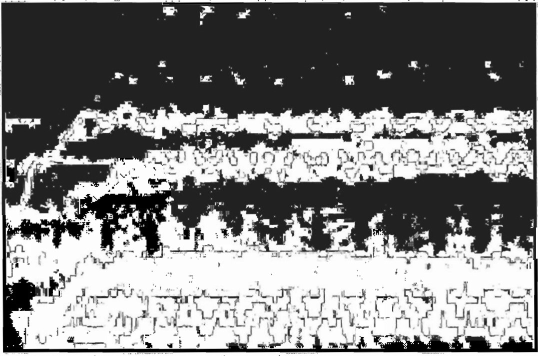
Acoustics Australia



- Operatic Duet Quality
- Aircraft Noise Information
- Vibration Isolator Parameters
- Hearing and Musicians
- Numerical Acoustic Applications

Australian Acoustical Society Vol. 28 No. 1 April 2000

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
http://www.users.bigpond.com/Acoustics

Australian Acoustical Society Enquiries see page 40

Acoustics Australia is published by the Australian Acoustical Society (A.C.N. 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 28 No 1 April 2000

CONTENTS

ARTICLES

COVER ILLUSTRATION: *Spectrogram of soprano duet singing. See paper by Duncan et al.*

From the President

Recently the need for 'good acoustics' has been reinforced in both our Victorian and National media. This augurs well for the Acousticians whose livelihood depends on solving acoustic problems.

Three recent acoustic issues were the belated solving of the acoustic difficulties at the Barbra Streisand Concert in the new Melbourne Colonial (Docklands) Stadium, the news that the Collins Class Submarines can now go undetected as they carry out whatever Australian submarines are supposed to do, and thirdly an article about the effective silencing of a young motorist fined for his loud radio while driving along Chapel Street, Melbourne.

Acoustic issues which have not made the news but are every bit as devastating for the people involved are typically:

- the poorly insulated new apartment walls,
- the neighbour's recently installed air conditioner,
- the school's new music department whose acoustic treatment was deleted for cost saving,
- the granting of an approval for a new residential development sandwiched between the highway and industrial estate.

These issues and many more like them are the ones which daily impact on the lives of many in our community who in their distress look to us - the experts - to provide the solution to their dilemma.

For those of us working at this particular 'acoustic coal face' it would seem an appropriate time to dust off our seven year old 'Code of Ethics', read it again and redouble our efforts to live up to the responsibilities we imposed upon ourselves as members when we first adopted the Code. The community are faced with many different and sometimes almost unresolvable acoustic issues. With sensitivity, honesty, integrity, application of our expertise with a balanced degree of imagination and a modicum of humour it is surprising how a solution can be found even for the most intractable acoustic problem.

Acousticians - there are indeed many problems to solve. Enjoy your work, it is so varied in scope, savour the solutions you find and at the end of the day you will have enhanced the field of acoustic endeavour, the foundation and reason of our Society's existence.

Geoff Barnes

AUSTRALIAN ACOUSTICAL SOCIETY - SUSTAINING MEMBERS

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

ACRAN
127 BANDARA STREET
RICHLANDS QLD. 4077

ADAMSSON ENGINEERING PTY LTD
PO BOX 1294
OSBORNE PARK 6916

ASSOCIATION OF AUSTRALIAN ACOUSTICAL CONSULTANTS
C/- HERRING STORER ACOUSTICS
34/11 PRESTON STREET
COMO WA 6952

BARCLAY ENGINEERING
31 FELSPAR STREET
WELSHPOOL 6106

BORAL PLASTERBOARD
676 LORIMER ST
PORT MELBOURNE 3207

BRUEL & KJAER AUSTRALIA PTY LTD
PO BOX 177
TERREY HILLS 2084

CHADWICK TECHNOLOGY
9 COOK STREET
FORESTVILLE 2087

CSR BRADFORD INSULATION
55 STENNETT ROAD
INGLEBURN 2565

DALLOZ SAFETY PTY LTD
19 TEPKO ROAD
TERREY HILLS 2084

ENCO NOISE CONTROL P/L
50 RIVERSIDE ROAD
CHIPPING NORTON 2170

G P EMBELTON & CO PTY LTD
147-149 BAKERS ROAD
COBURG 3058

INC CORPORATION PTY LTD
22 CLEELAND ROAD
OAKLEIGH SOUTH 3167

JOYCE FOAM PRODUCTS
5-9 BRIDGES ROAD
MOOREBANK 2170

NSW ENVIRONMENT PROTECTION AUTHORITY
PO BOX A290
SYDNEY SOUTH 1232

NOISE CONTROL AUSTRALIA P/L
70 TENNYSON ROAD
MORTLAKE 2137

NUTEK AUSTRALIA
UNIT 3, 10 SALISBURY ROAD
CASTLE HILL 2154

PACIFIC NOISE AND VIBRATION
71 CONSTITUTION AVENUE
CANBERRA 2601

PEACE ENGINEERING PTY LTD
2-20 MARIGOLD STREET
REVESBY 2212

PYROTEK PTY LTD
PO BOX 260
TOONGABBIE 2146

SOUND CONTROL PTY. LTD.
61 LINKS AVENUE NTH
EAGLE FARM 4009

VIPAC ENGINEERS AND SCIENTISTS LTD
PRIVATE BAG 16
PORT MELBOURNE 3207

WORKCOVER ACOUSTICS
919 LONDONDERRY RD
LONDONDERRY 2753

PRESIDENT'S PRIZE PAPER, AAS CONFERENCE 1999

VIBRATO FREQUENCY AND PHASE LOCK IN OPERATIC DUET QUALITY

Melanie Duncan*, Carol Williams and Gordon Troup*****

*Music Department, **School of Historical and Gender Studies, ***Physics Department, Monash University Clayton, Victoria.

*** Also Melba Memorial Conservatorium of Music, Richmond. Victoria.

Abstract: For a 'bel canto' trained singer, 'vibrato' is defined as a periodic variation of the fundamental frequency of the sung note, with an intensity variation of the same period. 'Tremolo' is a variation in the intensity only. The locking of vibrato frequencies in unison soprano choirs has been reported and studied. A 1982 review article on the physics of the singing voice suggests that the pleasing or less pleasing quality of harmony in a vocal duet, for example, depends on whether or not the vibratos of the singers synchronise. This does not appear to have been investigated. Recordings of Dame Joan Sutherland singing the "Flower Duet" from the opera *Lakme* by Delibes with each of 3 different singers were studied. The powerful *SpectraPro* software was used for analysis. Our results show one singer locking in phase with Dame Joan, another locking in antiphase and another exhibiting phase wander. It is quite remarkable that such a complicatedly coupled system should behave so like a classically coupled oscillator system, for which in phase, and out of phase locking is possible, as is also phase wander. Psychophysical coupling clearly occurs.

1. INTRODUCTION

Aim

The aim of the acoustic analysis was to demonstrate firstly, that in operatic duet singing, the vibratos of the two singers can synchronise and secondly, to determine whether or not there was vibrato synchronisation in any of the chosen excerpts of the "Flower duet" from Lakme by Delibes. This aim developed out of expressed interest in this phenomenon by several voice researchers, namely, Troup [1] and Sacerdote [2].

Previous studies

The vibrato patterns of the solo singer have been studied by many people in great detail. Seashore [3] defined vibrato and tabled average rates and extents for famous singers. Choirs and larger ensembles have been examined with Sacerdote [2] reporting on the locking of vibrato frequencies in unison soprano choirs. It came to our attention that the locking of vibrato frequencies in duet singing had not been investigated. In a review on the physics of the singing voice published in 1981 by Troup [1], the following surmise occurs: "It may well be that the pleasing or less pleasing quality of harmony in a vocal duet for example, depends on whether or not the vibratos of the singers synchronise."

Why the interest in this topic?

One of the researchers is a singer and it was her experiencing first-hand this locking of vibratos that has interested us in this particular topic. She has performed the duet for mezzo and soprano from *Lakme*, by Delibes several times with at least four different mezzo partners. However, it has only been with one of the partners that there was an audible buzzing each time they sang together in certain passages of the duet. They were not singing the same pitch but we believed that their vibratos were synchronised and that this was creating the audible buzz. This type of vibrato locking in duet singing does not seem to occur a great deal but we feel that it is perhaps the key to a successful rendition of a duet with someone. It is the type of connection between two singers that composers probably visualise as they write their music but is seldom heard in reality.

Relevance of the study

The relevance of the results found so far in this study is quite considerable, for singers, teachers, directors, conductors and perhaps even composers. The results of the project may lead us to question some of the structures and traditions of vocal pedagogy as we know it. A structure which in focusing entirely on the solo voice, neglects to develop sensitivity to the different requirements of ensemble singing.

This project prompts the following questions. In duet singing we wonder how many singers consider how their vibrato contrasts or matches that of their partner. Do they alter their vibrato rate and extent at all, and if they do is this a conscious or a subconscious event? Do both singers alter their vibratos in order to attempt synchronisation, or only one of the singers? Is it accepted that either the higher or the lower voice makes the changes or does each singer remain constant? The study provides statistics proving that vibrato synchronisation or locking does indeed occur in duet singing.

It is also our belief that the synchronisation of the vibratos in a duet results in a fusion of the voices that is preferred by listeners. Further research is being conducted in order to examine the relationship between this synchronisation and preference rating of voice specialists. These results will not be discussed in this paper but we can say that results so far indicate that this is indeed the case. The implications will be most exciting for the opera world in the following ways:

- performers will have reason to consider their duet partner's vibrato rate and extent and will collaborate more often with their partner on phrasing and phasing of their vibrato;
- vocal pedagogues may consider training their students more often with differing partners and assessing aurally and also perhaps measuring acoustically how their students

synchronise when singing duets;

- directors will have to consider where they place the performers on the stage so that they can have the best possible chance of synchronising;
- conductors will have good reason to argue with directors over the staging if it interferes with balance and synchronisation of the vibratos of the two singers in the duet.

2. METHODOLOGY

The procedure was to acoustically analyse the three duets and to obtain the exact rate and extent of the frequency vibrato of each singer. The software used for this analysis was the SpectraPro 3.32A, a PC-based system with high-resolution FFT signal analysis, editing and playback of the sounds of speech and singing. The results were obtained using the Spectrograph display window with settings as follows: Sampling rate = 22050 Hz; FFT size = 1024; Window = Hamming; Averaging = 2. The material analysed consisted of three commercially available CD recordings of Delibes' "Flower Duet" from Lakme. Details are given in Table 1. The singers are all internationally renowned. Joan Sutherland is the soprano for each and the three mezzo-sopranos are Hugette Tourangeau, Marilyn Horne, and Jane Berbie. The score of the "Flower Duet" was examined and notes of crotchet duration or more were chosen for analysis. Ten pairs of duet notes in all were selected for analysis ranging from B4 to F#5 for the soprano and G4 to D#5 for the mezzo-soprano.

Table 1. Details of source recordings

Sutherland - Tourangeau	Classic Options CO3532
Sutherland - Horne	Virgin VVD780
Sutherland - Berbie	Decca 436305-2

The duet notes that were selected for analysis were the sustained notes of constant frequency, and in some instances the passage from one note to another (portamento), in which the singers are singing simultaneously. Rates were determined for each singer by selecting a high, clear partial from the spectrographic display of the note and plotting the peak and trough of each cycle in a graph format in seconds. The measurements were graphed using Microsoft Excel graph spreadsheets. This provided both the frequency vibrato rate and extent for each singer on these selected notes. For this paper we will concentrate on only one of the selected pairs of duet notes, namely, the pair identified as number 9. For the soprano the note is a dotted crotchet on F#5 using the French nasalised vowel [ã]. The note for the mezzo-soprano is a dotted crotchet on D#5, using the same nasalised vowel [ã]. The reason we have chosen this pair of notes is because by showing these three examples we can demonstrate the in-phase lock, antiphase lock and wandering that occurs between the vibratos of the two singers in duet. This pair of notes also provided the longest time period to observe the vibrato of the singers.

The second part of the acoustic analysis, was the analysis of the singers in a solo capacity. At the beginning of the duet both singers sing by themselves. We have analysed the longer notes of these solo passages and will be able to compare what the singer is doing in duet and solo on the same pitch and in some cases also the same vowel. This has proved very useful in determining whether the changes in the vibrato rates that occur in the duet singing also happen during solo singing or whether the changes are only affiliated with duet singing. We will discuss two of the selected solo notes. The notes are the same pitches that the singers sing in the duet notes we have analysed for this paper and it is for this reason that we will discuss the analysis of them. Because of length limitations we are only able to discuss the solo singing of one of the excerpts, namely the Sutherland - Berbie excerpt. The same procedure was applied to selecting the solo notes of each singer for analysis.

Whilst the research has measured both the frequency and extent of the singers' vibratos, in this paper we will only be discussing the vibrato rates of the singers. The vibrato extents shown on the graphs are only approximate. We can say that the frequency vibrato extents are still under assessment and will be a major part of the study.

3. RESULTS

Figure 1 demonstrates clearly the phase wandering pattern. The exact time period for the sung notes is 2.81 seconds for Sutherland and for Tourangeau it is 2.84 seconds. Essentially Sutherland is maintaining a vibrato rate between 5.26 and 5.88 cycles per second. Tourangeau is more erratic and her vibrato rate changes from 5.26 to 8.33 cycles per second. At the onset of the note Tourangeau begins at an averaged 7.87 cycles per second she then dramatically drops this rate to 6.10 cycles per second. At this point we see the two singers are in an anti-phase motion. The bracket shows this brief moment of anti-phase lock. This anti-phase lock is not characteristic for these singers. In the results of the other nine duet notes we see that for the tendency for these two singers is what appears to be a slow drift in relative vibrato phase. The singers then move through a series of motions throughout the rest of the note, almost in-phase, out of phase and then wandering and never coming back into any phasing at all.

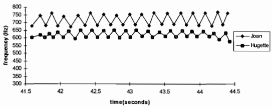


Figure 1. Pair 9 as sung by Joan Sutherland and Hugette Tourangeau.

Figure 2 shows a clear example of anti-phase lock occurring. The duration of the notes in this example are 2.74 seconds for Sutherland and 2.94 seconds for Horne. It takes almost 2 seconds for the pattern of anti-phase lock to emerge, but once it does the singers remain locked in this anti-phase mode until the end of the note which is for a further 0.74

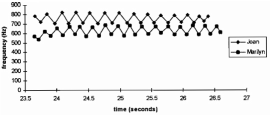


Figure 2. Pair 9 as sung by Joan Sutherland and Marilyn Horne

seconds. Although the singers' vibrato rates are obviously identical when they are in anti-phase lock the cycles are out of phase and this will still cause dissonance between the voices. The exact moment that anti-phase lock occurs is 1.99 seconds after Sutherland has begun to sing and 2 seconds after Horne has begun to sing. This point is at the time 25.65 seconds and is indicated by the arrow. We can see in this case that both singers change their vibrato rates significantly. If we break each of the notes into approximately 3 sections of almost 1 second each, we can see that this is the case. For the first second section the soprano is at 4.54 c/s, and for the second she is at 4.5 c/s. For the third second she is at an increase to 5.33 c/s. For the mezzo-soprano the first second section is at 5.43 c/s, the second section drops to 5.05 c/s and the third section increases again to match very closely with the sopranos third section at 5.31 c/s.

This anti-phase lock was a consistent characteristic for these two singers. In the 10 pairs of notes studied 5 of them exhibit cases of anti-phase lock which the most cases out of the three recordings.

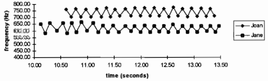


Figure 3. Pair 9 as sung by Joan Sutherland and Jane Berbie.

Figure 3 is most significant in that it depicts clearly what we recognise as vibrato synchronisation resulting in an in-phase lock. The two singers are Joan Sutherland and Jane Berbie. The duration of the notes in this excerpt are for the soprano 2.79 seconds and for the mezzo-soprano we captured 3.35 seconds. The perfect lock occurs on this time scale at the point 11.71 seconds which is 1.11 seconds after the soprano has begun her note and 1.59 seconds after the mezzo has begun her note. This point is indicated by the two arrows on Figure 3. The singers remain in a perfect lock for the rest of the duration of the note with only four exceptions. The four diversions from the perfect lock are only a difference of 0.01 of a second.

In order to see how this compares to when the singers are singing solo we will discuss the solo notes taken from the Sutherland - Berbie recording. These notes are the same pitch that the singers are singing in the duet notes we have already discussed.

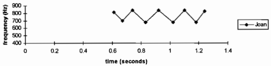


Figure 4. Note number 1 as sung by Joan Sutherland..

In Figure 4 we see that in this example of solo singing Sutherland is singing at a rate of 6.24 cycles per second and at the same pitch in duet her singing was an average of 5.53 cycles per second. This demonstrates the theory that singers alter their vibrato rates in operatic duet singing in order to synchronise. Sutherland uses a slower vibrato rate when she is singing in duet. The same pattern is evident for Berbie. Figure 5 demonstrates this.

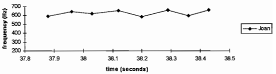


Figure 5. Note 14 as sung by Jane Berbie.

When Berbie sings at this pitch in solo her vibrato rate is an average of 6.54 cycles per second compared to an average of 5.35 cycles per second when she is singing at the same pitch in duet. The results of the full research indicate that this pattern is the same for the other singers.

