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Vol. 35 No. 1 April 2007

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Mrs Leigh Wallbank
P O Box 579
CRONULLA NSW 2230
Tel (02) 9528 4362
Fax (02) 9589 0547
wallbank@zipworld.com.au

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The editors, Acoustics Australia
School of Physics
University of New South Wales
Sydney 2052 Australia
61-2-93854954 (tel)
61-2-93856060 (fax)
aaeds@phys.unsw.edu.au
www.acoustics.asn.au
AcousticsAustralia@acoustics.asn.au
www.acoustics.asn.au

Australian Acoustical Society Enquiries see page 36

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

Printed by
Cliff Lewis Cronulla Printing
91-93 Parraweena Rd,
CARINGBAH NSW 2229
Tel (02) 9525 6588
Fax (02) 9524 8712
email: matt@clp.com.au
ISSN 0814-6039

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Cover illustration: Heidi Hereth. Photo: Densil Cabrera *(see page 8).*


ATAC

Message from the President

The media present evidence that the economy is in a boom time. This is not ‘news’ to the building industry, where my contacts all tell me of heavy workloads and work being turned away. Architects have jobs on the books that won’t start construction for a couple of years. I even hear of escalation figures for the escalation numbers in the contracts. This raises an important issue for the profession. How can we effectively cope whilst providing consistently high levels of professional attention to each job?

Increasing staff levels would be possible with a glut of skilled people to choose from. Unfortunately the number of trained people in our industry is relatively static so high workloads are likely to continue. The cost to companies to train people is very high. To take a graduate and provide ‘on the job training’ takes resources and time. In an organisation that is already under extreme workloads, this increases pressure on existing staff, and represents a major cost over a number of years until that new recruit has the required skills to take up some of the load.

A new initiative is the distance education course offered by the University of New South Wales, started in March 2007. Initially the course was advertised through the AAAC, resulting in 31 participants starting the course, though it is available to anyone in Australia or New Zealand. This is a major initiative in Australia as for the first time there will be a course available to assist in training of new recruits. The program has been designed to allow registrants to start at anytime so there is no need to wait for the start of the next semester/year to join the program. The Society’s web site (http://www.acoustics.asn.au/general/index.shtml) has more details.

Another strategy is to devise means of ‘Working smarter not harder’. Most people would consider research and development the responsibility of management to allocate funds and staffing. Whilst this is true for large projects, there is scope for all members of a firm to look critically at the tasks they are performing and ask themselves – is there a smarter way to achieve the same objective next time?

One analysis method is to break down projects into discrete sections, then to search for areas where similar sub tasks occur in other projects. Once suitable sub tasks are identified, you can try to develop a method which enables that task to be conducted faster yet with at least the same or higher level of professional expertise. In some cases, you might need more training i.e. in using spreadsheets to develop your own functions; creating templates of text/checklists for the reports; requesting custom software to be developed to interface with equipment, etc. Management may not be in the position to recognise many of these tasks, though most managers would quickly recognise the benefits.

Timing is important – don’t leave this until after the boom. The quicker you can make changes to your workflow, the quicker the benefits come in reducing the stress levels while improving the quality of the work. Many tasks may not be able to be dealt with in the company – especially when the solution requires additional training, external resources etc.

Terrance Mc Minn

From the Editors

The second year teaching lab at UNSW has recently been renovated and a demonstrator showed me an elderly, discrete-element transmission line discovered in the clean up: a long line of capacitors and ferrite-cored inductors. "Watch this pulse propagation", he said, connecting the channels of a storage oscilloscope across various pairs of points along the line. What intrigued his students was that, at the end of the line, the square pulse suddenly doubled in amplitude. "We know the extra voltage comes from the reflection, but where does the extra energy come from?" they asked.

Among the questions that most of us enjoy are those that we've already answered, in a different context. Our lab often investigates woodwind instruments. These are acoustical waveguides, which we occasionally analyse as transmission lines with discrete or continuously distributed components. So to my eyes, his transmission line looked a bit like a strange woodwind instrument – its bore closed at the far end, because his transmission line was open circuit. An answer that satisfied him was simple: at most points along the transmission line, there are two circuits on either side of any point. They are in parallel, so, for short time scales, the impedance at that point is half the impedance at the open-circuit end.

Co-editor John Smith used to work on transmission of voltage pulses along long, thin living cells – a rich area in biophysics. He points out that some of the acoustical software that he writes is easy because he’s done the problem before.

