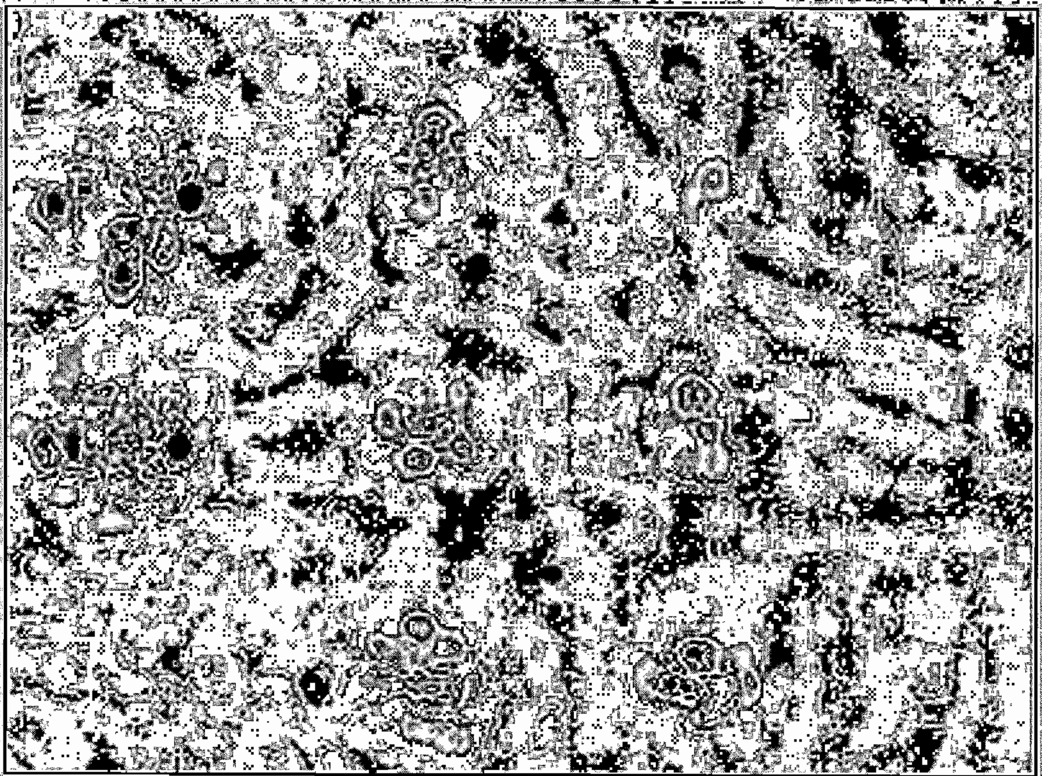
Acoustics Australia

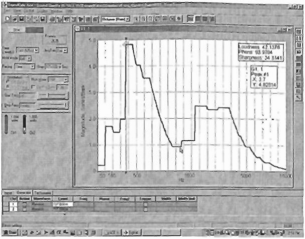


- Recording operatic voices
- Noise management in building
- Acoustic non-destructive testing
- Condenser microphone tutorial

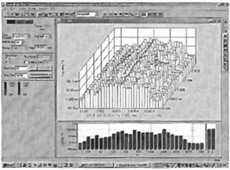
Australian Acoustical Society Vol. 30 No. 3 December 2002

SignalCalc® Sound Quality

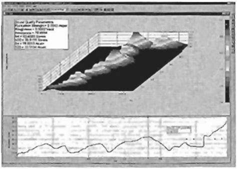
Sound Quality Qualification



Zwicker Loudness & Metrics



1/3 Octave & Waterfall



Spectrogram & slices

Toolbox of Metrics for Sound Quality
Includes line, waterfall & spectrogram of Loudness, Phons, Sharpness, RMS, RMS (A), RMS (C), Max, Min, Pk to Pk, Mean, Std Dev, Variance, SPL level and more.

Fast and Easy to use
Exceptional Graphics
Provided with Industry leading SignalCalc Analysers.
Portable and Expandable.

DATA PHYSICS CORPORATION SOLUTIONS IN SIGNAL PROCESSING

Supplied by
KINGDOM PTY LTD
Phone 02 9975 3272

Available for ACE, DP430Win, Mobilyzer, DP620 VXI for channel counts of 2 to 2048 channels.

Acoustics Australia

Acoustics Australia
General Business
(subscriptions, extra copies, back issues, advertising, etc.)
Mrs Leigh Wallbank
P O Box 579
CRONULLA NSW 2230
Tel (02) 9528 4362
Fax (02) 9523 9637
wallbank@zipworld.com.au

Acoustics Australia
All Editorial Matters
(articles, reports, news, book reviews, new products, etc)
The Editor, Acoustics Australia
Acoustics & Vibration Unit
Australian Defence Force Academy
CANBERRA ACT 2600
Tel (02) 6268 8241
Fax (02) 6268 8276
email: acoust-aust@adfa.edu.au
www.acoustics.asn.au

Australian Acoustical Society
Enquiries see page 132

Acoustics Australia is published by the Australian Acoustical Society
(A.B.N. 28 000 712 658)

Printed by
Cronulla Printing Co Pty Ltd,
16 Cronulla Plaza,
CRONULLA 2230
Tel (02) 9523 5954,
Fax (02) 9523 9637
email:print@cronullaprint.com.au
ISSN 0814-6039

Vol 30 No 3 December 2002

CONTENTS

Cover illustration: Image of a test panel with damage.
See paper by Dickinson and Thwaites

AUSTRALIAN ACOUSTICAL SOCIETY - SUSTAINING MEMBERS

ACOUSTIC RESEARCH LABORATORIES
LEVEL 7 BUILDING 2
423 PENNANT HILLS ROAD
PENNANT HILLS 2120

ACRAN
P O BOX 34
RICHLANDS 4077

ACU-VIB ELECTRONICS
UNIT 14, 22 HUDSON AVE
CASTLE HILL 2154

ADAMSSON ENGINEERING PTY LTD
P O BOX 1294
OSBORNE PARK 6916

ARMSTRONG WORLD INDUSTRIES
P O BOX 109
MORDIALLOC 3195

ASSOCIATION OF AUSTRALIAN ACOUSTICAL CONSULTANTS
PO Box 820
SPRING HILL 4004

BORAL PLASTERBOARD
676 LORIMER STREET
PORT MELBOURNE 3207

BRUEL & KJAER AUSTRALIA
6-10 TALAVERA ROAD
NORTH RYDE 2073

CHADWICK TECHNOLOGY
9 COOK STREET
FORESTVILLE 2087

CSR BRADFORD INSULATION
55 STENNETT ROAD
INGLEBURN 2565

G P EMBELTON & CO PTY LTD
P O BOX 207
COBURG 3058

HPS TECHNOLOGY PTY LTD
17 BALLANTYNE ROAD
KEWDALE 6105

INC CORPORATION PTY LTD
22 CLEELAND ROAD
OAKLEIGH SOUTH 3167

KELL & RIGBY INTERIORS
PO Box 888
STRATHFIELD SOUTH 2136

NAL CONSULTING
126 GREVILLE STREET
CHATSWOOD 2067

NOISE CONTROL AUSTRALIA PTY LTD
70 TENNYSON ROAD
MORTLAKE 2137

NSW ENVIRONMENT PROTECTION AUTHORITY
P O BOX A290
SYDNEY SOUTH 1232

PEACE ENGINEERING PTY LTD
P O BOX 4160
MILPERRA 1891

SOUNDGUARD PYROTEK
149 MAGOWAR ROAD
GIRRAWEEN 2145

SOUND CONTROL PTY LTD
61 LINKS AVENUE NTH
EAGLE FARM 4009

VIPAC ENGINEERS AND SCIENTISTS LTD
279 NORMANBY ROAD
PORT MELBOURNE 3207

WARSASH SCIENTIFIC PTY LTD
UNIT 7, 1-9 MARIAN STREET
REDFERN 2016

WORKCOVER
COMPLIANCE COORDINATION TEAM
LEVEL 3, 400 KENT STREET
SYDNEY 2000

From the Past President

Is the Society Tending To Self Destruct?

It is so easy to "leave it to others" and to convince yourself that you are so busy that you don't have time to go to a technical meeting or Society conference. Yet surely one of the main purposes of having an Acoustical Society is to facilitate interaction between members. If members continually fail to attend functions, ignore opportunities to exchange ideas and inform others of their activities, then much of the value of having a Society is lost. This lack of enthusiasm can spread. Even the dedicated few may become disheartened and gradually the Society will wither.

So often I have attended a technical meeting where only a handful of members have attended. I recall one embarrassing site visit where the four staff members who had waited back that evening to provide the technical explanations outnumbered the three Society members who managed to turn up. Other occasions may fare better; however, it is generally a sub-set of those twenty or so members who attend regularly. What happened to the many more members who never attend any event? You may claim that it is their loss, they miss out on the stimulation that a technical meeting provides. However, the loss is greater than that. Frustration gradually overwhelms the organisers. Is it worth attending meetings, wasting time arranging a visit or organising a guest speaker, when few appreciate your effort? Frustrated, they give up.

The Society includes many talented people. The recent elevation of four more members to the grade of Fellow is one pleasing aspect. The team that continuously produces this Journal to such a high standard deserves our acclaim. Each Division is powered by a group of individuals who continuously strive to introduce innovative technical meetings and stimulating conferences, as well as providing a social environment for its members. But a strong Society needs more than the dedicated few. Every member should try, at least occasionally, to take some role in Society activities. Encourage associates to join the Society, attend at least one or two meetings each year, contribute papers or news items to conferences or Acoustics Australia, and even volunteer to join Divisional Committees. Your involvement can help keep our Society from fading away due to lack of interest.

Charles Don

From the New President

I wish to express thanks to Charles Don for his stewardship of the Society during his three terms of office, 1995-6, 1996-7 and 2001-2 as President as well as terms as Vice President and Councillor. Charles is currently working on preparation for Wespac8 in April 2003. His message presented above weighs heavily on council's deliberations.

The new council elected after the AGM is taking on the task of reassessing the Society's priorities. The Society held its first formal meeting on 18th April 1971 with HV Taylor as President and has now been established for over 30 years. The Society is largely successful with nearly 400 members and over $250,000 in assets. We have held many successful Annual Conferences and International events, local technical meetings and social events. Acoustics Australia is a professional and internationally recognised acoustics journal.

Is this all we want? It is now time to pause, take stock and set a clear future direction to be sure that the Society is delivering what its members want. Council and Acoustics Australia will be attending an overnight workshop next year to identify, all we do, what we do best and what we should be doing. One outcome will be a members survey allowing the full membership to allocate priority to the identified possible future directions. I urge all members to *"Watch This Space."*

Ken Mikl

COUNCIL OF THE AUSTRALIAN ACOUSTICAL SOCIETY 2002-2003

President: Ken Mikl — **General Secretary:** David Watkins

Vice-President: Neil Gross — **Federal Registrar:** Terry McMinn

Treasurer: Gillian Adams — **Archivist:** David Watkins

Councillors

New South Wales	Queensland	South Australia	Victoria	Western Australia
Neil Gross	Gillian Adams	Byron Martin	Geoff Barnes	Tien Saw
Ken Mikl	Ian Hillock	Peter Teague	Charles Don	Terry McMinn

BANDICOOT — A NOVEL APPROACH TO USING A PITCH-CATCH ACOUSTIC PROBE FOR FIELD NON-DESTRUCTIVE TESTING†

Laurence P. Dickinson & Suszanne Thwaites
CSIRO Telecommunication and Industrial Physics, Sydney

ABSTRACT: The acoustic Pitch-Catch probe is commonplace in the world of aerospace non-destructive testing for the location of defects within a composite sandwich panel. However the usefulness of the technique is lacking in many respects, being cumbersome to use and generally very costly. Building on several years of experience, a new approach has been taken by CSIRO to produce a simple and versatile system that incorporates an optimised Pitch-Catch probe within an optical computer mouse and combined with a notebook computer, to provide a fully featured scanning system for a fraction of the cost of systems currently available. This paper describes the approach taken and some of the underlying research in developing the Bandicoot.

1. INTRODUCTION

The testing of composites consisting of a honeycomb core sandwiched between skins of various fibre composite mixtures presents some problems to the use of conventional ultrasonic methods. The impedance mismatch between the skin and core and the thickness of many of these constructions attenuates the ultrasound too much for good transmission or reflection. Thus it has become common to use alternative methods and, in particular, vibrational methods with frequencies less than 100 kHz. A range of such acoustic non-destructive testing (NDT) systems are commercially available and include the use of Pitch-Catch and Mechanical Impedance Analysis (MIA) techniques. Using existing commercial systems for the inspection of in-service damage to aircraft can be complicated and very costly. In many circumstances quantitative NDT cannot be carried out in the field due to the lack of skilled personnel and equipment, with the aircraft having to return to a service centre for inspection.

Traditionally acoustic probes have been used as hand pick-and-place devices . However, recently systems have become available where the probe can be attached to a C Scan system. An example is the MAUS system [1] built by Boeing where a track is attached to the structure by suction cups and the sensor is moved, by hand or automation along the track, allowing positional information to be encoded.

2. PITCH-CATCH ACOUSTIC PROBES

The Pitch-Catch principle is quite simple and widely used in acoustic, ultrasonic and many other wave propagation applications. The concept in its simplest form normally incorporates two transducers, one configured as a dedicated drive and the other as a dedicated receive channel (Hence the terms Pitch and Catch).

The type of pitch-catch probe shown in Figure 1 is typical of an acoustic frequency NDT device. In popular commercial systems the transducers are generally strengthened polarised ceramic bimorphs, consisting of bonded sandwiches of opposing polarised piezo-ceramic disks with a thin metal or ceramic shim between. When a voltage is applied to the transducers, one ceramic element will attempt to expand and the other to contract. This action couples through the adhesive bond to create a bending or flexing mode that achieves a much greater displacement amplitude than could be expected from thickness expansion of the ceramic elements by themselves. The bimorph ceramic disks are normally mounted with their edges free and mechanically coupled to the test specimen via a centrally located contact pin.

Excitation in various commercially available devices is usually a short tone burst or a swept sine chirp within the frequency range of 2 to 70 kHz. Various forms of often quite complex detection and analysis have been used to process the result and produce an output indicative of damage. In general these methods work quite well in that they are sensitive to the defects sought but in fact they are difficult to set up and to calibrate. Whilst this may not be a problem for skilled engineering personnel, it is very difficult to set up a system so that relatively unskilled operators can use it to make pass/fail decisions.

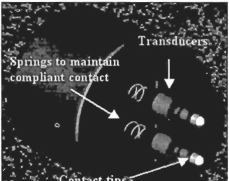


Figure 1. A typical Pitch-Catch probe configuration

† An earlier version of this paper was presented at the 2001 AAS Annual Conference, Canberra, November 21-23, 2001.

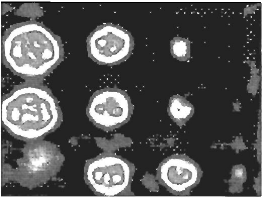


Figure 2. Pitch-Catch C-Scan of an impact damage test panel

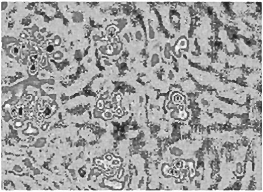


Figure 3. Same scan as shown in Figure 2 above, but this time the data was processed to highlight background scattering effects

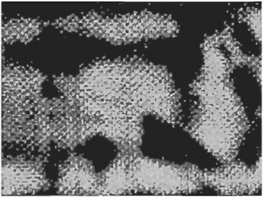


Figure 4. A scan of a panel analysed to highlight the honeycomb core.

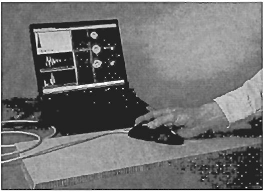


Figure 5. The Bandicoot demonstrator system examining a Nomex cored test panel.

3. THE CSIRO METHOD FOR NDT USING A PITCH-CATCH PROBE

In recent years CSIRO has been researching the use of a common acoustic Pitch-Catch probe for detection of soft impact damage to Nomex cored (paper resin honeycomb), carbon fibre reinforced polymer (CFRP) sandwich panels. This work [2] provided some very useful techniques for analysing the returned waveforms. In particular, analysis methods were developed that can isolate particular features within a test panel such as impact damage, background diffraction effects, and even the core itself. Examples of some relevant images are shown in Figure 2 to Figure 4.

The Bandicoot hand-held scanner

During the course of the study into soft impact damage in Nomex cored CFRP sandwich panels, the idea evolved that a practical outcome of the study could be the development of an improved Pitch-Catch probe, bundled with analysis software developed at CSIRO, and incorporated within its own low cost positioning system. The intended purpose of the design is to produce a simple and cheap NDT system.

The resultant demonstrator consisted of a Pitch-Catch probe housed with a dual optical positioning system, a PCMCIA digitisation card and a notebook PC. The system was given the name Bandicoot after a distinctly Australian mouse-like marsupial.

The hand-held probe

A typical implementation of the Bandicoot design can be seen in Figure 5. The handpiece contains the dual tipped Pitch-Catch sensors and two optical position detection units as well as several user defined contact switches. Also included within the probe are electronics for exciting the transmit sensor, and impedance matching and filters for the receiving channel.

The optical position detection units use light emitting diodes to illuminate a small area of surface that is imaged by a receiver. The two dimensional cross correlation between successive images is calculated giving x and y distances for any movement. As the two distance values are in the coordinate system of the unit, rotational motion cannot be detected and could cause positional errors. The approach taken in the Bandicoot to overcome this problem is to use two optical position units where the correction into the user coordinate system can be calculated knowing the distance between the optical detectors. All positional information is communicated back to a notebook PC via a standard USB port.

The base of the probe has 4 Teflon slides. These are distributed outside the area of the Pitch-Catch NDT sensors and the optical detectors so that the entire unit is held level with the test piece.

Micro switches are also set into the base of the probe to detect lift-off. This is necessary because if the probe is lifted off the panel the reference coordinate system is lost. A number of strategies are incorporated into the software to handle this contingency. The contact detection sensors are situated at the edge of the base in order to allow maximum sensitivity to lift-off.

4. EXCITATION IN TYPICAL COMMERCIAL PITCH-CATCH SYSTEMS

In most existing commercial instruments the user selects the operating points by looking for the parameters that give the greatest difference between good and bad sections of panel. This is one of the major contributory factors to the perceived unreliability of the method. Common pitfalls are:

¥ Selection of the wrong mode (eg. impulse, swept, other).
¥ Selection of the wrong frequency or frequency range.
¥ Selection of the optimal display mode. Data from the returned signal can often be displayed in a number of ways.
¥ Interpretation of the display.

Only some of these parameters will be controlled by the user and their uses are dealt with in the instructions accompanying the system. Even so, experience is required to implement them to the best advantage.

The Bandicoot excitation strategy

The Bandicoot system uses a somewhat unconventional excitation signal. Generally the excitation is quite broadband . In fact versions have been built where the excitation is a step function. However the optimum excitation, being a compromise between narrow and broadband excitation methods, is a burst of only two or three cycles of a sine wave.

A narrow band excitation gives a better detection in principle because most defects in sandwich panels have natural frequencies, determined by their size and type. In the past the reasoning behind the use of Pitch-Catch probes has been based on the idea that propagating Lamb waves are excited in the panel and detected as they pass the receive tip. Where there is a defect, the mechanical impedance of the panel is changed yielding both a delay, ie a phase shift, and an amplitude change between good and defective regions.

A lumped element model of a defect has been found to be most useful. The propagation velocity of flexural waves in sandwich panels are generally in the range 400 to 600 $m.s^{-1}$ and is non-dispersive [3]. Over much of the frequency range used for these probes this gives wavelengths larger than the defects, making propagation models problematic due to the small ratio of defect size to wavelength and the small tip separation.

If more energy is supplied at or around the frequency where the panel best responds, then there is a much better probability of detection and a more accurate estimate of defect boundaries. Where this frequency is known this is obviously a better choice. In fact it is not as difficult as has been traditionally thought to estimate this frequency to within a kHz or so, in some cases, on the basis of other known data [2].

On the other hand, if an appropriate frequency is not known, then a broadband excitation maybe more suitable. The main problem in using broadband excitation is that unwanted resonances, which often have a higher Q than the defect response, are also excited. These may come from the probe or from the test structure. All commercial probes have this problem. If this response falls at or near the defect frequency the functioning of the probe is seriously compromised. If it is sufficiently distant in frequency, band pass filtering will solve the problem but the filter needs to be of a very high Q itself to attenuate these resonances without attenuating the desirable part of the response.