4. INTENSITY CHANGE IN VIBRATO LOCK

The phase of intensity change with respect to frequency vibrato in the vibrato of individual singers has been extensively studied: a good summary of the literature and the findings is given by Horii [5]. There are singers with in-phase, others with antiphase intensity change with respect to frequency change, and still others with little or no intensity change. Horii explains this by considering what occurs to the fundamental and each harmonic when they interact with the vocal tract resonances (formants). A harmonic undergoing frequency vibrato will give rise to an in-phase intensity vibrato if the harmonic frequency is below the formant resonant frequency, and an antiphase intensity variation if the harmonic frequency is above the formant resonant frequency. At the resonant frequency there will be little or no intensity change at the vibrato frequency, but a small intensity change at the second harmonic thereof. Examples of this behaviour are given in Horii [5]. We have also observed in-phase and antiphase intensity change for various harmonics of the different singers studied. The intensity is shown in the Spectra-Pro presentation of spectra by either a grey scale, or a colour scale. It was found that the colour scale was preferable. In Figure 6 is shown an example of in-phase vibrato lock by Sutherland and Horne, in which one singer has an in-phase intensity change for a particular harmonic, and the other, an antiphase intensity change.

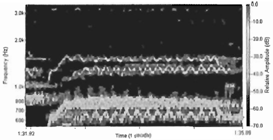


Figure 6. Spectrogram of a pair of notes sung by Joan Sutherland and Marilyn Horne, demonstrating vibrato phase lock.

5. CONCLUSIONS

The conclusions that we can draw from these results at this point are as follows. The aim of the paper was to demonstrate that locking of vibrato frequencies in duet singing can occur and to determine whether or not there was vibrato synchronisation in the chosen excerpts of the "Flower duet" from Lakme. This has been done. We have shown that the vibrato patterns of duet singers behave quite remarkably like a classically coupled oscillator system, for which in-phase, out of phase and also phase wander are possible. We can conclude that in one of the excerpts we have shown today that there is in-phase vibrato synchronisation. Results of the full acoustic analysis indicate that this exact synchronisation is a rare event and more common is phase wander and to a lesser extent anti-phase locking. However the results not yet published do reveal that this one case is not isolated and particularly in the Sutherland and Berbie recording there are several more cases of vibrato in-phase locking which prove that this was not a one off event.

A few of the questions raised in the relevance of the study can be answered. It is possible to say that in duet, singers do alter their vibrato rates. The results of the three examples described here show that a pattern has emerged. Results obtained by comparing notes of the same frequency from duet and solo notes analysed are further support to this hypothesis. Berbie and Sutherland significantly slow down their vibrato rates when singing in duet. The comparison of the 15 pairs of notes that are the same frequency in solo and in duet show that in 13 of the cases this occurred. The overall mean rates for the singers in solo, and duet are shown in Table 2, indicating that throughout the entire excerpt the trend is the same.

Table 2. Overall mean vibrato rates for solo and duet singing - 1968 recording

SINGER	Solo Singing	Duet Singing
Sutherland - 1968	6.38c/s	5.61c/s
Berbie	6.24c/s	5.5c/s

In the Sutherland/Tourangeau recording we find that of the 8 pairs of solo and duet notes compared in Sutherland's singing, 7 of the cases demonstrate that the trend towards slowing the vibrato rate when singing in duet is evident in this recording. Sutherland's overall duet note vibrato rate is again significantly slower than her overall solo note vibrato rate. Tourangeau exhibits the trend in only 3 of the 7 pairs of notes compared. In fact Tourangeau is quite significantly faster in some of her duet notes than her solo notes of the same frequency. This is the reason for the lack of in-phase synchronisation within this excerpt. Further evidence that supports this statement is the fact that in the duet notes number 3 and number 9 of the Sutherland - Tourangeau recording there is in-phase vibrato synchronisation and it is in duet notes 3 and 9 that Tourangeau has slowed her duet vibrato rate to less than her solo vibrato rate on the same note. Table 3 indicates that Tourangeau's overall duet vibrato rate is only marginally slower than her overall solo note vibrato rate. In summary it plausible that the lack of in-phase vibrato synchronisation within the Sutherland - Tourangeau recording is likely to have been caused by Tourangeau not slowing down her duet vibrato rate.

Table 3 . Overall mean vibrato rates for solo and duet singing - 1976 recording

SINGER	Solo Singing	Duet Singing
Sutherland - 1976	6.10c/s	5.78c/s
Tourangeau	6.85c/s	6.75c/s

In the Sutherland - Horne recording in all of the 15 pairs of notes compared, the duet notes have a slower vibrato rate than the solo notes of the same frequency. Both singers have overall duet note vibrato rates slower than their overall solo note rates and this is shown in Table 4.

This recording had the most examples of vibrato locking (8) occurring between the 10 duet notes that were analysed. Only 3 of the notes exhibited in-phase vibrato locking, the other 5 were examples of anti-phase locking. This demonstrates that the vibrato rate is only part of the equation when it comes to achieving in-phase vibrato lock. Even though these two singers were able to lock together their vibrate pulse rates, the majority of examples show an anti-phase locking. It still demonstrates that when singers slow their vibrato rates in duet the are more likely to achieve vibrato synchronisation.

Table 4. Overall mean vibrato rates for solo and duet singing - 1986 recording

SINGER	Solo Singing	Duet Singing
Sutherland - 1986	5.85c/s	5.29c/s
Horne	6.07c/s	5.80c/s

In regard to which voice is responsible for the lock we can say the following. In the first example it was the mezzo-soprano who altered her vibrato rate significantly. In the second example both of the singers had fluctuating vibrato rates and in the last example it is again the mezzo-soprano who alters her vibrato rate, this time with good result as the singers find perfect vibrato synchronisation. Overall results of analysis of the duet notes from all three recordings indicate that it is the mezzo voice that consistently seems to be responsible for the significant changes in rate which result in an in-phase synchronisation.

The three examples shown in this paper indicate that in order for singers to demonstrate vibrato in-phase lock two things must happen:

- the rates of vibrato in cycles per second of the two singers need to be the same; and
- the phases of the cycles of the two singers needs to be synchronised.

This raises the question of whether singers in a duet can hear if they are out of phase with their partner and if so whether they can alter the cycles per second in order to synchronise the cycle phase. Research published by Coleman [4] has concluded that when singing a sustained note in unison, two singers singing a duet adjusted their frequency modulation extent to less than 50% of that used in solo singing, presumably to "blend" into one tone. It is this conclusion that lead us to believe that singers would certainly do the same with their vibrato frequency rate in order "blend" or synchronise their cycles. The results indicate agreement with this hypothesis. When singing in duet, as opposed to solo singing, the singers used in this research reduced their vibrato rate cycles per second. We believe that this was in order to synchronise with their singing partner.

REFERENCES

[1] G. Troup "The physics of the singing voice" *Journal of Research in Singing*, 8(1), 1-26 (1982).

[2] G.G. Sacerdote "Researches on the singing voice" *Acustica* **7**, 61-68 (1957).

[3] C. Seashore *Psychology of Music* (Dover, New York 1938).

[4] R. Coleman "Acoustic and physiological factors in duet singing: A pilot study" *Journal of Voice* **8**(3), 202-206 (1994).

[5] Y. Horii "Acoustic analysis of vocal vibrato: A theoretical interpretation of data" *Journal of Voice* **3**(1), 36-43 (1989).

RETHINKING OUR APPROACH TO AIRCRAFT NOISE INFORMATION—GOING BEYOND THE ANEF

D Southgate

Airports Operations, Commonwealth Department of Transport and Regional Services, GPO Box 594, Canberra ACT 2601

ABSTRACT: A large number of environmental noise practitioners have had some involvement with aircraft noise issues and the Australian Noise Exposure Forecast (ANEF) system over the past twenty years. While the noise specialist generally finds the system rational and easy to use this is not the case for many decision-makers and members of the public. These latter groups treat the system, at best, with deep suspicion. Much of this negative attitude arose because of the way the ANEF was used in the EIS for the third runway at Sydney Airport - there was a widely held view that the EIS gave a very misleading picture of future aircraft noise distribution. In an attempt to gain back ground different ways to communicate with non-specialists on aircraft noise are now being developed by the Commonwealth Department of Transport and Regional Services. These 'new' approaches are based on 'numbers of events', rather than cumulated energy, descriptors since these more closely relate to the way a person is exposed to, and thinks about, aircraft noise. Very importantly detailed aircraft noise information is now being produced for areas which extend well beyond those covered by conventional ANEF contours.

1. BACKGROUND

Over the past 20 years the 'official' metric for describing aircraft noise in Australia has been the Australian Noise Exposure Forecast (ANEF) system. The system was established in the early 1980s following a major aircraft noise socio-acoustic study carried out by the National Acoustic Laboratories (NAL) [1].

This survey showed that the 10% 'seriously affected' level approximately equated to an aircraft noise exposure of 20 ANEF (approx 55 Leq 24hr). In line with conventional thinking this level became adopted as the line of 'acceptability' for aircraft noise and was incorporated into Australian Standard AS2021 'Acoustics—Aircraft Noise Intrusion—Building Siting and Construction' [2]. In essence the Standard recommends that sites with a noise exposure of less than 20 ANEF are acceptable for all land uses with regard to aircraft noise.

Despite the introduction of the ANEF system, and the effect that this has had on slowing urban encroachment around airports, the community's concerns with aircraft noise have continued and increased around some airports.

Contrary to the expectations of many people, these pressures are not coming from the high noise exposure areas. While the ANEF system describes areas with a noise exposure of less than 20 ANEF as 'acceptable', nearly all people who complain, and who put pressure on airports, live outside the contours. For example, approximately 90% of complaints at Sydney Airport come from residents living outside the 20 ANEF contour.

It could be argued that this is consistent with the findings of the 1980 NAL study—10% of the population still considers itself 'seriously affected' at 20 ANEF and hence, given the relative size of the populations within and outside the contours, for many airports the biggest 'noise affected' population is likely to live outside the contours.

2. WHY IS THE COMMUNITY CONCERNED ABOUT AIRCRAFT NOISE IN AREAS OUTSIDE THE 20 ANEF?

There are many reasons why particular individuals are highly sensitive to what the noise specialist might describe as the 'low' levels of aircraft noise exposure outside the 20 ANEF. Often the causes are very person specific and can only be addressed on a case by case basis.

However, it is possible to identify a common theme behind much of the 'anti airport' feeling expressed by the population living outside the 20 ANEF. In simple terms ANEF information has led these people to expect a much lower level of noise exposure than they are actually getting—it is considered the system is generating unfulfilled expectations.

Many of the 'misunderstandings' generated by ANEF information were scrutinised during the 1995 Senate Inquiry into Aircraft Noise in Sydney [3]. This Inquiry was established as a result of the public outcry that followed the opening of the third runway at Sydney Airport in 1994.

Conventionally the outer contour shown on an 'official' ANEF map is the 20 ANEF. No aircraft noise information is provided for residents of areas outside the contours other than in a table (extracted from AS2021) shown on ANEF maps which indicates that the areas are 'acceptable' for residential (and other) development. Residents of many suburbs around Sydney Airport told the Senate Inquiry that they believed (erroneously) that they would not be affected by aircraft noise after the opening of the third runway because they lived outside the 20 ANEF [4]. Other submissions to the Inquiry recognised that the noise could not stop at the 'line' [5] but they still had no 'real' information to indicate what the noise exposure would be like at their house site.

Compounding this lack of information for the population outside the 20 ANEF, describing aircraft noise by a single ANEF figure which relates to the amount of noise energy received on an annual average day conveys little 'real' information. It does not provide people with information they can readily relate to such as how many aircraft movements there will be. Therefore computing ANEFs to a lower value and telling a person that a house is exposed to say 15 ANEF would do little to address the problem.

The credibility of 'noise experts' was seriously damaged through the way the future noise exposure patterns were portrayed using the ANEF in the Sydney Airport Third Runway EIS. While the ANEF exposure patterns generated by the new runway following its opening were broadly in line with those predicted in the EIS, many people very strongly submitted to the Inquiry that they believed they had been misled by the ANEF. In addition to the claims from people living outside the 20 ANEF that they had been excluded from consideration, issues such as the ANEF's averaging out of the wide temporal fluctuations in aircraft noise generated significant negative comment. It is therefore not surprising that large numbers of Sydney residents had a strong adverse reaction to aircraft noise even at relatively low exposure levels.

3. MOVING FORWARD

While the ANEF system is not intrinsically difficult to understand, by its very nature it is a system set up by 'experts' for 'experts'. In essence the noise expert has been telling the public and the decision maker 'not to worry about it' since all the work has been done—on one side of the 'line' (the 20 ANEF) the noise is acceptable and on the other there are strategies for ameliorating aircraft noise impacts. The controversy surrounding the EIS for the third runway at Sydney Airport basically revealed the flaws of this approach. The public will no longer accept assurances from the noise expert that a certain amount of noise is 'acceptable'. In advising decision makers, the days of what Dr Hede terms the 'technofficial-centred approach' where noise advisers act as 'gatekeepers' [6] are over.

We are now in a situation where we as noise practitioners have to stop expecting non experts to talk our language when discussing aircraft noise and to begin providing direct answers to the questions people ask (eg where are the flight paths; how many movements will there be; etc?). Very importantly we need to provide information to everyone who is exposed to aircraft noise, however low the levels may be, and not just to a select group who we believe are the ones who will consider themselves 'affected'.

3.1 Relational Noise Indicators

The Department has extensive experience of dealing with members of the public and community representatives on aircraft noise issues. Over the past five years a wide range of ways of presenting aircraft noise information to the public has been trialed in Sydney. This work has shown that if we really want to communicate with the community on aircraft noise we have to develop what can be termed relational noise indicators—descriptors which portray aircraft noise in a way that relates to how a person experiences the noise.

Examination of the way people talk amongst themselves about aircraft noise, or make a telephone or written complaint to authorities, reveals that the layperson almost always reports, and thinks about, the problem in terms of a series of separate noise events. For example, it is not uncommon for a person to write a letter to the Minister which attaches a log of the numbers and times of overflights which they wish to object to. Alternatively, they specifically highlight aircraft movements at what they consider to be noise sensitive times—for example they use terminology such as 'three planes flew over my house this morning before 7am'. Letters often make specific reference to the location of flight paths of individual nominated aircraft movements.

Given this, we have reached the firm conclusion that we should be prepared to speak in this type of language when dealing with the community—where, when, how many. This does not of course prelude us from talking in terms of ANEF if this is the metric an individual wants to use (although this very rarely happens now that the 'new' metrics described below are available).

Figure 1 is an example of a descriptor that has been developed by the Department of Transport and Regional Services to answer the where, when and how many questions.

The Figure shows the broad spread of the jet flight paths at Sydney Airport under its current operating arrangements and gives some statistics on daily variations in the number of movements—the average day and the busiest and quietest day during the period. This gives information far beyond the area covered by the 20 ANEF and it also, very importantly from the community's point of view, shows where 'the noise' actually is (cf the ANEF which is generally little more than say a four pointed star following the extended runway centrelines).

The statistics on variations in the noise load shown in the boxes in Figure 1 are being produced in response to community criticism that information on the annual average day, such as that given by the ANEF, does not accord with their experience. There are generally wide variations in aircraft noise exposure from day to day and week to week—the average day is rarely the typical day.

This style of report has proven to be very useful in conveying aircraft noise information to the layperson. Copies have appeared a number of times in Sydney newspapers and are now produced on a monthly basis as part of the regular Airservices Australia monitoring reports for Sydney Airport. Similar reports have now been generated for most Australian airports in response to demand from other communities.

A similar form of presentation is being produced to provide information on the 'when' question particularly for sensitive times—these are being produced in response to community requests at Sydney to know how often particular areas get a break or 'respite' from aircraft noise. 'Respite' charts show, for each of the flight path zones identified in Figure 1, the proportion of hours in specified periods (eg mornings, evenings and weekends over one month) when there were no jet aircraft movements.

It is of course noteworthy that these relational noise indicators make no reference to, and are not underpinned by, sound pressure levels. Experience has shown that this is generally not a problem—the clarity this provides is probably

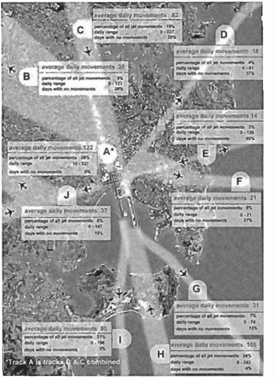


Figure 1 1998 Jet Flight Path Movements

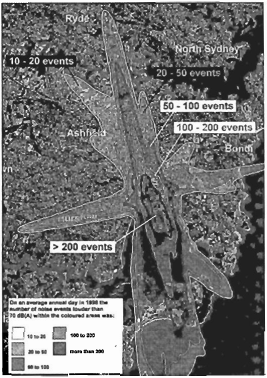


Figure 2 Contour map showing the number of noise events louder than 70 dB(A) on an average day in 1998.

a key reason for their acceptance. A person who lives under one of the flight paths has a 'calibrated ear'—they know what the planes sound like at their home—and they are for the most part not interested in a noise expert giving them information on sound pressure levels (in fact this can often cause deep suspicion because they believe that an attempt is being made to 'snow them' with technical information). The person is just interested in receiving less aircraft overflights, particularly at the noise sensitive times, and the representations in Figure 1 and the 'respite' charts allow them to track what is happening.

The danger in using the relational noise indicators arises of course when persons compare noise exposure patterns between different areas solely on the basis of the average number of movements on the respective flight paths. In discussions on relative impact it is vital that detailed noise information is available to underpin the debate.