Quantum computing expert and sometime acoustician, Lloyd Hollenberg, was the subject of a similar story told by a colleague from the Centre for Quantum Computing Technology. A group had been volubly discussing approaches to analysing the interactions between devices at either end of a nanowire. Lloyd, it was reported, had sat quietly making notes before announcing the solution. “How did you get there so fast?” he was asked. “I’ve been working on a similar problem” he said “in which the lips and the vocal folds of a didjeridu player interact from either end of the vocal tract”.

Whether in quantum mechanics, electromagnetism or acoustics, that which we call a wave, by any other name, would smell as sweet – or at least obey the same equation.

Joe Wolfe

ACOUSTICS OF SIX HISTORIC CINEMAS IN NEW SOUTH WALES, AUSTRALIA

Kamani Koralage and Densil Cabrera

Faculty of Architecture, Design and Planning, The University of Sydney. NSW 2006

d.cabrera@arch.usyd.edu.au

Historic cinemas, some of which were built before sound film, are often heritage listed, placing significant limitations on architectural modifications. Such cinemas may face challenges in complying with modern audio and acoustical standards and recommendations. This paper outlines the acoustical conditions in selected historic cinemas of New South Wales, Australia. Background noise, reverberation time, speech intelligibility and impulse response measurements were made, and the room and sound system configurations were noted. Deviations from modern acoustical standards were observed. Room size, interior finishes, and the presence of galleries sometimes pose challenges for acoustical performance.

1 INTRODUCTION

Thorne [1] has comprehensively documented Australia's historic cinemas in terms of their heritage features, with a listing of some 2040 venues in New South Wales that have screened films regularly, at least for a time. This paper considers the acoustical state of six of these historic cinemas, all of which are heritage listed for their historical, social and/or aesthetic values. Some are exclusively or mainly used as cinemas, while others have multiple uses. Of the six cinemas in this paper, all were built before the advent of television, and most of them are in the Art Deco style, popular in 1930s architecture, in an era when going to the movies was 'an occasion to dress for' [1]. The cinemas are Dungog community hall and cinema (which opened as a cinema in 1930), Grafton's Saraton Theatre (opened as a cinema in 1926), Mudgee's Regent Theatre (opened as a live performance theatre in 1925), Randwick's Ritz Theatre (opened as a cinema in 1937), Scone's Civic Theatre (opened as a cinema in 1938) and Sydney's State Theatre (opened as a cinema in 1929). The interior forms of these are illustrated in Fig. 1.

The development from the original 'talkies' through stereophonic to multi-channel surround sound formats has seen increasingly stringent acoustical requirements, which may pose considerable challenges for theatres constructed prior to film sound. One source of acoustical specifications for modern cinemas is the Society of Motion Picture and Television Engineer's standards [2, 3], which are developed further in Dolby's published guidelines [4]. We use these guidelines in comparison with our measurements made in the six cinemas. The main assessments are concerned with background noise levels and spectra, reverberation time, and speech intelligibility. The acoustical effects of some architectural features are also considered in this paper. This brief paper presents just a summary of our results.

2 APPROACH

Impulse response measurements were obtained in each auditorium. For this an omnidirectional loudspeaker was positioned just in front of the screen, in the centre (the cinema loudspeakers were not used). An omnidirectional measurement microphone was positioned at a height of 1.2 m, and placed at numerous seat positions. The selected

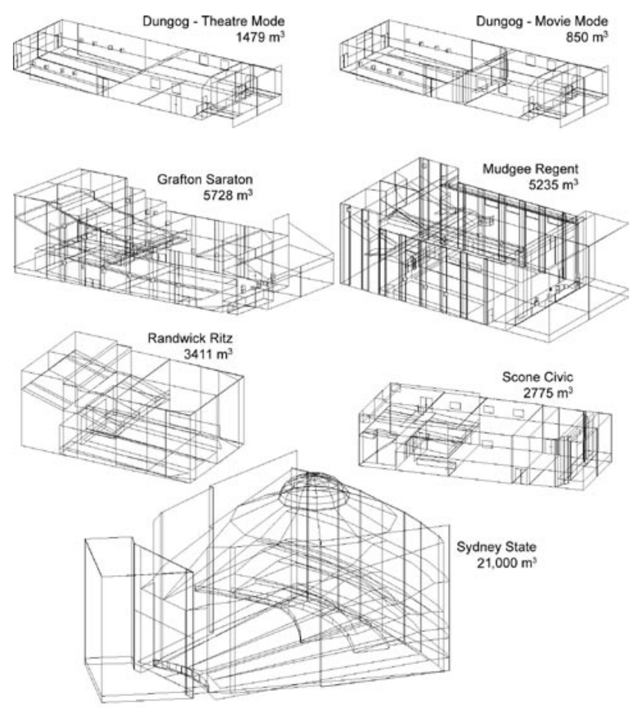

Fig. 1. Models of the cinema interiors.