Signal digitisation and processing

On board the Bandicoot probe, the received waveform is passed through a low pass filter for anti-aliasing, and a high pass filter to reduce mechanical, sliding and handling noise. Then it is digitised with a PCMCIA data acquisition card in a notebook PC. The current acquisition card has a maximum sample rate of 300 kHz and a 14-bit A/D converter.

The system is configured by the user in a set-up window, in which the digitised, windowed waveform and the FFT are displayed with the probe in a free running mode. Sampling rate, sample size, trigger delay and windowing function are all selectable but defaults are also included. The user can nominate a result to be the reference result or one may be retrieved from memory.

The frequency spectrum thus obtained is used for the defect detection. The time waveform is not used for the analysis because it is much less robust to handling noise or other interfering signals.

The spectrum usually contains data up to 50 kHz that appears quite complex and without further processing will not give a good result. It is necessary for the user to decide which parts of the spectrum are useful and which parts are artefacts of the equipment and test piece dimensions. On the basis of this knowledge a band of the spectrum can be selected for further analysis.

A selection can be made by viewing the spectrum collected over a good piece of panel. This reveals the frequency structure not introduced by the defect. Knowledge of the likeliest frequency band for defect response allows a range to be chosen where the effects of the defect are maximised compared to other structures, such as those introduced by the probe itself. A small number of built-in ranges are available for some popular sandwich constructions.

5. SCANNING

As mentioned above, the analysis is done in the frequency domain. A band of frequencies may have been selected, either

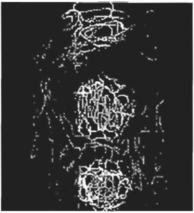


Figure 6. A typical Bandicoot scan

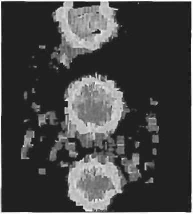


Figure 7. An enhanced image of the scan in Figure 6

by the user during set up or as the default or the complete spectrum can be used. The frequency data is compared to the reference data and a damage index calculated. This number is used to create a colour display of the scan area in the display graticule. An example scan is shown in Figure 6 and Figure 7.

Once a scan has been completed the data can be retrieved and the display recreated. Because the original waveforms have been stored, the software also allows the user to re-analyse them using a different frequency band or re-display the data using different colouring schemes. Areas and traverses of the image may be selected for dimensional measurements and a B Scan option is also available. In this mode the waveforms are displayed continuously in the data window as the mouse is moved over the display graticule.

6. THE NEXT GENERATION OF THE BANDICOOT

Due to the favourable response to the demonstrator, the Bandicoot is to be developed into a fully functional prototype. It is intended that this new design include some of the DSP technology that CSIRO has been at the forefront in developing. The new Bandicoot will contain within itself all electronics and processing required for comprehensive NDT without the need for expensive PCMCIA data acquisition cards. This leaves the notebook PC serving only as a data storage and display device.

Key features of the new design include the following:

¥ 48MHz microprocessor with 64KB of RAM.

¥ Communication and all power supplied by the USB port on a PC.

¥ Pitch-catch probe.

¥ 12-Bit, 400kHz data acquisition.

¥ 8-Bit Arbatry waveform generator.

¥ Dual optical encoders for millimeter accurate movement in X and Y directions, and rotational movement of the probe.

¥ Mechanical lift off detector and optical X-Y position reference (reflective spot) detector.

¥ Assorted LED indicators, Buttons and a Buzzer.

¥ Firmware fully configurable and downloadable from a PC.

By utilising existing CSIRO technology within the Bandicoot, development costs will be kept at a minimum while providing a capable unit that is simple to operate. The design also permits complete reconfiguration via downloadable software to enable the Bandicoot to adapt to new applications.

7. CONCLUSIONS

The Bandicoot is a novel [4] implementation of the acoustic Pitch-Catch probe technique for damage testing of composite panels. It uses new analysis algorithms designed to maximise reliability and increase sensitivity at the same time. The probe is housed in a computer mouse-like structure, which improves the reliability and reproducibility of the results. The probe interfaces with a PC in the conventional manner so a C Scan can be created on the display as the data is collected. Apart from the mouse, the only other hardware requirement is a suitable notebook computer.

ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the help and contributions made to this project by Bruce Gaffney, Denis Whitnall and Chris Cantrell. The CSIRO Bandicoot design and operating principles are filed under International Patent numbers PCT/AU02/00494, PCT/AU02/00501.

REFERENCES

1. Mobile Automated Scanner (MAUS), www.engineering atboeing.com
2. L.P. Dickinson and S. Thwaites, Characteristics of soft impact damage in composite sandwich panels using a Pitch-Catch acoustic probe *Acoustics Australia*, **27**(2), 37-40 (1999).
3. S. Thwaites and N.H. Clark, Non-destructive testing of honeycomb sandwich structures using elastic waves. *Journal of Sound and Vibration* **187**, 253-269 (1995).

IMPROVED NOISE MANAGEMENT FOR THE BUILDING INDUSTRY

Marion Burgess and Joseph Lai
Acoustics and Vibration Unit, School of Aerospace and Mechanical Engineering
The University of New South Wales at The Australian Defence Force Academy,
Canberra, ACT 2600

ABSTRACT: There is great potential for excessive noise exposure for workers in the general building industry as not only can the individual tools and equipment produce high noise levels but also the worker is usually close to the source of the noise. Effective noise management procedures are required to minimise the loss of hearing of workers on building sites. This paper reports on a project sponsored by WorkCover NSW for which the aims included identification of a baseline of current noise exposure levels on a representative range of building sites, assessment of the extent of the implementation of noise management codes on building sites and suggestions for strategies for improved implementation.

1. INTRODUCTION

Exposure to high levels of noise is common in the building industry as almost all the activities are noise producing. The statistics from around Australia for the building industry show that the high number of compensation claims for hearing loss, approximately 7%, is exceeded only by claims for sprains, strains, fractures, wounds etc [1]. The types of noises that construction workers are exposed to include those which are almost constant in sound level, such as from pumping, those which are intermittent such as grinding and sawing etc and those which comprise many short impact noises, such as from hammering, compacting etc. The worker is usually close to the machine or to the tool which is the source of the noise so the potential for excessive noise exposure is great. The nature of employment in the industry is quite different from most other industries. Only a small proportion of the workers are employed by a construction company and most of the workers on the sites are self-employed contractors or sub-contractors.

The general consensus is that there is an ongoing problem with the implementation of occupational health and safety (OHS) in general on building sites. Even basic safety precautions, such as the wearing of hard hats and safety boots, are sometimes overlooked in order to get the job completed quickly. Protection of hearing is low on the priority list particularly as hearing loss does not become noticeable in the immediate short term. Australian National and State Codes of Practice for Noise Management [2,3] and Standards [4] have goals to minimise occupational noise-induced hearing loss and tinnitus and include sections on Noise Control Planning, Engineering Noise Control Measures, Administrative Noise Control Measures, Personal Hearing Protectors, Training and Education, Noise Assessments and Audiometric Testing. It is obvious from the high number of compensation claims that these codes are not being adequately implemented on building sites. The aims of this project, sponsored by WorkCover NSW, included identification of a baseline of current noise exposure levels on a representative range of building sites, assessment of the extent of the implementation of noise management codes on building sites and recommendations for strategies for improved implementation. The full and condensed versions of this study report are available from the internet [5,6].

2. BACKGROUND

A literature search showed that only limited information was available on the noise exposure levels for the range of tasks on building sites. Many of the reports dealing with noise on building sites were focussed on the control of environmental noise for the nearby residents and not on the control of the noise for the workers on the sites.

One study from Australia was that by Milhinch and Dineen [7] which investigated workers views on noise and risk on a building site in Victoria. This study, funded by Incolink, the consortium responsible for workers compensation payments, sought to assess the noise hazards and the views of the individual workers on a major building site. Dosimeters were used to determine the noise exposures for a range of workers. Many of the workers were found to be exposed to high occupational noise levels but also there was great variability in the exposures for different workers in the one trade. For example, the noise exposure for plumbers ranged from 81 to 99 dB(A). The views of the individual workers indicated that the workers understood the importance of hearing but that they were more concerned about safety on site than hearing damage. In the second stage of this study, Dineen et al [8] investigated the efficacy of a hearing education program "Knock out Noise Injury" in modifying the beliefs of workers and their use of hearing protectors. The workers responded well to the education program which was based on examples of situations on building sites. They reported significant changes in their beliefs about hearing hazards. Those supplied with custom-made uniform-attenuation earplugs reported using the plugs more frequently than those provided with conventional hearing protection.

Another Australian study was that by Savage [9] who undertook a comprehensive investigation of noise exposures for workers on three high-rise building sites in Brisbane. The dosimeter data from 238 workers from 20 occupational groups showed 8-hour noise exposures greater than 85 dB(A) for all groups except the electricians and the plumbers, but only those work groups likely to be exposed to excessive noise were chosen for the study. Savage also found that the peak levels for seven of the 20 groups exceeded the limit with the highest being 146 dB(lin) for a formworker. These results must be considered with some caution as there is the possibility that the dosimeter data may include peak levels which were not directly related to the work.

3. NOISE EXPOSURE LEVELS

The limits for an unacceptable risk of hearing loss are specified in the various State and Territory legislation. Over recent years these have been changed to conform to the standard for occupational noise in the National Standard [2]. Thus in Australia the exposure to noise in the workplace should not exceed an 8 hour noise level equivalent of 85 dB(A) or a peak level of more than 140 dB(C). At the time the measurements were commenced this latter criterion was expressed in terms of dB(lin).

The determination of the 8 hour noise level equivalent is based on both the noise level and time duration for each activity during the day. For a structured working environment where the activities are regular and predictable, the determination is reasonably straightforward for either a daily assessment or for an average over a week. For a building site where the activities can vary greatly throughout the day and from one day to another, the determination is far more complex.

The first step was to obtain data on the noise levels for a range of activities and on a range of building sites. Four different types of building sites were identified: large city sites; large rural sites; small city sites; and small rural sites. Many tools and procedures are common to all sites but others are only used on larger sites. Visiting a range of sites also enabled assessment of any differences in work practices and in implementation of noise management procedures. Details of the sites and the noise levels for a range of activities are listed in the full report [5] and these are compared with and supplemented by published information from Australia and overseas.

The aim of the project was not to determine the noise exposure for any particular worker but to assess the potential noise exposure for the industry as a whole, and for particular parts within the industry. The goal was to identify and rank those areas of the industry that are at greatest risk of excessive noise exposure. This meant the data had to be consolidated while still being meaningful.

As described above the noise exposure is based on the noise level and the time, so both these aspects needed to be consolidated. Different tools are used for different time periods and even the same tool may be used for different periods for different tasks. Observations and discussions with those in the industry led to the use of three categories for the typical usage times:

long	2 hours or more per day
medium	30 mins to 2 hours per day
short	less than 30 minutes per day

The noise level for any particular task can vary with the actual job and with the workplace. A convenient method for categorising the noise levels was to use overlapping 10 dB noise level ranges with an additional category of less than 85 dB(A).

Table 1. Ranking of tasks by noise exposure based on the types of tasks

Range for $L_{Aeq,8h}$	Tasks	Comment
100 to 110 dB(A)	Work involving cutting into concrete, such as wall chasing.	On large sites this could be done by one person for most of the day with the only breaks being the time necessary to move and set up at the next wall.
95 to 105 dB(A)	Work involving cutting and chipping concrete, such as use of Kanga Hammer	On large sites it is quite common for this task to be undertaken by one person for most of the day with the only breaks being the time necessary to move and set up at the next location.
90 to 100 dB(A)	Work involving cutting and sawing timber Work involving a considerable amount of metal grinding	Even on the smaller sites it is possible for one person to spend most of the day using power tools for cutting and sawing of timber. Metal grinding is usually for lesser time periods.
85 to 95 dB(A)	Work involving cutting of concrete blocks and bricks Work involving mechanical rollers	The operator could spend about half the day actually cutting with the remainder of the day spent measuring, stacking etc. These can operate continuously throughout the day.
80 to 90 dB(A)	Use of most power tools Work such as driving excavators	While many of the noise levels for individual tasks may be high, the time duration for these tasks can be quite short and the noise exposure depends on the number of times they are repeated during the day.
less than 85 dB(A)	Most general labouring work	Main risk is the proximity of other noisy activities.

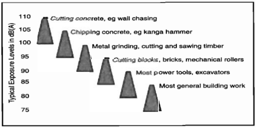


Figure 1. Ranking of tasks by noise exposure based on the types of tasks. The triangular shape indicates that the number exposed to the higher end of each range is less than the number at the lower end of the range

Comparing the types of activities, the noise level category and the time period category a ranking of the tasks in terms of noise exposure was attempted. The ranking which eventuated from this analysis is shown in Table 1 and summarised in Figure 1. It is important to note that this ranking does not allow for the additional contribution to the noise exposure from other activities in the vicinity of the worker.

In order to gain an indication of the noise exposure for various trades, they were categorised into four main groups commonly used in the industry, namely:

Plant includes excavation, bobcats, backhoes etc

Materials Handling includes rigging, dogging, fork lifts, cranes, scaffolding etc

Construction includes concreting, bricklaying, external carpentry etc

Fitout and Finish includes plastering, tiling, painting, internal carpentry, etc

The noise exposures were estimated from the typical tasks undertaken by the various trades and are shown in Fig 2. This type of analysis shows that a large proportion of the workers on building sites are likely to have noise exposures greater than 85 dB(A) with a smaller proportion having much higher exposures. This emphasises that there is clearly a need for effective noise management programs for building sites.

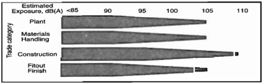


Figure 2. Estimation of noise exposure for different trades. About 50% of the workers in each trade would be within the rectangular area

The other important criterion for assessment of excessive noise is that the peak noise level should not exceed 140 dB(C). In this study the use of explosive tools was the only event found to produce levels above 140 dB. The level depended on the charge used and for the most commonly used size the measured value of 155 dB agrees well with the 150 dB measured by Savage [9] for a ramset gun. The hammering for the erection of the scaffolding was next in ranking of impulsive noise with peak levels in the range 130-140 dB.

4. IMPLEMENTATION OF THE CODE OF PRACTICE

There is a similarity between the codes of practice for noise management for each of the States as they rely on the same basic principles. Following is a summary of the assessment of the extent of implementation of each part of the code on the building sites visited in NSW. This assessment was based on discussions with the various representatives from the industry and site inspections.

Noise control planning – the essence of this section of the code is that a written noise control policy and program of action should be developed in consultation with employees and employee representatives. There was no evidence that planning for noise control was considered except where there were environmental noise constraints.

Engineering noise control measures – an important objective of the code is the requirement to minimise noise exposure by engineering noise control measures. Essentially this involves two options: noise control at the source and control of the spread of noise. The only evidence noted was the use of low noise blades in brick saws, of placement of generator away from the workers on the site perimeter and improved design of the cabs of earth moving equipment.

Administrative noise control measures – these measures generally involve job rotation to reduce the time of exposure to the higher noise levels. There was no evidence that these measures were considered.

Personal hearing protectors – the code states that personal hearing protectors should only be regarded as an interim measure while the control of noise by other measures is being implemented. On most building sites this appears to be the only approach to the management of noise exposure. While the protectors were available they were usually not personally issued nor was their use enforced. Effective use of personal hearing protectors also requires adequate consideration of a number of aspects including indication signs, selections of suitable protectors, inspection, maintenance, clean storage and instructions for use. Commonly these aspects were not catered for.

Training and education – this should be considered to be an integral part of a preventive strategy. General OHS training usually includes some reference to use of hearing protectors but this had clearly not been adequate.

Noise assessment – this is required in all workplaces where it is considered that the noise levels may be excessive and the reports on assessments should be available to management, worker representatives and relevant authorities. There was no evidence that such occupational noise assessments had been undertaken.

Audiometric testing – audiometric testing alone does little to reduce on- going hearing loss but a comprehensive noise management program should include comparison of audiograms and investigations when hearing loss is *identified.* While ad hoc audiometric testing was available for the employees of the larger companies or by the Union, there was no evidence of regular audiometric testing programs.

5. STRATEGIES FOR IMPROVED IMPLEMENTATION

Government agencies faced with the task of improving noise management programs need to consider the actions which will be most effective for that particular industry while conforming to the government policies. For example, regular inspections and substantial fines for infringements may be effective but may not be in accordance with current policies. There are two main considerations within agencies regarding implementing policies and procedures:

priority in taking action — ie high, medium and low priority
time to implement strategy — ie short , medium or long time

Based on the findings from this particular study, over 24 strategies were recommended with almost half being in the highest priority suggesting immediate action. It was estimated that some strategies would only need a few months for implementation while others may take around two years. The issues addressed by the strategies for the main areas of the code of practice are summarised below.

Noise control planning

A major limitation in adequate planning to minimise noise exposure is a lack of knowledge of the noise levels for plant and noise exposures for various activities. Legislation in some States includes requirements for the provision of noise level data for plant and equipment. Enforcement is needed to ensure that suppliers do in fact provide this noise level information as part of the technical data.

Many of the codes of practice for various trades, trade courses and OHS inductions include general advice about noise levels but this is not sufficient for adequate noise control planning. Information is available to update and revise these documents to assist adequate noise control planning.

The implementation of work methods statements which are being required for construction projects should encourage planning but they need to be checked for adequate inclusion of noise management.

Engineering noise control measures

Australia imports most of the items of plant and equipment used on building sites. Thus the focus should be on encouraging the purchase or hire of those items with lower noise levels. The provision of noise data in specifications and promotional material is essential to encourage selections of items with low noise output.

Promotional material from the suppliers and the government agencies should include examples of the use of noise enclosures and simple screening as well as the importance of maintaining these noise control elements.

Administrative noise control measures, job rotation etc

The encouragement of multiskilling in the building industry effectively leads to job rotation which has great benefits in many aspects of OHS including opportunities for reducing noise exposure. There does need to be an effective plan and appropriate record keeping to achieve the reduction in noise exposure. Again promotional material and codes of practice can be used to encourage this aspect of noise management.

Personal hearing protectors

Undoubtedly these will continue to be the major form of noise management on building sites. Therefore high priority should be given to this part of the noise management program.

Unlike other protective equipment, such as hard hats and safety boots, hearing protectors are only required at specific locations on building sites so the placement of warning signs at the entry of the site is not appropriate and they are usually ignored. The warning signs should be placed at the location of the noisy activity as well as on the individual items of equipment for which typical use could lead to excessive noise exposure.

Hearing protectors should be part of the personal safety issue to each worker and not just available from a common store area. They should be readily available so that the worker does not have to travel across the site for issue of disposable plugs.

All aspects of selection, use and care of the protectors should be an important part of the OHS induction training. Building sites can be particularly dirty environments so special attention to cleanliness and care is essential. Promotional material for the various trades should emphasise that other methods of noise control should be considered. When personal protectors are required they must be selected for personal issue in consultation with the employee to ensure comfort and suitability and to encourage consistent and correct use.

Training and education

Training programs need to be targeted specifically at the building industry. A well presented training package which caters for the differing backgrounds of those working in the industry should include examples specific to the building sites. An effective mechanism would require visual presentation such as a video. Such a training package has been developed by Comet Training in NSW and was reviewed in a recent issue of this journal [10].

Regular items submitted to trade journals, newsletters and the general public media should increase the awareness of and maintain the emphasis on noise management.

Noise assessment

Government inspectors and union officers should be encouraged to undertake noise measurements as part of their visits to sites. These assessments should be primarily used for guidance to those on site for identifying potential excessive noise levels. Quantifying the noise levels would increase the general knowledge on typical noise levels and provide the opportunity to reinforce the education and training programs.

Audiometric testing

While it is not a control measure itself, regular audiometric testing is an important tool for a noise management program. In particular it can be used to identify early loss of hearing and to reinforce the other aspects of the noise management program. For many jurisdictions in Australia such testing cannot be enforced nor made a pre-requisite for continued employment or insurance cover. Under these circumstances encouragement may be provided with an incentive, such as a reduced insurance premium for regular testing.

6. CONCLUSIONS

This study has shown that the noise exposure for many on building sites can be excessive. Those trades involved with cutting and chipping concrete experience the higher noise exposures. The high number of claims for compensation for hearing loss indicates ineffective noise management on building sites. The study of practices on a range of sites showed that the implementation of codes of practice for noise management is still far from satisfactory.