3.2 Sound Pressure Level Information—The N70

Clearly it is important that aircraft sound pressure level information is available to those members of the public that are seeking it. Consistent with the earlier discussion concerning relational indicators, experience has shown that when members of the public are interested in the sound pressure level information they want to know the noise levels of individual flights rather than the cumulated noise energy on the annual average day (ie ANEF information). For example, the report on the Long Term Operating Plan for Sydney Airport [7] included a significant amount of information on single event noise levels in direct response to requests from community representatives.

To produce single event noise level information for every flight path and every aircraft type operating at an airport would clearly involve producing a multiplicity of charts. It is therefore necessary to aggregate the information in some way. There is also a need to incorporate information on the number of noise events since examining single event contours in isolation can be misleading because they do not show how many movements there will be for the particular aircraft types on each of the flight paths.

The most useful way to portray aggregated information on single event noise levels that the Department has identified to date is the N70—a metric reporting the number of events exceeding 70 dB(A) over the period in question. N70 contours were first produced by the Department as part of the process of drawing up the Sydney Airport Long Term Operating Plan [8] and were prepared in response to community requests for this type of information. Figure 2 shows an N70 contour map for Sydney Airport for the average day in 1998.

The N70 contour suffers equally from one of the weaknesses of an ANEF contour—it can give the (erroneous) impression that there is no noise beyond the outer contour. In order to address this problem the Department likes to issue Figures 1 and 2 as a 'matching pair'. The N70 and the flight path movements charts make an excellent combination when viewed together as it allows a good visual feeling to be gained of how many of the movements on a particular flight path were 'loud' and it clearly shows that the noise goes beyond the N70 contours.

The 70 dB(A) threshold has been used as this equates to a maximum single event sound pressure level of 60 dB(A), inside a house with open windows, recommended in AS2021. It is of course possible to select other threshold levels in order to present a more complete picture. N80s have been produced for Sydney Airport [9] and a number of N60s appeared in the Environmental Impact Statement for the Second Sydney Airport [10].

4. GOING BEYOND COMMUNITY REACTION—EMPOWERING THE INDIVIDUAL

How does the information discussed above help us in practice? Primarily, because it can be readily understood and covers a much greater geographic area than conventional ANEF contours there is much less likelihood of persons feeling they have been misled by official aircraft noise information. However, possibly more importantly, this information permits us to progress beyond the black and white 'acceptable' / 'unacceptable' thinking that underpins the ANEF system.

One of the bases of socio-acoustic studies is that a determination is made on the level of community reaction at specified noise exposure levels. While this information is useful for setting broad standards (eg selecting the 10% seriously/highly affected level as the line of 'acceptability') it is generally only of academic interest to the individual. For example, telling a person that around 5% of the population will consider themselves 'seriously affected' at 15 ANEF effectively gives them no information that will help them to decide whether to buy a house in an area with that level of noise exposure.

By way of contrast, giving them the type of information in Figures 1 and 2 (eg on average there will be say 30 overflights a day; on a third of the days there will be no movements but on the busy days there will be 80 movements, etc) enables them to form a good mental picture of the noise patterns. They are then able to make a judgement as to whether they would be likely to find the noise acceptable if they were to move into the area. This represents a major step forward from conventional ANEF information which would simply tell the person, in effect, that the site is 'acceptable'.

5. ARE THERE LESSONS FOR THE WAY WE DEAL WITH OTHER NOISE SOURCES?

Our experience with the ANEF leads one to ask a number of questions. For example, if people believe they have been misled about aircraft noise through unnecessary 'techno-speak' and the inappropriate use of standards does the same apply to our approach to other noise sources? Does the averaging of noise by using descriptors such as Leq give a misleading picture, particularly when the noise is characterised by a relatively small number of discrete events which have wide temporal fluctuations?

While it's beyond the scope of this paper to delve into these questions it is clear that our experience with aircraft noise does have some broad lessons. In particular our journey with the ANEF has amply demonstrated that we will not get our message across, even if our information is technically correct, if the target audience cannot understand it or it fails to provide answers to the questions that the audience is asking.

There is little doubt that if the public believes it has been misled on noise predictions then there is going to be a negative reaction which far exceeds that which would otherwise be expected from a particular level of noise exposure.

Further details of the concepts put forward in this paper can be found in a Discussion Paper entitled 'Expanding Ways to Describe and Assess Aircraft Noise' which is being released by the Commonwealth Department of Transport and Regional Services. A copy of the Discussion Paper may be obtained by contacting the Department through email at david.southgate@dotrs.gov.au

The views expressed in this paper do not necessarily reflect those of the Commonwealth Government.

REFERENCES

1 Hede A J and Bullen R B, *Aircraft noise in Australia: A survey of community reaction,* NAL Report No 88, Australian Government Publishing Service, Canberra, 1982.

2 *Acoustics—Aircraft noise intrusion—Building siting and construction, Australian Standard AS2021-1994,* Standards Australia, Homebush, 1994.

3 *Falling on Deaf Ears?, Report of the Senate Select Committee on Aircraft Noise in Sydney,* Commonwealth of Australia, Canberra, 1995.

4 *Ibid*, paragraph 8.116.

5 *Ibid*, paragraph 8.105.

6 Hede A J, 'Towards a Normative Model of Public Policy for Environmental Noise', *Acoustics Australia,* Vol 26, No.3, 1998.

7 *The Long Term Operating Plan for Sydney (Kingsford Smith) Airport and Associated Airspace,* Airservices Australia, Canberra, 1996.

8 *Sydney Airport Long Term Operating Plan Proponent's Statement,* Commonwealth Department of Transport and Regional Development, Canberra, 1997, Figure 3.15.

9 *Ibid*, Figure 3.16.

10 *Draft Environmental Impact Statement, Second Sydney Airport Proposal*, PPK Environment and Infrastructure Ltd, Concord West, 1999, Volume 3, Supplement to Draft, section 8.6.4.

METHODS TO MEASURE THE FOUR-POLE PARAMETERS OF VIBRATION ISOLATORS

J. D. Dickens
Maritime Platforms Division
Defence Science and Technology Organisation (DSTO),
Aeronautical and Maritime Research Laboratory (AMRL),
P.O. Box 4331, Melbourne, Victoria, Australia 3001

ABSTRACT: This paper describes the background to the development of a test facility and associated methods for measuring the four-pole parameters of vibration isolators under service conditions. The experimental methods of measuring the four-pole parameters of passive and active vibration isolators are discussed. Improvements to the measurement techniques are outlined, and implemented in a test rig capable of testing passive, semi-passive and active vibration isolators with feedback control.

1. INTRODUCTION

Vibration isolators are important vibration control elements used in industrial, maritime and military applications. For example, the control of vibration and structure borne noise transmission is of paramount importance in naval surface ships and submarines to decrease the probability of detection by unfriendly sonar receivers. The acoustic signature management of naval vessels at frequencies up to about 2 kHz is crucial, and of particular concern are the longitudinal standing waves that occur in the rubber elements of vibration isolators. These standing waves significantly reduce the effectiveness of the vibration isolators and may cause an unwanted increase in the radiated underwater noise.

The dynamic properties of a vibration isolator primarily depend upon its exciting frequency and amplitude, static load and temperature. Thus its properties should be measured over an appropriate frequency range and under its service load and temperature.

2. METHODS OF MEASURING THE FOUR-POLE PARAMETERS

The four-pole parameters may be used to describe the dynamic performance of a vibration isolator [1]. A vibration isolator may be dynamically represented as a pseudo-linear system, where the dynamic force and velocity at its input are denoted by F_1^* and V_1^* respectively, and the dynamic force and velocity at its output by F_2^* and V_2^* respectively. Complex numbers are represented with the superscript *, and real numbers are not superscripted. Let α_{11}^*, α_{12}^*, α_{21}^* and α_{22}^* denote the four-pole parameters, which are complex, time invariant functions of the frequency. The four-pole parameters are defined by

$$\begin{bmatrix} F_1^* \\ V_1^* \end{bmatrix} = \begin{bmatrix} \alpha_{11}^* & \alpha_{12}^* \\ \alpha_{21}^* & \alpha_{22}^* \end{bmatrix} \begin{bmatrix} F_2^* \\ V_2^* \end{bmatrix} \tag{1}$$

Vibration isolators may be passive, semi-active or active. Passive vibration isolators have only passive elements, semi-active vibration isolators have passive and active elements, and active vibration isolators have only active elements. A passive element includes a resilient material such as a rubber, metal spring, cork, felt or air-bag. An active element incorporates an actuator designed to supply a dynamic force in response to the signal from a controller, which may operate on the feedback or feedforward principle. Hansen and Snyder [2] describe various actuators, including pneumatic, proof mass, electrodynamic, electromagnetic, magnetostrictive, shape memory alloy, piezoelectric (electrostrictive) and electrorheological fluid types.

2.1. Passive vibration isolators

Passive vibration isolators are bi-directional in nature. Assuming that Rayleigh's reciprocity theorem in the form of Maxwell's reciprocal deflections theorem applies to the resilient element of a passive vibration isolator, it may be shown that [1]

$$\alpha_{11}^*\alpha_{21}^* - \alpha_{12}^*\alpha_{21}^* = 1 \tag{2}$$

An experimentally convenient arrangement has the vibration isolator with a blocked output. This yields

$$\alpha_{11}^* = \left.\frac{F_1^*}{F_2^*}\right|_{V_2^*=0} \tag{3}$$

and

$$\alpha_{21}^* = \left.\frac{V_1^*}{F_2^*}\right|_{V_2^*=0} \tag{4}$$

Equation (2) yields

$$\alpha_{12}^* = \frac{\alpha_{11}^*\alpha_{22}^* - 1}{\alpha_{21}^*} \tag{5}$$

2.1.1. Symmetrical vibration isolators

Symmetrical vibration isolators are defined as those that behave the same if their input and output ends are interchanged. For such a vibration isolator it may be shown that [3]

$$\alpha_{11}^* = \alpha_{22}^* \tag{6}$$

Therefore the four-pole parameters of a symmetrical vibration isolator may be determined by measuring the input force, input velocity and output force of the blocked vibration isolator, and applying equations (3) to (6) [3].

2.1.2. Asymmetrical vibration isolators

Asymmetrical vibration isolators are those vibration isolators that do not behave the same if the input and output ends are interchanged. For asymmetrical vibration isolators, equation (6) is no longer valid and so additional information must be obtained. This is normally been done by reversing the vibration isolator in the test rig so that its input and output ends are interchanged [4]. Consider this reversed configuration and denote the input force and velocity by F_{1R}^* and V_{1R}^* respectively, and the output force and velocity F_{2R}^* and V_{2R}^* respectively. Equation (1) then becomes

$$\begin{bmatrix} F_{1R}^* \\ V_{1R}^* \end{bmatrix} = \begin{bmatrix} \alpha_{22}^* & \alpha_{12}^* \\ \alpha_{21}^* & \alpha_{11}^* \end{bmatrix} \begin{bmatrix} F_{2R}^* \\ V_{2R}^* \end{bmatrix} \tag{7}$$

For the blocked situation, $V_{2R}^* = 0$ and so from equation (7),

$$\alpha_{22}^* = \left. \frac{F_{1R}^*}{F_{2R}^*} \right|_{V_{2R}^*=0} \tag{8}$$

and

$$\alpha_{22}^* = \left. \frac{F_{1R}^*}{F_{2R}^*} \right|_{V_{2R}^*=0} \tag{9}$$

Equation (8) provides the additional relationship to determine α_{22}^*, and equation (9) may be used to experimentally check the value of α_{21}^*. This technique is called the blocked reversal method, and requires the measurement of the input force, input velocity and output force of the blocked vibration isolator in its normal and reversed configurations.

The reversal technique may also be applied to the unblocked situation, where $V_2^* \neq 0$ and $V_{2R}^* \neq 0$. For this unblocked situation, equations (1), (2) and (7) may be combined to give [5],

$$\alpha_{12}^* = \frac{F_1^* F_{1R}^* - F_2^* F_{2R}^*}{V_1^* F_{2R}^* + V_{2R}^* F_1^*}, \tag{10}$$

$$\alpha_{11}^* = \frac{F_1^* - \alpha_{12}^* V_2^*}{F_2^*}, \tag{11}$$

$$\alpha_{22}^* = \frac{F_2^* + \alpha_{12}^* V_1^*}{F_1^*} \tag{12}$$

and

$$\alpha_{21}^* = \frac{V_1^* - \alpha_{22}^* V_2^*}{F_2^*} \tag{13}$$

This technique is called the unblocked reversal method, and requires the measurement of the input force and velocity, and output force and velocity of the unblocked vibration isolator in its normal and reversed configurations.

The blocked reversal method is experimentally simpler than the unblocked reversal method, because it does not require the measurement of the output velocity. These methods of reversing the vibration isolator in the test rig assume that the vibration isolator is bi-directional and may be operated with its input and output ends interchanged.

2.2. Active vibration isolators

Generally vibration isolators incorporating some form of active feedback control are examples of uni-directional vibration isolators. A vibration isolator is defined to be uni-directional if it operates in only one direction and interchanging its input and output ends is inadmissible. The methods described in Sections 2.1.1 and 2.1.2 cannot be used if the vibration isolator is uni-directional.

Feedback systems may be described in terms of the four-pole parameters, provided that the feedback signal may be expressed as a linear function of the input or output forces or velocities of the active vibration isolator. Feedforward systems do not have such linear relationships, and consequently are not amenable to four-pole parameter characterisation.

The requirement is to measure the four-pole parameters of a uni-directional vibration isolator that may be symmetrical or asymmetrical, under static load. It is assumed that the vibration isolator has pseudo-linear dynamic operation at and near its operating point, i.e. equation (1) may be considered to be valid. Equation (2) is derived from Maxwell's reciprocal deflections theorem and applies for passive elements. It therefore cannot be assumed to be true for an active vibration isolator. Equation (6) is only true for symmetrical vibration isolators. Therefore the constraining equations (2) and (6) cannot be applied in this situation.

Dickens and Norwood proposed the two mass method for measuring the four-pole parameters of uni-directional vibration isolators [6]. They showed that the method may be regarded as a universal testing method, and applicable to symmetrical, asymmetrical, uni-directional and bi-directional vibration isolators. Dickens presented experimental data for a uni-directional asymmetrical vibration isolator [7].

The two mass method measures the input and output forces and velocities of the unblocked vibration isolator with its output terminated by two different mobilities. The test configurations are identical except for the output terminations, and produce two sets of data. The data is then used to determine the four-pole parameters of the vibration isolator. Let the two output terminations have mobilities of H_{21} and H_{22}, and let the corresponding forces and velocities be respectively denoted by the second subscripts 1 and 2. It may be shown that the four-pole parameters are given by [6]

$$\begin{bmatrix} \alpha_{11}^* \\ \alpha_{12}^* \\ \alpha_{21}^* \\ \alpha_{22}^* \end{bmatrix} = \frac{1}{F_{22}^* V_{21}^* - F_{21}^* V_{22}^*} \begin{bmatrix} -V_{22}^* & 0 & V_{21}^* & 0 \\ F_{22}^* & 0 & -F_{21}^* & 0 \\ 0 & -V_{22}^* & 0 & V_{21}^* \\ 0 & F_{22}^* & 0 & -F_{21}^* \end{bmatrix} \begin{bmatrix} F_{11}^* \\ V_{11}^* \\ F_{12}^* \\ V_{12}^* \end{bmatrix} \tag{14}$$

By definition, the mobility equations are

$$V_{21}^* = H_{21}^* F_{21}^* \tag{15}$$

and

$$V_{22}^* = H_{22}^* F_{22}^* \tag{16}$$

Substituting equations (15) and (16) into equation (14) gives

$$\begin{bmatrix}\alpha_{11}^* \\ \alpha_{12}^* \\ \alpha_{21}^* \\ \alpha_{22}^*\end{bmatrix} = \frac{1}{\Delta^*}\begin{bmatrix} -H_{22}^* F_{22}^* & 0 & H_{21}^* F_{21}^* & 0 \\ F_{22}^* & 0 & -F_{21}^* & 0 \\ 0 & -H_{22}^* F_{22}^* & 0 & H_{21}^* F_{21}^* \\ 0 & F_{22}^* & 0 & -F_{21}^* \end{bmatrix}\begin{bmatrix}F_{11}^* \\ V_{11}^* \\ F_{12}^* \\ V_{12}^*\end{bmatrix} \quad (17)$$

where

$$\Delta^* = F_{21}^* F_{22}^* \left(H_{21}^* - H_{22}^*\right) \quad (18)$$

Clearly for equation (14) to be valid $\Delta^* \neq 0$, which implies that the outputs cannot be free and the two output terminations cannot be equal. Dickens and Norwood implemented the method by using two different blocking masses in the vibration isolator test rig [6].

3. PREVIOUS WORK

This Section reviews the work undertaken previous to the AMRL studies, which are covered in Section 4.

After their introduction to the analysis of dynamic mechanical systems by Molloy [1], the four-pole parameters have been applied to vibration isolation by other researchers, Snowdon [3, 8, 4], Veit [9], Klyukin [10] termed transfer matrix, Meltzer and Melzig-Thiel [5], Vakakis [11], Jacobsen and Ohlrich [12], Norwood [13], Hixson [14], Ha et al [15], Easwaran et al [16] and Ha and Kim [17]. Of these researchers, Molloy, Snowdon, Vakakis, Hixson and Easwaran et al gave theoretical studies with no experimental work. Ha and Kim presented a theoretical investigation with experimental results for a beam structure. Snowdon [4] referred to experimental work by Schloss [18]. The remaining researchers and Schloss [18] gave results of experiments that were all conducted at the ambient temperatures, and are discussed in the following paragraphs.

