jeju Island, an island of myths, picturesque scenery and mild weather and most of the most popular tourist destinations in Korea. Abstracts are due November 30 2002 and full papers by March 31 2003.

More information from http://www.internoise2003.com and internoise2003@covanpco.co.kr

ICSV10

The tenth International Congress on Sound and Vibration (ICSV10) is to be held 7-10 July 2003, in Stockholm, Sweden at KTH (the Royal Institute of Technology). Participants will be able take part in a Congress with a first rate scientific program, and also experience the many sites of historical and general interest in and around Stockholm. The ICSV10 banquet will be held at the Vasa Museum. The Vasa was a Swedish warship, which sank on its maiden voyage in the 17th century.

This Congress is sponsored by KTH (the Royal Institute of Technology), IIAV (the International Institute of Acoustics and Vibration) and SVIB (the Scandinavian Vibration Society). Abstracts are invited and details can be found from http://www.iiav.org.

NOISE AS A PUBLIC HEALTH PROBLEM

The eighth International Congress on Noise as a Public Health Problem will be held in Rotterdam, Netherlands, from 29 June to 3 July 2003. The primary aim of the congress is to promote the exchange on knowledge on the biological effects of noise. Other objectives are to encourage international cooperation and promote communication among those working in the field.

The program is organised around the nine teams that define the International Commission on Biological Effects of Noise (ICBEN). These themes include: noise Induced hearing loss, noise and communication, non auditory physiological effects, effects on performance and on sleep, community response to noise, noise and animals, noise combined with other agents and regulations and standards. In addition to the scientific program will be a trade exhibition and a social program. More information from www.icben2003.nl

News Items

Bad Vibrations is the title for a Handbook on whole body vibration exposure in mining that has been compiled and written by Barbara McPhee, Gary Foster and Airdrie Long for the Joint Coal Board Health and Safety Trust. The handbook aims to assist people in the mining industry to identity and manage the risks associated with vibration exposure. It is divided into sections with an accompanying checklist and other information to help reader identify, asses and control risks associated with Whole Body Vibration and to evaluate corrective action. Although it is aimed at the mining industry it contains a wealth of information that could be utilised in other work environments where there is the potential for excessive whole body vibration. Details from the Joint Coal Board, tel 02 9291 5666.

Loudness of TV Advertisements There is a common perception that the noise levels for advertisements on TV are louder than the surrounding programs aimed at drawing attention to the item being promoted. The Australian Broadcasting Authority has recently released its report on an investigation into this issue. They have concluded that limiting, equalising and compression of signals are techniques which can be used to make the advertisements sound louder. The outcome of the investigation is that the industry will be required to develop a Code of Practice that ensures there is better balance between the loudness of the advertisement and the adjacent programs. More information from www.aba.gov.au

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Sound Thinking. Acoustic Research Laboratories (ARL) and Acoustic Technologies have joined forces to form The Sound Thinking Group of companies. Sound Thinking Group brings together the technical expertise of the two companies to greatly enhance the service they can give to the acoustic fraternity in Australia.

ARL is the Australian distributor of the Rion range of sound and vibration measuring instruments. ARL is also the designer and manufacturer of portable noise and vibration loggers. Acoustic Technologies' background is in the development of acoustic recording, processing and analysis systems for military applications. The lateral thinking expertise that is available within Acoustic Technologies is now available to a wider market while utilising the sales and technical expertise available within ARL across a wider range of industries.

The Sound Thinking Group will be based in Sydney with offices in Melbourne and South Australia and agents in other states. Contacts for the Sound Thinking Group are tel 02 94840800 or www.soundthinking.com.au

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DAVIDSON Contacts The new Davidson Measurement contact number, 1 300 SENSOR (1 300 736 767), gives quick access to solutions for a wide range of sensor and instrumentation requirements. Now everyone in Australia has a simple phone number to use when making general sales enquiries, wanting to have repairs carried out or needing calibration of pressure, vacuum and electrical measurement devices all at the cost of a local call. Davidson Measurement continues to develop ways to make it easier for you to access information and assistance when measuring pressure, vibration, displacement, strain, acoustics and force. Remember 1 300 SENSOR for your sensor and instrumentation needs.