Strategies for encouraging improved implementation of the requirements of the codes of practice for noise management have been suggested. There is a need for greater emphasis on education and training which is focussed for those in the building industry. Also promotion of the noise levels for different tools should encourage selection of low noise items. Personal hearing protectors are likely to continue to be the main method of noise management and greater attention should be given to selection, care and maintenance.

It is rewarding to note that the sponsors of this project, WorkCover NSW, accepted that actions were required to improve the implementation of noise management on construction sites. It was identified as a key issue and a group of inspectors have received additional training in effective noise management as it could be applied to construction sites. As well as focussing on noise issues during their inspections these officers participated in a series of seminars held by WorkCover for the industry. It is early days yet but there is optimism that improved implementation of noise management will be eventually achieved.

Around the time this project was being undertaken, there was some relevant action in the USA driven by the Labourers' Health and Safety Fund of North America. The Construction Noise Control Partnership has been established. This is a coalition of unions, contractor associations, insurance companies, universities and government agencies dedicated to promoting quieter construction sites. Updates on progress with a best practice guide for noise control can be found on the website [11]. This working group has also been involved with the United States Occupational Safety and Health Administration, OSHA, seeking rulemaking to revise the construction noise standards. This revision is aimed at including a hearing conservation component for the construction industry that provides a similar level of protection to that afforded to workers in general industry. The proposal [12] was released in August 2002 for a 4 month public comment period.

ACKNOWLEDGMENTS

This research was funded under the WorkCover New South Wales Injury Prevention, Education and Research Grants Scheme. The research conclusions and any views are not necessarily those of WorkCover. The authors are grateful for the financial support and technical advice from WorkCover NSW. The work would not have been completed without the enthusiastic support from the representatives of the bodies involved with OHS issues in the industry including the Construction Forestry, Mining and Energy Union, the Master Builders Association, COMET Training, Multiplex, Painter Dixon, John Holland plus various contractors and consultants to the construction industry.

REFERENCES

1. Worksafe Australia (1995) *Compendium of Workers Compensation Statistics*
2. Worksafe Australia (2000) *Occupational Noise National Standard, NOHSC:1007*, and *National Code of Practice*, NOHSC:2009
3. WorkCover NSW (1996), *Code of Practice Noise management and protection of hearing at work,*
4. Australia/New Zealand Standard (1998) *Occupational noise management – Parts 0 – 4* AS/NZ 1269
5. Burgess M. and Lai J.C.S. (1999) *Noise Management For The Building Industry Current Practices and Strategies for Improvement Condensed Report*, WorkCover NSW (available at http://www.workcover.nsw.gov.au)
6. Burgess M. and Lai J.C.S. (1999) *Noise Management For The Building Industry Current Practices and Strategies for Improvement – Full Report*, WorkCover NSW (available at http://www.unsw.adfa.edu.au/AMEC/avu)
7. Milhinch J and Dineen R (1997) *Noise and Hearing in the Construction Industry*, Incolink, Vic, Australia
8. Dineen R, Reid J and Dineen C (1998) *Knock Out Noise Injury - An evaluation of the influence of education on workers' understanding and management of noise hazards in the building and construction industry*, Incolink, Vic Australia
9. Savage M (1997) *A report into workers exposure to occupational noise within the high-rise construction industry*, Masters Research Project QUT, Australia
10. Burgess M (2001) Review of Education Package, *Hear today gone tomorrow: Noise management and protection of hearing at work* produced by Comet Training, Acoustics Australia 29,3, pp 123
11. Laborer s Health and Safety Fund of North America, Construction Noise Control Partnership at: www.lhsfna.org/_noise_partnership.html
12. United Stages Government Federal Register, Proposed Rules Vol. 67, No. 150, pp.50610- 50618 (2002)

RECORDING THE OPERATIC VOICE FOR ACOUSTIC ANALYSIS

Densil Cabrera§, Pamela Davis #, Jennifer Barnes#, Margaret Jacobs* and David Bell#
§ School of Architecture, Design Science and Planning, # The Conservatorium of Music, and the * Faculty of Health Sciences, The University of Sydney NSW 2006.

ABSTRACT: This paper considers a number of factors related to the recording of the voices of operatic singers for acoustic analysis. We wanted to develop a technique for recording these singers in non-anechoic environments so we tested head-mounted microphones. We tested their effectiveness in recording the direct sound produced by the singer with relatively little interference from the reflections of the sound in the recording environment. We examined the effectiveness of various near-field microphone positions using a head and torso simulator in anechoic conditions and applied these observations to recording an operatic soprano, comparing the head-mounted and reference microphones. We also determined, that, for this singer, there was appreciable movement of the head and body during operatic singing, even when the singer tried to avoid moving.

1. INTRODUCTION

Successful operatic performances rely on the ability of singers to produce a voice that will be audible unamplified in large theatres, over an orchestral accompaniment and other singers. Audibility of an operatic voice in such circumstances appears to rely upon selective amplification of the voice in the part of the spectrum at which the human ear is most sensitive. The term "singer s formant" is in widespread use following observations that bass, baritone, tenor and mezzosoprano operatic singers project their voice over an orchestra by their 3rd, 4th and 5th formants with a relatively high energy peak at ~3 kHz [1-4]. The lower frequency range is important for articulatory and fundamental frequency features and there is harmonic energy up to at least 8 kHz. The recording system (microphone, pre-amplifier, recorder and digitisation hardware /software) must be able to encode the voice signal in this range, with as little error or distortion as possible and with an acceptable resolution so that features of the singing voice may be interpreted from spectral analyses.

There are other considerations in choosing a technique for the successful recording of operatic voices for research. One of these is that the singer may move during performance, depending on the expressivity of the music and the singer s emotional connection to it. Some opera pedagogues teach singers to use a shift of weight to the back foot just prior to a high note, which may be thought to assist postural support for the high note. Any shift of body weight or movement is likely to be associated with a change in the distance of the mouth to a fixed microphone. Mellody et al. [5] allowed operatic singers to move freely but this resulted in them reporting that the signal-to-noise ratio was affected by background noise, apparently from movement of their microphone which was mounted on the singer s clothing.

Singers are usually asked to maintain a constant microphone to mouth distance because the sound pressure level (SPL) diminishes as source-receiver distance increases, and a relatively small change in microphone to mouth position can significantly affect the measured SPL. Instructions to maintain a constant microphone to mouth distance, even by the placement of measuring rods between the microphone to rest on the subject s chin [6], may avoid these errors but vigilance is required on the part of the singer and the experimenter to monitor closely the distance during recording and to repeat tasks if movement occurs. It is likely that this level of vigilance on the part of the singer will interfere with his/her emotional expression, particularly in less experienced singers, and this may distract the singer from realising the experimental task successfully. Another approach has been to place a microphone on a harmonica holder on the subject s chest [7] although they acknowledge that head movements of the subject may result in microphone to mouth distance variation.

An alternative approach places the recording microphone at relatively longer distances from the singer, such as 40 cm [8], 50 cm [9] or 6 feet (approximately 183 cm) [10] as small variations of microphone to mouth distance will have a relatively smaller effect on the overall measured SPL. However, the transfer function from singer to microphone will be affected by reflections in the room, with the potential for significant comb-filtering effects. Furthermore, the longer-term room acoustical effects of reverberation and certain room resonance modes may also affect the measured sound spectrum. Closer recording distances will maximise the strength of the direct sound of the singer in non-anechoic rooms.

Head mounted microphones have been advocated recently for voice recording, with comparable data for voice features being recorded by a head-mounted condenser microphone as compared to a larger, professional grade, stand-mounted condenser microphone [11]. Microphone to mouth distance has been varied from 38 mm [12] to 51-76 mm [10]. A focus of this and other recent studies [11,13] has been how the choice of microphone may affect the measurement of parameters often used to describe impaired voice quality. There has been relatively little study on recording techniques appropriate for recording operatic voices.

There are other factors that may affect the selection of a head-mounted microphone technique to record operatic voices. Operatic singers may not always be available to be recorded in an anechoic chamber, or wish to sing in such an unusual artistic environment. A technique that would record the direct sound of the singer in preference to the reflected sound in the room would yield additional research recording opportunities if recording could take place in quiet rooms that were not sound-treated. A singer should be able to perform as naturally as possible, without limiting head and body movement, and so it is important to determine whether the mouth to microphone distance of a head-mounted microphone varies with performance and the effect of small variations in the recording distance on the recorded sound.

The vocal signal is not radiated uniformly around the head [14-16] and the sound spectrum is affected by the microphone position. The air flow from the mouth is likely to cause noise for a microphone in the air stream, making near-field axial microphone positions impractical without a substantial windscreen and high pass filtering. Dunn and Farnsworth [14] found that positioning a microphone 45¡ off axis produces little spectral weighting of speech (relative to the axial spectrum), and removes the air flow problem. For example a microphone 50 mm from the mouth, 45¡ to the side, suffers a 2 dB range of deviations from the axial spectrum for the eight 1/2-octave bands covering the 500 Hz — 8 kHz range.

Near-field mouth radiation data are also given by ITU-T Recommendations P.51 and P.58 [17-18], which specify the performance of an artificial mouth and a head and torso simulator. The mouth reference point of an artificial mouth is 25 mm in front of the lip plane on the mouth axis, and would be subject to air flow distortion in a real person. Like other published data, the ITU-T data show a relative reduction in high frequency sound pressure when the near-field measurement position is shifted off axis, with a greater reduction for larger angles.

A directional microphone, such as one with a cardioid directivity pattern, could be used in non-anechoic environments to reduce the effect of the indirect sound. However this approach has the accompanying problem of the proximity effect , where low frequencies are boosted in the near-field because of the microphone s sensitivity to pressure gradient [19]. A further practical disadvantage of a directional microphone is that its orientation must be carefully maintained.

As the measured pressure spectrum of a singer is affected by the microphone s relative position, comparing study results that use different microphone positions can be treacherous, especially as the ~3 kHz singer s formant is likely to be affected by microphone position. A utopian solution would be for all studies to apply the same measurement position. More practically, difference spectra between measurement positions could be used, tentatively, for comparisons between studies. However, the frequency-dependent radiation pattern varies with the mouth opening shape (and other factors), and hence between phonemes [15,16]. More research is required before such transformations can be executed with confidence using data from singers.

It is worth noting that in a typical unamplified operatic performance, the audience is likely to receive more reverberant sound energy originating from the singer than direct sound energy. This suggests that the overall sound power spectrum, integrating sound radiated to all directions, could make at least as good a reference measure as any of the pressure measurements previously discussed. Of course, the difficulty is measuring the sound power of a time-varying and moving performer — it is not really practical to do that in a naturalistic setting.

This aims of this paper are to determine: (a) the relationship between the sound power spectrum and pressure spectrum for various near-field microphone positions; (b) the optimal mouth to microphone distance and position for recording operatic voices using a commercially available head-boom mounted microphone; (c) whether a head-boom mounted microphone is successful in being able to record the direct sound produced by the singer with relatively little interference from the reflections of the sound in the recording environment; and (d) to report on applications of these techniques to record the singing voices of operatic singers.

2. SOUND POWER AND PRESSURE OF A HEAD AND TORSO SIMULATOR

Method

The Br el & Kj r Head and Torso Simulator (HATS) is equipped with an artificial mouth, consisting of a high compliance electrodynamic loudspeaker mounted inside the head, such that the sound is emitted from a rectangular mouth area 30 mm wide and 11 mm high. The mouth radiation properties comply with the cited ITU-T recommendations. The purpose of this part of the study was to relate a series of SPL measurements, close to side of the mouth, to the radiated sound power of the HATS. The interest in these side measurements was because it is quite easy to position a head-mounted microphone in line with the lips, horizontally displaced from the corner of the mouth.

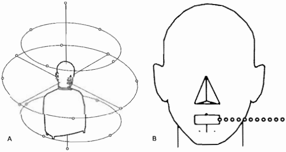


Figure 1. A. Illustration of the eighteen microphone positions used to determine the spatially integrated radiation spectrum and directivity pattern of the HATS. Each microphone position (represented by a small circle) was 1 m from the centre of the head at mouth height, and measurements were conducted in an anechoic room. B. Illustration of the eleven near-field microphone positions extending in a line to the left of the HATS mouth.

With the mouth radiating a constant pink noise stimulus, measurements were initially made in an anechoic room at a distance of 1 m from the centre of the head at mouth height, at 18 positions evenly distributed across a sphere surface (Fig. 1A). Eleven measurements were also made at 10 mm intervals in a line extending horizontally from the mouth edge to the side (Fig. 1B), and a twelfth at the mouth reference point. In the series of eleven measurements, the closest measurement was 0 mm from the mouth edge, meaning that the microphone was almost touching the HATS. A B&K 4135 1/4-inch microphone was used for all measurements described in this section. 1/3-octave measurements were made using a B&K 2131 spectrum analyser.

It is important to note that the axial distance measurements given in the ITU-T recommendations are from a lip plane 6 mm in front of the physical mouth orifice. However, the measurements reported in this paper are stated in terms of the distance from the physical mouth orifice. The principal reason for this is that we were interested in studying lateral microphone positions in line with the physical lip plane, because of the aforementioned simplicity in positioning microphones along this line.

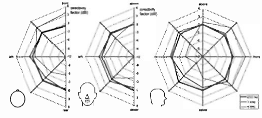


Figure 2. Octave band directivity factors for 250 Hz, 1 kHz and 4 kHz for the HATS at a distance of 1 m.

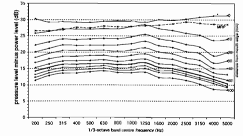


Figure 3. Difference between sound pressure level and sound power level for the eleven lateral measurement positions, as well as for the mouth reference point (MRP). The spectrum for 70 mm is in bold.

Results

In absolute terms, the measured sound power of the HATS is of little interest, because it depends on the signal spectrum and amplifier gain. However, as a reference, the sound power can be used in the determination of directivity factor, and also as a reference for the close microphone measurements. Directivity factor is the ratio of sound intensity radiated in a specific direction to the average intensity radiated in all directions, and can be expressed as a simple ratio, or else in decibels. Although measurements of directivity factors were made in 1/3-octave bands, they are presented just for three 1-octave bands in Figure 2 for the sake of succinctness and legibility. As might be expected, the directivity factors increase in the frontal axis in the high frequency range, due to the size of the mouth (as radiator) and head and torso (as barrier/reflector). The measurements also show that three of the 90¡ positions (left, right, and above) have directivity factors not far from 0 dB across the 200 Hz-5 kHz measurement frequency range, and might therefore be good choices for microphone positions if the overall radiated sound is of interest.

Similar results, for a custom-built dummy and for singers, can be found in Flanagan [15] and Marshall and Meyer [16] respectively, although those studies do not express the radiation in terms of directivity factor. The sudden decrease in high frequency intensity that occurs beyond 90¡ from the mouth axis is also found in those studies.

The results for the close measurements are shown in Figure 3. Between 30 mm and 100 mm the sound spectral components decrease by about 5 dB per doubling of distance, and this is reasonably independent of frequency. This may be contrasted with the 6 dB per doubling of distance (inverse-square law) which is found for this distance range in axial measurements [15, 18-19].

Figure 3 also shows the relationship between pressure level and power level at the mouth reference point (MRP), which is 26 mm in front of the physical mouth opening. As might be expected, the MRP sound pressure measurement contains relatively more high frequency sound than the power spectrum. On the other hand, most of the close lateral measurements show a reduction in high frequency sound (relative to the power spectrum), and a minor peak at 1.25 kHz.

The spectrum for the 70 mm distance is marked in bold because this distance was ultimately selected for measuring opera singers. The fact that the spectral contours in this region show a high degree of parallelism means that some inaccuracy in positioning a microphone will not significantly affect the resulting spectral profile.

3. TESTS OF A HEAD-MOUNTED MICROPHONE AND NON-ANECHOIC CONDITIONS

Method

Two miniature condenser omnidirectional microphones were tested for use in recording operatic voices: an AKG C477 WR oc/P (called here microphone 2) and an AKG 577 (called here microphone 3). The AKG C477 is manufactured with the microphone mounted on the left side and the AKG 577 is an earlier model not supplied with a head boom. These microphones were selected on the basis that the manufacturer s specifications include a relatively flat frequency response from 0.1-10 kHz, which encompasses the range of interest for operatic voice analysis, and a stated A-weighted signal-to-noise ratio of >68 dB.

The free-field frequency responses of these microphones were assessed by comparison to a B&K 4190 1/2-inch free-field microphone, using a JBL 4206 loudspeaker as the source, at a distance of 1 m on axis. The spectrum of a pink noise signal for each microphone in the reference position was obtained using a B&K 2034 FFT spectrum analyser. The frequency response of microphones 2 and 3 were determined by subtracting the sound level spectrum of the B&K 4190 from their raw sound level spectra.

Testing was carried out with author Jennifer Barnes, who is an operatic soprano rated as a "national — major principal [3.1a]" on the Bunch and Chapman [20] taxonomy of singers. Initial tests revealed that peak clipping was difficult to prevent with the AKG microphones 2 and 3 set at distances of 50 or 70 mm from the corner of the subject s lips, especially on the high soprano notes. The manufacturer s specifications are that the maximum SPL of the AKG C477 microphone is 133 dB (re 20 micropascals) and this seemed adequate for the very powerful operatic voice. A microphone pre-amplifier which permitted a two stage preamplification (Behringer 2200) solved the clipping problem, using auditory as well as visual monitoring via oscillographic real-time display of the recorded signal.

Comparison was made of simultaneously recorded AKG microphone 3 set at 50 mm laterally and a calibrated B&K 4190 microphone set at 300 mm on axis. The singer was recorded in a recording studio singing the first verse of *"Advance Australia Fair"*. Spectra of the recorded samples were digitised (sr=16 kHz, Loughborough Sound Images PC/C32 board) and analyzed using Soundswell Version 4.00 software (Hitech, Sweden). The two song raw spectra levels (125 Hz intervals) were calibrated to the SPL for the two calibration signals recorded for each microphone system. The spectrum recorded from AKG microphone 3 was corrected for its frequency response.

To assess movement of the microphone to mouth distance, the subject was fitted with microphone 2 on the head boom at 70 mm and asked to sing parts of an operatic song (*"Torna a Surriento"*) and an aria (*"Un bel di"* from *Madama Butterfly*) moving her head as little as possible. This was repeated with the AKG microphones set on fixed rods at various distances up to 100 mm from the side of her lips. A video camera was used to film her head and neck from the front and the side during singing. A 20 mm measurement grid was placed on a fixed rod at the level of the microphone and was used to measure the distance of the subject s lips to the boom-mounted microphone. Images of the singer and the microphones were printed and magnified, and distances were measured using the grid.

A software program called MLSSA (Maximum Length Sequence Signal Analyzer) was used, together with a sealed 4-inch loudspeaker (prior to the HATS s availability), to quantify the effect of the non-anechoic recording environment on the signals recorded from microphones 2 and 3. MLSSA uses a pseudo-random noise signal with a white spectral envelope to determine the impulse response of a system by cross-correlating the test signal with the measured signal. The impulse response shows the pattern of reflections produced by the system, as well as the general reverberant sound decay. The transfer function of the system is determined by applying a fast Fourier transform to the impulse response. Tests were done in a recording studio (10 m x 6 m plan, 0.4 s mid-frequency reverberation time) and a quiet office (3 m x 4 m).

Results

Frequency responses of the head-mounted microphones

Free field measurements found that the two AKG head-mounted microphones exhibit significant variation in sensitivity across the frequency range, with a notch in the vicinity of 3.5 kHz, and a peak around 4.0 kHz (Fig. 4). Microphone 2 had the wider variation, with sensitivity range of 8 dB between these frequencies. The large spectral irregularity in this region is of particular concern because it is in the range of the singer s formant. In fact, the singer s formant ranges between 2.5 and 3.5 kHz meaning that the microphone characteristics need to be factored into an analysis of this aspect of the singing voice.

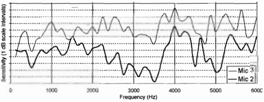


Figure 4. The measured free field frequency response of the two AKG head mounted microphones.

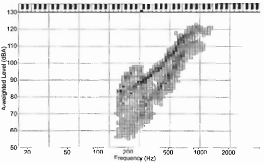


Figure 5. Phonetogram of a soprano voice, indicating a dynamic range of 63 dB.

Operatic voice recording

The phonetogram generated by the singer subject singing successive notes through her range is illustrated in Figure 5. Measured from microphone 2 at 70 mm lateral from the corner of the lips on the headphone boom, there was a 63 dB dynamic range over the singing range from 56 dB(A) on D3 (147 Hz) to 122 dB(A) on her top note E6 (1319 Hz). This is typical for soprano voices of similar experience and such a range presents a challenge to record the highest notes without distortion.