Veit [9] investigated the sound transmission attenuation through the liquid and walls of compensators, which are rubber bellows for coupling together pipes. He showed experimental plots of the magnitudes of the four-pole parameters over the approximate frequency range from 100 Hz to 3 kHz.

Klyukin [10] presented experimental data of the force transmissibilities of vibration isolators over the frequency range from 60 Hz to 5.44 kHz, in the form of octave bands.

Snowdon [4] proposed that the testing apparatus of Schloss [18] be utilised to measure the four-pole parameters of vibration isolators, and is discussed in Section 4.

Meltzer and Melzig-Thiel [5] used a test rig that could measure the four-pole parameters of a small vibration isolator at static loads up to 1 kN. Their frequency range of interest was up to 1 kHz and they presented data for a vibration isolator over the approximate frequency range from 70 Hz to 1.25 kHz.

Jacobsen and Ohlrich [12] tested a small vibration isolator by assuming that its dynamic properties were negligibly affected by static load, and consequently used the experimentally attractive method of a free output [3]. They presented plots of the four-pole parameters α_{11}^*, α_{12}^* and α_{21}^* in third octave bands from 40 Hz to 12.5 kHz, and stated that the data were not reliable at high frequencies.

Norwood [13] measured the characteristics of a small, unloaded vibration isolator over the frequency range from 4 Hz to 3 kHz, and presented them in narrow-band plots of the magnitudes of the four-pole parameters.

Ha et al [15] investigated the vibration transmission from the engine through the body to the steering wheel of a car. They presented plots of the magnitude of the four-pole parameter α_{21}^* over the frequency range from 0 to 50 Hz.

In summary, only Meltzer and Melzig-Thiel [5] have presented results of the four-pole parameters for statically loaded vibration isolators. They presented data for a small vibration isolator of rubber mass 56 g over the approximate frequency range from 70 Hz to 1.25 kHz.

4. AMRL STUDIES

To investigate vibration isolators used for naval applications, it was necessary for AMRL to develop a vibration isolator test facility that was capable of measuring the four-pole parameters of statically loaded large vibration isolators over the frequency range from 5 Hz to 2 kHz, and temperature range from 10 to 60°C. The required static loads were from 1 to 30 kN.

The literature search of Section 3 indicated that consideration should be given to the methods used by Meltzer and Melzig-Thiel [5], and proposed by Snowdon [4] using the testing apparatus of Schloss [18]. Meltzer and Melzig-Thiel were the only researchers to measure the four-pole parameters of a statically loaded vibration isolator.

Meltzer and Melzig-Thiel [5] used the test rig shown in Figure 1. Their test rig transmitted the static load to the vibration isolator via the moving element of the shaker, and the maximum static load was 1 kN. Consequently their test rig was only suitable for small vibration isolators. However, AMRL wished to test large vibration isolators, and so the test rig of Meltzer and Melzig-Thiel was not suitable for the current study.

Schloss [18] used the test rig shown in Figure 2 to measure the blocked transfer impedance and blocked driving point impedance of vibration isolators under static load. Results were presented over the approximate frequency range from 20 Hz to 2 kHz for a vibration isolator under a static load of 3.6 kN. Schloss claimed to have measured frequencies up to 5 kHz

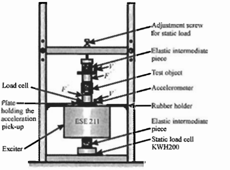


Figure 1: Test rig of Meltzer and Melzig-Thiel, after Meltzer and Melzig-Thiel (1980)

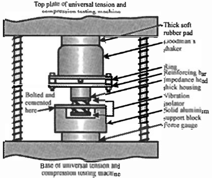


Figure 2: Proposed test rig of Snowdon, after Schloss (1965)

and static loads up to 44 kN. His test rig assumed a blocked output and measured the input and output forces, and input acceleration. Snowdon [4] proposed using the test rig of Schloss to measure the four-pole parameters, by also assuming a blocked output and measuring the input and output forces, and input acceleration. This method of using a blocked output was experimentally convenient, and consequently the investigation of measurement methods in this study began with a developmental test rig that utilised a blocked output and measured the input and output forces, and input acceleration.

4.1. Developmental test rig

To study techniques for measuring the four-pole parameters, a developmental test rig was initially required. It was required to measure dynamic forces, either indirectly or directly. The measurement of the direct forces of large vibration isolators at high frequencies is experimentally difficult, because of the large vibration isolator masses and forces involved. The indirect method infers the forces from other measurements, and it is experimentally convenient to determine the forces by considering inertial forces calculated from acceleration measurements. Hence the indirect method was initially incorporated.

Thus a developmental test rig was required that provided a blocked output and measured the indirect input and output forces, and input acceleration. Verheij [19-20] described a method for measuring the indirect blocked output force. He developed a method for determining the blocked apparent mass of a statically loaded vibration isolator. The Institute of Applied Physics (TPD) test facility is based on Verheij's work and is capable of characterising vibration isolators over the approximate frequency range from 20 Hz to 2 kHz with static loads applied hydraulically up to 1 MN [21]. However, the characterisation is in terms of the apparent mass and dynamic stiffness, and not the four-pole parameters. The results are presented as third-octave band plots. Notwithstanding, the current study was commenced using Verheij's method of indirectly measuring the blocked output force.

A test rig that could be made suitable by modification, was the test rig developed by Farquharson [22]. Farquharson developed a test rig based on the measurement method of Verheij, and designed to measure the blocked apparent mass and blocked transfer mobility, i.e. blocked four-pole parameter α_{21}^{*}, of a vibration isolator under static load. It measured the indirect output force and input acceleration. No experimental results were presented because the commissioning results were unsatisfactory due to structural resonances and flanking vibration transmissions.

The type of test rig used by Schloss shown in Figure 2 is prone to the same measurement problems as Farquharson's test rig emanating from structural resonances and flanking vibration transmissions. The parameter of concern for Schloss's test rig is the output force. The output is assumed to be blocked and the output force is measured directly. The machine used by Schloss was the screw type designed for quasi-static tests, and would have numerous lightly damped modes throughout and near the frequency range of interest. The reaction forces transmitted by the shaker to the frame of the test rig would excite some frame modes in the frequency range of interest, which may affect the measurement of the output force. Also the reaction forces transmitted from the shaker may generate a flanking vibration path via the frame to the output force gauge. Additionally, Schloss does not specify the method of supporting the test rig, and the effect of ground borne vibrations on the measurement was not mentioned.

In the measurement of the output force, the test rig of Farquharson had one stage of vibration isolation via air-bags located between the output force measuring mass and the frame of the test rig, which the test rig of Schloss did not have. Even so, it was found necessary to modify the test rig of Farquharson to reduce the effect of the structural resonances of the frame of the test rig, flanking vibration transmissions and the ground borne vibrations. The modification to reduce the effect of the structural resonances and flanking transmissions was realised by supporting the shakers with soft vibration isolators supported from a separate frame to the frame enclosing the test vibration isolator. The modification to reduce the effect of the ground borne vibrations was brought about by mounting the test rig on a large seismic mass supported on air-bags, instead of the laboratory floor.

The modified and improved test rig is termed the developmental test rig, and could measure the four-pole parameters of a vibration isolator under static load [23-25]. It measured the indirect input and output forces, and input acceleration, Figure 3. It could measure up to a frequency of 1 kHz, and was excited by a pair of shakers with a combined

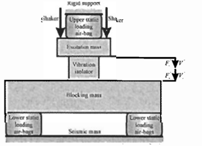


Figure 3: Schematic diagram of develpmental test rig.

force capability of 200 N [25]. Improvements to the measurement technique were investigated using the developmental test rig, and are discussed in Sections 4.2 to 4.5.

4.2. Blocking and Floating Masses

The developmental test rig used Verheij's method to measure the output force. The blocking mass was supported on soft mounts, and was assumed to be effectively blocked above a lower frequency limit. However, the blocking mass still had a small but measurable acceleration that could be used to determine the blocked output force on the vibration isolator, termed the indirect output force measurement.

The limitations of the blocked mass method were the imposition of a lower frequency limit dependent on the modal behaviour of the masses, and a limit on the upper frequency caused by the requirement to measure a small acceleration of a large mass. Dickens and Norwood [6] proposed an alternate measurement method, called the floating mass method, in order to overcome these deficiencies. This method does not assume that the blocking mass in Figure 3 is blocked, but rather considers it to be floating and corrects for its velocity. The floating mass method reduces the lower frequency limit of measurements. It is therefore possible to use a lighter blocking mass, since the lower frequency limit is not determined by the blocking mass.

4.3. Force Measurement

The input and output forces to the vibration isolator may be measured by the indirect or direct methods. The indirect input force is calculated by measuring the input force to the excitation mass and its acceleration, and then subtracting the inertial force of the excitation mass from its input force. The indirect output force is determined by measuring the acceleration of the blocking mass and calculating its inertial force.

The direct force method measures the forces directly by transmitting the input and output forces using force transducers mounted in force measuring assemblies [7]. The inertial effects of associated masses, such as mounting end plates, are accounted for by measuring their accelerations.

Dickens and Norwood [24] studied the direct and indirect force measurements. They found that the error magnitude of the input force measured indirectly was significant for high frequencies, and that conversely the error magnitude for the indirect measurement of the output force was significant for low frequencies. Use of the indirect measurement imposed a lower frequency limit on the input and output force measurement, which was primarily determined by the modal behaviour of the blocking mass at low frequencies. In general, the method of using indirect input and output force measurements was inaccurate, and generated significant errors in the measured four-pole parameters. The accuracy of the direct force measurement was predominantly determined by the intrinsic precision of the force transducers, and was fundamentally more accurate than the indirect method. Consequently, Dickens and Norwood proposed the direct measurement of the input and output forces. If the direct input and output forces were measured, then there was no lower frequency limit of measurements imposed by the modal behaviour of the masses.

Verheij [20] was primarily concerned with measuring the blocked apparent mass of the vibration isolator defined as the output force divided by the input acceleration, and related to the four-pole parameter . The results derived in this way were not significantly affected by the error in the input force, and were mainly affected by the errors in the blocked mass assumption as explained by Dickens and Norwood [6]. At lower frequencies it was sufficient to use this to describe the vibration isolator performance, but as the frequency increases the other four-pole parameters become important in the determination of the vibration isolator effectiveness.

4.4. Correction for Velocity Errors Introduced by Force Measuring Assemblies

To measure the input and output direct forces, force measuring assemblies were introduced serially into the system and so their effect on the modal behaviour of the system needed to be considered [7]. Their effect was to produce inaccuracies in the measurement of the velocities at high frequencies, since the measuring accelerometers were attached to the excitation and blocking masses and not the ends of the vibration isolator, Figure 4. This also introduced errors into the inertial force corrections to the direct forces, to account for the associated masses such as the end plates of the force measuring assemblies.

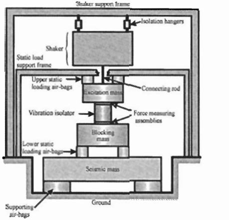


Figure 4: Schematic diagram of vibration isolator test rig.

To be able to measure with confidence up to 2 kHz, a method was required to account for these inaccuracies introduced into the measurement of the velocities. If the velocities were correctly measured, then so also were the direct forces. One technique was to actually measure the accelerations of the ends of the vibration isolator. However, this was practically difficult because of space restrictions and the necessity to have large sensitive accelerometers to measure the small output motions.

Another approach was to separately characterise the force measuring assemblies, and then correct for their influence on the measured velocity data. This latter approach was proposed and practically demonstrated by Dickens [7]. It was termed the method of correcting direct force measurements. This method removed the modal limitations of the force measuring assemblies used for the direct force measurement, and extended the upper frequency limit of measurements. The upper frequency limit was then governed by the ability of the instrumentation to measure forces and accelerations with confidence, which in turn was practically dictated by the force capability of the shaker or shakers.

4.5. Universal Testing Method

As discussed in Section 2.2, the two mass method is a universal test method suitable for passive, semi-active and active vibration isolators with feedback control.

4.6. Vibration isolator test facility

A vibration isolator test rig was developed that incorporated the floating mass method, measured the direct forces and implemented the method of correcting direct force measurements [7, 26, 27]. The static load was applied to the vibration isolator by the upper and lower static loading air-bags, Figure 4. The test rig had two frames with constrained layer damping, air-bags, isolation hangers and a 22 t seismic mass to minimise modal and coupling influences, and flanking and ground borne vibration transmissions. The test rig formed part of the vibration isolator test facility and was capable of applying the two mass method. The vibration isolator was enclosed within a temperature enclosure that maintained a constant temperature. The facility was demonstrated to be capable of measuring the four-pole parameters of small and large vibration isolators over the frequency range from 5 Hz to 2 kHz, with static loads over the range from 1 to 30 kN and over the temperature range from 6 to 60ºC. Details of the facility [7] are to be published elsewhere.

The facility is capable of implementing the unblocked reversal method and the two mass method, Sections 2.1.2 and 2.2. Vibration isolators in vertical and inclined orientations can be tested. By using two vibration isolators of the same type, the facility can also be used to measure their lateral four-pole parameters. It is capable of testing symmetrical, asymmetrical and uni-directional asymmetrical vibration isolators.

5. CONCLUSIONS

A passive vibration isolator is bi-directional, and its four-pole parameters may be conveniently measured experimentally with its output end blocked. If it is symmetrical, then it is sufficient to measure its input force, input velocity and output force. If the vibration isolator is asymmetrical then it is necessary to use the blocked or unblocked reversal methods. The blocked reversal method requires the measurement of the input force, input velocity and output force of the blocked vibration isolator in its normal and reversed configurations, whereas the unblocked reversal method also requires the measurement of the output velocity.

The methods of measuring the four-pole parameters of passive vibration isolators are not applicable to active vibration isolators. A suitable technique for measuring the four-pole parameters of active vibration isolators with feedback control is the two mass method, which may be regarded as a universal method and is suitable for symmetrical, asymmetrical, uni-directional and bi-directional vibration isolators.

A vibration isolator test facility has been developed at AMRL that incorporated the floating mass method, measured the direct forces and implemented the method of correcting direct force measurements. It was demonstrated to be capable of measuring the axial and lateral four-pole parameters of small and large vibration isolators under static loads and controlled temperatures, in vertical and inclined orientations. The facility is capable of implementing the unblocked reversal method and the two mass method. It is capable of testing symmetrical, asymmetrical and uni-directional asymmetrical vibration isolators, including passive, semi-active and active elements with feedback control.

ACKNOWLEDGMENTS

The author gratefully acknowledges Dr Chris Norwood, Maritime Platforms Division, DSTO, and Dr Hugh Williamson from the University of New South Wales, for discussions on themes of this paper. He also appreciates the support of AMRL during this study, as part of the work for a PhD from the University of New South Wales.

REFERENCES

[1] C.T. MOLLOY, "Use of four-pole parameters in vibration calculations" J. Acoust. Soc. Am. 29, 842-853 (1957).

[2] C.H. HANSEN, and S.D. SNYDER, Active Control of Noise and Vibration E & FN Spon, London (1997).

[3] J.C. SNOWDON, "Mechanical four-pole parameters and their application" J. Sound Vib. 15, 307-323 (1971).

[4] J.C. SNOWDON, "Vibration isolation: use and characterisation" J. Acoust. Soc. Am. 66, 1245-1274 (1979).

[5] G. MELTZER and R. MELZIG-THIEL, "Experimental determination and practical application of the four-pole parameters of structure-borne sound isolators" Arch. Acous. 5, 315-336 (1980).

[6] J.D. DICKENS and C.J. NORWOOD, "Measurement of four-pole parameters using floating masses" Proc. Aust. Acoust. Soc. Conf., Canberra, 9-11 Nov. 1994 pp. 57-65.

[7] J.D. DICKENS, "Dynamic characterisation of vibration isolators" Ph.D. Thesis, University of New South Wales, Canberra (1998).

[8] J.C. SNOWDON, "Transmission matrices" Pennsylvania State University, Applied Research Laboratory report to the U.S. Naval Sea Systems Command, report no. TM 76-122, Philadelphia (1976).

[9] I. VEIT, "Bestimmung der schallubertragungsdampfung von kompensatoren durch messung ihrer vierpolparameter" (translated as "Determination of sound transmission attenuation by compensators through measurement of four-pole parameters"), Proc. Fortschritte der Akustik (translated as Progress in Acoustics) conf., Germany (1976). Original in German.

[10] I.I. KLYUKIN, "Vibration attenuation of resilient mounts and dampers underneath actively vibrating machines (review)" Soviet Phys. - Acous. 25, 181-191 (1979).

[11] A.F. VAKAKIS, "Dynamic analysis of a unidirectional periodic isolator, consisting of identical masses and intermediate distributed resilient blocks" J. Sound Vib. 103, 25-33 (1985).

[12] F. JACOBSEN and M. OHLRICH, "Vibrational power transmission from multipoint mounted machinery to supporting structure" Technical University of Denmark, Acoustics Laboratory report no. 35, Lyngby (1986).

[13] C.J. NORWOOD, "Vibration isolator properties and performance prediction" Odegaard & Danneskiold-Samsoe report no. 87.199, Copenhagen (1987).

[14] E.L. HIXSON, "Mechanical impedance" in Shock and Vibration Handbook ed. C.M. Harris, McGraw-Hill Book, New York, third edition (1988) Chapter 10.

[15] J.Y. HA, K.J. KIM, J.H. KIM and S.G. JUNG, "Experimental analysis of the vibrations of car body and steering wheel system of a passenger car using the four-pole parameter method" Mach. Vib. 1, 190-196 (1992).