Transcat a division of Transmation, Inc.(Nasdaq: TRNS), a leading distributor of test, measurement and calibration instrumentation, has announced that Davidson Measurement Pty. Ltd., is now representing Transcat in Australia and New Zealand. Davidson will provide sales, distribution, repair and NATA certified calibration services for Transcat's products, including the exclusive Transmation and Altek brands. Davidson Measurement can be contacted by phone on 1 300 SENSOR, fax 03 9580 6499, www.davidson.com.au or email info@davidson.com.au

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Davidson eCalibration results from the combination of Davidson Measurement and IntelEng Pty Ltd to offer a total solution to calibration management. They will be known as Davidson eCalibration Services a division of Davidson Measurement. Davidson eCalibration Services will offer a total solution to calibration, which includes NATA accreditation and on site calibration, including value added services such as web-based technology, asset management, sales, service and repairs. Davidson eCalibration can be contacted on telephone: 1-300-SENSOR or www.ecalibration.com.au

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Acu-Vib Electronics your one stop Acoustic and Vibration Sales / Calibration / Rental & Repair laboratory moved to larger premises in July. The new address is Unit 14, 22 Hudson Avenue, Castle Hill NSW 2154. The telephone and fax numbers will remain the same: Tel: (02) 9680 8133 Fax: (02) 9680 8233 Mobile: 0413 809 806, www.acu-vib.com.au

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IINCE, International Institution of Noise Control Engineering, the sponsor body for Internoise Conferences has a new www page http://www.i-ince.org/

New Products

NUWAVE

Noise Barrier Products

A whole new range of products aimed at noise control in buildings is about to hit the market when a new production plant being built in Sydney's south west is completed in the next couple of months. NuWave barrier is a very flexible and dense polymer which is able to move slightly under the impact of sound waves and reduce most of the energy from them. This results in high levels of noise reduction right across the frequency range; so even noise sources like home theatre systems and loud voice levels are markedly reduced.

They provide a much simpler solution than complex systems with several layers of noise rated plasterboard or masonry and glass or polyester wool insulation. Simplicity and maximum performance is the goal for NuWave.

The range will include;

Nuwave flexible high performance barriers for both framed and solid walls to stop noise transmission.s.

NuWave "Low Profile" Wrap for waste water pipes in buildings to minimise noise intrusion at all hours of the day and night.

NuWave "Impact" which is a simple and inexpensive solution to reduce impact noise between floors of buildings. This unique system has been developed with the assistance of input from architects and acoustic consultants.

All these products will be further developed under a research and development program costing over $200,000 and NuWave is encouraging industry input and feedback from architects, consultants, building owners and developers and the building trades as the new noise reduction standards of the Building Code of Australia come into place.

Information: Nicholas McGloin, NuWave Noise Barrier Products, PO Box 427 Jannali 2226, Tel 02 9792 8288, Mob 0417 244019 Fax 02 9792 8088, nicmcg@bigpond.com

ARL

Rion Sound Level Meters

Two new sound level meters are available from Rion and both comply with the new IEC/CDV 61672-1 standard. The Rion NL-22 meets the requirements of Class 2 while the NL-32 is a Class 1 instrument under the new standard.

Both meters feature the simultaneous measurement of Lp, Leq, LE, Lmax, Lmin and 5 selectable Ln values according to the selected time and frequency weightings chosen. Auxiliary processing functions enable the simultaneous measurement of an additional selectable function.

Both meters have an internal memory but most data is stored on Compact Flash Cards for easy transfer to a computer. For example, the storage capacity of a 16 MB card is 864,000 data sets or 200 hours of data. For those who prefer it, the capability to download data via a cable output to a computer using either an RS232 or USB connection is available

These new meters can accept program cards. The cards currently available enable both meters to measure 1/1 and 1/3 octaves on a step through basis while the second is a universal filter. An audio recording card, a real time 1/1 – 1/3 octave card and an FFT analysis card will be available in the near future.