Extent and effect of head movement

During singing, the microphone to mouth (corner of lips) distance to the AKG microphones fixed on a rod placed lateral to the singer showed considerable change (range 8 mm shorter to 12 mm longer over various tasks) compared to the rest position. These observations were from video images recorded front-on and did not take into account the degree of front-back movement. However, two lateral video recordings revealed that there was considerable movement forward and backward with up to 80 mm movement between the lips and a fixed object during the operatic song and 100 mm for the more emotional aria. This lateral video recording also revealed much greater vertical movement (up to 80 mm) during performance of the aria. Such movements imply large changes in the mouth-microphone transfer function.

There were smaller changes in the microphone to mouth distance during singing using the head-mounted C477 (mean 4 mm longer, SD 2 mm) and some of these changes appeared to relate to changes in mouth shape as the mouth opened and closed for the various phonemes, a topic which warrants more detailed study. There appeared to be negligble front-back and up-down movement artefact as the microphone moved with the singer.

Effect of non-anechoic environments

The recording studio used to record the singer exhibited a number of room reflections (from the MLSSA data), the strongest being at 21.5 ms at —30 dB relative to the direct impulse. This corresponded to a glass wall 3.4 m in front of the subject. When the equivalent FFT plots for the anechoic room and the recording studio were overlaid, there was negligible effect in the frequency range of interest, with less than 1 dB difference in the high range. In the office, two reflections were apparent around 12 ms and a level of —30 dB, corresponding to a large glass window. When the anechoic and office data were compared, there was less than 2 dB differences across the spectrum range of interest. No voice recordings were carried out in this office although this was used for subsequent experiments recording opera singers simultaneously with laryngeal endoscopy [21-22].

4. DISCUSSION

This paper has described a technique to record operatic voices with a wide dynamic range. A head-mounted microphone allows the microphone position relative to the mouth to be well-defined and stable. Positioning the microphone to the side avoids the problem of air-flow-induced noise, and also has the advantage of a simple measurement for positioning. The close side position suffers a loss of high frequency sensitivity, compared both to the axial frequency response and the overall sound power frequency response.

The AKG C477 and C577 head-mounted microphones show a degree of spectral irregularity which would substantially influence the interpretation of data (such as formant frequencies and strengths) unless compensation is applied. Measurement grade microphones, which would not require compensation, have rarely been used in singing studies.

Previous studies have used an anechoic chamber to achieve accuracy in recording [1,3]. The recording system described here, which optimises the singer s sound in preference to the recording environment, has been particularly useful in recruiting professional operatic singers who have volunteered to be recorded in places such as a rehearsal room near their workplace rather than having to travel to an anechoic chamber with its associated artistic unfamiliarity.

Movements of a singer relative to a fixed microphone seems unavoidable even when the singer is unusually disciplined (as our subject was) and attempting to remain as still as possible. These variations in the mouth to microphone distances appear to preclude the use of fixed microphones in the near field for recording voice for acoustic analysis.

A recent paper Mellody et al. [5] recorded operatic voices using a body-mounted microphone and reported that the recording levels were continuously altered during recording to avoid overloading due to the dynamic range produced by the singers. This technique of optimising the energy levels is common among audio engineers in music theatre, television and radio broadcasts but it effectively precludes meaningful acoustic analysis of the voice energy. In another recent study of soprano vowels, Weiss et al [10] reported that strong voices that were close miked (two to three inches from the mouth) produced an "almost square wave pattern" which assumed a more normal shape as levels decreased, suggesting that the recording levels were too high or, more likely, the microphone had been overloaded at these high levels of operatic voices. These reports add to some of our earlier observations that the dynamic range of operatic voices recorded with close microphones deserves special consideration.

The well-known observation of the directivity of the higher frequencies, illustrated in Figure 2, has important pedagogical applications. A singer hears their singing voice with the air-conducted sound having a considerable loss of energy in the "singer s formant" region. It is understandable why young singers need to rely upon recordings made from the front and upon their pedagogue s ear. The successful opera singer appears to have the ability to rely upon the proprioceptive sensations from their body to achieve projection over an orchestra, more so than their auditory feedback. This must be a very hard lesson for young opera singers as it is this quality that translates to audition success. This area warrants further investigation, as it has practical application to pedagogy.

REFERENCES

1. G. Bloothooft, and R. Plomp, "The sound level of the singer s formant in professional singing" *J. Acoust. Soc. Am* **79**, 2028-33 (1986)
2. J. Sundberg, "Articulatory interpretation of the singing formant" *J. Acoust Soc. Am.* **55**, 838-844 (1974)
3. J. Sundberg, " The Acoustics of the Singing Voice" *Scientific Am.* **3**, 82-89 (1977)
4. J.Sundberg, "Level and center frequency of the singer's formant" *J. Voice* **15**, 176-86 (2001)
5. M. Mellody, F. Herseth, and G.H. Wakefield, "Modal distribution analysis, synthesis, and perception of a soprano's sung vowels" *J. Voice* **15**, 469-482 (2001)
6. J. Michel and J. Grashel, "Vocal vibrato as a function of frequency and intensity", In: Lawrence V.L., ed., Transcripts of the Ninth Symposium: Care of the Professional Voice, New York, The Voice Foundation, 45-8 (1980).
7. D.B. Price & R.T. Sataloff, "Technical note: a simple technique for consistent microphone placement in voice recording" *J. Voice* **2**, 206-207 (1988).
8. S.D. Foulds-Elliott, P.J. Davis, S.J. Cala, and C.W. Thorpe, "Respiratory function in operatic singing: effects of emotional connection" *Logopedics*

Phoniatrics Vocology **25**: 152-169 (2000)
9. J.P.H. Pabon, and R. Plomp, "Automatic phonetogram recording supplemented with acoustical voice-quality parameters" *J. Speech Hear. Res.* **31**, 710-722 (1988)
10. R. Weiss, W.S. Brown, Jr. and J. Morris, "Singer's formant in sopranos: fact or fiction?" *J. Voice* **15**, 457-68 (2001)
11. W.S. Winholtz, and I.R. Titze, "Miniature head-mounted microphone for voice perturbation analysis" *J. Speech, Lang. Hear. Res.* **40**, 894-899 (1997)
12. R.E. Stone, C.J. Bell, and T.D. Clack, "Minimum intensity of voice at selected levels within the pitch range" *Folia Phoniatrica* **30**, 113-118 (1978)
13. V. Parsa, D.G. Jamieson and B.R. Pretty, "Effects of microphone type on acoustic measures of voice" *J. Voice* **15**, 331-343 (2001)
14. H.K. Dunn, and D.W. Farnsworth, "Exploration of pressure field (sic) around the human head during speech" *J. Acoust Soc. Am.* **10**, 184-199 (1939)
15. J.L. Flanagan, "Analogue measurements of sound radiation from the mouth" *J. Acoust Soc. Am.* **32**, 1613-1620 (1960)
16. A.H. Marshall and J. Meyer, "The directivity and auditory impression of singers" *Acustica* **58**: 130-140 (1985)
17. International Telecommunication Union (1996) ITU-T Rec. P.51 Artificial mouth.
18. International Telecommunication Union (1996) ITU-T Rec. P.58 Head and torso simulator for telephonometry.
19. J. Eargle, *The Microphone Handbook*. ELAR Publishing, Commack NY. (1981)
20. M. Bunch, and J. Chapman, "Taxonomy of Singers Used as Subjects in Research" *J. Voice* **14**, 363-369 (2000)
21. P. Davis, J. Oates, D. Kenny, J. Livesey, J. Chapman, and D. Carbrera, "Singer s formant characteristics in a group of opera chorus artists" *The Australian Voice Association 6th Voice Symposium, Adelaide*, October (2002) http://www.plevin.on.net/voice2002/
22. M. Jacobs, P. Davis, J. Livesey, and A. Connolly "Acoustics and perception of vocal control in operatic sopranos following anaesthetic and endoscopy" *The Australian Voice Association 6th Voice Symposium, Adelaide*, October (2002) http://www.plevin.on.net/voice2002/

CONDENSER MICROPHONES—A TUTORIAL

Neville Fletcher
Research School of Physical Sciences and Engineering
Australian National University
Canberra ACT 0200

ABSTRACT: This tutorial discusses the operation of several types of condenser microphone including standard omnidirectional measuring microphones, simple cardioid microphones, and studio microphones with adjustable response pattern. The physics underlying their operation is discussed, and the approach to a detailed analysis using electrical network analogs is outlined.

1. INTRODUCTION

Fifty years ago the number of microphone types in common use was very large. Dynamic microphones were the most common, and came in both omnidirectional and cardioid response patterns, but broadcasting and recording studios often used ribbon microphones, usually with figure-eight response patterns. Omnidirectional condenser microphones were in use for acoustic measurements, and were beginning to penetrate the recording and broadcasting fields. Today the situation is very different: nearly all microphones in common use are condenser types, from simple cheap microphones in telephones and other voice recorders, through studio microphones with variable response patterns, to sophisticated measuring microphones. .It is the purpose of this tutorial paper to give a brief survey of these condenser microphone types and to explain their operating principles, particularly in relation to frequency response and directional pattern.

Because microphones are so fundamental to the practice of acoustics, most classic books on practical acoustics, such as those by Olson[1], Beranek[2], Kinsler et al.[3], and Rossing and Fletcher[4] have a chapter on various common microphone types and their operation. More recently there is a whole book devoted to microphones, edited by Michael Gayford[4], and a specialised book on condenser microphones of the measurement type edited by George Wong and Tony Embleton[5]. Despite this, it is not easy to find a treatment along the lines to be attempted here.

2. ELECTRIC NETWORK ANALOGS

The behaviour of mechanically simple systems can usually be analysed by considering quite directly the motion of the mechanical elements when acted upon by an acoustic pressure signal. As the system becomes more complex, however, so does the analysis, and it has been found simplest to calculate this behaviour in terms of an electrical analog in which voltage V represents acoustic pressure p and electric current i represents acoustic volume flow U. (The same idea can be applied to mechanical systems by taking voltage to represent force rather than pressure, and current to represent velocity rather than volume flow, but it is simpler to use the acoustical analog from the beginning.) The one significant limitation of this approach is that it is essentially one-dimensional like the wires of an electrical circuit. More complex three-dimensional ideas have to be added later.

In this electric analog system an acoustic resistance, such as a layer of felt, becomes an electrical resistance, and Ohm s law $V=iR$ becomes the acoustic flow law $p=RU$. Similarly, a mass m that presents an area S to the acoustic pressure is represented by an electrical inductance $L=m/S^2$ and a mechanical spring by a capacitance C proportional to the compliance of the spring. A sealed cavity of volume V is represented by a capacitance of magnitude $C=V/\rho c^2$, where ρ is the density of air and c the velocity of sound in air, these relations being derived by considering the physics of the resulting motion or air flow. All the standard techniques of electrical circuit analysis can then be applied to work out the behaviour of the acoustic system being studied. In what follows we shall sometimes use these techniques, but also try to explain in physical terms what is going on.

3. MEASUREMENT MICROPHONES

An omnidirectional measuring microphone of standard design is shown schematically in Fig. 1(a). A strong thin metal diaphragm is stretched tightly over the entry to the microphone capsule and a plane insulated electrode is positioned about 20μm away from it. The capsule is sealed except for a fine capillary tube that provides a leak and prevents long-term build-up or deficit of pressure inside the capsule. The electrode is perforated by a number of holes for a reason that will become clear later.

When an oscillating acoustic pressure is applied to the outside of the diaphragm, this tends to move it towards the electrode, but the motion is resisted by the need to accelerate the mass of the diaphragm, by the diaphragm stiffness, and by the need to move air from between the diaphragm and the electrode through the vent holes and into the cavity behind the electrode. This back cavity itself has some acoustic elasticity, as noted above, and there is the vent to outside to be considered, but we ignore these for the moment. The microphone behaviour can therefore be analysed in terms of the analog circuit shown in Fig. 1(b), in which we want to calculate the current through the diaphragm impedance in terms of the applied pressure. The small extra stiffness from the air in the air enclosed in the cavity can be neglected in comparison with the diaphragm stiffness, which we do by assuming the analog cavity capacitance to be very large, and we also neglect the effect of the slow leak into the cavity, shown by the dashed-line part of the network. At low frequencies, diaphragm stiffness impedance $1/j\omega C$ is dominant over the diaphragm mass impedance $j\omega L$ and resistive losses R, and the diaphragm displacement is simply proportional to the acoustic pressure.

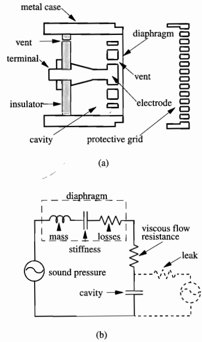


Figure 1. (a) Schematic diagram of an omnidirectional condenser measurement microphone. (b) Electrical analog network for the microphone in (a); the added effect of the slow leak is shown with dashed lines, since it is important only at very low frequencies.

In use, the microphone electrode is charged to a potential of perhaps 200 volts through a very large resistor (perhaps 1000 megohms). This charging may take several seconds, so that effectively the charge on the electrode is constant. The electrical capacitance C_E between the electrode and the diaphragm is $\varepsilon_o S/d$ where S is the electrode area, d is its separation from the diaphragm, and ε_o is the permittivity of free space. Since the charge on this electrical capacitor is fixed despite the rapid diaphragm motion, the voltage across it is inversely proportional to the capacitance C_E, and therefore proportional to the diaphragm spacing d, which follows the acoustic pressure with just a change in sign. The electrical signal will therefore be a faithful replica of the acoustic pressure signal.

At higher frequencies things get more complicated. The motion of the diaphragm must now be considered in terms of its mass, its stiffness, and the resistive losses provided by the viscosity of the air as it is forced to move between the diaphragm and the electrode. As shown in Fig. 1(b), these elements are all in series, as is plain when it is considered that each one is separately resisting the diaphragm motion, which is equivalent to the electrical current in the circuit. The circuit is that of a simple resonator with resonance frequency f^* given by $2\pi f^* = (1/LC)^{1/2}$, and quality factor $Q = mf^*/2\pi R$, where the acoustic analog values are used for L, C, and R. The existence of this resonance means that the diaphragm motion will be increased by a factor Q at the resonance frequency f^*, the width of this resonance being about f^*/Q. Above the resonance, the diaphragm response will decline by 12 dB/octave.

To make a microphone with a good flat frequency response therefore requires a high resonance frequency f^*, and sufficient damping that the response peak near f^* is not too prominent. Measurement microphones have strong metal diaphragms that can be tensioned so as to give resonance frequencies in the range 15 to 50 kHz, the higher frequencies applying to microphones of smaller diameter. The damping can be adjusted by changing the diaphragm spacing and also the diameter and spacing of the holes in the electrode so that the resonance peak is nearly eliminated, but too much damping will also reduce the response at frequencies a little below the resonance

There are a few other things to be considered in design of this simple type of microphone. The vent hole in the capsule has already been mentioned, and the addition this makes to the network is shown dotted in Fig. 1(b). If the vent has an acoustic flow resistance R_V, then the time constant for pressure equalisation within the capsule by flow through the vent is $R_V C$ where C is the acoustic analog capacitance of the cavity volume. The vent resistance is normally adjusted so that this lower cut-off frequency is about 10–20 Hz, since that is below the range of human hearing, and this prevents the microphone from being too sensitive to pressure changes from shutting doors or other influences.

The second thing is that the one-dimensional model is too simple sound can reach the microphone from different directions and this can have an effect. If the sound incidence direction is along the axis of the microphone and normal to the diaphragm, then there is no problem at low frequencies, and the microphone diaphragm samples the pressure in the acoustic wave. If, however, the diaphragm diameter were to be very large, then the wave would be reflected from it, and the pressure on the diaphragm would be doubled, an increase of 6 dB. This increase occurs when the sound wave frequency is high enough that the sound wavelength is less than the diameter of the diaphragm. At this same sort of frequency, the microphone response also becomes increasingly directional, favouring signals arriving normally from along its axis. The reason for this can be seen by examining a signal arriving at right angles to the axis and thus tangential to the diaphragm. If the wavelength is about equal to the diaphragm diameter, then half of the diaphragm will feel a positive acoustic pressure and half a negative pressure, nearly cancelling.

All these things have to be taken into account in the design of a microphone, particularly if it is to be used for precise measurements for which accuracy better than 1 dB is required over the whole frequency range. For this reason these microphones are divided into sub-classes designed for measuring either free fields or else simply acoustic pressure, which is more suitable for randomly incident sound.

4. SIMPLE MICROPHONES

A variant of the design discussed above is used in many practical microphones. The main difference is that the diaphragm is made from polymer material about 10–20 μm in thickness, and has an evaporated gold film over its central portion to make it electrically conducting. The electrode then becomes part of the microphone case, which is held at ground potential, and there is a separate connection to the metallised part of the diaphragm. The main difference that this design change makes is that, because the plastic diaphragm cannot support a large tension, its resonance frequency is only about 1–3 kHz, depending upon the diameter of the microphone. To obtain adequate frequency response it is therefore necessary to make use of the added elastic stiffness provided by the air enclosed behind the diaphragm to raise the effective resonance frequency to 15–20 kHz. In the case of measurement microphones, the diaphragm tension was so high that this extra contribution to stiffness could be neglected.

The electric analog circuit for this case is identical with that in Fig. 1(b). The difference is that the cavity stiffness can no longer be neglected and is, indeed, now much larger than the diaphragm stiffness. The circuit arrangement can be justified by the consideration that air flow caused by displacement of the diaphragm, which activates its mechanical stiffness, flows equally into the cavity, as does the electric current in the analog circuit. Analysis of the resonance behaviour is similar to that for a measurement microphone.

Use of a plastic diaphragm rather than a metallic one has another consequence. When the electrical potential is applied to activate the microphone, this imposes a mechanical stress on the diaphragm attracting it towards the electrode. In the case of a measuring microphone with a metallic diaphragm this causes very little displacement because the diaphragm tension is so high, but for a plastic diaphragm the normal displacement is perhaps as great as 5–10μm. It can further be shown that, if this displacement exceeds about one fifth of the total separation between diaphragm and electrode, then the diaphragm will collapse against the electrode and the microphone will become inoperative. For this reason, the electrical polarising voltage used in a microphone of this type is generally much less than in a measurement microphone, and the initial diaphragm separation is larger, which decreases the sensitivity.

One further feature used in some of these microphones is to do away with the external polarising voltage altogether and use instead an electret film deposited on the surface of the electrode, or sometimes built into the diaphragm itself. The great advantage of not requiring an external power supply makes electret microphones ideal for portable apparatus and also reduces the overall cost. The only disadvantage is that the polarisation of the electret material gradually changes with time, so that the microphone sensitivity is less stable than for an externally powered design.

5. DIRECTIONAL MICROPHONES

The simplest sort of directional microphone is the pressure-gradient design. Suppose that sound is allowed equal access to both sides of the diaphragm and that the entry ports to the two sides are a distance d apart. Then if a sound wave of amplitude p and frequency f is incident at an angle θ to the axis of the microphone, the pressure tending to move the diaphragm is $p_1 - p_2$ where

$$p_1 = p\exp(jkd/2); \quad p_2 = p\exp(-jkd/2) \qquad (1)$$

with $k=2\pi f/c$ and $j=\sqrt{(-1)}$. If the separation between the two ports is much less than the sound wavelength, then $p_1 - p_2 \approx jpkd$. If we extend this model to sound coming in at an angle θ to the microphone axis, then the effective distance between the two ports is not d but rather $d\cos\theta$, and the amplitude of diaphragm motion is proportional to $pkd\cos\theta$, so that the microphone has a figure eight or $\cos^2\theta$ directional response. Such a microphone thus responds to the component of the acoustic pressure gradient parallel to its axis, and has a response proportional to f and thus rising with frequency at 6 dB/octave unless some other design feature enters. We shall see later what this is.

There is another feature of ideal pressure-gradient microphones that should be noted. Since a spreading spherical pressure wave has a form like $p(r) = (1/r)\, e^{j(\omega t - kr)}$, differentiating this to find the gradient inserts a factor $[1 + (kr)^{-1}]$ relative to a plane wave and so gives a strong bass boost if $kr<1$, which means within about $\lambda/2\pi$ of the source. This boost must be corrected for, or at least recognised.