[16] V. EASWARAN, V.H. GUPTA and M.L. MUNJAL, "Relationship between the impedance matrix and the transfer matrix with special reference to symmetrical, reciprocal and conservative systems" J. Sound Vib. 161, 515-525 (1993).

[17] J.Y. HA and K.J. KIM, "Analysis of MIMO mechanical systems using the vectorial four pole parameter method" J. Sound Vib. 180, 333-350 (1995).

[18] F. SCHLOSS, "Recent advances in mechanical impedance instrumentation and applications" U.S. Navy David Taylor Model Basin, report no. 1960, Washington (1965).

[19] J.W. VERHEIJ, "Sound transfer via resilient mounts for separate excitation with orthogonal translations and rotations: development and test of a measurement technique" Institute of Applied Physics TNO-TH report no. 908.835, Delft (1980).

[20] J.W. VERHEIJ, "Multi-path sound transfer from resiliently mounted shipboard machinery" Ph.D. Thesis, Institute of Applied Physics TNO-TH, Delft (1982).

[21] TNO, "Flexible components" Institute of Applied Physics TNO-TH information brochure on testing capability, Delft (1989).

[22] E. FARQUHARSON, "Vibration isolator test rig for Materials Research Laboratory" Swinburne Institute of Technology ME 582 Engineering Project, Melbourne (1991).

[23] J.D. DICKENS, C.J. NORWOOD and R.G. JUNIPER, "Four pole parameter characterisation of isolator acoustic transmission performance" Proc. Aust. Acoust. Soc. Conf., Glenelg, 9-10 Nov. 1993 pp. 110-117.

[24] J.D. DICKENS and C.J. NORWOOD, "Measurement of four-pole parameters using direct forces" Proc. Aust. Acoust. Soc. Conf., Fremantle, 15-17 Nov. 1995 pp. 15-21.

[25] J.D. DICKENS and C.J. NORWOOD, "Vibration isolator test facility" Defence Science and Technology Organisation, Aeronautical and Maritime Research Laboratory, report no. DSTO-TR-0357, Melbourne (1996).

[26] J.D. DICKENS and C.J. NORWOOD, "Design of a vibration isolator test facility" Proc. Aust. Acoust. Soc. Conf., Brisbane, 13-15 Nov. 1996 paper no. 3.

[27] J.D. DICKENS and C.J. NORWOOD, "Design of a test facility for vibration isolator characterisation" Acoust. Aust. 25, 23-28 (1997).

HEARING AMONG MUSICIANS AND MUSIC PERFORMANCE

Donald Woolford
W-P-Consulting Pty.Ltd.
GPO Box 278, Sydney NSW 2001,

A Transcript of Ockham's Razor program with Robyn Williams and Donald Woolford, broadcast over ABC Radio National on November 21, 1999.

Robyn Williams: Do you play a musical instrument? If you do I suppose you take it for granted that it helps to hear the noise you make. Some of the audience, on the other hand, especially if the performers are someone else's adorable children, have been known to pray for deafness to escape the ordeal. But frankly, do you need good hearing to be a good musician? That sounds like a daft question, but it isn't. Donald Woolford is an acoustics engineer and found there is a difference between the hearing you need to perform music as opposed to what you rely on for other work. And when you think about it, there are many examples of supreme musicians whose ears worked hardly at all. And Donald Woolford is a musician himself.

Donald Woolford: Many of us know of Scottish born Evelyn Glennie, world famous percussionist, and perhaps seen her perform. Evelyn Glennie, who started to lose her hearing at age 8, was quite deaf from early teens. She has performed widely in the UK, also in Europe, North America, Japan and Australia. Her autobiography, 'Good Vibrations', is a story of great determination. Even though the nature of percussion lends itself to touch, sight and vibration perception as feedback in performance, determination and innate musicianship must have contributed to her magnificent achievements.

One of the attributes of musicianship is the ability to transcend the purely physical aspects and structure of music. Most of us can distinguish between just a technical performance and a truly musical or an even magical one that enters the spirit of the music. Another attribute of musicianship is the ability to play together with others, artistically.But some reliable auditory feedback is necessary for musicians who play pitch producing instruments, to produce and monitor their own music output, as well as listen and adjust to other instruments. Orchestral players of such as strings, woodwind and brass instruments regulate their music with auditory feedback to control pitch, loudness, timbre and ensemble, together with applying acquired technical, musical and cognitive skills. Sight is also a very important factor.

Recent research into musicians in major orchestras has revealed that a larger than expected proportion of players have acquired some sort of hearing changes due to a wide variety of causes, to include presbyacusis or ageing of hearing. It may seem surprising that those affected perform well and presumably stress free. Indeed the musical function of hearing in conjunction with all the other elements of music performance among these musicians appears unaltered. One conclusion we may postulate is the robustness of musical hearing. Another, that musicians make the most of residual hearing because of their highly developed auditory skills, and is supported by an investigation into frequency discrimination of complex sounds by Drs Murray Spiegel and Steve Watson in 1984. Members of the St Louis Symphony Orchestra performed better initially in these tests compared to non-musicians. Nevertheless the non-musicians caught up with and even out-performed the professional players in purely discrimination testing, but only after extensive and directed training over a period. In the book 'Music and the Brain; Studies in the Neurology of Music', J.D. Hood reported that Smetana at the age of 56, totally deaf, performed Chopin's Nocturne in B and his own Polka in A Minor. A contemporary wrote of his performance as towering above all other pianists. Hood also reported Beethoven's attempt to conduct 'Fidelio' in 1822, which has disastrous consequences because of his deafness. But deafness appeared not to inhibit Beethoven's composition. Vaughan Williams was reported as having presbyacusic deafness in his later years, but continued to conduct successfully until his 85th year, even though he was unsure of orchestral balance and had to consult with Sir John Barbirolli and Sir Adrian Boult in conducting recordings of his own works, since he could not hear high tones of some instruments.

Dr Barrie Morley, neurologist of Queensland, summarised the main contemporary views. For example, there appears to be a right brain hemisphere dominance for music execution, that music talent involve different brain functions. Dr Oscar Marin of Portland, Oregon, in Diana Deutsch's book 'The Psychology of Music', mentions documented cases of aphasia among professional or amateur musicians in whom musical abilities were not noticeably affected. There thus appear to be diverse brain functions for music faculty. Research into musicians' hearing has foundation in the advent of rock music, and published papers date back to the 1960s. Later work has looked at the hearing of orchestral and other types of musicians and audience to establish the effect of the music upon hearing. For example, in the Swiss Romande Orchestra, Rabinowitz found that 22 out of 110 players had changed hearing levels presumed due to the music alone. Drs Alf Axelsson and Frederik Lindgren of Sweden listed 42% of players in two Swedish orchestras as having pure-tone thresholds worse than expected for age. Although intense music was a suggested diagnosis of 36% of these players, other diagnoses included disease, gunfire, heredity, injury, presbyacusis and previous noisy job. Some players had up to three different diagnoses. It is significant that many causes of changed hearing levels from other than intense music were identified. Also apparent from these and other studies, is the wide variation in susceptibility for hearing loss resulting from intense sound exposures.

The medical assessment of hearing is directed to establish type, extent and source of hearing impairment if one exists, and determine remedies and predictions about aural abilities in everyday life. However, measurements were not devised to test aural abilities in music perception, or monitoring sounds created by a musician, or in loudspeaker listening by a sound recordist, where that kind of accuracy is required. Indeed in the cases of musicians from standard measurements, one might predict difficulty to perform efficiently because of hearing losses, even though performance efficiency is already demonstrated.

There is evidence that music may cause less damaging effect upon hearing than industrial noise of the same energy spectrum. For example, Alf Axelsson in Sweden surveyed 53 rock and pop musicians in 1973, and again in 1993, and found that although they had hearing slightly worse than the average populace for age in 1973, presumed due to the music, were collectively within the average populace in 1993. Why? It may be because their music performances are for short periods of a few minutes, even though very high level, with frequent rest periods, that they work a shorter week, or what is called the aural reflex, a middle-ear phenomenon that limits energy through to the cochlea, or inner ear. Axelsson found however, that some players had permanent tinnitus or ringing in the ears, and some hyperacusis, that is, increased sensitivity to loud sounds. In an article about loud music and hearing loss in *'Audio Magazine'*, Dr Mead Killion of Chicago, who developed the Musician's Ear Plug, is quoted as saying, 'God protects musicians, otherwise they'd all be deaf!' Whether or not musicians are thus favoured, there is science that suggests musicians lose less hearing than expected due to the music. Axelsson and Lindgren established that music with the same energy as industrial noise produces less temporary hearing loss. Garry Foster, of Worksafe Australia, said the evidence suggests that although music is a risk to hearing, the risk is much less than the equivalent exposure to industrial noise. In a series of studies in the 1980s, Dr Norm Carter at National Acoustic Laboratory, found that amplified music and recreational noise consistently showed little or no effect on hearing acuity of young people as a group, and young adults up to 30 years. It was concluded that long-term exposure to occupational noise remained the main source of noise-induced hearing loss. Although a person's measured hearing appears normal for age, researchers using comparatively new oto-acoustic emission testing claim a different scenario. It is considered that cochlea hair cells may already be damaged due to noise exposures, which is not apparent from the audiogram.

It is an intriguing question as to how a musician can perform with some-thing less than so-called normal hearing. Audiograms of some musicians who perform well and presumably stress free, exhibit little sensitivity for the higher harmonic structure of music sounds. For example, a tenor in Tennessee needs a hearing aid for everyday life, but takes the aid off for singing. An orchestral pit musician in USA with a high tone hearing loss has problems in discriminating female speech, with its higher frequency content. The second oboist in a famous orchestra cannot discriminate all the sound of the violin solo in 'Scherezade', at least from where he sits in the orchestra.

Two of these players were older, and it may be their hearing changes were the result of both ageing and exposures to intense sounds. Whatever, they were still performing music at a professional level, presumably stress free.

As an orchestral player, my observation is that much older players perform well, even though one could expect them to have at least changes in hearing due to age. Indeed, many players in major orchestras in the USA continue well into their seventies. The late A.T. Welford, Professor of Psychology at Adelaide University, said 'Where specific tasks were done under deficiencies due to age, fatigue or injury, the performer compensates to achieve the same objective.' If we can apply this to hearing in music performance, how much hearing deficiency can be tolerated before other performance elements have been stretched to their limits? We do not know, but is probably to include such as the type of instrument and individuality.

To my knowledge, there is little science that relates hearing to the function of music perception in music performance, combining the perception of music and the precise production of musical sounds. Any investigations should involve binaural hearing perception rather than the one-ear-a-time health tests. Professor Steven Colburn, Director of the Hearing Research Center at Boston University, has authored papers about binaural perception for various kinds of hearing impairments. In Steven Colburn's Center, I am working on the effects of simulated hearing impairments in the performance of some orchestral instruments. Preliminary results appeared in a recent issue of *'Acoustics Australia.'*

I consider that musicians deserve special attention into the effects of loud music upon their hearing and the possibility of noise induced hearing loss. In particular, to re-examine the criteria for the conservation of their hearing, since the present industrial criteria were derived from industrial noise. Music, with its often fluctuating levels and intermittent nature, is different in character. Even so, sound levels get quite high in an orchestra, more so in an orchestral pit. Secondly, it may be that special measurements can be devised that relate music perception to hearing in the function of production of music. Definitely not to scientifically measure performance quality and competence. In this the final arbiters are listeners, one's peers, and should remain so, considering the nature of music. In my opinion, part of the beauty of music performance is the unexpected and artistic variability.

Since medical interest in hearing is oriented to health and communication, and measurements thereto are not directed to music, special measurements for application by health professionals, in addition to the standard battery of tests, could bring science and music closer. But the final gap may never be bridged, because of the nature of music. Nevertheless the application of special measurements directed to music may be the catalyst to admit a partially deaf person to a music school, or help resolve industrial matters for musicians. It may be inspiration from the Glennie determination will result in a positive advance.

Robyn Williams: Evelyn Glennie, that incredible percussionist, who appears to be completely unrestricted by her deafness. That was Donald Woolford, who used to lead orchestras in Adelaide but now plays in a string quartet in Sydney. He's also an acoustics engineer.

SOME APPLICATIONS OF NUMERICAL ACOUSTICS

Joseph Lai

Acoustics and Vibration Unit
School of Aerospace & Mechanical Engineering
University College, The University of New South Wales
Australian Defence Force Academy, Canberra, ACT 2600, AUSTRALIA

ABSTRACT: The advantages and disadvantages of finite element and boundary element methods and geometrical acoustics methods are discussed. Applications of these methods to solving a range of vibro-acoustics problems and architectural acoustic problems are illustrated with practical examples including structural radiation, noise barriers and acoustic quality of rooms. In all these examples, comparisons of predictions are made with measurements to illustrate the accuracies, limitations and usefulness of these numerical methods.

1. INTRODUCTION

In acoustics, the propagation of sound is governed by the Helmholtz equation, first given by Euler in 1759 and then by Helmholtz in 1860. However, it was difficult to obtain analytical solutions with complex geometries and/or complex boundary conditions. With the advent of powerful desktop computers/workstations, numerical techniques based on geometrical acoustics (primarily ray tracing and mirror-image source methods for high frequencies) have been applied to problems in room acoustics and environmental acoustics. While commercial finite element software has been available for over three decades for engineering applications such as stress analysis, it is only recently that commercial software utilising advanced numerical techniques such as finite element and boundary element methods (primarily more suitable for low frequencies) has been made available. It has often been claimed that the most effective noise control method is the control of the source through engineering means but this is often very difficult to achieve unless prior considerations have been given to the design of a product. With the use of computational methods for acoustics, it is now possible to incorporate 'numerical' acoustic analysis in the design process so that noise radiation can be analysed even before prototypes are built and innovative engineering techniques in reducing noise radiation may be examined. However, there is generally a lack of verification of computer models against measurements except for simple geometries [1]. The objectives of this paper are to describe our experience in the use of boundary element and geometrical acoustics methods for applications in acoustics. Comparisons between predictions and measurements are made.

2. GOVERNING EQUATION AND BOUNDARY CONDITIONS

The propagation of sound waves in a medium is governed by the familiar wave equation:

$$\nabla^2 p - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = 0 \quad (1)$$

where c is the speed of propagation of sound waves; p is pressure; t is time; and ∇^2 is the Laplace operator.

By assuming a steady state harmonic motion of the form $p(x,y,z,t)=p(x,y,z)e^{j\omega t}$, ($j$ is the imaginary number $\sqrt{-1}$), equation (1) can be reduced to the Helmholtz equation:

$$\nabla^2 p + k^2 p = 0 \quad (2)$$

where k is the wavenumber $= \omega/c$ and ω is the circular frequency in radians/sec.

Equation (2) can be solved by imposing appropriate boundary conditions on boundary surfaces which involve prescribing usually (a) the surface pressure (p_s); (b) the normal surface velocity(v_n); or (c) the normal surface admittance(A) or impedance as follows:

$$p = p_s, \qquad \frac{\partial p}{\partial n} = -j\rho\omega v_n, \qquad \frac{\partial p}{\partial n} = -j\rho\omega A p \quad (3)$$

where n is the coordinate normal to the surface.

Furthermore, for external radiation problems, the acoustic field vanishes at points farther than $c(t-t_o)$ because a wave disturbance initiated at time (t_o) would not have reached that distance in the time (t) of interest. This condition is known as the Sommerfeld radiation condition [2] and may be expressed in spherical coordinates as

$$\lim_{r\to\infty} r^{\alpha}\left[\frac{\partial p}{\partial r} + jkp\right] \to 0 \quad (4)$$

where r is the distance from the surface of source excitation and α is 1/2 for 2-D problems and 1 for 3-D problems.

The boundary-value problem as described by equations (2)-(4) is difficult to solve analytically except for very simple geometries and boundary conditions. Approximate analytical solutions can be obtained for high and low frequencies using perturbation methods [3]. Consequently, numerical methods have to be sought for general problems.

3. NUMERICAL METHODS

3.1 Finite element/Boundary element Methods

A good description of the implementation of finite element and boundary element methods (FEM/BEM) to solve the acoustic wave equation is given in [4, 5]. The basic differences between FEM and BEM are that in FEM, the whole solution domain has to be discretised while in BEM, only the boundary surface of the model has to be discretised as shown in Figure 1. Although FEM performs quite well for interior radiation problems, it is not so suitable for solving exterior radiation problems which would require an 'infinite' expansion of the finite element mesh. Nevertheless, 'infinite' elements and 'wave envelope' elements are being developed to solve exterior radiation problems [6]. Users of BEM must be aware that for exterior radiation problems, the solution obtained may not be unique at frequencies that correspond to the interior cavity resonant frequencies but this can be overcome by using special procedures as described in [5].

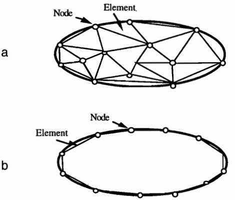


Figure 1 Discretisation of the solution domain.
(a) Finite element (b) Boundary element

3.2 Methods based on Geometrical acoustics

Solving equations (1)-(4) at high frequencies using FEM/BEM for large spaces would require an enormous amount of computer memory and disk capacity and can be prohibitively time consuming. At high frequencies, where the dimensions of the room are large compared with the wavelength, sound can be considered to behave as rays and the principles of specular reflection (ie the angle of incidence equals the angle of reflection) can be applied. There are now numerous commercially available software programs for doing such calculations. The algorithms used for such computer models are normally based on either the mirror image source method, the ray tracing method or the beam method [7]. Comparisons between results obtained by 14 different programs and measurements indicate that there are large differences between predictions by various algorithms [8]. Areas identified for further improvement include diffuse reflections.