Information: Acoustic Research Laboratories Pty Ltd (a Sound Thinking Group company). www.soundthinking.com.au.
Tel 02 9484 0800

BRUEL & KJAER

PULSE Data Manager

Get more out of your data with PULSE™ Data Manager, a family of data management solutions that enables measurements from PULSE or any of its applications to be labelled and saved to a database. The measurement data can then be easily retrieved for display, simple comparison or reporting via a range of query options. Based around Microsoft® SQL databases, PULSE Data Manager streamlines data handling, test documentation and archiving for PULSE. The software can run independently or from within PULSE and integrates with PULSE WorkFlow Manager Type 7756.

PULSE Lite

PULSE™ Lite is a lighter, simpler version of Brüel & Kjær's Windows-based PULSE Multi-analyzer. One, two, three clicks and novice and expert alike can start troubleshooting and making valid sound and vibration measurements right away. With its strength in its simplicity, PULSE Lite is especially suitable for those who do not require a system as sophisticated as a full PULSE system.

The task-oriented user-interface consists of a simplified menu bar with standard functionality, default setup values and a task bar. If you work with TEDS transducers and accept the pre-set measurement configuration (covers 60 – 80% of measurements) you can start measuring immediately. PULSE Lite does not become obsolete but rather forms the foundation for an easy upgrade to a more powerful PULSE solution. To upgrade, all you need to do is to buy a new software license. The hardware remains the same!

Room Acoustics

DIRAC Room Acoustics Software Type 7841 is used for measuring a wide range of room acoustical parameters. Based on the measurement and analysis of impulse responses, DIRAC supports a variety of measurement configurations. For accurate measurements according to the ISO 3382 standard, you can use the internally generated MLS (maximum-length sequence) or sweep signals through a loudspeaker sound source. Survey measurements are easily carried out using a small impulsive sound source, such as a blank pistol or even a balloon.

Speech measurements can be carried out in compliance with the IEC 60268-16 standard, for male and female voices, through an artificial mouth-directional loudspeaker sound source or through direct injection into a sound system, taking into account the impact of background noise. DIRAC is not only a valuable tool for field and laboratory acoustics engineers, but also for researchers and educational institutions.

PocketEar

PocketEar is designed to help you look after your hearing by showing you the noise level in the environment you are in. A red light will appear if the level exceeds the pre-set level which can be one of three levels – 65, 85 or 105dB.

The 65dB level should be used for situations where concentration and effortless conversation are required, for example, schools and offices. The 85dB level is the noise-at-work limit for 8-hour exposure. If you are exposed to more than 85dB, the risk of hearing damage is significantly increased and it would, therefore, be a good idea to use hearing protection. The 105dB level is useful at concerts, music rehearsals, etc.

As the name implies, PocketEar fits in your pocket, measures a mere 4.5 x 7 x 2cm and can be attached to your key ring. Each PocketEar comes in a small display box that also includes two high-quality earplugs from Alpine MusicSafe, a multilingual instruction leaflet and a Type CR2430/3V battery.

LIMA™ Noise Mapping

This is the first software package especially designed for large-scale noise mapping. Widely used by leading noise mapping authorities, LIMA offers a range of powerful data handling and analysis tools that make it ideal for large scale noise mapping with fine resolution for a range of source types according to a wide range of national and international standards. Versions for smaller-scale calculations are also available.

Noise Calculation Software

ENPro™ is a PC-based software package for the easy modelling, precise prediction, and cost-effective simulation and design of indoor and outdoor environmental noise. It is ISO 9613 compliant and its advanced 3D graphic user-interface tools allow you to quickly model complex noise environments such as directional noise sources, multi-sloped barriers and cylindrical towers.

It can provide cross-sectional and 3D visualisation of a noise map in a geographical area to show noise population exposure and to identify noise problems. ENPro can also quickly calculate future scenarios by identifying their differences from the results of the current scenario. "Scenario comparison" and "source rank" maps intuitively inform you how to effectively reduce noise in both existing multi-source areas and future land development.

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KINGDOM

HTBASIC VERSION 9

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Information and a demonstration CD from Kingdom Pty Ltd tel 02 9975 3272.

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Fantech has expanded its range of rectangular silencers to suit its popular series of Powerline in-line centrifugal and multiflow fans. The silencer can be coupled to the inlet or outlet of the Powerline fan and has been designed to achieve optimum acoustic performance.