6. CARDIOID MICROPHONES

A figure-eight directional response is sometimes useful, but more often the requirement is for a response concentrated in the forward direction along the microphone axis. If some way could be found to combine the response pattern of a pressure-gradient microphone with that of a simple pressure microphone, then the result would be

$$p(A + B\cos\theta) \qquad (2)$$

where A and B are constants. If the value of B/A could be varied, then a variety of directional patterns could be achieved, ranging from omnidirectional for $B = 0$ to figure-eight for $A = 0$ and with a particular cardioid (heart-shaped) pattern for $B = A$. These possibilities, plotted on a polar decibel scale, are shown in Fig. 2. The one remaining problem is the frequency dependence of the gradient response, which would cause the pattern to be omnidirectional at low frequencies and gradient-like at high frequencies because the pressure gradient at a given pressure amplitude increases with increasing frequency as shown by (1).

A solution to all these problems is given by the design in Fig. 3(a). Here we see the cavity behind the perforated electrode of a simple microphone vented to the surroundings through some sort of partition with an acoustic impedance Z_P. If Z_D is the acoustic impedance of the diaphragm and Z_C that of the cavity, both of which we have discussed before, then the whole microphone can be represented by the network analog shown in Fig. 3(b). The topology of the network can be understood by considering the paths by which acoustic volume moves from one component to anotherif the same flow moves through each, then they must be in series, while if the flows

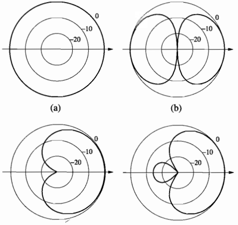


Figure 2. Response patterns obtainable by varying the constant A in equation (2): (a) omnidirectional when $B = 0$; (b) figure-eight when $B/A >> 1$; cardioid when $B/A = 1$; (c) a form of hypercardioid when $B/A = 1.5$. Relative levels are in decibels in all cases.

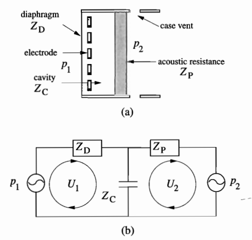


Figure 3. (a) Design of a simple cardioid microphone.
(b) Analog network circuit for this microphone.

combine then they must be in parallel. Solution of this network is simple, and the calculated value of the acoustic volume flow through the diaphragm, caused by its movement, is

$$U = [Z_P\, p_1 + Z_C(p_1 - p_2)]\, [Z_P\, Z_D + Z_P\, Z_C + Z_C\, Z_D]^{-1} \qquad (3)$$

where p_1 and p_2 have the form given in (1). If the impedance Z_P of the partition is made a simple resistance R, then the numerator of this expression, which is the only part containing the angular factor $\cos\theta$, takes the simple form $R + d\cos\theta/cC$, where C is the analog capacitance of the cavity. This is of just the form in equation (2), and the response can be made cardioid in form by arranging that $R = d/cC$, the frequency dependence of this part of (2) cancelling out. The denominator of (3) is nearly inversely proportional to frequency over most of the operating range, so that U is nearly proportional to frequency and the diaphragm displacement is nearly independent of frequency, as it should be for a flat response. Because it is not possible to vary the various impedances once the microphone has been built, its directional characteristic, generally either cardioid or hypercardioid, is fixed at the design stage.

Looked at physically, what happens is that, if the partition is simply resistive, then the pressure acting on the inside of the diaphragm for a given sound wave amplitude varies inversely with frequency above the value of $1/RC$ for the cavity, and this cancels out the frequency-dependent rise in the magnitude of the pressure gradient, giving a constant response amplitude and pattern. This no longer holds for frequencies below $1/RC$, when the internal pressure approaches the external pressure and the response declines.

7. STUDIO MICROPHONES

The final type of microphone to be discussed is the studio microphone, which generally has a response characteristic that can be varied between all the patterns shown in Fig. 3. The general idea, developed more than thirty years ago, is essentially to mount two condenser microphones back-to-back with some sort of acoustic coupling between them, and then to control the directional response by varying the voltages applied to the two diaphragms.

Figure 4(a) shows the design of a traditional studio microphone. The electrodes are made of thick metal with cavities to provide acoustic stiffness to the plastic diaphragm, and about half of these cavities lead through small holes to the thin central space which provides a resistive coupling between the two microphone elements. We can identify two basic modes for this microphone. In the first the two diaphragms move inwards together so that there is no flow through the central space, and the response is essentially to the pressure signal at the mid-point of the microphone axis. In the second mode, one diaphragm moves in while the other moves out, and the main impedance to the motion is the resistance of the central space through which the acoustic current must flow. The response in this case is to the difference between the pressures on the two diaphragms, and thus to the gradient of the acoustic wave pressure. If the diaphragm tension is low, so that the impedance to motion is largely that of air flow through the central resistance, then the diaphragm velocities will be proportional to the pressure gradient and their displacements will have a $(\text{frequency})^{-1}$ factor that cancels out the frequency factor in the gradient, thus giving a flat response for the figure-eight pattern.

In the accompanying electric preamplifier, the two diaphragms are connected to a differential input. If, therefore, the polarising voltages on the two diaphragms are equal, the response to a simple pressure signal will be zero, but the response to a gradient signal will be a maximum. Conversely,

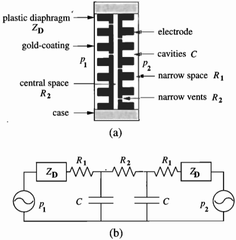


Figure 4. (a) Design of a simple studio microphone.
(b) The analog circuit

if the polarising voltages are equal and opposite, then the gradient response will be zero and the pressure response will be at a maximum. Somewhere in between, perhaps with one voltage nearly equal to zero, the response will have a cardioid pattern.

Fig. 4(b) shows the analog circuit for this microphone from which the motion of the two diaphragms under the influence of a signal at angle θ to the microphone axis can be calculated, and the design parameters varied to give the desired frequency response and directional pattern. Solution of the network equations is straightforward but algebraically a little complicated, since there are three separate meshes to the network, implying three equations, and each is complex so is really two separate equations. Nevertheless these equations were solved long ago and microphone designs with excellent frequency response and directional characteristics were produced. Some of these designs, with improved manufacturing and the use of transistor rather than valve preamplifiers, are now widely sought after in the recording industry. The microphone capsule, of course, is mounted within a metal mesh enclosure, both to provide mechanical protection and also to reduce breath noise.

8. CONCLUSION

There has been space in this review to consider only the basic types of microphone design, and even within this limited field there is an immense amount of technical variation, from large studio microphones with double capsules up to 30 mm in diameter to tiny microphones for in-ear hearing aids with diameter less than 2 mm. Diaphragms of thin taut metal and of much softer plastic have been mentioned, but some microphones now use diaphragms etched out of crystals of silicon so that they can be in close proximity to components of the electronic circuit. With sight and hearing providing the primary sensory links between humans and the environment, the development of new microphone types is bound to continue.

REFERENCES

1. H.C.F. Olson, *Acoustical Engineering*, (Van Nostrand, Princeton NJ 1947).
2. L.L. Beranek, *Acoustics*, (McGraw-Hill, New York 1954, reprinted by the Acoustical Society of America, New York 1986).
3. L.E. Kinsler, A.R. Frey, A.B. Coppens and J.V. Sanders *Fundamentals of Acoustics*, third edition (Wiley, New York 1982).
4. T.D. Rossing and N.H. Fletcher, *Principles of Vibration and Sound*, second edition, (Springer-Verlag, New York, in press for 2003)
5. M. Gayford (editor) *Microphone Engineering Handbook*, (Focal Press, Butterworth-Heinemann, Oxford 1994).
6. G.S.K. Wong and T.F.W. Embleton (editors), *AIP Handbook of Condenser Microphones*, (American Institute of Physics, New York 1995).

ROAD TRAFFIC NOISE —THE SELECTION OF A PREFERRED ROUTE

Neil Gross
Wilkinson Murray Pty Limited, 123 Willoughby Road, Crows Nest NSW 2065

1. INTRODUCTION

For new road projects the route selection process is an essential part of determining the preferred route. This includes many selection parameters of which noise is just one. Technical information which includes some form of noise assessment needs to be provided at the Value Management Workshop which would occur early in the road design and is a requirement of the EIS process. However, normally little or no data is available regarding the different options with the exception of several coloured lines on a map. The required input to the VM workshop is that these route options need to somehow be ranked. Time frame is 1 week and the budget may only be a few thousand dollars.

This article should not be considered as a research paper but rather as a technical note which may prove beneficial to those assessing road traffic noise in order to satisfy RTA requirements.

Wilkinson Murray s involvement in road traffic noise projects which have required a route selection process has led to the development of a simple assessment procedure. The procedure is described in this article

When faced with 6 different coloured lines on a map which represent 6 route options to be assessed, how can you decide which is the best overall from a noise perspective? Are 10 residences set back 50m from a new road better or worse than a combination of 5 residences set back 25m with a further 5 residences set back 100m. What happens if some of these residences are already affected by road traffic noise. Imagine how much harder the selection becomes when there are possibly 400 to 500 residences at varying distances up to 300m and beyond.

Without a site visit or the option of doing detailed calculations (the route selection assessment is normally restricted to a desktop study with limited budget and without a detailed road design) the assessment has to be based on professional judgement and intuition.

An assessment procedure has been developed, which probably supports the intuition, which uses a simple numbers approach to break the overall selection process into a number of smaller packages that allow comparison and can be handled with greater ease.

To assess the future likely impact of road traffic noise, three basic parameters have been chosen.

¥ Number of residential properties potentially affected.
¥ Future absolute noise level at each residence.
¥ Change in noise level (both increase and decrease) from existing situation at each residence.

In other words, the more residences affected the worse the route, the higher the noise level, the worse the route and the bigger the increase the worse the route.

2. WHAT DO YOU NEED ?

Aerial photography and perhaps the opportunity to speak on the phone with someone (Project Manager) who is reasonably familiar with the area;

¥ a scale rule;
¥ a simple spreadsheet; and
¥ the ability to count.

3. WHAT IS THE BASIS OF CALCULATING EXISTING AND FUTURE NOISE LEVELS ?

In the absence of information at the early stage of any project it is likely that the number of vehicles, vehicle distribution, traffic speed and road surface will all remain the same for each route. The parameters which will vary are, distance to each residence, natural shielding and road gradient. Since the road design (ie cut, fill and gradient) is not fixed at this early stage then it is impossible to account accurately for these factors. Realistically, distance from the centre line of the proposed road alignment to each residence is the only readily available parameter to assess future noise levels. In a similar fashion, distance from the centre line of the existing road alignment is the only readily available parameter to assess existing noise level.

4. WHAT TO DO ?

Previous assessments conducted by Wilkinson Murray have considered a region 300m either side of the route centre line. This has been based on the area over which information has been readily available. The recent change in EPA guidelines may indicate that 500m or even further is a more appropriate distance within which to include residences.

The procedure requires counting residences along each route option and compiling a spreadsheet for each route option (including the do nothing). A sample spreadsheet is attached.

The first step involves getting a decent size map and enough space on the office floor to spread it out. It is then necessary to split the areas either side of the existing and new routes into the following different distance categories from each route: 0-50m, 50-100m, 100-200m, 200-300m. Just use a scale rule and draw lines parallel to each of the route options. The first distance category realistically deals with residences within 25-50m from the edge of a road. The move from one distance category to the next therefore typically represents equal changes in traffic noise level when allowing for geometric spreading and ground effects.

The second stage involves dividing the route options into different sections along their length (chainages) which simply makes residences easier to count and recount. This should typically be about 10 sections and preferably based on obvious features such as intersections with existing roads.

Thirdly, for any one of the 6 options for each residence it is necessary work out how far the residence is from the existing road and how far it would be from the route option being assessed. For example, if a residence will end up being 50-100m from the new alignment, this residence must be added to one of the columns within the 50-100m category depending on its distance from the existing alignment.

The fourth stage involves repeating this process for all the other options.

The fifth stage involves applying the various weightings shown at the top of each column. The weightings have been selected by using a paired comparison procedure in conjunction with experience in the likely effects of absolute traffic noise level and of changes in traffic noise level on potential annoyance. This is explained in more detail below.

The weightings range from 0.4 to 6.4 and have been selected starting with a weighting of 1. This represents the situation where there is no change in noise level at a residence set back 200-300m from the existing road. If noise levels are higher (residences are closer) or increases are bigger, a weighting greater than 1 needs to be applied since it would represent a greater impact. Similarly if noise levels were to reduce a weighting less than 1 needs to be applied.

However for the same change in noise level either up or down the procedure recognises that the increase is perceived to be worse than the decrease. For example a route which improves noise at 50 residences but makes it worse at 50 is not considered to be as as good as a route, for the same changes in noise level, which increases noise at 10 and reduces noise at 10.

Since a 10dBA increase in noise level is widely accepted to be a subjective doubling in noise, this has been used to loosely set the weightings by comparing the different distance categories. The weightings have then been refined by comparing different situations and deciding which would be better or worse.

Finally, it is necessary to total the number of residences affected and calculate the total weighting for each route option. Basically the lowest total is the route which affects the least number of residences and the lowest weighted total is the route with the least impact.

Impress the client by issuing a report with a clear ranking and be satisfied with the quality of your work. Don t be disappointed when you realise there were at least 25 other route selection assessment parameters and the quietest route didn t win. At least the fees for future noise control may make up for the disappointment that noise was not the most important selection parameter.

5. SUCCESS AND IMPROVEMENTS

The success of the procedure is hard to define since noise is only 1 of many selection parameters and of course all 6 route options are never built or even assessed in more detail. However the procedure has certainly helped the author prepare a quantitative assessment which appears to match the intuition.

This procedure is far from perfect in many ways but does meet its objective. Minor adjustments have already been made to this procedure when dealing with specific projects. Two examples are given below.

Some projects have had one route option, which involves an upgrade of an existing alignment with the other options in virgin areas. This means the existing route would remain open to traffic but with a lower flow. In these instances it has been necessary to adjust the weighting for any residence. This has been done by moving it into a different distance category depending on the difference in traffic numbers between the existing and future flow.

Some projects have had route options in undulating terrain and it has been quite obvious where cut and fill will be required. Again adjustments can be made by moving the number of residences from one distance category to another to account for more shielding or reduced ground effects. These adjustments require professional judgement but in shallow cut where shielding of approximately 5dBA would be achieved would be similar to approximately a change of 1 distance category. For a deeper cut this may equate to a change of 2 distance categories.

In using this technique I have been able to criticise it and feel that it could be improved. However this would require more detailed input information and time to assess these details, both of which are not available at the early stage. In addition the improvement in accuracy that they may bring is not considered warranted at this early stage of a project when noise is just 1 of many selection parameters.

The author would welcome any feedback

Option	Distance from Proposed Alignment																			
	0 - 50					50 - 100					100 - 200					200 - 300				
Distance from existing alignment	>300	200-300	100-200	50-100	0-50	>300	200-300	100-200	50-100	0-50	>300	200-300	100-200	50-100	0-50	>300	200-300	100-200	50-100	0-50
Weighting	6.4	5	3.7	3	2.2	4	3	2.3	1.7	0.9	2.2	1.7	1.3	.85	.7	1.5	1	.8	.6	.4
Chainage Wilkinson Rd to Murray St	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0
Murray St to Heggie Ave	10	5	0	10	5	0	10	5	0	10	5	0	10	5	0	10	5	0	10	5
Heggie Ave to Athol Ln	0	0	10	0	0	10	0	0	10	0	0	10	0	0	10	0	0	10	0	0
Athol Ln to Benbow Pde	5	10	0	5	10	0	5	10	0	5	10	0	5	10	0	5	10	0	5	10
PROPERTIES	20	15	10	20	15	10	20	15	10	20	15	10	20	15	10	20	15	10	20	15
PROPERTIES x WEIGHTING	128	75	37	60	33	40	60	35	17	18	33	17	23	13	7	30	15	8	12	6
WEIGHTED TOTAL			333					170					93					71		
										PROPERTY TOTAL		305								
										WEIGHTED GRAND TOTAL		667								

Book Reviews

MATHEMATICS AND MUSIC

G Asssayag, H G Feichtinger and J F Rodrigues (Ed)

Springer-verlag, 2002, 288 pp, ISBN 3 540 43727 4 (hard cover) Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price A$132.00

This is a collection of papers presented at a mathematical forum assembled simultaneously in three different cities. The encyclopaedist Diderot, whose name is invoked in the title, expressed the Pythagorean or Platonic sentiment that "it is by number and not by perception that one may value the sublime in music". Some of the authors here seem to cling unreasonably to these ideals: one paper, on geometrical methods of approximating equal temperament for fretboards, admires the precision obtained using geometrical approximations, while neglecting the larger imprecisions due to finite bending stiffness and the increased tension in a stopped string.

The first four papers/chapters are historical. The musicologist Manuel Ferreira gives a history of proportion, in both harmony and rhythm, from Pythagoras to the Middle Ages. Eberhard Knobloch reviews combinatorics in baroque and classical music. How many different melodies are possible? is a question that amused not only Mersenne, Kircher, Leibniz but also Mozart, whose dice music is one of the oldest known examples of a composition algorithm.

There are two formal papers: Marc Leman develops a formal logic for musical coherence and Guerino develops a topos geometry for music. There is also a 'dialectical analysis' of music, which defends the thesis "that music is not a science and that its logic is musical, not mathematical, physical nor psycho-physiological".

Several chapters might be classified as miscellaneous. One is an essay on Lagrange (who liked music because he could only listen to it for the first three bars: thereafter he was completely oblivious to it and could concentrate on mathematics). Others include a paper about the 'ethnomatics' exhibited in the ostinati on plucked string instruments and another describing the various roles in musical communication (composer, performer listener) and their interaction.

Three papers--my favourites--give good reviews of areas in which mathematics is currently involved in music and music research. Dubno and Assayag review prediction methods including Markov methods. De Poli and Rocchesso give a clear and interesting review of a computational model of sound sources. The scientist and composer Jean-Claude Risset gives an excellent review of the relations between mathematics and music, concentrating on the areas in which he has made notable contributions, such as synthesis and auditory illusion. The latter allows him to counter latter-day Pythagoreans with Aristoxenus' argument that music is in the ear of the hearer rather than in pure, mathematical reason.

The sixteen papers cover a wide range of topics and are only loosely related to each other. They also exhibit a wide range of quality. I expect that any reader with a background in music and mathematics will find several papers interesting, and will probably read nearly all of them.

Joe Wolfe

Joe Wolfe is a physicist (and composer) who researches music acoustics at the University of New South Wales. The lab's web site is www.phys.unsw.edu.au/music

VIBRATION CONTROL OF ACTIVE STRUCTURES

Andre Preumont

Klower Academic publishers, 2002, 364 pp, ISBN 1 4020 0496 6 (hard cover). Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price A$276.55

This book on active vibration control of structures is a delight to read. In the very first chapter examples of its practical application are described in a way that holds the reader's attention. Its application to the achievement of clearer images from the Hubble telescope is described in brilliant detail as is its application to two earthbound telescopes. All of the complex issues involved in applying active vibration control to telescopes are described simply so that the reader gains confidence in his or her ability to tackle the later more difficult chapters. The first chapter concludes with a simple discussion on smart materials, an explanation of the difference between feedback and feedforward control and a discussion of the steps involved in the design of an actively controlled structure.

In chapter 2, the basic concepts of structural dynamics, including vibration modes, modal decomposition and the concept of a collocated sensor and actuator are discussed. Chapter 3 is devoted to a discussion of actuators and active structures. A wide range of actuator types suitable for active control of structures are described and piezoelectric actuators are analysed in detail. Models are derived for describing the moments and forces developed by constrained actuators as a function of the applied voltage. Various actuator shapes are discussed as are their application to modal filtering on simple structures. Also the advantages of shell theory over simple beam theory are discussed for modelling piezoelectric patches applied to planar structures. An addition to this chapter that doesn't seem to quite fit but is interesting anyway is a discussion of an active truss which includes some struts that consist of active elements capable of providing expansion and contraction forces.

In chapter 4, the author demonstrated how collocated control guarantees asymtotic stability for a wide range of problems and is much more robust than the non-collocated case for lightly damped structures. The need for damping in non-collocated control arrangements to maintain stability is emphasized. Chapter 5 is a discussion of active damping as well as the various types of simple feedback control systems such as velocity, position, force and acceleration feedback.

In chapter 6 the fundamental concepts that characterise active vibration isolation are discussed in detail and a 6 degree of freedom vibration isolator based on the Stewart platform is analysed and discussed. Vehicle suspensions are also briefly mentioned.