4. EXAMPLES

All calculations reported here were made on a SUN SPARC20 workstation. Calculations using BEM were made using SYSNOISE version 5.3A while those using geometrical acoustics were made using RAYNOISE version 2.1

4.1 BEM

Radiation from an electric motor

It has been shown that the sound power level radiated from simple structures such as plates [6,9] and circular cylindrical shells [10] can be predicted with reasonable accuracy using BEM. In this example, the sound radiation efficiency of a 2.2 kW induction motor subjected to random mechanical excitation applied to a point on the casing has been determined experimentally and using BEM.

In the experiment, the sound power spectrum due to the mechanical excitation was measured in an anechoic room using a two-microphone sound intensity probe while the vibration spectra at 130 points distributed over the motor casing and the base plate were measured using an accelerometer. The sound radiation efficiency was then determined from these measurements.

In the numerical calculations, the motor structure was modelled using two concentric cylindrical shells, one for the casing and the other for the stator. As shown in Figure 2, the motor casing was modelled using 1128 quadrilateral shell elements and the stator was modelled using 720 solid elements. In this structural model of 3423 elements analysed using a commercial finite element code ANSYS version 5.4, the rotor has not been included because its contribution to the noise radiation is only significant for frequencies below 500 Hz [11]. Various factors affecting the accuracy of modelling a motor structure using finite elements have been discussed by Wang and Lai [11]. By using the results of the vibration response of the structural model as an input to the acoustic boundary element model, the sound radiation efficiency from the motor structure can be calculated.

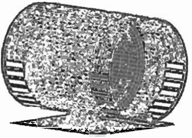


Figure 2 Perspective view of the structural model of an electric motor (with end shields removed).

As shown in Figure 3, there is reasonable agreement between the calculated and measured sound radiation efficiencies. The discrepancies at low frequencies can be attributed to the omission of the rotor in the model. Nevertheless, this example shows that such a model can be used to examine the effects of geometrical parameters such as thickness, stiffness, ribs, etc. on the sound radiation from a motor structure.

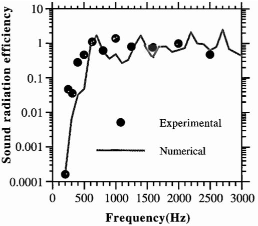


Figure 3 Sound radiation efficiency of a 2.2 kW induction motor.

Noise barriers

While it is rather routine to predict analytically or empirically the insertion loss of simple barriers such as shown in Figure 4(a), such prediction for innovative design is by no means trivial. The noise reducer (as shown in Figure 4(b)) is a cylindrical absorptive structure generally fitted to the top of a flat barrier. According to its manufacturer, Nitto Boseki Co., Ltd. in Japan, the noise reducer increases the effective height of the barrier by at least double the diameter of the noise reducer. It presents, therefore, a good opportunity to use the BEM calculations to assess the manufacturer's claim.

In this example, the ground is reflective, the source is a cylindrical line source located at 15 m from the barrier and the receiver is located at various distances (15 m, 25 m and 50 m) from the barrier. In order to eliminate interference effects due to ground reflections, calculations were made for both the source and the receiver at ground level.

a

b

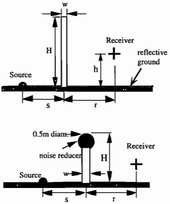


Figure 4 Schematic of barrier configurations.
(a) Flat barrier (b) Barrier fitted with Noise Reducer

a

b

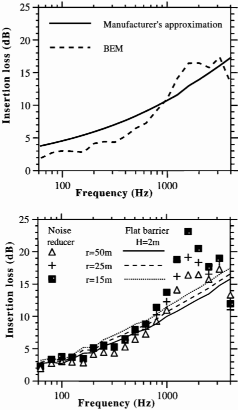


Figure 5 Insertion Loss.
(a) Noise reducer (b) Noise reducer and a flat barrier

Figure 5(a) shows that there are discrepancies between the BEM predicted insertion loss and the manufacturer's simplified approximation perhaps due to the assumed flow resistivity of the absorption material used in the noise reducer and the simplified cylindrical geometry used for modelling the noise reducer. Nevertheless, the predicted insertion loss is quite acceptable. More importantly, it allows the assessment of the effectiveness of a noise reducer fitted to a flat barrier with a total height of 1.5 m compared with that of a 2m high reflective flat barrier. Figure 5(b) shows that at frequencies above 800 Hz, the noise reducer has increased significantly the effective height of the barrier. The effectiveness of the noise reducer at 2000 Hz is illustrated by the sound pressure fields shown in Figure 6.

4.2 Geometrical Acoustics

Figure 7 shows a room with a volume of approx 3,700 m^3 modelled using geometrical acoustics. Measurements were made in octave frequency bands using a white noise sound source. The agreement between the predicted and measured early decay time (EDT) is generally within 0.2 sec over the important speech frequency range (Figure 8(a)) for two

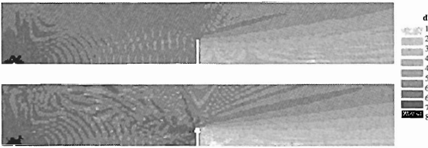


Figure 6
Sound pressure field at 2000 Hz

(a) reflective flat barrier with H=2 m

(b) reflective flat barrier with noise reducer with H=1.5 m

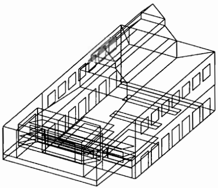


Figure 7 Room model.

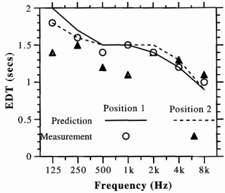


Figure 8(a) Comparisons of EDT.

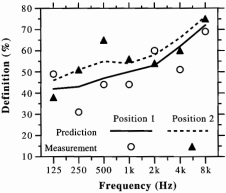


Figure 8(b) Comparisons of Definition.

different positions in the room. One indicator of speech clarity is 'Definition', D50, which is the ratio of the sound energy received in the first 50 ms to the total sound energy. A value for D50 of about 65% is equivalent to almost 95% speech intelligibility. Comparisons between the predicted and measured D50 in Figure 8(b) show agreement, generally to within 10-20%. It is important to point out that in this type of modelling, the source has to be modelled as accurately as possible. As seen in Figure 9, an omnidirectional source yields substantially different results from those of a directional source used in the experiments. It can be seen from Figure 10(a) that the predicted D50 at 1 kHz in the seating areas range from as low as 35% to around 60%. Numerical modelling allows the effects of any proposed changes on the acoustics quality to be assessed. Figure 10(b) shows that by implementing the proposed architectural modifications to the room, the predicted D50 at 1 kHz has been significantly increased to around 60-70%.

5. CONCLUSIONS

Applications of numerical acoustics methods (primarily boundary element and geometrical acoustics methods) are illustrated by practical examples from an electric motor, noise barriers and architectural acoustics. Results show that although there are some discrepancies between predicted and measured values, the general trend is reasonably well predicted. These predictive methods are particularly useful for assessing the impact of design changes on acoustics.

ACKNOWLEDGMENTS

Part of the work presented here has been supported by the Australian Research Council.

REFERENCES

1. G. Naylor, "Editorial" Applied Acoustics.38, 89-92(1993)
2. A.D. Pierce, Acoustics : an introduction to the physical principles and applications. McGraw-Hill, New York (1981)

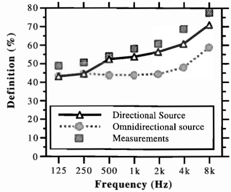
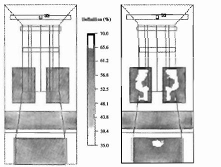


Figure 9 Effects of noise source.



(a) existing room (b) room with architectural modifications.

Figure 10 Predicted contours for Definition at 1 kHz.

3. D.G. Crighton, Modern methods in analytical acoustics. Springer-Verlag, London (1992)
4. M. Crocker, Encyclopedia of acoustics. John Wiley & Sons, New York (1997)
5. R.D. Ciskowski, R.D. and C.A. Brebbia,. Boundary element methods in acoustics Elsevier Applied Science (1991)
6. J.P. Coyette, J.P. and L. Cremers, "Comparative study of boundary element and finite element formulations for evaluating sound radiation from plates" Proc. 5th Int. Cong. On Sound and Vibration 2, 801-808 (1997).
7. H. Lehnert, "Systematic errors of the ray-tracing algorithm" Applied Acoustics 38, 207-221 (1993)
8. M. Vorlander, "International round robin on room acoustical computer simulations" Proc.15th ICA II, 689-692 (1995)
9. J.F. Milthorpe, J.C.S. Lai and N. Huynh, "Acoustic radiation from a circular plate: Comparison between numerical prediction and experiment" Inter-noise 93, Late papers (1993)
10. C. Wang and J.C.S. Lai, "Acoustic radiation from finite length cylindrical shells using boundary element method" Proc. 5th Int. Cong. On Sound and Vibration 2, 877-884 (1997)
11. C. Wang and J.C.S. Lai "Vibration analysis of induction motors" J. Sound & Vibration 224(4), 733-756 (1999)

Obituary

DENIS JOHN BYRNE 1935-2000

Scientists world-wide are mourning the death on March 23, 2000 of Dr Denis Byrne, Research Director of the National Acoustic Laboratories (NAL) of Australia. Dr Byrne is well-known for his pioneering role from 1972, in developing methods by which hearing aids can be prescribed and adjusted to provide the maximum help to individuals with hearing loss.

Denis Byrne received a degree in Psychology in 1957. He commenced work as a clinician with NAL, then known as the Commonwealth Acoustic Laboratories, in May 1958. During the following 13 years he worked as a clinician and hearing centre manager at clinics in Sydney, Melbourne, Hobart and Adelaide. During this time as a clinician, Dr Byrne became acutely aware of the need for more effective procedures for prescribing and adjusting hearing aids. Although the widespread beliefs of the day were that there was little benefit to be gained by individual prescription of hearing aids, Dr Byrne became convinced that this was not true. He considered that a scientifically derived and validated procedure was likely to offer considerable benefit to hearing-impaired people, and he developed an interest in research methods.

In 1971, Dr Byrne moved to full-time research with NAL in Sydney, where he was placed in charge of hearing aid research for the organisation. He researched and published on several aspects of hearing aids. In 1976, he and William Tonnison published the derivation of the first NAL procedure for prescribing the frequency response of hearing aids. This procedure became widely used throughout the world and was influential in the adoption of the practice of prescription itself. Dr Byrne made the astute observation that even critics of prescriptive formula in fact used them - it was just that those who used 'experience and judgement' as the basis of hearing aid selection and adjustment were using formula that were vague, were not visible to others, and could therefore not be examined or evaluated using scientific method.

A quest to find out what worked and what did not was a hallmark of Dr Byrne. While many clinicians around the world were content to simply use the first NAL procedure, Dr Byrne set out to systematically and critically examine whether it accomplished its stated aims. His research over several years during the early 1980s, which also earned him a Ph.D., showed that the 1976 formula had the correct rationale, but that the formula was not appropriate to meeting this rationale as accurately as was possible. His work led to the revised NAL-R formula published in 1986. Further research by Dr Byrne and colleagues led to an extension of the rule that catered for the special needs of children and adults with severe and profound hearing loss. These rules (NAL-R and NAL-RP) are still widely used today.

In 1989, the National Acoustic Laboratories were re-organised and Dr Byrne became the first Director of Research. Apart from directing the research of others, he continued to engage in research personally. During the last decade his work included experimental investigations into the localization of sound, development of procedures for fitting non-linear hearing aids, and a philosophical re-think of the directions that hearing aid fitting seemed to be taking. Dr Byrne's work was always original; he disliked following the crowd and thought it a waste of valuable research resources. As a result he frequently led the field rather than just responding to it. He was certainly happier when he could challenge beliefs with sound evidence and arguments than when he could only support them. Nonetheless, a guiding principle of his was that research studies must be designed so that something useful is learned no matter which way the findings may fall.

Denis often described some practices in audiology as "missionary-based", rather than science-based, in that proponents of an idea sometimes espoused the idea with a vigour that exceeded the evidence available. Binaural fitting was a case in point. Based on his results in the 1970s, Denis was one of the earliest proponents for binaural amplification, but never considered that it was the better option for everyone, or the better option in all listening situations. The publications of Denis and his colleagues made a clear distinction between the definite benefits of binaural listening versus the situationally-dependent benefits of wearing two hearing aids.

Behind Denis, success at research lay several key attributes. His beginnings as a practising clinician gave him an acute awareness of what was practical, what was real, and what was valuable. He applied these tests to the design and interpretation of each study. In all things, he was careful, systematic, and thorough. In a world where some people are convinced only by evidence and some are convinced only by reasoned argument, Denis held both in high regard. He held to a belief strongly only when he could see that theory and evidence had fully come together. Each of his 120 or so publications was painstakingly worked over and over and over to achieve consistency, structure, and clarity. He thought, long and hard, and often talked to himself while he argued back and forth.

Dr Byrne was a founding member of the Audiological Society of Australia, served as its President, and was the founding editor of the Australian and New Zealand Journal of Audiology from its inception in 1979 (as the Australian Journal of Audiology) to the present. His systematic, theoretically sound, evidence-based approach to hearing aid fitting became the philosophy of the public service-delivery system in Australia. This guidance helped clinician and client immensely. Following the introduction of the first NAL prescription procedure into clinics around Australia, annual battery consumption rose by over 50%, mostly because hearings aids became more useful to their wearers.

Dr Byrne was a man of surprises. Denis was a modest man, not one who wanted to be in the social centre of big parties, and was invariably underestimated by people at their first meeting with him. He actually excelled at everything he did - tennis, wine-making, magic (in fact he earned a living from it prior to becoming a clinician), fly fishing, and of course his research career. In the last few years, Denis started learning the piano. He had a quiet but very incisive humour.

Denis had a great sense of perspective, could see both sides of most arguments, and was impeccably fair and honest. Better than the rest of us, Denis could distinguish the essential and the things of lasting value from the trivial and the ephemeral, professionally as well as personally. He detected humbug instantly, and he was frank but courteous to the purveyors of it. He was quick to listen, slow to speak and his words were always well-considered. People who sat near Denis in the audience at a conference and heard a quiet "mmmmmmm" would know that some untruths or faulty logic were being presented from the stage, and would be the wiser for it.

Denis Byrne is survived by his wife Morag, and sons Nick and Malcolm. Malcolm has been confined to a wheelchair since being injured in a surfing accident some 16 years ago, and has been cared for by Denis and Morag.

Those of us who worked closely with Denis, those who renewed their friendship with him from time to time, those who have read any of his publications, and those millions of hearing-impaired people who have benefited from his work without ever having heard of him, have all been enriched by him. The closer one got to Denis, the more one valued, appreciated, loved, and was in awe of him.

Harvey Dillon

Book Review

Acoustics: Basic Physics, Theory and Methods

P. Filippi, D. Harbault, J.P. Lefebvre and A. Bergassoli

Academic Press 1999, pp.317, hard cover. ISBN 0 12 256190 2. Australian Distributor: DA Information Services, 648 Whitehorse Road, Mitcham, 3132, Australia, tel 03 9210 7777, fax 03 9210 7788. Price A$109.25

They say that you can't judge a book by its cover, and sometimes it is also difficult to judge the contents from the title. In the case of the present volume, the cover is an attractive multicolour image of wavefronts and the title suggests an elementary book with a good deal of description. A brief glance inside, however, reveals that it is a graduate level text that might have been more appropriately titled "Mathematical Methods in Acoustics". This is not a book for the faint-hearted: eigenfunction expansions, Green's functions and integral equations are used freely, and concepts such as distributions and Hilbert and Sobolev spaces also appear, though with appropriate definitions.

The book is the outcome of a six-month graduate level course given by the authors at the University of Aix-Marseille in France and, as pointed out by Phil Doak (Editor-in-Chief of Journal of Sound and Vibration) in the preface, it reflects the French tradition of "rational mechanics" rather than the usual English or American approach to the subject. It will be of little use to a reader seeking help with a practical problem, but should be most valuable to someone wishing to understand the mathematical basis in detail.

After an introductory chapter on sources and wave propagation, successive chapters treat in turn the acoustics of enclosures, diffraction of acoustic waves, outdoor sound propagation (mostly diffraction around obstacles, with a little on layered media), approximation methods, boundary integral equation methods, guided waves (in ducts and in shallow water), and transmission through thin plates. In each area the discussion concentrates on basics, and there is no digression towards applications. The book is nicely written, and the English translation by the authors is clear and precise. The bibliography presents an interesting selection, as the references are mostly either to standard advanced text books or to papers in French journals. The index, only a little over one page in length, is unfortunately, quite inadequate.

Within its domain of discourse the book is, I think, very effective, and there is nothing else quite like it available. It should prove valuable to those interested in the mathematical fundamentals of the subject. I fear, however, that this community may be rather small.

Neville Fletcher

Neville Fletcher is a Visiting Fellow in the Research School of Physical Sciences and Engineering at the Australian National University.

News...

ACOUSTICS 2000

Acoustics 2000, the AAS Annual Conference will commence on Wednesday, 15 November, with registration and a social function. Two parallel papers sessions will run on Thursday 16 November. The Conference Dinner will be held on the Thursday evening. A further papers session and Workshop will be held on the Friday, and there will be trade displays both days

The emphasis of the Conference will be on practical applications of acoustical science and technology and practical solutions to acoustic problems. Typical subjects will include architectural acoustics, environmental noise, occupational noise, engineering noise control, speech and hearing. Topics for the workshop session for the Friday morning 17 November may include active noise control, aircraft noise, the effects of noise on people and otoacoustic emissions.