Information: Fantech, tel 03 9560 2599, info@fantech.com.au

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SmartCut is a revolutionary new service with the ability to cut glasswool and rockwool to specific shapes using a method that is both time and cost effective. The unique service uses state of the art computer controlled high powered water jet as the cutting mechanism. The resulting cut is extremely accurate and lends itself to complicated designs which means insulation is no longer dictated by conventional shapes.

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Insulco Acousti-Max is the most sophisticated program for the prediction of noise transmission loss in walls and floor/ceiling systems. An essential tool for estimating the Transmission Loss (TL) over a range of frequencies, as well as Weighted Sound Reduction Indices of STC and Rw, as required by the Building Code of Australia. Acousti-Max comes packed with features and functions. With extensive drop down menus to select materials and simple choices for construction details, you can quickly evaluate different constructions and insulation materials. Acousti-Max also provides an on-screen picture of your construction and a graph (or table) of the Transmission Losses. It offers fundamental productivity and workflow benefits to acoustic consultants and architects.

Information: tel 1300 65 44 44 or insulco@tasbuildpro.com.au.

Letter

Seeking acoustics papers and records

I feel sure that among our more senior members there must now be some who have over the years accumulated numerous most useful acoustics papers and other records which, in our retirement or semi-retirement, we no longer need. At this stage, we tend to dispose of them as waste paper. I'm sure that much information about notable past acoustical work, and about the early days of the AAS has in this way been completely lost to posterity.

I would like to make a very strong plea indeed to all who have such accumulations of acoustics papers and records to seriously think of donating and sending them to the AAS Archive rather than throwing them out as rubbish.

The most important items to be retained in an archive are AAS division committee minutes, especially but not only from the period 1964 to 1971 when there was an NSW and a Victoria Division before the society was incorporated as an Australian Society in 1971, together with periodical news and technical bulletins, conference etc proceedings, technical papers given at conferences, seminars and technical meetings, and records of these conferences, seminars and technical meetings.

Those historians amongst us, who are compiling accounts of the acoustical work, researches, successes and achievements of our current and former members and other acousticians working in this country are all too aware that there are large gaps in our current records.

At present, although this Archive has some records of these kinds, they are far from complete. Our plea is that all who have collections of acoustics papers and records think seriously of donating them to the AAS Archive. The general secretary, David Watkins, or myself would be very pleased to hear of, and help you to dispose of, such valuable records in the Archive.

Louis Fouvy,
Victoria Division Committee

Obituary

DR RONALD GEORGE BARDEN

18.06.1924 – 04.07.2002

Ronald and his twin brother Ernest were born at Rochester in England. When 15 he obtained a keenly contested apprenticeship as a Fitter and Turner and Design Draughtsman at the Royal Dockyard, Chatham. A few months later the Second World War broke out and the dockyard was placed under intense pressure, maintaining and repairing ships of the Royal Navy. At the conclusion of his apprenticeship, Ron had gained top place of all the students who had entered the Royal Dockyard Schools throughout Britain in that period. He then won by examination a Whitworth Scholarship enabling him to begin an engineering course at London University. After graduating, his first move from practical engineering to the academic was an appointment as Lecturer at the Battersea Polytechnic.

However, Australia beckoned and he arrived in Sydney with his wife Betty in September 1949 to take up an appointment on the engineering staff of the University of New South Wales. An appointment as Senior Lecturer at the University of Adelaide followed in 1952 and it was there that he obtained his Doctorate. In 1963 he became Foundation Professor of Fluid Mechanics and Chairman of the Department of Mechanical Engineering, Monash University, Melbourne guiding the Department in a period of rapid development with great success. Having a keen interest in noise and vibration he incorporated the subject into the regular Engineering Course and started special Short Courses for people employed in industry.

During 1969 he was the Visiting Professor at the Institute of Sound and Vibration Research (I.S.V.R.) at Southampton. Returning to Monash he worked hard to promote the subject more widely and to prepare for a large conference of great significance. This was the "Noise, Shock and Vibration" Conference sponsored by his Department of Mechanical Engineering, the Australian Acoustical Society and the Institution of Engineers, Australia, was held at Monash in May, 1974, the keynote speaker being Dr L.L. Beranek.