Chapters 7, 8 and 9 discuss the fundamentals of state space control, frequency domain methods and optimal control respectively with emphasis on the concepts that are applicable to structural vibration control. The discussion in Chapter 7 includes the most important concepts, such as transfer functions, poles and zeros, pole placement, LQR control, observer design, reduced order observer and Kalman filtering, which are discussed in much more detail in in-depth books on feedback control, but more importantly, the discussion is lucid and written in a way that would be easily understood by students. Examples used to illustrate the concepts include the inverted pendulum, the single oscillator and the two-mass problem. In Chapter 8, the discussion includes gain and phase margins, Nyquist stability criterion, Nichols chart, unstructured uncertainty, robust performance and stability, Bode plots and non-minimum phase systems. In addition, lag, lead, PI and PID compensators (or feedback controller) are discussed and clearly explained. In Chapter 9, deterministic and stochastic LQR control are discussed, as is a full state observer, the Kalman Bucy filter, LQG control, spillover as a result of excitation of residual vibration modes as a result of control, integral control and frequency shaping.

Chapter 10 contains a discussion of controllability and observability, including an introduction to important concepts such as sensitivity and model reduction, and Chapter 11 is devoted to a discussion on stability. Chapter 12 is a discussion of semi-active control. The introduction to magnetorheological fluids is followed by a discussion of feedback implementations of semi-active control including continuous control, on-off control and force feedback.

An interesting chapter is number 13, titled "Applications". In addition to describing specific applications, some of the practical issues associated with digital implementation of control systems are explained. This is followed by a detailed analysis of the application of active control to a truss structure, an analysis of a 6 degree-of-freedom generic interface for structural isolation and damping, active damping of a plate and a beam and volume velocity sensing.

Chapter 14 is concerned entirely with the active control of cable structures such as used suspension bridges, towers roofs and stadiums. Means of actively damping these elements is explained and an approximate linear theory is also developed. Applications to space structures and cable stayed bridges are discussed in detail.

In addition to the clear explanations of complex phenomena, the book has a number of sample problems at the end of each chapter (113 problems in total), which will be most valuable to students a well as structural or mechanical engineers concerned with vibration control.

The book could be improved by the inclusion of more practical applications of active vibration control such as vibration isolation of electron microscopes, control of high-rise building vibrations in strong winds and earthquakes. The discussion of transient excitations such as caused by earthquakes has also been omitted and the discussion of vehicle suspensions is a bit brief and shallow. Nevertheless, this is an excellent book, which would be useful as a text in a graduate course on active vibration control as well as a reference for researchers and consultants working in the field. I am glad to have a copy and recommend it as a valuable addition to anyone's library of books on vibration and its control.

Colin Hansen

Colin Hansen is a professor at Adelaide University and has researched, developed and written books on active noise and vibration control.

WAVELETS IN SIGNAL AND IMAGE ANALYSIS

A A Petrosian & F G Meyer (Editors)

Klower Academic publishers, 2001, 543 pp, ISBN 1402000537 (hard cover). Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price A$310.62

Despite its relatively recent introduction as a research topic within the mathematical theory, we have witnessed an incomparably rapid development of the wavelet theory over the last 15 years. Wavelets are very promising for the design of effective and elegant solutions to various problems in the field of signal/image processing and analysis, and have attracted a vast interest from numerous researchers working in the area. However, notwithstanding many advances, it has been noticed that a certain gap has appeared between wavelet researchers working in the theoretical field and those who directly apply this approach to practical problems.

This book attempts to bridge this gap as it strives to "clearly outline specific practical areas where the application of wavelets has indeed proven to be effective." It contains a collection of papers that describe applications of the wavelet theory to a variety of practical problems. Each paper represents a significant contribution within its particular research topic of interest.

The papers are grouped in four sections or parts. The introductory part is short and provides some background mathematical information on wavelet design, frames and the related topics. Though this information can help an informed reader to understand subsequent chapters, a general knowledge of basic wavelet- and signal processing techniques on the part of the reader is presupposed. Part 2 contains six chapters that cover the emerging problems and possible solutions related to the issues of multiscale Bayesian estimation, filter banks, and analysis of the image symmetry and locality, as well as selection of textural features, and fusion of images using wavelets. Parts 3 and 4 are devoted to signal/image compression, and to the application of the wavelet theory to processing some specific signals, such as biomedical and seismic signals.

The book provides an excellent overview of the current trends in applied wavelet research in the area of signal/image processing. Described techniques are innovative and can be efficiently implemented using the information provided in the book, and used either in practical applications or for research. The papers also contain a relatively large number of numerical and graphical examples that illustrate described signal/image processing techniques and contribute to their better understanding. This book can be very useful to graduate students, as well as to engineers and researchers working in the field of signal and image processing, and is recommended for scientific/engineering libraries.

Dragana Carevic

Dragana Carevic is a Research Scientist within the Maritime Operation Division of Defence Science and Technology Organisation. Her main research interests are in the area of signal processing and detection and estimation theory.

AN APPROACH TO THE VALIDATION OF ROAD TRAFFIC NOISE MODELS

APT 14, Austroads, 2002, ISBN 0 85588 605 6. Available as free download from www.austroads.com.au

This report was brought to our attention as worthy of reviewing because of its particular relevance to Australia and its easy availability. It was prepared for Austroads by Neil Huybregts and Tim Marks from Marshall Day Acoustics. The draft was circulated to the various agencies, researchers and consultants who all had input to the final version.

A stated aim of the project was to provide the technical basis for a consistent approach to traffic noise modelling within a framework of choice by authorities and users. The document provides guidance in the preparation and assessment of road traffic validation studies. The results from a number of validation studies are listed and the "correction" factors that are necessary to get good agreement is most interesting. This is of particular interest to any who have observed the ways traffic noise prediction data is used in the consultation process for new and upgraded roads.

The concepts of incorporating safety factors and assessing the level of risk of the measured noise level exceeding the predicted noise level are discussed. It is interesting that taking these into consideration it is recommended that one of the methods, which shows a difference of 4 dB(A) with a standard deviation of 2.7 dB, should not have any calibration factor applied.

For any involved with the assessment of traffic noise impact, this is certainly a report well worth downloading and reading.

Marion Burgess

Marion Burgess is a research officer at the Acoustics and Vibration Unit, UNSW at ADFA. She has spent many hours attempting to assess the impacts of traffic noise and trying to communicate the findings to the community.

AAS Council

The Council of the Society for 2002/03 comprises Ken Mikl as President, Neil Gross as Vice-President, Gillian Adams as Treasurer, Terrance McMinn as Registrar and Charles Don, Geoff Barnes, Ian Hillock, Peter Teague, Byron Martin, Tien Saw as councillors. David Watkins continues in his role as General Secretary

Summary of the Council Meetings in Adelaide.

- The Education Grant scheme will be continued with a maximum grant of $5000.
- Council would like to keep members informed of the activities of Standards Australia Committees. The Society representatives on these Committees will be asked to provide reports on the activities on their Committees which will be published in *Acoustics Australia* and the Society website.
- The Directory of Members will be placed on the Society website with password protection so that only members can access it. In addition, members of the Society will be supplied with their own passwords that will enable them to update their details themselves. Safeguards will be provided so that all changes are checked by the Registrar to ensure that they are correct. Members who do not have access to the internet will be able to obtain a CD-ROM or printed version of the Directory.
- Sustaining Members listed on the Society website will be invited to have a link placed to their company website. This will enable members to easily find Sustaining Member company websites.
- The membership fees for 2002/03 will remain the same.
- It is proposed to hold a combined New Zealand and Australian Acoustical Societies conference in New Zealand during either 2005 or 2006.
- The Society is represented on the following International Institute of Noise Control Engineering (I-INCE) Technical Study Groups:- I-INCE TSG#1 Outdoor Recreational Activities (Marion Burgess and David Eager), I-INCE TSG#2 Noise Labels for Products (Warwick Williams), I-INCE TSG#3 Noise Policies and Regulations (Warren Renew and Marion Burgess), I-INCE TSG#4 Noise Control for Schoolrooms (Gary Woods and Warwick Williams), I-INCE TSG#5 Noise as a Global Policy Issue (Les Huson).

Council Initiative

The establishment of a Sub-Committee to prepare guidelines that can be used by organisations such as local councils. The guidelines will probably be based on Australian and ISO Standards and EPA guidelines. It is proposed to eventually publish the guidelines on the Society website. More information can be obtained from the Chairperson of the Sub-Committee, Mr Geoff Barnes (03) 9894 8508.

Future Direction

Council will be looking at the future direction of the Society during a workshop to be held early next year. Membership of the Society has remained stagnant over a number of years and there are many acousticians working in Australia who are not members of the Society. It is important that the Society represents the needs of people working in the fields of Acoustics and Vibration. It is proposed to hold a survey of members to find out what type of Society and what services members want from the Society. Members are welcome to provide comment to the Chairman, Ken Mikl.

Educational Grant

The Society launched a new education initiative during 2002 to assist in the teaching and promotion of acoustics. The winning entries were announced at the National Conference in Adelaide. Two entries were judged worthy of receiving grants.

Dr Fergus Fricke, on behalf of the Acoustic and Audio Laboratory of the University of Sydney, was awarded $2,600 for the purchase of ODEON software. Postgraduate research students, postgraduate coursework students and final year undergraduate engineering students will use the software. ODEON software is used for research into room acoustics and for learning about the behaviour of sound in rooms. It is being used by the Acoustic and Audio Laboratory to generate data to train neural networks as well as to test theoretical models and for auralization work in acoustic simulations.

Marion Burgess and Joseph Lai, Acoustics and Vibration Unit, U.N.S.W., were awarded $2,400 to identify the top ten issues of concern to the acoustics community and ways of addressing the problems identified. There is real concern about the lack of support at all levels of government for research and education in acoustics in Australia. The Society is a member of the Federation of Australian Scientific and Technological Societies (FASTS) which is a lobby group with links into all levels of government. The project will enable the top issues of concern to be identified and a plan to be formulated with FASTS in its lobbying with government.

The Education Grant will be continued next year and is open to anyone seeking funds to assist in the teaching and promotion of acoustics. The grant can be used for scholarships, funding for research projects, equipment for educational purposes and any other worthwhile use.

Four New Fellows

Council has awarded the grade of Fellow to four members. One of these was presented at the recent conference and the other three will be presented at Wespac 8 in April 2003. The citations for these awards of Fellow are:

Colin Hansen has a distinguished research and teaching record in acoustics and vibration both nationally and internationally. He has published books and presented papers, including invited distinguished papers, at many conferences around the world. Under his leadership, acoustics and vibrations have become mainstream components of the mechanical engineering degrees from the University of Adelaide. Colin has made a major contribution to this Society over the past 20 years. He has held many executive positions, undertaken a leading role in national and international conferences and has encouraged the participation of others in the activities of the Society.

Marion Burgess In recognition of her technical and educational contribution to acoustics, her dedication in promoting acoustics, her tireless service over a sustained period of 30 years to the administration of the Australian Acoustical Society, the organisation of numerous conferences and as a member of the editorial team of the Society's journal, Marion Burgess has been elevated to the grade of Fellow.

Stephen Samuels has had a longstanding commitment to the Australian Acoustical Society through his participation in all aspects of the Society activities and a number of senior positions over the years including President of the Society and Chairman of the Victoria and New South Wales Divisions. Stephen has been extensively involved in promoting the acoustical profession and the Society through many activities such as organising and participating in A.A.S. conferences. He has also made substantial contributions to acoustics through research in the areas of road pavement and road traffic noise. He worked on a variety of projects dealing with road design, vehicle performance and the environmental impacts of roads and traffic, with particular specialisation on road traffic noise.

Joseph Lai has a distinguished research record in engineering aspects of sound and vibration and has published widely in this field. Under his leadership, the Acoustics and Vibration Unit of the Department of Aerospace and Mechanical Engineering at ADFA has developed an excellent reputation and carried out valuable consulting and extension work. Joseph has also made major contributions to the Society, principally through his position as one of the three Editors of Acoustics Australia.

Excellence in Acoustics Award

The finalists in the inaugural 2002 Excellence in Acoustics Award sponsored by CSR Bradford Insulation were recently announced at the Annual Conference in Adelaide. The award aims to foster and reward excellence in acoustics and entries are judged on demonstrated innovation from within any field of acoustics. The finalists were selected from the first round of submissions and the final judgement will be made following assessment of an additional submission and announced at the time of Wespac8 in Melbourne in April 2003.

The range of projects submitted show the diversity of acoustics. The topics included hearing protection software, use of neural networks for prediction of sound reduction performance, noise reduction for a test cell, noise control for bridge joints, sound absorption product, musical acoustics and reverberation enhancement. The judging panel, two from the Society and two from CSR, were presented with quite a challenge to select the finalists.

"All entries were of outstanding quality and identifying finalists from such a strong group of candidates was not easy" stated Mr Marc Clifford, Marketing Manager, CSR Bradford Insulation. "Those finalists chosen were rewarded for exceptional submissions which were viewed by the judges as a significant contribution to the acoustics field" he said.

The two finalists, who were both considered to provide a demonstrated innovative application of acoustics, are:

RTA Road and Bridge Technology whose project is "Engineering Methods Of Noise Control For Modular Bridge Expansion Joints". As vehicles travel over the joints annoying environmental noise can be produced. The group investigated a number of methods for controlling this noise. They found that the use of a specially designed Helmholtz absorber tuned to the dominant acoustic frequencies and installed in the void spaces of the bridge provided a reduction of 10 dB(A).

Musical Acoustics Group from the School of Physics, UNSW whose project is "Flute Acoustics: New Understanding And New Tools For Musicians". Their research uses a novel technique for the measurement of acoustic transfer functions with high accuracy, dynamic range and speed. These studies led to an expert system to rank all possible notes. A flexible 'musician friendly' web service was then developed to provide the world's flautists and composers with easier, better ways of playing difficult passages and chords.

These finalists each received a gift to the value of $250. The next step is for them to provide a comprehensive submission to the judging panel for the selection of the award winner. The winner to be announced at Wespac8 in Melbourne will receive a personalized plaque and a prize to the value of $2,500.

AAS Educational Grant

Submissions due by 30 June 2003

To: General Secretary
PO Box 903, CASTLEMAINE
VIC 3450

watkinsd@castlemaine.net

Future Meetings

WESPAC8

Fusion And Dolphins Amongst The Noise

Hey, something's wrong! WESPAC8, in Melbourne during April 2003, is an acoustics conference not one about nuclear fission. Ah! Perhaps you haven't heard of sonoluminescence, where an acoustic wave propagating through a liquid can cause light emission. Oscillations of gas bubbles in the liquid may produce sufficiently high temperatures that there is the possibility of nuclear fusion or sonofusion to occur. These intriguing ideas will be discussed during a special talk by Larry Crum of the USA, in addition to his Plenary Lecture on the medical applications of Ultrasonics.

WESPAC8 will truly be an international conference, covering a wide range of topics. One paper will consider ground borne noise from blasting a tunnel for a rapid rail link in South Africa. A suggestion from Japan involves using sound to determine, in a non-contact way, the number of pieces of cloth being sewn together in a factory situation, while techniques for analysing vibration signals are discussed in a paper from France. From Russia is a paper on sound signals propagating in shallow water while the design of concert hall diffusers is considered in a paper from Korea. In fact, papers have been offered from 24 countries, including Canada, China, Denmark, India, Italy, New Zealand, Taiwan and even Australia.

At WESPAC8, modes of vibration created when a circular array of jets in the base of a rocket blasts from a hard base can be contrasted with the noise generated by an underwater gas jet, if you attend papers scheduled in the noise and vibration area and an underwater acoustics session. More musical resonances will be considered in the acoustics of Panpipes and when determining the plate profiles of guitars by magnetic field measurements.

In the psychological and physiological acoustics area, a keynote speaker will consider the fidelity of reproduced sound fields. The interface between noise control and sound quality is the topic of one of the six distinguished lectures to be presented at WESPAC8. Others involve the visualization and auralization of sound fields for room acoustics, and the acoustics of speech in classrooms and meeting places, while two develop aspects of speech: for the mobile environment and in science and technology. About 40 papers are expected covering all aspects of building acoustics, with a strong emphasis on auditorium and concert hall design. Noise policies in Australia, traffic noise problems in Hong Kong, new European standards for traffic noise reducing devices, tyre/road noise emission and aircraft noise, are but a handful of the topics considered in the sessions covering environmental and transport issues. As well as two distinguished lectures, over 25 papers are expected in the general area of speech, including speech recognition and enhancement, audiometers, speaking styles and detecting the change of speaker in multi-party meetings.

And what about the Dolphins ? The largest number of papers at WESPAC8 are in the underwater acoustics section, where there is a strong emphasis on the bio-aspects. The use of sound by dolphins, the sonar of whales, and the acoustic behaviour of seals are among the fascinating topics to be treated, along with mapping seabed vegetation, acoustic cavitation thresholds in ocean waters, and the identification of underwater targets.

Unfortunately, this brief summary of some of the intriguing topics to be discussed at WESPAC8, in Melbourne from 7 - 9 April, 2003, could not include all the papers which have been offered. But with well over 200 papers expected, running in six parallel sessions, it is impossible to mention everything. So for further information, please look up the list of abstracts given on the conference web site at www.wespac8.com, or better still, come to WESPAC8 itself, where there will be a technical and trade exhibition, lots of interesting company, good food and a plethora of informative papers.

Tenth International Congress on Sound and Vibration

The Tenth International Congress on Sound and Vibration (ICSV10) will be held on 7-10 July 2003, in Stockholm Sweden at KTH (the Royal Institute of Technology). The Congress is sponsored by KTH, IIAV (the International Institute of Acoustics and Vibration) and SVIB (the Scandinavian Vibration Society).

The Congress will include distinguished keynote addresses, invited and contributed papers in the area of sound and vibration. Distinguished keynote addresses will be presented by: Yuri Bobrovnitskii, IMASH, Moscow, Russia on Measurement of the vibration energy characteristics on structures. David Burnett, La Spezia, Italy on Finite-element methods for structural acoustics: physics, mathematics and modelling, Ann Dowling, Cambridge University, on The interaction of acoustic waves and combustion, Fridolin Mechel, Germany on Duct acoustics, Jean Louis Guyader, LVA, INSA-Lyon, France on Energy residual: A tool to study the dispersion of vibroacoustic performances of structures, Otto Gartmeier, Daimler-Chrysler, Germany on Possibilities and limits of NVH CAE applications in daily engineering practice and Zi Qiang Hou, Institute of Acoustics, Beijing, China on Application of DSP in acoustics and vibrations.

Further information on the contributed papers, technical exhibition and the social program from http://www.congrex.com/icsv10, Fax:+46 8 661 91 25 or icsv10@congrex.se

Ultrasonics International (UI03)

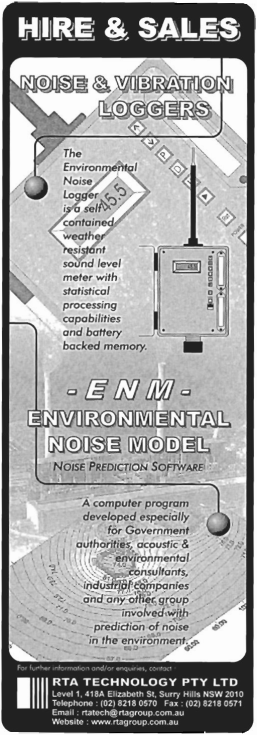
This conference will be held 30 June to 3 July 2003 in Granada, Spain. UI03 is the 19th Conference in this international series devoted to the science and technology of ultrasound. The conference will comprise of Special and Regular Sessions on current topics in the field of ultrasound and will include Invited Plenary Lectures, Contributed Orals and Poster Presentations plus an Exhibition of ultrasonic instrumentation.

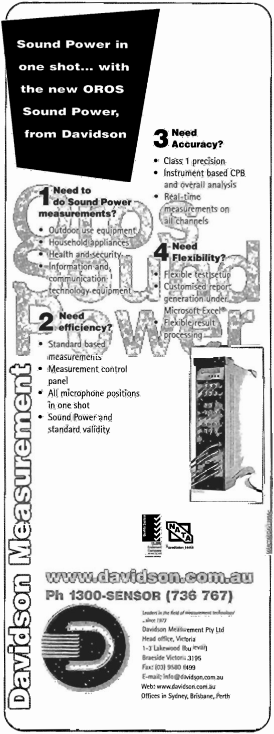
Further information from www.ui03.com or j.benoist@elsevier.com

Inter-noise 2003

The 32nd International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2003) is to be held at the International Convention Center in Seogwipo, JeJu Island, Korea, August 25~28, 2003. The Congress is sponsored by the International Institute of Noise Control Engineering (I-INCE) and co-organized by the Korean Society for Noise and Vibration Engineering (KSNVE), and the Acoustical Society of Korea (ASK).