Critical dates: abstracts 31 July 2000, final papers 8 September 2000, early registration 20 October 2000

As part of the conference a visit has been arranged for the Friday afternoon to the DSTO at Garden Island (about 40 minutes drive south from Perth). This includes the Submarine Escape Training facility and the Naval Base where a visit to a submarine, Anzac ship or Range Assessing Unit (which runs the tracking range) may be possible depending on vessel movements and Defence commitments. There will be limited places available in the visiting group so book this excursion early to avoid disappointment.

Further information: Australian Acoustical Society, WA Div, PO Box 1090, West Perth, WA 6872, Tien Saw (08) 9458-0028 barclays@iinet.net.au or Daniel Lloyd (08) 9321-5200 dlloyd@ermperth.erm.com.au

Speech Science & Technology Conference

The 8th Australian International Conference on Speech Science & Technology (SST-2000) will be held in Canberra, 4-7 December, 2000. The conference covers fundamental spoken language research in the areas of linguistics, phonetics, language acquisition etc.; together with technologically motivated research such as speech and speaker recognition, speech synthesis and speech understanding systems. Since the inception of SST in 1986 the integration and balance between these two aspects of spoken language research has been the strong, recurring and unifying theme. SST-2000 has two keynote speakers: Professor Sadaoki Furui of Tokyo Institute of Technology, Japan; and Professor Mary Beckman of the Ohio State University, USA.

Submissions are invited with abstracts by 21 July 2000. Submissions can be by full paper or by abstract. In both cases, all submissions will be peer-reviewed and accepted papers will be published in the conference proceedings and outstanding papers will be recommended to the editors of the journals Acoustics Australia and Speech Communication for publication. Details: SST-2000, School of Computer Science, ADFA, Canberra ACT 2600, spike@cs.adfa.edu.au,
http://www.cs.adfa.edu.au/sst2000

History of Occupational Health Conference

A one off conference on History of the Prevention of Occupational and Environmental Disease will be held in Brisbane, 4-6 September 2000. This conference is sponsored by the Scientific Committee from the International Commission on Occupational Health (ICOH) with the support of NOHSC and other allied organisations. The conference will feature parallel streams including -history; contemporary issues; general issues with workshops and a special stream on OHS needs in the building and construction industry. Details: 2000 ICOH Conference, fax 07 463 1264, edding@usq.edu.au

WESTPRAC VII

The seventh Western Pacific Regional Acoustics Conference, will be held in Kumamoto Japan from 3 to 5 October, 2000. The city of Kumamoto is about two hours from Tokyo by air and about two hours from Fukuoka International Airport By Express Bus or Train. This conference will continue the tradition of Westprac Conferences with some plenary, distinguished and contributed papers. The presenters for the plenary lectures will be Neville H. Fletcher from Australia and Keniti Kido from Japan. The distinguished lecturers Masakazu Konishi (U.S.A), Hugo Fastl (Germany), Koeng-Mo Sung (Korea) and Seiichi Yamamoto (Japan).

The topics for the contributed papers will include a broad range of topics including general acoustics, noise and vibration, ultrasonics, architectural acoustics, underwater acoustics etc. In addition there will be a technical exhibition and a social program.

Details: WESTPRAC VII, Department of Computer Science, Kumamoto University, 2-39-1 Kurokami Kumamoto, 860-8555, Japan, Fax: +81 96 342 3630 http://cogni.cs.kumamoto-u.ac.jp/others/westprac7/

ICSV7

Planning is proceeding well for the 7th International Congress on Sound and Vibration (ICSV7) to be held July 4 - 7, 2000, in the modern Convention Center of Garmisch-Partenkirchen, the famous mountain resort in the Bavarian Alps, Germany, about one hour south of Munich. The congress is sponsored by the International Institute of Acoustics and Vibration, IIAV. Around 500 abstracts of papers have been submitted for presentation and this should become a most valuable conference. Further information from http://www.bs.dlr.de/icsv7/ and the Congress Secretariat ICSV7, Congress & Seminar Management, Industriestrasse 35, D-82194 Groebenzell, Germany. Fax: +49 8142 54735 info@csm-congress.de

New Zealand Conference

The New Zealand Acoustical Society will be holding its Biennial conference in Wellington 7 - 8 September, 2000. Those seeking more information on the conference or wishing to present a paper contact the Technical Programme Manager at info@noise.co.nz or at PO Box 11-294, Wellington, fax (+64) 4 473 0456. The deadline for submission of abstracts is 2nd June.

INTER-NOISE 2000

Planning is proceeding well for the 29th International Congress on Noise Control Engineering, Internoise 2000, to be held in Nice on the French Riviere from August 28-30, 2000. The theme of will be closely related to transport and community noise but all subjects in noise and vibration engineering will be discussed and details can be seen on the web pages. A technical exhibition will be held during the conference and there will be a full social program. Details: Congress Secretariat SFA, 23 avenue Brunetière, 75017 Paris, France;
Fax: +33 1 4788 9060;
http://internoise2000.loa.espci.fr/

NOVEM

Noise & Vibration: Pre-design and characterisation using energy methods. NOVEM is a follow-up of 4 international congresses on acoustic intensity. It will cover energy methods which show industrial potential and applicability. The aim is to expose the current level and explore the future evolution of these methods when used for either early design or characterisation of noise and vibration. It will be held from 31 August - 2 September 2000, in Lyon, France. Details: Goran Pavic, novem@lva.insa-lyon.fr fax: +33 4 7243 8712 http://lva.insa-lyon.fr/novem2000/

STANDARDS AUSTRALIA

Standards Australia Committee AV/3, Acoustics, Human Effects, recently initiated a new project to revise the physical test requirements for hearing protectors specified in AS/NZS 1270:1999 *Acoustics—Hearing protectors*. In Europe, the EN 352 Standards define physical and acoustic test requirements for hearing protectors. Revised versions of these Standards are scheduled for publication in early 2001, and will incorporate extensive physical tests for a range of hearing protector types. In contrast, in the United States hearing protectors are viewed as relatively low cost safety products with a life expectancy of a year or so. The reduction in product variability achieved through physical testing is seen as relatively unimportant compared to other variables in the system. Consequently ANSI Standards do not specify any physical test requirements for hearing protectors. After careful consideration of the European and U.S. approaches, and detailed review of the proposed new European Standards, Committee AV/3 decided to adopt a compromise approach to physical testing similar to that embodied in the current edition of AS/NZS 1270. Hearing protectors will be required to undergo a limited number of physical tests, which will be selected on the basis of their effectiveness in assessing product performance. In line with the new European Standards, the revised AS/NZS 1270 will apply to active/specialist devices operating in a passive mode, as well as to conventional hearing protectors. It is anticipated that a draft of the revised AS/NZS 1270 will be available for public comment in late 2000.

Committee AV/4, Acoustics, Architectural, is continuing its review and revision of the Standards in its portfolio, with reference to international Standards as appropriate. AS/NZS 2499:2000 *Acoustics—Measurements of sound insulation in buildings and of building elements-Laboratory measurement of room-to-room airborne sound insulation of a suspended ceiling with a plenum above it* is scheduled for publication within the next few weeks. This Standard has been adopted with national modifications from ISO 140-9:1985. Other Standards in the ISO 140 series are being considered in the course of revising AS 1191-1985 *Acoustics—Method for laboratory measurement of airborne sound transmission loss of building partitions* and AS 2253-1979 *Methods for field measurement of the reduction of airborne sound transmission in buildings*. Australia is represented on the ISO working group, *Sound insulation of buildings*, which is responsible for development and revision of the ISO 140 Standards. Committee AV/4 also plans to adopt ISO 11654:1997 *Acoustics—Sound absorbers for use in buildings—Rating of sound absorption*. This Standard provides a method whereby the frequency-dependent values of the sound absorption coefficient can be converted into a single number. This single number rating is useful in formulating requirements and describing acoustical properties of sound-absorbing products for use in routine applications in normal offices, classrooms, hospitals and the like.

Committee EV/10, Acoustics, Community Noise, has initiated a project to revise AS 2377—1980 *Methods for the measurement of airborne sound from railbound vehicles*. The main objectives of the revision are to: (1) update the vehicle tests to reflect advances in technology, e.g. higher speeds, different forms of braking; (2) update requirements for measuring equipment; and (3) extend the scope of the Standard to include the determination of descriptors other than the A-weighted sound pressure level. In particular, the revised Standard will define procedures for immissions tests that provide data for the proposed new Standard, *Acoustics—Railway noise intrusion-Building siting and construction*.

Inquiries about the above activities: Jill Wilson, Projects Manager, Standards Australia, jill.wilson@standards.com.au. tel (02) 9746 4821, fax (02) 9746 4766,

• • • •

Standards Australia **AS 4390** 'Records Management' is currently under review. It is keen to put compliance into the Standard so that it will become a best practice benchmark. It is particularly relevant now with the imminent GST requiring careful attention to records.

The **AS 1127** Series of Standards on Sound system equipment have been withdrawn. This set of 10 standards covered subjects from microphones to matching values for interconnecting sound systems. The background is that Committee TE/8 has been disbanded and its standards withdrawn because the practical need for Australian Standards in the field has receded as technology and market needs have changed since the committee was established. The International Electrotechnical Commission's series of standards 60268, Sound system equipment covers the same area. Information on the 60268 series can be found at the IEC's website http://www.iec.ch/cgi

Four recently updated standards in the **AS 1807** Series on cleanrooms, workstations, safety cabinets and pharmaceutical isolators relate to acoustic and vibration measurements: AS 1807.16-2000 Determination of sound level in cleanrooms, AS 1807.17-2000 Determination of vibration in cleanrooms, AS 1807.18-2000 Determination of vibration in workstations, safety cabinets and pharmaceutical isolators, and AS 1807.20-2000 Determination of sound level in workstations, safety cabinets and pharmaceutical isolators

Australian representatives have taken an active role in the work of ISO/TC 181 developing the new ISO Standard on children's toys which will become ISO 8124—1:2000 **Safety of toys** - Part 1 Safety aspects of mechanical and physical properties. The intention is that the Standard will give children worldwide the same level of protection from dangerous, even potentially lethal, toys. Noisy toys such as rattles, squeeze toys and musical instruments have long been popular gifts for children, although less popular with their carers. The rise in popularity of toys which are held close to the ear have given rise to questions about the most appropriate means of measuring the noise emitted.

OH&S Publication

Consensus Books, Standards Australia's specialist publishing house has recently published the *Australian Encyclopedia of Occupational Health and Safety*. This substantial volume of around 800 pages looks set to become the definitive reference book on OH&S n Australia. It should assist business to catalyse action for effective OH&S programs which will provide many secondary benefits to individuals, business and the society at large. The Encyclopedia is available in hard copy or CD from Standards Australia On Line service centre on 1300 65 4646.

American Standards

The latest version of the American National Standards on Acoustics is now available. This and all the latest information on national and international standards distributed by the Acoustical Society of America can be found on the ASA home page http://asa.aip.org

I-INCE Technical Committees

Four technical initiatives were put forward for consideration at the last I-INCE General Assembly in Ft Lauderdale last December. All four were adopted and Australia agreed to participate in the technical committees.

Outdoor Recreational Activities
Noise Labels For Products
Noise Policies And Regulations
Noise Control For Schoolrooms

Any members of the AAS who would like to be involved in this important work are invited to provide a brief description of their experience in the particular field to the AAS General Secretary watkinsd@melbpc.org.au

NSW Industrial Noise Policy

On 16 December 1999 the Environment Minister Bob Debus launched a new policy on noise that will substantially improve the way noise is handled in NSW. Mr Debus said the NSW Industrial Noise Policy would help protect the community by identifying ways of combating noise from mines, quarries and other large industrial sites. "Past policies focussed on how to measure noise and said little about how to manage it,"

The NSW Industrial Noise Policy allows individual solutions and agreements to be negotiated between communities and industry. "These agreements could include less noise at particular times, the use of quieter equipment, the use of noise barriers, trading higher noise levels for other benefits and/ or noise proofing of residences in severe cases. ... It also gives industry clear goals to be met as well as a range of noise reduction strategies which can be used to achieve these goals." Mr Debus said the NSW Industrial Noise Policy has a more scientific basis than earlier policies and is more in keeping with World Health Organisation and European Community standards.

The NSW Industrial Noise Policy will be phased in for a six month period and the EPA will be providing a phone information line and training. The Policy can be obtained by contacting the EPA's Pollution Line on 131 555 or accessing the EPA website at http://www.epa.nsw.gov.au/noise

Queensland's Nuisance Laws

Queensland's Environmental Protection Agency (EPA) has introduced nuisance laws to help make Queensland a more livable place. The purpose is to strike a balance between protecting our quality of life and the reasonable pursuit of activities that have the potential to annoy others. These laws are complaint driven so when a complaint is made, it will be investigated by an administering authority (usually EPA or local government) and appropriate action will follow.

The new laws specify conditions, hours of operation and noise levels for a number of activities including:

* building works and construction sites;
* regulated devices (including power tools and lawn mowers);
* barking dogs and noise from other domestic animals;
* indoor venues and open air events;
* air conditioners;
* amplified devices (including public address systems and telephone bells);
* swimming pool pumps and spas; and
* powerboats and jet skis.

The laws provide specific conditions, for example, in the case of barking dogs or other domestic animal noise, the following requirements apply:

* 7 am - 10 pm - no more than six minutes of noise in an hour; and
* 10 pm - 7 am - no more than three minutes of noise in any 30 minute period.

On 16 February, AAS, Queensland Division, invited the Manager of the Local Government Unit of the EPA to present Queensland's new nuisance laws at one of the technical meetings. This meeting was a success as it was well attended by members of the Queensland Division including other interested persons such as local government officers.

Namiko Ranasinghe

Noise & Vibration Workshop

The SA Division of the AAS organised a successful workshop on Noise & Vibration on 20 July 1999 at the University of Adelaide (Mechanical Engineering). This was attended by over 40 people including OH&S reps, EPA reps, council reps, planners, plant managers, plant/maintenance engineers. The workshop covered the principles and practice of occupational and environmental noise assessment, control and planning as well as machine condition monitoring. It included sessions on Environmental Noise, Environmental Planning Issues, Occupational Noise, Machine Condition Monitoring and "hands-on" Instrumentation/Measurement and Software demonstrations. The presenters included experienced acoustic consultants, lecturers/researchers and service engineers.

The SA Div is organising a similar Workshop on 19 July, followed by a more detailed course covering specific issues/cases in a range of acoustics areas later in the year.

Occupational Noise Meeting

The first technical meeting of the Victorian Division for 2000 was held on Feb 16 where, Janice Milhinch and Ross Dineen spoke on the subject of *Workers' decisions about dangerous noise.*

The aim of their research was to measure the levels of noise to which a representative group of carpenters, crane drivers, electricians, plasterers, plumbers, scaffolders and steel fixers were exposed while working on building sites, and to relate the measured levels to these workers' beliefs about the noise to which they are exposed, their attitudes towards the need to hear, their views on hearing protection, and their hearing conservation behaviour.

Measurements (including those from 30 representative workers equipped with noise dosemeters) showed that all workers were exposed to at least some excessive and dangerous noise, typical levels being from 97 to 137 dB. Most workers accepted the noise as inevitable, it came with the job! They agreed the noise was emotionally disturbing; up to 30 minutes appeared tolerable, longer exposure was intolerable. Though some used hearing protection, others didn't because they believed it made them less able to hear sounds warning of approaching danger. And in many workplaces noise conservation protocols are not applied.

Education programs were thus found necessary. Because over 25% of workers were illiterate, visual aids were needed. This education included the training of workers to be able to hear speech communication while wearing ear plugs or muffs, the personal testimony of those who wanted to protect their hearing, and the training of workers to be able to recognise the signs and symptoms of noise-induced hearing loss. Employers also, had to be persuaded that this education was necessary for the continuing well-being of their workers. The concluding advice was that professionals have an important role in setting a good example (eg, of wearing hearing protection in noisy locations). In all, a most interesting evening, for which the speakers were heartily thanked.

Louis Fouvey

Antique Equipment

A highlight of the 1999 AAS Conference was the display of old acoustic equipment. Some of the equipment of historic value was donated to the Society and is now being stored by the Archivist. It is possible that members may have equipment of historical interest that they no longer want. It was agreed at the last Council meeting that the Society should attempt to preserve such equipment. Please contact the Archivist if you have any old acoustic equipment worth preserving:-

David Watkins, PO Box 4004, East Burwood Vic. 3151 phone (03) 9887 9400 or watkinsd@melbpc.org.au.

AAS Membership Stamp

It has been proposed to Council that a rubber stamp should be made available to members. The stamp would show the members name, membership number, grade of member, and the statement "Member of the Australian Acoustical Society" beside the Society logo. The stamp would be sold to members at cost and could be used on reports and correspondence signed by the member to indicate that he is member of the Society.