seat positions were at multiples of 5 m from the loudspeaker, along the centre line of the theatre, as well as in at least one parallel line 5 m to the side. In the State Theatre, measurement positions were 0 m, 5 m, 10 m and 15 m from the centre line (yielding 33 receiver positions). Impulse response measurements were made using the maximum length sequence (MLS) technique [5]. Reverberation times and echo patterns were derived from these impulse responses. Objective speech transmission index (STI) measurements were also taken at most of the receiver positions used for the abovementioned impulse responses, with the MLS signal filtered to match the long term average speech spectrum [6]. STI yields a value between 0 and 1 representing speech intelligibility, determined from modulation transfer functions from source to receiver (0.45-0.6 is classed as 'fair', 0.6-0.75 is classed as 'good', and 0.75-1.0 is classed as 'excellent', although 'excellent' results are uncommon in room acoustical measurements) [7]. Background noise measurements for ambient noise levels were carried out integrating over 60 second periods.

3 MEASUREMENTS

3.1 BACKGROUND NOISE

The steady state background noise level in cinemas should be below NC 25, with NC 30 being the worst case acceptable in modern recommendations [2]. The background noise due to intermittent events should not exceed NC 35. With four of the cinemas in quiet country towns, in most cases the steady state noise floor was low enough to satisfy the recommendations, at least when the heating, ventilation and/or air conditioning (HVAC) systems were not operating. In some cases the building relied on natural ventilation, and ceiling-mounted fans and/or wall-mounted heaters could be used.

The HVAC systems produced considerable noise at two of the cinemas (Dungog and Scone) where the noise floor was otherwise acceptable (NC 22 and NC 23 respectively). In Scone, the cause was an installed ducted ventilation system that makes no concessions for acoustic design. The effect of this was most significant in the ground level auditorium (NC 37), but fortunately the cinema audience is restricted to the gallery (NC 29). In Dungog, simple fan-forced heaters produced considerable noise. They were mounted on the rear wall, and a decision between noise and cold could be made in winter months. Not only was the level of the heater noise (NC 44) very high, but the noise was characterised by a 2 kHz octave band peak, which more sophisticated noise rating methods treat as a severe spectral imbalance (e.g., Room Criterion mark II rates the noise as 44(HF), QAI = 19).

Intermittent noise levels could be a problem in some of the quiet country towns, with passing trains or road traffic significantly affecting the background noise level, although this intrusion of road traffic noise in to the structure may have been less severe when the cinemas were opened. In many cases doors are lightweight, are not sealed, and the buildings rely on natural ventilation, so that sound can easily enter the buildings. In Grafton, a bus stop was located directly outside the cinema entrance, so that the diesel engines introduced sustained noise for periods of time. In Mudgee, an automotive mechanic works next door, generating noise such as hammering during the day (which is not a problem for evening screenings).

3.2 REVERBERATION TIME

Dolby recommends cinemas to have reverberation times as short as possible, within reason, and a spectral profile flat at mid frequencies, potentially increasing at low frequencies and decreasing at high frequencies. A large volume room is permitted to have a longer reverberation time than a small room, but the mid frequency reverberation time should not exceed 1.5 seconds (applying to a volume of approximately 30,000 m^3). More generally, the optimum reverberation time for auditoria depends on the purpose of the room, and somewhat longer reverberation times are recommended for drama theatres of equivalent volume [8]. With cinemas the prime requirement is clear direct sound from the loudspeakers because all the required effects of spatial impression and reverberance are added at production stage, calling for low reverberation times. The desired concert hall effect of strong early lateral reflections to increase the apparent source width [9] becomes a hindrance. Of course, great acoustic absorption demands greater electro-acoustical power to reach the high sound pressure levels at maximum audio system output required for digital film sound.

Measured octave band reverberation times are shown in Figure 2 (1/3-octave band data are not presented here for succinctness). Recommended mid-frequency reverberation times for these cinemas range between 0.3 and 1.3 seconds depending on the room volume. Two of the cinemas met the design criterion (the Randwick Ritz and the Sydney State cinemas), not only in terms of the mid-frequency reverberation time, but also the variation of reverberation time with frequency. However the rural cinemas tended to have long reverberation times, especially in the mid frequency range. The presence of the large areas of exposed plaster on the walls, and in some cases the original leather upholstered seating, are largely responsible for these long reverberation times.