The main theme of the Congress is "Noise and Vibration Control for Human and Environment", while various topics related to noise and vibration. Details on the conference are available from www.i-ince.org, fax +82-2-764-9580 or +82-2-762-4946, internoise2003@covanpco.co.kr


HIRE & SALES
NOISE & VIBRATION LOGGERS
The Environmental Noise Logger is a self contained weather resistant sound level meter with statistical processing capabilities and battery backed memory.
- ENM -
ENVIRONMENTAL NOISE MODEL
NOISE PREDICTION SOFTWARE
A computer program developed especially for Government authorities, acoustic & environmental consultants, industrial companies and any other group involved with prediction of noise in the environment.
For further information and/or enquiries, contact :
RTA TECHNOLOGY PTY LTD
Level 1, 418A Elizabeth St, Surry Hills NSW 2010
Telephone : (02) 8218 0570 Fax : (02) 8218 0571
Email : rtatech@rtagroup.com.au
Website : www.rtagroup.com.au


Sound Power in one shot... with the new OROS Sound Power, from Davidson
OROS Sound Power
1 Need to do Sound Power measurements?
• Outdoor use equipment
• Household appliances
• Health and security
• Information and communication technology equipment
2 Need efficiency?
• Standard based measurements
• Measurement control panel
• All microphone positions in one shot
• Sound Power and standard validity
3 Need Accuracy?
• Class 1 precision
• Instrument based CPB and overall analysis
• Real-time measurements on all channels
4 Need Flexibility?
• Flexible test setup
• Customised report generation under Microsoft Excel®
• Flexible result processing
Davidson Measurement
www.davidson.com.au
Ph 1300-SENSOR (736 767)
Davidson Measurement Pty Ltd
Head office, Victoria
Fax: (03) 9580 6499
E-mail: info@davidson.com.au
Web: www.davidson.com.au
Offices in Sydney, Brisbane, Perth

Meeting Reports

Victoria

Dow "Quash" Sound Management Foams

The technical meeting held at Dow Chemicals, Altona, on Oct 16 was to enable Dow Chemicals in conjunction with Latimer Acoustics to launch a new range of "Quash" sound management foams. It was a meeting organized by the ANCE to which AAS members also were invited. Richard Latimer of CMG Latimer Acoustics addressed the meeting and described the various acoustical and technical properties of the new range of sound management foams.

"Quash" is an extruded large closed cell polyolefin foam in which acoustic energy is dissipated through membrane and cavity vibration. This contrasts with fibrous or open cell conventional materials (such as the widely used Acoustop foam rubber) in which acoustic energy is dissipated through air flow and friction. As an extruded material "Quash" is made in a variety of sizes and thickness and is usually colored white or black.

"Quash" may be used as either a sound absorber or noise barrier. Because it is a closed cell material it also has other advantages such as very low water absorption, which result in its physical and acoustic properties being highly stable in comparison with other materials having higher water absorption. Its low water absorption also means that it can be readily cleaned and washed (including water blasting) without its performance being adversely affected. It is a low density, light weight material, which won't deteriorate or promote corrosion. It is relatively rigid, having an inherent mechanical strength, and so easy to install. In general, it is a versatile acoustical material with wide use in wrapping, lagging, shielding, industrial, marine and automotive applications. With suitable additional treatments during manufacture, "Quash" materials can exhibit high temperature and high fire ratings.

At the close of the meeting, John Upton on behalf of all present thanked Richard Latimer for his presentation, the vote of thanks being carried by applause.

AGM AT MELBOURNE'S CONCERT HALL

On Aug 7, a technical meeting and AGM was held at the Melbourne Concert Hall. Andrew Nicol, a senior associate, and manager of Arup Acoustics, and Darren Golding of the Concert Hall spoke on the acoustics of the Hall and its sound system. Approximately 35 members and friends were present.

Andrew Nicol began by saying that Arup Acoustics was studying the acoustics of the Concert Hall as a result of continuing comments that improvements were needed, and because its 20th anniversary was seen to be an opportunity to address these. Designing the hall began in 1973, with Roy Grounds as architect and the US consultants, Bolt, Beranek, Newman (BBN) Inc undertaking the acoustical design. The general design of the Hall was thus influenced by that of the Old Massey Hall, Toronto, Canada, which at the time of design was considered acoustically successful. Two other concert halls, in San Francisco (Louise M Davies Symphony Hall) and Toronto (Roy Thompson Hall), were being similarly designed by the same acoustic consultants. All three halls had a similar basic shape, different from the previously adopted and acoustically successful rectangular "shoebox" design, in order to accommodate audiences greater than 2000 and up to 2500.

As built, the Melbourne Concert Hall auditorium has an interior volume of 26900m^3, and a mid-frequency reverberation time of 2.2s. This could be varied with the use of drapes, though the claim that reverberation at higher frequencies could be reduced to 1.5s does not appear to have been sustained in practice. Considered by BBN to be the most critical acoustic element is the array of 24 oval perspex sound reflecting panels, originally set at about 9m above the stage. Both angle and height above stage of these panels can be varied, a feature used by some of the hall's concert performers.

The Concert Hall was opened in 1982. Almost immediately, there were criticisms, both favorable and adverse, of its acoustics, one group of critics naming it "Tympany Hall". As a result, the auditorium has experienced some superficial periodic acoustic modification since then. Now, after 20 years, and as a result both of continuing dissatisfaction and of new developments in acoustical design, the hall's acoustics are undergoing a thorough re-appraisal. This is being carried out in two initial stages.

In Stage One, the Hall's acoustic qualities are to be the subject of consultation, diagnosis, in order to thoroughly understand what needs to be fixed. Such understanding is most important. Stage Two will involve developing an acoustic design brief for its refurbishment, through establishing its boundaries, and developing conceptual proposals for refurbishment options.

As part of stage one, the VACT, John Hopkins (orchestra conductor and former head of the neighboring College of the Arts), other conductors, orchestras, soloists and experienced listeners are being consulted. Key acoustic parameters such as clarity, reverberance, loudness, balance, ensemble, envelopment, sustainability, and background noise are being studied. Evaluating the comments on these is a statistical process.

So far, comments from performers on the platform indicate that clarity is not very good, with the stringed instruments' sounding 'muddy' but variable ; reverberance being mediocre, but with a tendency to being 'live' rather than 'dead' ; and sound on the platform being generally very loud (particularly from brass instruments). By contrast, listeners in the auditorium commented that clarity and reverberance tended to be poor (with a tendency toward 'deadness'); while the sound generally would benefit from being louder.

Interim conclusions are that

- There is a lack of envelopment – the sound is mainly frontal, with very little reflected from the side walls. In this respect, the balcony differed from the circle and stalls in that here there was some degree of envelopment resulting from the greater adjacent wall and ceiling area.
- There is considerable variation in sound quality from seat to seat as well as a significantly greater loss of reverberation and sound power under balconies than out in open areas of the hall.
- There is a proscenium-like interruption of sound between performers and audience. Performers on stage receive little sound back from the auditorium.
- The limited sequence of reflections means that the sound is insufficiently sustained throughout the auditorium.
- There appeared to be a general lack of low frequency sound.
- The Hall when empty under normal operation is relatively noisy, due to aging of mechanical services, etc. Originally, background sound levels were designed to be around NR20 ; they are now around NR30. Also, when the air conditioning is turned off, other noises are heard (eg, trams from the street outside). Higher than necessary levels of this background sound reduce the signal-to-noise ratio, thus decreasing the effective possible dynamic range of musical performances. By contrast, quiet environments beneficially influence audience behavior. Threshold noise levels in Australian auditoriums tend to

be higher than in Europe and the USA. Birmingham Symphony Hall with its very low background noise level is excellent in this respect.

For the future, these findings point to a desire to improve the Hall's acoustics, and to the need for some aesthetic improvements and increased use of electro-acoustic equipment.

Darren Golding then described past and current use of such equipment in the Concert Hall. The original plan (when the audio specification was prepared in 1968!) was that the Concert Hall would be an acoustic auditorium with only a PA system. However, because many performing groups insisted on having additional sound amplification, they often went elsewhere because of the considerable extra cost entailed. Eventually in the late 1990s, the management, after around 9 years of lobbying the state government, obtained the funds to install a suitable fixed system. The Concert Hall is now a very desirable venue for a wide variety of performers and performances, and recent groups have not needed to provide additional sound amplification.

The current system is comprehensive, with the aim that all performances should sound better. It comprises 57 independent loudspeaker units, each with their own appropriate time delay. With each unit also incorporating its own amplifier, and using digital technology, there are no difficulties in balancing the various outputs.

These provide both general sound amplification and sound boosting for "dull" spots A remaining problem is that groups using the full amplification provided require to properly balance their stage sound with that heard in the hall. An additional feature of the sound system is that all, rather than only a limited number of seats are now so equipped that those with hearing aids have complete choice of location and can tune in and receive the amplified sound.

Inspection of the auditorium from the stage area enabled those present to gauge the hall's acoustics, and see the perspex sound reflecting panels above the stage, and other more recently installed sound reflecting panels on the side walls.

Musical Instruments

At the Division's end-of-year dinner on Nov 20, the guest speaker was Assoc Prof Joe Wolfe of the University of New South Wales. He began with the musical family of woodwind instruments by naming those in wide use at present — flute, oboe, English horn, clarinet, saxophone and bassoon. Whereas with stringed instruments, such as those of the violin family, the player's arm provides the energy to produce sound, with all wind instruments the initial energy is provided by the player's breath.

Apart from the flute, and its close relative the flute-à-bec or recorder, which are excited by air jet, the remaining woodwinds are excited by vibrating reeds. All have some combination of instrument bore and air column, bell mouth and keys as part of their resonating and impedance matching systems, with their air columns behaving as linear oscillators having high Q, thus allowing precise tuning. Their air jets and reeds, termed the instruments' control oscillators, are highly non-linear, and exhibit phase locking and harmonic behavior. Their individual timbres arise from the various harmonics and transients which are generated when they are played.

A small music box, which can be heard only when placed on a suitable base, was used to demonstrate the need for some instruments such as stringed instruments to have an impedance transformer in order to radiate substantial acoustic power into the air. In the case of the woodwinds the resonator is already air, so little matching is required. A further demonstration showed that a reed when blown can not only open, but when blown too hard can close the air passage into the bore. The graph showing Rate of Air Flow into an instrument as a function of Mouthpiece Air Pressure confirmed this, with a maximum air flow, beyond which, with increasing pressure, the flow decreased eventually to zero, a region of negative resistance.

A clarinet reed and flute mouthpiece (part of its head-joint) demonstrated that when blown they could indeed produce a musical note, but needed the body of each instrument to produce controlled notes. The next demonstration showed how a "string" suitable for such purposes could vibrate in not only its fundamental mode (with one maximum at its centre) but in several higher harmonic modes.

Human nerve responses impose a speed limit such that sounds do not become audible until the frequency of their pressure variations exceeds around 20 to 30 Hz, which is of the same order as the number of video frames per second required to avoid flickering.

The flute, equivalent to a hollow cylindrical pipe open at each end, was demonstrated to be able, when overblown, to produce both odd and even harmonics up to the eighth. By contrast, the clarinet, equivalent to a cylindrical pipe closed at one (the reed) end, could produce only the odd harmonics. A further demonstration, using a hybrid instrument consisting of a clarinet mouthpiece suitably coupled to a flute minus head joint, referred to as a "flarinet", showed the resulting tone to resemble that of a clarinet rather than a flute.

At this point Prof Wolfe introduced the concept of Acoustic Impedance, equal to the acoustic pressure divided by the volume velocity (of the medium in the instrument bore). In addition, he showed several graphs of the variation with Exciting Frequency of the Input Impedance of a given length of bore. While the impedance maxima characterized the behavior of reed instrument bores, the minima characterized that of the air jet instruments.

The clarinet and oboe instrument families are reed instruments, but differ in that clarinets have a cylindrical bore whereas oboes, English horns and bassoons (and also the saxophone family) have conical bores, the result being that the harmonic content of their tone includes even as well as odd harmonics. For details on this, the audience was here referred to the UNSW website (physics – musical acoustics).

Because an oboe reed is small and restricts a player's blowing, oboists usually need to breathe out rather than in after playing a musical phrase. This was demonstrated with the playing of the first six measures of Bach's Sinfonia to Cantata no. 156 (slow, not fast music) in one breath.

Prof Wolfe also demonstrated the wide range of the bassoon in its several registers, from the lowest (B-flat at 58 Hz, at which the vibrations can be almost heard) to its highest (using the opening measures of Stravinsky's *Rite of Spring*). He also demonstrated that it has become possible to play two flute notes simultaneously, in this example two notes a fourth apart (C and F, then C# and F#).

With the higher pitched woodwinds the keys are within finger span; with the lower pitched instruments such as the bassoon some extra mechanical devices are needed to facilitate convenient fingerings. With these instruments, also, there are up to around 200 000 possible combinations of open and closed keys for achieving the different notes of the musical scale throughout around three octaves. Musical tuning is highly critical; ±1% (approximately equal to one-sixth of a semitone) is not nearly good enough. A computer program developed by a student in the UNSW group is now available for determining optimum fingerings to obtain accurately tuned notes and achieve comfortable (rather than awkward) fingerings in running passages.

The final demonstration was of Genevieve Lacey playing a composition — The Nightingale : theme and variations — by the 17th century Dutch composer, Jacobi van Eyck (1589-1657), on an Australian Fred

Morgan descant recorder.

After several questions had been answered, Norm Broner thanked Joe Wolfe and Genevieve Lacey for a most interesting talk and demonstration, a vote carried with applause.

Louis Fouvy

West Australia

DSTO Visit The Defence Science and Technology Organisation (DSTO) visit at the HMAS Stirling Navy Base also included tours of Collins Class Submarine training simulator facilities and the non-explosive torpedo maintenance area, and received rave reviews!

Division State Conference was held at the Aquarium of Western Australia on the 29th August. The conference room featured a wonderful view of a rather stormy Indian Ocean, but despite this distraction the speakers were able to hold the audience's attention. The first three papers were particularly appropriate for the venue, being on various aspects of underwater acoustics, commencing with a paper on acoustic noise fault detection in submarines by David O'Mara (Visionary Systems). This was followed by two papers from postgraduate students at Curtin University's Centre for Marine Science and Technology: a study of 3D wave propagation effects in 2.5D acoustic modelling by Ahmad Zakaria, and an account of the use of acoustic techniques for benthic habitat assessment presented by Justy Siwabessy.

After the coffee break there were three papers from the Department of Mechanical and Materials Engineering at the University of Western Australia. Jie Pan continued the marine theme with a description of techniques developed to characterize the transmission of propeller force fluctuations through a thrust bearing, and then the focus shifted to dry land with a paper from Jingnan Guo describing an innovative noise barrier dubbed the wave-trapping barrier. The final paper before lunch was from M. Roshun Paurobally who described the basic principles of active noise control and some recent applications.

The Divisional AGM was held before lunch. Then followed a description of a cumulative noise model of the Kwinana Industrial Area by Jim McLoughlin (SVT), a paper from Peter Asotoff (DEP) on gunshot noise, and a detailed look at the proposed draft building code of Australia (section F5) and the AAAC acoustic star rating of buildings by George Watts and Allan Herring (Herring-Storer Acoustics).

NSW

Sound Insulation

On Wednesday 16th October 2002 approximately 30 members attended a NSW Divisional Meeting on sound insulation and the star rating system at CSR *design*LINK, Pyrmont Bridge Road, Ultimo.

Michael Ryan of CSR designLINK started by explaining the 'spectrum adaptation term - Ctr', this gives an indication of the low frequency performance of partitions. Michael then presented some of CSR's new systems and products such as the steel lined 'SecurityWall', which offers high acoustic performance (up to Rw 63) with relatively lightweight constructions, 'Cinema Wall' with ratings up to Rw 81 and the use of 'Soundchek 13', which is a high-density 13 mm thick plasterboard. Michael also spoke about a new method ('silencer') for enclosing services in walls while still maintains Rw values up to 63.

Peter Knowland of PKA Acoustic Consulting then discussed the concepts of the new AAAC Star Rating System. The Association of Australian Acoustic Consultants (AAAC) has been concerned for a long time that architects, developers and builders have selected the acoustic provisions of the Building Code of Australia (BCA) as "The Standard". The BCA is a minimum acceptable community standard that balances affordability of housing with appropriate construction standards. The BCA does not ensure quality and has resulted in a high level of residents being dissatisfied with their acoustic environment.

The AAAC has prepared a Star Rating System to encourage an acoustic quality standard in apartment buildings. The Star Rating System goes well beyond the scope of the BCA and projects are already being designed to 5 Star Rating. It covers not only sound insulation between dwellings but also noise from outside, internal service noise including noise from car park door motors, elevators, toilet systems, etc. Peter explained that they are using the 'spectrum adaptation term - Ctr' even though this was not totally satisfactory. This is mainly because of the acceptance in Australian and International Standards. The Star Rating System utilises another European term the Dntw which is a measured level difference with standardization on a reverberation time of 0.5 seconds. Peter explained that 3 star rating is an approximation to the current BCA and 4 star rating is what could have been an improved version of the BCA. The 2 star rating shows an indication that the sound insulation would be below the current BCA. The 5 star rating would be very high quality while the 6 star rating would be almost impossible to achieve outside of the purpose-built multimillion-dollar home.

Questions related to the low frequency noise problems and how developers would obtain the star rating certification for their constructions. This was followed by a hearty thanks to both speakers and a continuation of the discussion of the contentious issues over finger food and glass of wine.

Ken Scannell

Sten Ternström Sings

Dr Sten Ternström from the Docent of Music Acoustics, Stockholm, Sweden presented a talk to the NSW Division on 24 July entitled "How to invent a musical instrument". The talk posed questions about the applications of acoustics and music and the features that are important in hearing musical instruments. An idea was discussed of a relationship between the ease of playing the instrument and a relationship between the number of simultaneous tones and the control parameters per tone. Degrees of freedom of various instruments were illustrated, with sound. A checklist of how to invent a musical instrument was offered, with suggestions to choose between many options including: a set of timbres, principal perceptual parameters, control methods, maximum number of simultaneous tones, transform the perceptual parameter space to the acoustical parameter space, implementation domains, model for sound generation and a number of other features for variations and feedback to the performer. No information was given on how to find musicians who are willing to put your new instrument to the test!

Fergus Fricke

New Members

NSW

Graduate:	Mr Scott Hughes,
	Mr Stephen Kozakiewicz

QLD

Member:	Dr Nicole Kessissoglou
Graduate:	Mr Joseph Carroll

WA

Member:	Dr Jingnan Guo

Standards Australia

In December Committee AV-001 *Acoustics - Terms, units and symbols* intends to publish its revision of AS 2533: 1982 Acoustics – *Preferred frequencies of measurement.*

AV-001 also continues to work on its revision of AS 1633:1985 Acoustics – *Glossary of terms and related symbols* which has been a lengthy project but is planned to be finalised in the next few years. AS 1469:1963 *Acoustics-Method for the determination of noise rating numbers* is also being reviewed for revision. A new Standard dealing with recommended graph scales and preferred graph ratios is also being developed.

AV-003 *Acoustics – Human Effects* has published three of a four part series of the IEC Audiometers series. The remaining part is planned for publication by the end of year with a slight technical change.

AV-004 *Acoustics – Architectural* is considering the revision of AS 1045:1988 *Acoustics – Measurement of sound absorption in a reverberation room*, AS 2822:1985 *Acoustics – Methods of assessing and predicting speech privacy and speech intelligibility* and AS 1277:1983 *Acoustics – Measurement procedures for ducted silencers.*

EV-010 *Acoustics – Community Noise* is still waiting for the release of the NSW EPA new railway policy. After its release EV-010 will recommence its development of a Standard dealing with siting and construction near railways.

EV-016 Acoustics – Wind Turbine Noise was formed to provide a Standard for wind farm developers and regulatory authorities with a method for prediction and measurement of noise from wind turbines. EV-016 has commenced drafting the Standard using New Zealand Standard *NZS 6808:1998 Acoustics-The assessment and measurement of sound from wind turbine generators* as a base.

Australian delegates attended International Committee ISO TC 43 Acoustics in May in Paris and IEC TC 29 *Electro-acoustics* in Frankfurt in June.

One main reported outcome of the TC 43 meeting was the proposed restructure of the ISO 140 *Measurement of sound insulation in building and of building elements* series. The restructure suggested split the existing Standards into new classes: laboratory, airborne, impact, measure and quality, and test codes.