As the first Chairman of the Acoustic Society in Victoria, Ron Barden displayed the same energy and enthusiasm that he put into any job he tackled and as the application of acoustic principles and practice developed Ron was made the Chairman of the Acoustic Committees of the Standards Association.

Late in 1974 the great variety of noise and vibration problems dealt with in private practice attracted him and he decided to make a change from university life by joining the practice which the writer had established in 1959. The partnership of Riley, Barden and Kirkhope came into being. Giving Ron the opportunity to apply his great expertise and knowledge in many important projects.

Community Service as always important to Ron and he did a great deal for the Deafness Foundation (Vic.,) of which he became President. This work was extended to "Taralye", the Advisory Council for Children with Impaired Hearing (Vic.) which he assisted in many ways.

Ron's professional standing was recognised by many Institutions: Fellow, Institution of Mechanical Engineers, London; Fellow, Institution of Engineers, Australia; Fellow, Faculty of Engineering, Monash University; Fellow, Australian Acoustical Society.

There is no doubt that his contribution for acoustics in Australia was great. He arrived on the scene when all too few understood its importance in engineering and to society, and he proceeded to spread the message very effectively.

Ronald Barden was a man of integrity and high principle, with an underlying sense of humour, for whom his colleagues, his staff, and all those who knew him well had great respect. He had been deeply saddened by the death of his wife Betty in 1985 and it was only a few years later that he decided to retire from private practice devoting his time to his family and especially his grandchildren. He took up golf and bridge and in 1996 entered into a happy marriage with Shirley Hogan who was his bridge partner. He is survived by Shirley and by his children Annette, Penelope and John, and by his grandchildren.

Gerald Riley

Retirement

ROBERT GREEN MAAS

Robert Green joined the Commonwealth Department of Works during the mid-1950's when they had just been given control of design and construction for an ABC works program of major new TV and Radio buildings. Because of his experience in acoustics and physics Bob was invited to join the architectural team engaged in the documentation of these works. During a five year period, under the leadership of Senior Architect Colin Day, he supervised the detailed architectural acoustic design, including noise isolation and air borne noise control for the new TV broadcasting production complexes at Sydney, Brisbane, Adelaide, Perth and Hobart and the Perth Rosehill Radio complex. This was a very stimulating period of fellowship when the Australian acoustics industry and profession had been boosted by the simultaneous construction of so many ABC and commercial TV production centres.

Bob's work brought him into contact with ABC personnel and in late 1959 he was invited to join them in the position of Architect in their Building Services Department at the Sydney Head Office. Over a period of 19 years he was involved in many major ABC studio projects in Port Moresby, Rabaul, Darwin, Alice Springs, Cairns, Townsville, Mackay, Toowoomba and Brisbane, until forced to resign for health reasons in 1979. Subsequently he went into private acoustic practice as consultant to local and overseas organizations, operating as Acoustec Pty Ltd, until recent times.

From the early days, when Australian acoustics was a much smaller fraternity, Bob was well known and became one of the foundation members of the Society. He played an active role in advancing the science and practice of the discipline. He enjoyed Professor Anita Lawrence's inspiring two-year Graduate Diploma course in Advanced Acoustics course at the University of New South Wales in 1967 and 1968. He involved himself in Society activities, preparing and delivering a number of technical papers. From 1973 to 1975 he wrote, lectured and tutored at the UNSW in courses on Statistics, Acoustics and Climatology, as well as lecturing in Materials Science. With Bob Mitchell, he also presented a segment on Acoustics for University of the Air.

Bob was deeply interested in research. He had dreamed of researching the stricter application of acoustic principles to Radio and Television studio problems by developing performance tested prefabricated constructions as far as possible. One such demountable studio was actually built as a private project. It did perform excellently, but was never adopted; such radical approach was hardly a priority within a busy broadcaster. He also carried out joint research with the late E (Ted) Weston (whom Bob remembers with affection and respect). Ted was interested in Bob's theoretical investigations of the critical effects of placement on absorbent efficiency. He gave Bob assistance and access to the Commonwealth Building Research Laboratory's sophisticated facilities, enabling almost 8000 separate experiments to be made to verify Bob's hypothesis. This work was published.