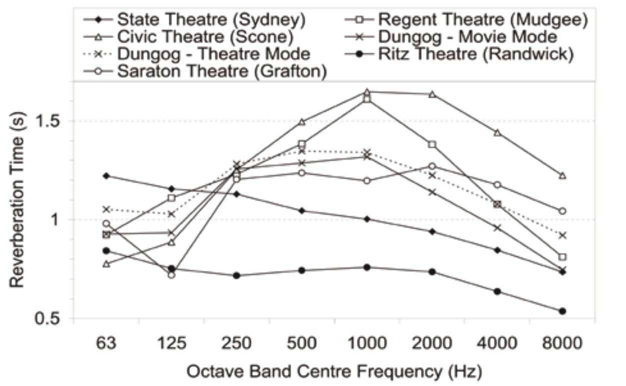

Fig 2. Measured spatially averaged reverberation times (T30) for the six cinemas.

Dungog cinema, which also functions as a community hall, is a long hall, divided into two sections when used in cinema mode (Fig. 1). The screen lowers from the ceiling, and plush curtains are used to create an intimate cinema space within an otherwise excessively long room. The three main loudspeakers are positioned behind the screen (which divides the room), with plywood wings to reduce the acoustic effect of the room's remaining volume. However, the introduction of these features actually makes little difference to the reverberation time, as shown by Fig. 2. The room meets the reverberation time requirements for a drama theatre (1.2 s, measured with a source on the stage, with the room in theatre mode), but has more than twice the recommended mid-frequency reverberation time for a cinema of its volume (0.3-0.5 s for the cinema volume, or 0.4-0.6 s based on the full room volume). Nevertheless, with all of the seats relatively close to the loudspeakers, reverberation is relatively innocuous.

Grafton's Saraton Theatre is used for live performance as well as cinema screening, as it is the sole major auditorium in the town. Because it is quite voluminous, a fairly long reverberation time (for a cinema) is recommended (0.6-0.9 s) – and the theatre comes close to meeting this. This is also close to the 1.25 s reverberation time that is recommended for drama theatre use. The dip in the low frequency reverberation times (Fig. 2) is mainly due to the existing original wooden floor – a feature in other cinemas tested. Even though this might result in lack of warmth for live performance [8, 9], for cinema acoustics this is a benefit (being in the recommended range for cinemas and so avoiding a 'boomy' or 'muddy' bass).

Upon entering the Mudgee Regent cinema, the art deco interior, large stage and high lofty ceiling make a striking impression (Fig. 4). It has the largest Cinemascope screen in NSW, which nevertheless seems relatively small in this spacious cinema (similar in volume to Grafton's Saraton, but shorter and taller). The large volume and extensive plasterwork result in long reverberation times. For live performances the mid-frequency reverberation times are longer than recommended (1.25 s recommended), and so are substantially longer than recommended for a cinema of this volume (0.6-0.9 s). Similar to the Grafton Saraton and Randwick Ritz, the gallery has more absorptive surface materials than the ground level auditorium. The auditorium has a wooden floor which is the likely reason for the short reverberation times at low frequencies. When we visited this cinema, the audience was restricted to the gallery.

Fig 3. View of the interior of Dungog Cinema in movie mode

The Randwick Ritz is a remarkably well-adjusted theatre in acoustical terms. It has plush modern seating. The floor is carpeted with modern cinema carpeting, and drapery is used around the side and rear walls. Nevertheless, significant heritage architectural features in the front section of the cinema visually dominate the interior. Our measurements show the cinema's reverberation time spectrum to be a near-exact match to that recommended for a cinema of this volume (a mid-frequency reverberation time of 0.5-0.8 s is recommended).

The Civic theatre in Scone has similar proportions and volume as the Ritz, but when we visited, it had less absorption than its original state because seats had been removed from the main floor area. The original leather cinema seats remained in the gallery. The main wooden floor was exposed, and had ten double couches with wooden coffee tables, and a bar. The ground floor of the theatre was used mainly for social functions and gatherings with the occasional live performance as entertainment for these functions. While the recommended mid-frequency reverberation time for a cinema is 0.5-0.8 s, or 1.2 s for a theatre, our measurements yielded values exceeding 1.5 s at 1 and 2 kHz, contrasting with little reverberation in the low octave bands. Because of its similarity to the Ritz Randwick, the prospect of meeting the acoustic recommendations for cinemas should be high.

The State Theatre (Fig. 5) has acoustics that suit its purpose well, especially considering that it is such a large theatre. The auditorium is mainly used for amplified performances, meaning that a longer reverberation time is not required for theatrical productions. It also hosts the annual Sydney International Film festival. The reverberation time criterion recommended by Dolby (0.9-1.3 s) is satisfied by the cinema.