Council would like to receive comments to determine if members are in favour of the proposal. Please forward your comments to:-

David Watkins, General Secretary,
Australian Acoustical Society,
PO Box 4004, East Burwood Vic. 3151,
or watkinsd@melbpc.org.au

Anglo-Australian Fellowships

Anglo-Australian Post Doctoral Fellowship scheme funds placements for young post-docs to carry out research in the U.K. The National Physical Laboratory would be interested to support applications from Post Docs in the acoustics area. These are offered annually with closing date in November. More information the Royal Academy at www.raeng.org.uk or from hilary.mcneill@npl.co.uk

OHS Solutions

The National Occupational Health and Safety Commission is attempting to make available 2000 practical solutions of the SHARE format by the end of the year 2000 on their web-site. An electronic proforma can be obtained to for any who are willing to submit and share their practical solutions, start at http://www.nohsc.gov.au/

Acoustic Demonstrator

The CSR Commercial Design Centre in Pyrmont, Sydney has set up an Acoustic Demonstrator which provides a unique opportunity for architects, specifiers and clients to experience the actual acoustic performance of rooms with a variety of sound transmission loss values. Four individually sealed rooms have been set up and the listener can experience being on either side of walls with noise reduction indices of 35, 45, 50 and 55. The types of sound sources available via the loudspeaker in each room include rock music, traffic, a dinner party, garbage truck, kitchen and bathroom noise. This highlights the importance of considering the type of noise and not just the use of the single number rating.

This acoustic demonstrator is part of the designLINK service provided by CSR which provides qualified design assistance at nil cost. Also the full range of CSR products can be accessed at www.csr.com.au. Further information and bookings for the acoustic demonstrator Michael Ryan on 02 9552 8251.

Merit Award

Council of the AAS have awarded **Stephen Samuels** a Merit Award in recognition of his outstanding contribution to the committees of the Society. He has served on Divisional Committees for 20 years and been a member of Council for 15 years. In addition he has been President of the Society and has been involved in the organisation of a number of annual conferences. Stephen has recently taken a well deserved rest from the committees of the Society.

Acoustics Competition

I.N.C. offers an exciting challenge within the acoustics industry with the creation of the DECI-TEX® Innovation In Acoustics Award. Imagine sunning yourself on Broome's famous Cable Beach. Visiting pearl farms, or exploring the mighty Kimberley region of North Western Australia. This is the major prize. 2nd PRIZE is 5 nights accommodation with Hilton Hotels in any Australian Capital City 3rd PRIZE, 1 doz. Bottles of Wynns Coonawarra Shiraz. All entries receive 1 Aerotex® golf top per company.

Entries in this competition must design, develop, or use DECI-TEX® Acoustic textiles in an innovative application. Not every idea is totally original. Even if your idea has been mentioned in applications for the product, there is still scope for originality. To enter, simply register your interest by contacting I.N.C. requesting a DECI-TEX® information pack on CD. Entry is open to individuals and companies that practice in the field of Acoustics. It is envisaged that entries will be received from consultants and contractors in acoustics, architects, engineers and possibly even students.

Entries will be considered by a panel of four judges consisting of two I.N.C. personnel, one consultant, and one member of the Committee of the Australian Acoustical Society. Judges may enter the competition, but cannot assess their own entry. I.N.C. employees are not eligible for entry. Closing date for entries is 30 October 2000. The winner will be announced at the AAS Conference in 2000.

For more information contact INC, 22 Cleeland Road, Oakleigh South Vic. 3167 Australia, Tel (03) 9543 2800, Fax: (03) 9543 8108

Air Check Pty Ltd are now the agents for Cirrus sound and vibration measuring equipment. The contact is Con Williams of Air Check in VIC, Tel (03) 03-952-84568, Fax (03) 03-953-24306, conwilliams@aircheck.com.au

Dr Rob Bullen has recently joined Sydney consultants Wilkinson Murray Pty Ltd as a Director. Rob is best known for his work in aircraft noise, and has developed modelling techniques for road and rail noise calculation. Rob says he is enjoying the challenges of the new position.

New Members

NSW	
Member	Mr Jeffrey Lee, Mr Gerald Stewart
QLD	
Subscriber	Mr John Cristaudo
Graduate	Miss Namiko Ranasinghe
SA	
Subscriber	Mr Martin Blunt
VIC	
Member	Mr Mark Debevc, Mr Peter Pirozek

FASTS

FASTS, Australia's peak council for scientists and technologists called for a proper analysis of Government figures to assess the extent of the "brain drain" of Australian scientists, when it released its 'Ten Top Issues' for 2000. "The 'Ten Top Issues' for 2000 boil down to three key factors:

- greater Government investment in public good science
- increased investment by industry in research to generate the products of tomorrow
- a shared determination by Australians to seek a future based on satisfying, well-paid jobs in high-technology industries

The **Innovation Summit** has come and gone, and worked better than most people expected. FASTS President reports that there was a positive mood during the three days, despite the absence of any hard announcements. It was a big plus to have the attention of Australia's politicians focussed on research and innovation, if only for a week. The Summit was addressed by Cabinet Ministers Minchin, Alston and Kemp, as well the Prime Minister. The Prime Minister's statement has been widely interpreted as a strong hint of good things in the air. Certainly he succeeded in raising expectations across the sector. There was broad agreement on what has to happen before Australia can take full advantage of our high-quality science. If it is to be judged a success, the Summit must lead to:

- increased national investment in research;
- change the reward structure in research organisations, to encourage innovative behaviour;
- a new culture which recognises R&D as the driver of innovative industries;
- mentoring and incubators to assist commercially-minded scientists and technologists;
- structures to encourage movement between industry and research organisations;
- more realistic and sophisticated handling of IP issues.

More information on FASTS documents can be obtained from www.usyd.edu.au/fasts/

COURSES

A variety of courses on sound and vibration measurement, occupational noise and environmental noise are held throughout the year and around Australia by Bruel & Kjaer. For details: Bruel & Kjaer, Tel (02) 9450 2066 Fax (02) 9450 2379 bk@spectris.com.au.

Letter...

Internship in Australia

I am studying "Building-Physics" in Stuttgart, Germany in the 3rd Semester at the "Fachhochschule Stuttgart, Hochschule für Technik". My studies include themes like acoustics, thermal engineering, humidity in buildings and solar technology. The 5th and 6th semester consist of work experience. I will complete the first of these in Germany and would like to complete the second in Australia. This internship is for 100 working days and would take place between February and June 2001. I would like to gain experience in the field of acoustics and would be willing to undertake any work in this area. I look forward to the opportunity to visit Australia and to work in acoustics.

Christian Handwerk
Richard-Wagner-Str. 46, 70184 Stuttgart, GERMANY Tel (++49)711/2349389,
hachp110@pandora.rz.fht-stuttgart.de

New Products

RION

Real Time Analysers

The Rion SA-29 (single channel) and SA-30 (two channel) one third octave band real time analysers are now available in Australia. The features of these new analysers include -

- Simultaneous analysis of 1/1 octave and 1/3 octave bands
- Versatile trigger functions to start measurement and analysis automatically.
- Memory card (PCMCIA) allows storage of large amounts of data and easy data exchange with a computer.
- Built in printer.
- Serial interface and multi-channel capability for control of several SA-29/SA-30 units from a single computer.
- Large colour display with touch-panel function makes operation.

These new analysers are c-tick approved and can be used for noise or vibration measurements. The supplied infrared remote control allows the user to change measurement parameters and to control operation from a convenient location.

Further Information from Acoustic Research Laboratories Tel 02 9484 0800, Fax 02 9484 0884, your local branch of ARL or www.hutch.com.au/~acoustic

Ono Sokki

Sound Level Meters

The new LA-1200 series of sound level meter from Ono Sokki is designed to provide a user-friendly solution for accurate and efficient measurements in the field. The series offers application specific features from direct measurements to environmental logging with RS-232C output.

The LA-1210 and LA12-1220 are for general stationary sound level measurements

The LA-1240 is an integrating sound level meter with memory which is ideal for non stationary industrial and work environment measurements

The LA-1250 is an integrating sound level meter for environmental measurements and is ideal for road traffic noise.

Further Information from Vipac Engineers and Scientists, Tel 03 9647 9700, Fax 03 9646 3427, sales@vipac.com.au or www.vipac.com.au

Diary...

2000

June 5-9, INSTANBUL
Int Conf On Acoustics, Speech & Sig Proc
Details: Tülay Adali, University of Maryland Baltimore County, Department of Computer Science and Electrical Engineering, 1000 Hilltop Circle, Baltimore, MD 21250 USA; Fax: +1 410 455 3969; http://icassp2000.sdsu.edu/

June 6-9, ST.PETERSBURG
5th Int Symp Transport Noise & Vibration
Details: EEAA, Moskovskoe Shosse 44, 196158 St.Petersburg, Russia; Fax: +7 812 127 9323; noise@mail.rcom.ru

July 4-7, GERMANY
7th Int. Cong. on Sound and Vibration
Details: ICSV7, Congress & Seminar Management, Industriestrasse 35, D-82194 Groebenzell, Germany. Fax: +49 8142 54735 info@csm-congress.de, http://www.iiav.org

July 10 - 13, LYON
5th European Conf on Underwater Acoustics.
Details: LASSSO, 43 Bd. du 11 novembre 1918, Bat. 308, BP 2077, 69616 Villeurbanne cedex, France, Fax: +33 4 72 44 80 74; www.ecua2000.cpe.fr

August 23 - 25, NANJING
ACSIM 2000, 2nd Asia-Pacific Conf Systems Integrity & Maint.
Details: Anna Maltozos, Dept Mech Eng, Monash Uni, Caulfield East, VIC 3145, Australia. Tel: +61 3 9903 2335 Fax: +61 3 9903 1084; anna.maltezos@eng.monash.edu.au, http://www-mech.eng.monash.edu.au/

August 28-30, NICE
INTER-NOISE 2000
Details: SFA, 23 avenue Brunetière, 75017 Paris, France; Fax: +33 1 4788 9060; http://inter-noise2000.loa.espci.fr/

Aug 31 - Sep 2, LYON
Int Conf Noise & Vib Pre-Design & Charact. Using Energy (NOVEM)
Details:LVA, INSA de Lyon, Bldg. 303, 20 avenue Albert Einstein, 69621 Villeurbanne, France; Fax: +33 4 7243 8712 lva@insa.insa-lyon.fr http://lva.insa-lyon.fr/novem2000/

***September 4-6, BRISBANE**
History and Prevention of Occupational and Environmental Diseases
Details: 2000 ICOH Conference, Fax 07 463 1264, edding@usq.edu.au

September 7-8 WELLINGTON
New Zealand Acoustical Society Biennial Conference
Details: Tech Prog Manager, PO Box 11-294, Wellington, tel (+64) 4 472-5689, fax (+64) 4 473 0456, email info@noise.co.nz

Sep 13-15, LEUVEN
Int Conf Noise & Vib Eng (ISMA 25)
Details: ISMA 25, K.U.Leuven Dept Mech Eng, PMA, Celestijnenlaan 300B, B-3001 Leuven, BELGIUM Fax (+32) 16 32 29 87, lieve.notre@mech.kuleuven.ac.be http://www.mech.kuleuven.ac.be/pma/events

Sept 17 - 21, VILNIUS
1st Int Conf (10th Anniversary).
Details: Acoustical Soc Lithuania, Kriviu 15-2, 2005 Vilnius, Lithuania; Fax: +370 2 223451; daumantas.ciblys@ff.vu.lt

October 3-5 KUMAMOTO WESTPRAC VII
Details: Dept Computer Science, Kumamoto Uni. 2-39-1 Kurokami, Kumamoto, 860-0862.
Tel: +81 96 3423622 Fax: +81 96 3423630 westprac7@cogni.cs.kumamoto-u.ac.jp http://cogni.cs.kumamoto-u.ac.jp/others/westprac7/

October 16-20 BEIJING
6th Int. Conf. on Spoken Language Processing
Details: ICSLP 2000 Secretariat, Institute of Acoustics, PO Box 2712, 17 Zhong Guan Cun Rd, Beijing 100 080, China, Fax: +86 10 6256 9079, mchu@plum.ioa.ac.cn

*** November 15-17, PERTH**
Acoustics2000
Putting the Science and Technology to Work.
Details: AAS–WA, P.O. Box 1090,West Perth, WA 6872, barclays@iinet.net.au

December 4-8, NEWPORT BEACH
Meeting of the ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, web: asa.aip.org

***December 4-7, CANBERRA**
8th Aust Int Conf Speech Science & Tech, SST-2000
Details: SST-2000, School of Computer Science, ADFA, Canberra ACT 2600, spike@cs.adfa.edu.au, http://www.cs.adfa.edu.au/sst2000

2001

June 4-8, CHICAGO
141th Meeting of the ASA
Details: ASA, 500 Sunnyside Blvd, Woodbury, NY 11797-2999, USA, Fax: +1 516 576 2377, Web: asa.aip.org

July 2-6, HONG KONG.
7th Int. Cong. on Sound and Vibration
Details: Dr K M Li, Dept Mechanical Engineering, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, Fax: + 852 2365 4703, http://www.iiav.org/, mmicsv8@polyu.edu.hk

Aug28 - 30, THE HAGUE
INTER-NOISE 2001
Details: secretary@internoise2001.tudelft.nl; Web: internoise2001.tudelft.nl

September 2-7, ROME
17th Int. Cong. on Acoustics
Details: A. Alippi, 17th ICA Secretariat, Dipartimento di Energetica, Universitá di Roma "La Sapienza", Via A. Scarpa 14, 00161 Roma, Italy, Fax: +39 6 4424 0183, www.uniroma1.it/energ/ica/html

September 10-13 , PERUGIA
ISMA 2001 ,
CIARM & Catgut Acoust Soc
Details: c/o "Perugia Classico" - Comune di Perugia, Via Eburnea,9, I-06100 Perugia, Italy, Fax: +39 75 577 2255, perusia@classico.it

*** November 21-23, CANBERRA**
Acoustics 2001
AAS Annual Conference
Details: Acoustics 2001, Aust Defence Force Academy, Canberra, ACT 2600, avunit@adfa.edu.au

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) 9887 9400
email: watkinsd@melbpc.org.au
http://www.users.bigpond.com/Acoustics

SOCIETY SUBSCRIPTION RATES

For 2000/2001 Financial Year:

Fellow and Member	$94
Associate and Subscriber	$75
Retired	$31
Student	$21

Plus applicable 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: Mr D Eager
Tel (02) 9514 2687
Fax (02) 9514 2665
david.eager@uts.edu.au

AAS - Queensland Division
PO Box 760
Spring Hill Qld 4004
Sec: Michael Caley
Tel: (07) 3367 3131
Fax: (07) 3217 0660
ronrumble@uq.net.au

AAS - SA Division
C/–Department of Mech Eng
University of Adelaide
SOUTH AUSTRALIA 5005
Sec: Robert Koehler
tel: (08) 8303 3556
Fax: (08) 8303 4367
rkoehler@mecheng.
adelaide.edu.au

AAS - Victoria Division
PO Box 417 Collins St. West PO
MELBOURNE 8007
Sec: A/Prof C. Don
Tel (03) 9905 3695
Fax (03) 9905 3637
charles.don@sci.monash.edu.au

AAS–W A 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 Centre, 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$ 52	A$ 64
2 year	A$ 88	A$112
3 year	A$125	A$161

plus applicable GST
Overseas subscriptions go by airmail
Discounted for new subscriptions
20% Discount for extra copies
Agents discount 15% of surface (Aust) rate

ADVERTISING RATES

B&W	Non-members	Sus Mem
1/1 Page	$550	$500
1/2 Page	360	325
1/3 Page	275	250
1/4 Page	235	220

Spot colour: $100 per colour
Prepared insert: $250 (additional postage may apply)
Column rate: $18 per cm (1/3 p 5.5cm width)
plus applicable GST

Discounted rates for 3 consecutive ads in advance
Special rates available for 4-colour printing

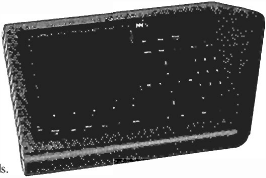
All enquiries to: Mrs Leigh Wallbank
Tel (02) 9528 4362 Fax (02) 9523 9637
wallbank@zipworld.com.au

ACOUSTICS AUSTRALIA ADVERTISER INDEX - VOL 28 No 1

DATA ACQUISITION SYSTEMS

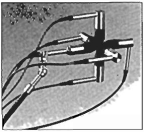
NORSONICS

Environmental Sound Analyser Nor-121



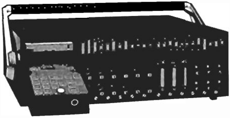
SPL All these values measured in parallel
L_{max} with all time constants (F, S and I) and
L_{min} with A-, C- and Flat-weighting.
L_{eq}
L_E Except for L_{peak} these functions may also
L_{peak} be measured in octave and 1/3 octave bands.

Measurement results and raw data may be stored on HD or standard PC card.
The instrument may be operated in a stand-alone mode or be integrated into a comprehensive area noise monitoring system controlled over its computer interface.



G.R.A.S. *Sound and Vibration*

- Condenser microphones
- Outdoor microphone systems
- Intensity probes and calibrators
- Probe and Array Microphones
- New series of Hydrophones and associated preamplifiers



Racal-Heim DATaRec A-series recorders

Multi -channel high speed data acquisition, using DAT, DLT, AIT, S-VHS (and reel to reel) tapes are available with following features:–

- high bandwidth, eg. DC-20kHz per channel for up 32 channels, more than 2 hours recording.
- high frequency channels up to 500kHz for under water acoustics.
- direct data filetransfer to PC via SCSI for post acquisition analysis.
- direct connection to vibration transducers, microphone preamplifiers or strain gauges.
- integral signal conditioning.
- separate recording of voice, rpm and speed.
- remote set up facility via PC.

... Real-Time Analysis during acquisition is provided by "front end operation" and protects against acquisition failure requiring re-runs.

ETMC Technologies

619 Darling Street ROZELLE NSW 2039
Tel: (02) 9555 1225 Fax: (02) 9810 4022 Web: www.ozpages.com/etmc