It was in Adelaide, South Australia where, as an ABC engineer, I first met Bob Green during his visits regarding building matters for radio and television studios at Collinswood, South Australia, and country centres. Bob's high standard of professionalism was apparent and rated equally with his ability to entertain with his anecdotes and pithy good humour.

Bob Green recently celebrated his 80th birthday. He followed in the tradition of those professionals in acoustics, both here and overseas, who cannot quit at the recognised retiring age, but continue to make a contribution. We wish Robert Green a happy and enjoyable retirement.

Donald Woolford

FASTS

The $2.9 billion dollar Innovation Statement was launched in January 2001. At the time FASTS welcomed the funding boost as a promising first step. But it needs far more than $2.9 billion over 5 years to allow Australia to catch up to the average OECD expenditure in science and research. The president of FASTS has recently written to the Prime Minister asking him what his Government was planning to do about the next step, the "second leg" of the Innovation Statement. The Prime Minister has responded, saying that his Government is still monitoring the outcomes of the initiatives announced in 2001. FASTS will continue to press for a proper national investment in science and research.

FASTS supports any actions of the Government to maximise the return to Australia of our research efforts, by concentrating research in areas where we have a competitive advantage and putting new efforts into areas of weakness where we should have a stronger presence.

FASTS is proposing to run capacity-building workshops for the Member Societies. The first stage is to establish the content of the workshops and any comments are welcomed.

The "Science Meets Parliament" Day will be on Tuesday-Wednesday 12-13 November in Canberra. It has several new features this year, including a science-industry-Parliamentarians dinner on Wednesday night, at prestigious Members' Dining Room at Old Parliament House. The success of this day relies on the participation of the member organisations.

FASTS web site is a central source of information on science policy. As well as carrying the latest information on events such as "Science meets Parliament" Day, the site also links readers to information on current issues like the research priority-setting exercise. www.fasts.org.

Standards Australia

Condition Monitoring

Australia has had a significant involvement with ISO/TC 108/SC5, Condition monitoring and diagnosis of machines, since its inception in 1993 as Professor Joseph Mathew of QUIT has been Chairman. The subcommittee published ISO 13380:2002 'Condition monitoring and diagnostics of machines – General guidelines on using performance parameters'. Future standards in this series will cover a range of other aspects including data processing and interpretation, prognostics, tribology based monitoring, thermal imaging, optimisation etc

From The Australian Standard July 2002

Wind Turbine Noise A new Standards Australia Committee, EV-016 - Acoustics - Wind Turbine Noise, has been formed to develop a new standard on the measurement and assessment of environmental noise from wind turbines and wind farms. Dr Peter Teague and Ken Williams have been nominated to be the AAS Representatives on this committee based on their experience and knowledge. Other committee members will include representatives from the National Environment Protection Council, the Australian Wind Energy Association, Planning and Local Government Associations, Universities and other special interest groups. The first meeting of the committee was held in Brisbane on August 2 and will involve wind turbine noise expert Dr Andrew McKenzie from the UK as guest speaker.

EU Directive on Human Vibration The text of the Physical Agents (Vibration) Directive was published in the Official Journal of the European Communities (L177 Vol 45, p12) of 6.07.2002 and can be found at http://europa.eu.int/eur-lex/en/oj/2002/l_17720020706en.html. EU Member States have three years from 6.07.2002 to implement the Directive and so we may see an increased interest in this issue in Australia. Under the Treaty, the Council is encouraging improvements, especially in the working environment, to guarantee a better level of protection of the health and safety of workers. Such directives are to avoid imposing administrative, financial and legal constraints in a way which would hold back the creation and development of small and medium-sized undertakings.

For hand-arm vibration the daily exposure limit and action values standardised to an eight-hour reference period shall be 5 m/s^2 and 2,5 m/s^2 respectively. For whole-body vibration the daily exposure limit and action values standardised to an eight-hour reference period shall be 1,15 m/s^2 and 0,5 m/s^2 respectively.

It is considered necessary to introduce measures protecting workers from the risks arising from vibrations owing to their effects on the health and safety of workers, in particular muscular/bone structure, neurological and vascular disorders. These measures are intended not only to ensure the health and safety of each worker on an individual basis, but also to create a minimum basis of protection for all Community workers in order to avoid possible distortions of competition.