In the TC 29 the delegates were involved in discussions for the development of the IEC Standards on sound level meters, filters, microphone, audiometers and hearing aids

For inquires about the above activities contact Suzanne Wellham at Standards Australia on 02 8206 6821 or at suzanne.wellham @standards.com.au

FASTS

"Science meets Parliament" Day has once again proven to be a wonderful opportunity for 154 scientists and technologists to put the case for science to the 128 MPs who agreed to participate. Among the science and research issues currently being considered by Parliament are the Higher Education Review, priority research areas and triennium funding for Government-funded research agencies. These are matters where the science community has well considered views. The event generated good radio and newspaper coverage.

Tuesday 12 Nov. The National Press Club lunch was eloquently addressed by Dr Keith Williams, CEO of Proteome Systems Ltd. His company has rapidly expanded to be one of the world forces in proteomics, and employs about 60 PhD graduates. Lunch was followed by a comprehensive Briefing Session for the scientists. Lord Robert May, President of the Royal Society, Robin Batterham, Chief Government Scientist, John Tierney from the Liberal Party, ALP Science spokesperson Kim Carr, Senator Natasha Stott Despoja, the Speaker of the House and the President of the Senate all contributed to an informative afternoon. Education Minister Brendan Nelson, and Science Minister Peter McGauran hosted a Cocktail Reception at Parliament House.

Wednesday 13 Nov. After breakfast at Old Parliament House, society representatives commenced the rounds of appointments with MPs which continued throughout the day. There was a meeting with the Leader of the Opposition Simon Crean, a Press Conference given by a panel of young scientists and morning tea hosted by the Science Minister Peter McGauran. A new feature this year was a special dinner in the dignified and atmospheric Members' Dining Room at Old Parliament House, with guests drawn from participating scientists, from business and industry, and from selected Members of Parliament. The after-dinner speaker was Mr Bob Herbert, CEO of the Australian Industry Group. This dinner was arranged as an optional extra for participants wishing to build dialogue with MPs and industry. **Thursday 14 Nov.** FASTS held the 2002 Annual General Meeting, Council Meeting and Board Meeting. The President-elect for 2003/2005 is Professor Snow Barlow, Head of the School of Agricultural and Food Systems, University of Melbourne. Assoc. Prof. John Rice was re-elected as Treasurer, and Assoc. Prof. John O'Connor was elected as Secretary.

FASTS 2002 Policy Document Professor Chris Fell, President of FASTS, said that some industries and some government portfolio areas have a clear sense of direction, but the country as a whole needs a national vision. "We lag behind advanced countries when it comes to investing in the ingredients of a modern economy." "Australia seems to be afflicted by short-termism," Professor Fell said. "We need to escape from our national love affair with real estate, and commit to a long-term national plan with a future." He said in any international comparison, there are the advanced countries, and then there is Australia. "We drag at their coat-tails, always running eleventh or fifteenth". "Science and technology drive our economy and solve our environmental problems, and yet we accept our international status as one of the also-rans. We don't accept the mediocre in sport - why do we accept it in science, where it really counts?" Professor Fell said the policy document puts forward a comprehensive set of policies aimed at driving Australia into the top third of OECD countries by 2012.

Science Minister Peter McGauran said "Many of the issues that concern FASTS are similar to that of the Government, but more importantly there is a high level of agreement as to how we should address the challenges outlined in the document". He stated "This Government places great value on Australian science and the work of Australian scientists. It is important that science policy is supported by a whole-of-government approach, as evidenced by *Backing Australia's Ability.*

The complete document is available at www.fasts.org.au..

Letter

I am a student in ESM2, a French engineering school, and follow mainly acoustic and vibration courses. One of the graduation requirements is a 4-6-month internship from March, 2003. The purpose of this is to introduce students to various professional and technical aspects of working within the engineering field, and to apply what was learned. I will have to write a report on my project.

I would be interested in working in environment or civil engineering, using my knowledge in mechanics and acoustics. Moreover, I would like to make better use of my languages. So I would jump at the opportunity of working in a foreign country, all the more since Australia really appeals me.

I look forward to hearing from you,

Miss Christelle PELLOUX
christelle.pelloux@esm2.imt-mrs.fr

ACOUSTIC FRIDGE

Thermoacoustic refrigerators, which employ sound waves to chill or freeze items and have been limited to military and space use, may finally reach consumers following advances by American researchers. Scientists at Pennsylvania State University, US, led by Professor Steven Garrett and Mathew Poese, revealed that they had developed a loudspeaker that is 10 times better at converting electric power into sound - making thermoacoustic fridges more efficient. "We have achieved proof-of-concept for making a compact chiller that has a volume which is substantially smaller than earlier thermoacoustic chillers," Garrett said in a statement. "The coldest temperature we have achieved with this test rig is -8C… - well below the freezing point of water."

The idea of using sound waves for refrigeration was first developed in the 1980s by scientists at the Los Alamos National Laboratory, a defence research institute in New Mexico, USA. Improvements in efficiency have since made thermoacoustic devices competitive with conventional gas-chemical systems in certain industrial and defence applications, such as the space shuttle and U.S. naval vessels.

Conventional refrigerators chill items by compressing and expanding chemicals called refrigerants, which transfer heat from inside the fridge to the outside, cooling the inside. But refrigerants are now known to deplete the Earth's ozone layer, and replacement chemicals have recently been discovered to be 3,000 times more effective at contributing to global warming than carbon dioxide.

Thermoacoustic fridges, however, rely on the compression of normal air, using extremely powerful sound waves from an especially tuned loudspeaker. But up until now, efficiency has been a problem. The efficiency of a typical musical loudspeaker is less than 1% - that is, only 1% of the power going in is extruded as sound. One reason is that speakers need to produce a very large range of frequencies at similar levels: from the low notes produced by a bass or tuba to the high notes of a triangle or a piccolo.

Garrett and his team developed a loudspeaker which produces just one special frequency - the one which creates the best resonance with the container in which it sits. This resonance enables amplification up to reach 173 dB. The researchers report that their souped-up loudspeaker has demonstrated efficiencies as high as 89% at up to 5 kW of power - all without the use of lubricants or sliding seals - which means it has the potential for a very long life with low maintenance.

Fortunately, there's no chance of people being accidentally exposed to the hyper-intense sound: it can only be generated by the resonance conditions maintained by the pressurised gas inside the container. Dr Ben Cazzolato of the University of Adelaide's School of Mechanical Engineering - who with his students is attempting to develop a thermoacoustic refrigerator - was very excited about the development. "I think it's a really cool technology," he told ABC Science Online. "It would nice to see it move into the domestic sphere."

From ABC Science Online, 5 Dec 2002, Anna Salleh

RTA Anniversary

Renzo Tonin & Associates Pty Ltd is celebrating its **20th anniversary**! To this very day, the company carries the same words in its promotional material as it did on its first day - "providing high technology service to architects, engineers, town planners and builders" and offering "a high-tech engineering approach to acoustics and vibration". In 1989, Renzo Tonin formed RTA Technology Pty Ltd to promote his software program ENM - Environmental Noise Model and his environmental noise loggers. Both products are under continuous development to ensure they remain at the forefront of acoustics in their respective classes. In 1991, Renzo Tonin formed Windtech Consultants Pty Ltd to provide expert consulting services in wind engineering. The company runs the largest private wind tunnel facility in Australia.

Renzo Tonin thanks his staff for a job well done and aspires to expanding his team of experts into new directions in the coming years. www.rtagroup.com.au

B&K News

Brüel & Kjær's **Automotive Newsletter** is distributed in PDF format four times a year and includes information on new and existing products which have special relevance to the automotive industries. It includes interesting applications and solutions developed around the world. If you would like to receive future issues, just send your name, position/title, and your company's name and address to automotive@bksv.com.

The first issue of Brüel & Kjær's **Aerospace and Defence Newsletter** is now available. It is distributed in PDF format twice a year and includes information on new and existing products which have special relevance to the aerospace and defence industries. If you would like to receive future issues, just send your name, position/title, and your company's name and address to aerospace@bksv.com.

2002 marks the **60th anniversary** of the founding of Brüel & Kjær. Managing Director Karl Nielsen attributed the company's long and dominating presence in the industry to 60 years of knowledge and experience, the high quality of its products and after-sales service and support, and its continued commitment to working with and listening to its partners and customers.

News from G+H

A Joint Operation Alliance has been established between **hps/HVAC** and the German based **G+H Group** for the supply of acoustic products to the power generation, automotive and aviation industries. This means **hps/HVAC** will engineer, manufacture and install world-leading acoustic solutions with technical support and engineering backup from the **G+H** Group. More information from www.hpsb2b.com

Unit Conversion

A handy on line unit coversion is available from the Davidson website at http://www.davidson.com.au/tools/convert/. This tool will instantly convert units from one form to another. There are 17 categories and within each category a very comprehensive range of possible conversions. Seeing the number of different units that have been used makes us grateful for the adoption of standardisation in units over the last decades.

Electronic Journal

The Journal "Technical Acoustics" publishes accepted papers in the Internet. Electronic Journal "Technical Acoustics" (EJTA). This is a peer-reviewed journal publishing original articles in all areas of acoustics. EJTA has the benefits of an electronic journal: speed of publication and wide distribution. EJTA is principally funded by article charges from authors of published papers. It is available, without charge to readers via http://webcenter.ru/~eeaa/ejta/. For more information eeaa@online.ru

New Products

ARL

Program Cards

Program cards are now available to enhance the capabilities of the Rion NL-22 / 32 integrating sound level meters. The NX-22RT card enables these meters to be used to measure octaves and third octaves in real time. Data is stored on the program card for easy transfer to a computer for later analysis.

The NX-22J card lets you add audio recording capacity to your NL-22 / 32 meter. During noise measurements, event recording (triggered when a preset level is exceeded) or interval recording (activated at preset time intervals) is possible. The NX-22FT card adds an FFT analyser function to your NL-22/32 meter.

All of these program cards have been designed by Rion to give the user options not usually available in an integrating sound level meter.

Further information: Acoustic Research Laboratories. Tel 02 9484 0800, www.acousticresearch.com.au.

STELL

SOLO: Digital integrating sound level and vibration meter

The result of 15 years' experience, SOLO represents the newest generation of 01dB-Stell digital integrating sound level meters. SOLO complies with the latest international standard (IEC 61672-1) on sound level meters. Its versatility allows for various applications such as vibration measurements, vehicle noise, sound and vibration monitoring, 1/1 and 1/3 octave real-time frequency analysis, etc. The 24-bit analogue-digital conversion allows for measurement on a single dynamic range (117 dB) and the large memory capacity for storage of all data measured in parallel. Also, the USB interface turns SOLO into an acquisition front-end for real-time analysis on a PC. Using a modem or a GSM phone, SOLO may be remotely monitored and interrogated to retrieve all measured data, without disrupting the current measurement session.

Information: ACU-VIB Electronics 02 9680 8133, www.acu-vib.com.au

CAUSAL SYSTEMS

Engineering Noise Control ("ENC") software

This software evaluates practically all of the expressions and algorithms in the book, "Engineering Noise Control" 2nd Edn. by DA Bies and CH Hansen. The software is divided into seven modules. Module 1 covers the first four chapters of the book, including speed of sound, addition and subtraction of levels, noise criteria, hearing damage risk etc. Module 2 covers sound chapters 5 and 6 of the book, including sound power and outdoor sound propagation calculations for a range of propagation models and sound source types. Module 3 covers chapter 7 in the book and included calculations for modal density, modal overlap, absorption coefficients from flow resistance, panel absorber design and reverberation time using a number of formulae and sound propagation in long and flat rooms. Module 4 covers calculation of sound transmission loss for single and double walls (including multi-leaf walls) using both Sharp and Davy theories, enclosure design, outdoor and indoor sound barrier design, and pipe lagging insertion loss. Module 5 covers reactive mufflers, wave tubes, Helmholtz resonators, low pass filter design, lined duct (or dissipative silencer) design, plenum chamber design, exhaust stack directivity and duct break-out, break-in calculations. Module 6 covers vibration isolation (SDOF and 4-mount systems), vibration absorbers and the effect of flexible support structures on vibration isolation performance. Module 6 is concerned with the estimation of the sound power output of a range of source types, including fans and control valves, as detailed in chapter 11 of the book.

A demo version of the software, user manual and order form can be downloaded from http://www.causalsystems.com/.

LARSON DAVIS

System 824 SLM/RTA

The Larson Davis System 824 combines sound level meter and real-time analyser capabilities in one small, rugged package. It measures Slow, Fast, Impulse, Peak and Leq levels for A, C and Flat weightings simultaneously. The System 824's optional accessories give the unit the capability to do full and 1/3 octave measurements (SSA option), environmental logging (LOG option), high speed real time frequency analyser for RT60 calculations (RTA option) and fast Fourier transform analyser (FFT option).

Data, Navigation and Analysis Software

Larson Davis' DNA (Data, Navigation and Analysis) software makes analysing noise and vibration data, as well as presenting it in a meaningful way, a simple operation. DNA software displays, analyses and reports all project measurement data for you. It replaces the need for several different software applications to achieve what you really want. DNA quickly produces high quality charts, reports and presentations. Real-time Display Mode: DNA displays and controls measurement data in real-time, while maintaining access to all of the instrument's measurement and analysis functions. DNA interfaces with the Larson Davis Models 812, 814, 820, 824, 870B, 2800, 2900, & 3200 via RS-232 and RS-422. It provides instrument set-up and direct conversion and display of data files.

Head Acoustics

NoiseBook Mobile Noise Analysis System

The mobile noise analysis system NoiseBook is a user-friendly, easy-to-handle and cost-effective tool enabling binaural recording, analysis, archiving and playback of noise. The record/playback unit is the Headset MHS II, providing headphones and binaural HEAD microphone all-in-one. With the aid of the NoiseBook software, analysis and archiving of recorded noises is possible with any standard notebook. A database is optionally available to manage the noise files and associate them with any relevant additional data. NoiseBook provides technicians with an easy-to-operate tool for mobile sound recording. Current measurements can be analysed in the field and compared with samples from the sound database.

ArtemiS - Analysis Software

"ArtemiS", the Advanced Research Technology for Measurement and Investigation of Sound and Vibration, runs under Windows operating systems and can analyse, filter, display and document acoustic and vibration measurement data in a wide range of modes. Yet an outstanding feature of this software is the possibility of including the aural sense of the human user in signal analysis. ArtemiS introduces an innovative operating concept, making not only the analysis of individual measurements, but also entire measurement series, into a structured and transparent operation. The user decides what is displayed on-screen by configuring which windows, tools, data files, diagrams, etc., are displayed. The user is able to define button bars and hotkeys individually, thus matching the system to his own requirements. Using this concept, both maximum clarity and an extensively equipped analysis platform are achievable.

Further information from Davidson, 1-3 Lakewood Boulevard, Braeside, Victoria, 3195, Tel 1300 SENSOR (1300 736 767) Fax: 03 9580 6499 info@davidson.com.au http://www.davidson.com.au

Diary...

2003

06 - 10 April, Hong Kong
IEEE International Conference on Acoustics, Speech, and Signal Processing
Wan-Chi Siu, Hong Kong Polytechnic University, Hong Kong; http://www.en.polyu.edu.hk/

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

19 - 21 May, Naples
Euronoise 2003.
DETEC, University of Naples Federico II, P. le Tecchio 80, 80125 Napoli, Italy, Fax +39 81 239 0364, http://www.euronoise2003.it

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

23-25 June, Cleveland
2003 Nat Conf Noise Control Engineering.
INCE Business Office, Iowa State University, 212 Marston Hall, Ames, IA 50011-2153, USA, Fax +1 515294 3528, ibo@ince.org

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/

24-27 August, Korea
Internoise 2003
Fax +82 2 762 4946, internoise2003@covanpco.co.kr, www.internoise2003.com

1-4 September, Geneva
Eurospeech 2003.
SYMPORG SA, Avenue Krieg 7, 1208 Geneva, Switzerland, Fax: +41 22 839 8485, http://www.symporg/eurospeech2003

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

23 -25 September, Senli
2nd Int Symp on Fan Noise.
CETIAT, B.P. 2042, 69603 Villeurbanne cedex, France, Fax: +33 4 72 44 49 99, http://www.fan-noise2003.org

5 -8 October, Honolulu,
2003 IEEE Int Ultrasonics Symposium.
W. D. O'Brien, Jr., Bioacoustics Research Laboratory, University of Illinois, Urbana, IL 61801-2991, Fax: +1 217 244 0105, http://www.ieee-uffc.org

2004

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

03 - 07 August, Evanston
8th Int Conf of Music Perception and Cognition.
School of Music, Northwestern University, Evanston, IL 60201, USA,
http://www.icmpc.org/conferences.html

24 - 27 September, Prague
Inter-Noise 2004.
I-INCE, Herrick Laboratories, Purdue University, West Lafayette, IN, USA, Fax: +1 765 494 0787, www.i-ince.org

WWW Listing
Meetings Calendars are available on www.icacommission.org/calendar.html and www.i-ince.org

AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

NATIONAL MATTERS

* Notification of change of address
* Payment of annual subscription
* Proceedings of annual conferences

General Secretary
AAS– Professional Centre of Australia
Private Bag 1, Darlinghurst 2010
Tel/Fax (03) 5470 6381
email: watkins@castlemaine.net
www.acoustics.asn.au

SOCIETY SUBSCRIPTION RATES

For 2002/2003 Financial Year:

Fellow and Member	$103.40
Associate and Subscriber	$82.50
Retired	$34.10
Student	$23.10

Including GST

DIVISIONAL MATTERS

Enquiries regarding membership and sustaining membership should be directed to the appropriate State Division Secretary

AAS - NSW Division
Professional Centre of Australia
Private Bag 1,
DARLINGHURST 2010
Sec: Ken Scannell
Tel (02) 9449 6499
Fax (02) 9402 5849
scannell@rivernet.com.au

AAS - Queensland Division
PO Box 760
Spring Hill Qld 4004
Sec: Rebecca Donovan
Tel: (07) 3367 3131
Fax: (07) 3367 3121
rebecca@ronrumble.com.au

AAS - SA Division
C/–Department of Mech Eng
University of Adelaide
SOUTH AUSTRALIA 5005
Sec: Simon Hill
Tel: (08) 8303 5469
Fax: (08) 8303 4367
simon.hill@mecheng.adelaide.edu.au

AAS - Victoria Division
PO Box 417
Collins St. West
PO MELBOURNE 8007
Sec: Elizabeth Lindqvist
Tel (03) 9925 2144
Fax (03) 9925 5290
elindqvist.gharding@projectx.com.au

AAS–WA Division
PO Box 1090
WEST PERTH 6872
Sec: Mr J Macpherson
Tel (08) 9222 7119
Fax (08) 9222 7157
john_macpherson@environ.gov.au

ACOUSTICS AUSTRALIA INFORMATION

GENERAL BUSINESS

Advertising Subscriptions

Mrs Leigh Wallbank
PO Box 579, CRONULLA 2230
Tel (02) 9528 4362
Fax (02) 9523 9637
wallbank@zipworld.com.au

ARTICLES & REPORTS NEWS, BOOK REVIEWS NEW PRODUCTS

The Editor
Acoustics Australia
Acoustics & Vibration Unit, ADFA
CANBERRA ACT 2600
Tel (02) 6268 8241
Fax (02) 6268 8276
email: acoust-aust@adfa.edu.au

PRINTING, ARTWORK

Scott Williams
16 Cronulla Plaza
CRONULLA 2230
Tel (02) 9523 5954 Fax (02) 9523 9637
email: print@cronullaprint.com.au

SUBSCRIPTION RATES

	Aust	Overseas
1 year	A$ 60.50	A$ 70
2 year	A$ 104.50	A$125
3 year	A$148.50	A$180

Australian rates include GST.
Overseas subscriptions go by airmail
Discounted for new subscriptions
20% Discount for extra copies
Agents rates are discounted.

ADVERTISING RATES

B&W	Non-members	Sus Mem
1/1 Page	$638.00	$572.00
1/2 Page	412.50	374.00
1/3 Page	319.00	286.00
1/4 Page	269.50	242.00

Spot colour: $115.50 per colour
Prepared insert: $346.50* (additional postage may apply)
Column rate: $20.90 per cm (1/3 p 5.5cm width)
All rates include GST
* Conditions may apply

Discounted rates for 3 consecutive ads in advance
Special rates available for 4-colour printing
All enquiries to: Mrs Leigh Wallbank
Tel (02) 9528 4362 Fax (02) 9523 9637
wallbank@zipworld.com.au

ACOUSTICS AUSTRALIA ADVERTISER INDEX - VOL 30 No 3