This Directive lays down minimum requirements, thus giving Member States the option of maintaining or adopting more favourable provisions for the protection of workers, in particular the fixing of lower values for the daily action value or the daily exposure limit value for vibrations.

The level of exposure to vibration can be more effectively reduced by incorporating preventive measures into the design of work stations and places of work and by selecting work equipment, procedures and methods so as to give priority to reducing the risks at source. Employers should make adjustments in the light of technical progress and scientific knowledge regarding risks related to exposure to vibration, with a view to improving the safety and health protection of workers. In the case of sea and air transport, given the current state of the art it is not possible to comply in all circumstances with the exposure limit values for whole-body vibration; provision should therefore be made for duly justified exemptions in some cases.

New Members

NSW

Member: Conrad Weber, Max de Salis, Tom Harper, James Campbell

SA

Member: Ivailo Dimitrov, Dr Damien Leclercq

Vic

Member: Kerry Dumicich

Diary...

2002

16 - 21 September, SEVILLA
Forum Acusticum 2002 (Joint EAA-SEA-ASJ Symposium) http:/www.cica.es/aliens/forum2002, fax: +34 91 411 76 51

16-18 September, LEUVEN
Int Conf Noise and Vibration Engineering
http://www.isma-isaac.be ,
lieve.notre@mech.kuleuven.ac.be fax:: (+32) 16 32 29 87

17-20 September, DENVER
Int Conf on Spoken Language Processing
http://cslr.colorado.edu/icslp2002

29- 31 October, MISSISSIPPI
Oceans 2002 Conference
www.OCEANS2002.com

13-15 November, ADELAIDE
Acoustics 2002
Department of Mechanical Engineering, Adelaide University, SA 5005, AUSTRALIA. Tel: +61-8-8303 5469; Fax: +61-8-8303 4367; aas2002@mecheng.adelaide.edu.au, www.acoustics.asn.au

21-22 Nov, AUCKLAND
New Zealand Society Conference
mms@bitz.co.nz
www.acoustics.org.nz

30 Nov–8 Dec, MEXICO
1st joint meeting of ASA, Iberian Fed. Acoustics, Mexican Inst Acoustics
http://asa.aip.org/cancun.html

19-21 Dec., TENERIFE
3rd WSEAS International Conference on Acoustics, Music, Speech And Language Processing
www.wseas.org/conferences/2002/tenerife/icamsl

2003

7 - 9 April, MELBOURNE.
WESPAC8
Acoustics on the Move
http://www.wespac8.com

18-23 May, CAIRNS
21st ARRB and 11th REAAA Conference
Transport - our highway to a sustainable future
http://www.arrb.com.au/conf21

16 - 18 June, CADIZ
ACOUSTICS 2003
Third International Conference on Modelling and Experimental Measurements in Acoustics
http://www.wessex.ac.uk/conferences/2003/acoustics03/index.html, rgreen@wessex.ac.uk

18-20 June, BRISBANE
2003 National Environment Conference
Environmental Engineering Society (IEAust)
www.eesq.com.au, dgaudie@ieaust.org.au

29 June – 3 July, ROTTERDAM
8th ICBEN Congress - Noise as a public health problem
www.icben.org

7-10 July, STOCKHOLM
ICSV 10
Fax:+46 8 661 91 25, icsv10@congrex.se, www.congrex.com/icsv10

14-16 July, SOUTHAMPTON
8th Int Conf Recent Advances in Structural Dynamics
http://www.isvr.soton.ac.uk/sd2003/

6-9 August, STOCKHOLM
Stockholm Music Acoustics Conference SMAG03
www.speech.kth.se/smac03/

24-27 August, KOREA
Internoise 2003
Fax +82 2762 4946, www.internoise2003.com, internoise2003@covanpco.co.kr

September 7-10, PARIS
World Congress on Ultrasonics
http://www.sfa.asso.fr/wcu2003

2004

04 - 09 April, KYOTO,
18th International Congress on Acoustics (ICA2004).
http://ica2004.or.jp

WWW Listing
The ICA meetings Calendar is available on
http://www.icacommission.org/calendar.html

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* Payment of annual subscription
* Proceedings of annual conferences

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