Fig 4. View of the interior of Mudgee's Regent Theatre.

3.3 SPEECH TRANSMISSION INDEX

Speech intelligibility factors depend greatly on reverberation and ambient sound level. The recommended reverberation times and background noise limits of the Dolby guideline would also help to achieve the desirable high speech intelligibility. It was possible to experience a film screening at one of the cinemas (the Regent theatre - Mudgee), and a private screening of film trailers at two others (Grafton's Saraton and the Dungog cinema). With the audience restricted to the gallery level at Mudgee, the subjective assessment of all who watched the movie was of poor speech intelligibility. This is reflected by STI values ranging between 0.55 and 0.61, which are overwhelmingly determined by the reverberation (rather than background noise). This cinema's long mid-frequency reverberation time, coupled with the distance from the screen, are the primary reasons for lack of clarity.

It is instructive to compare Mudgee's Regent Theatre with Dungog's cinema, as they exceed the recommended reverberation time by a similar ratio, but the subjective impression of listening to trailers in the Dungog cinema was very positive. When in movie mode, the Dungog cinema's STI ratings range from 0.67 to 0.70, which is substantially better than the Mudgee ratings. Like Mudgee, the STI values at Dungog are controlled by reverberation time, but the ratings are higher because the reverberation times are somewhat shorter in absolute terms, and the distance between the loudspeakers and audience is much shorter.

The State Theatre had a wide range of STI ratings (from 0.57 to 0.73), some of which were influenced more by discrete echoes than reverberation. Features contributing to these echoes are discussed in the next section.

The Randwick Ritz yielded the best STI ratings (from 0.71 to 0.76), with the lower ratings under the gallery. Grafton's Saraton theatre and Scone's Civic Cinema shared similar STI values - between 0.57 and 0.61. In both cases the galleries created acoustical difficulties in maintaining speech intelligibility

4 ARCHITECTURAL FEATURES AND THEIR EFFECTS

Of the six cinemas measured, five have galleries. Galleries are discouraged in recommendations, because it is very difficult to direct the front loudspeakers (which are behind the screen) into the areas both under and above a gallery. Barron [10] recommends that depth of a gallery overhang be less than the height, at least in a concert hall, and a similar rule-of-thumb might be applied to cinemas, where a similar problem of maintaining loudness and definition from a frontal source applies. Apart from Mudgee's Regent Theatre (H/D of 1.3), the height-to-depth ratios are substantially less than suggested by Baron for concert auditoria (0.3 for Grafton, 0.4 for Scone and 0.5 for Randwick). Impulse responses measured deep under the galleries of Grafton and Scone are characterised by a weak direct sound relative to the reverberant decay.

Galleries can also introduce distinct reflections and echoes. In both Scone and Grafton, seats in the stalls in front of the gallery received substantial reflections from the face of the gallery, and in some cases this reflected sound was stronger than the direct sound.

An interesting effect occurs in the State Theatre, which has a series of domes in its ceiling. These focus the sound from the centre of the stage onto the rear centre seats of the upper gallery, and the resulting reflections are substantially stronger than the direct sound. The sound from the stage is surprisingly loud at this centre rear position, reminiscent of the whispering gallery effect.

Fig 5. View of the interior of Sydney's State Theatre, showing the measurement source on the stage.

5 CONCLUSIONS

This paper compares acoustical characteristics of six historic cinemas with recommended values for the demands of modern digital surround sound. Cinemas generally meet the background noise recommendations, at least when their HVAC systems are not operating. However, there were some cases where HVAC caused excessive noise. Noise intrusion from external sources was sometimes a problem. Reverberation times were generally excessive in the country cinemas, but met recommendations in the city cinemas.

This survey raises the question of whether meeting acoustical recommendations is necessary in historic cinemas – or whether a 'historic' sound might be considered a positive feature of a cinema. Noise generally is undesirable in cinemas – the intrusion of traffic noise or hammering certainly would be distracting, but the crackling noise of film projectors may be tolerated and even add to the enjoyment of the experience. A steady-state noise from HVAC might be useful in masking an intractable intermittent exterior noise problem in quiet sections of a film. It is also possible that reverberant characteristics matching the grandeur of a large theatre could be desirable so long as intelligibility is maintained.

Modern cinemas are often neutral environments, with drapery as the main architectural feature. By contrast, the historic cinemas in this study mostly have significant architectural appeal in their interiors, which gives the visitor a richer experience than visiting a fully draped room (the exception is Dungog, which is a heavily draped room when in cinema mode). The renovation of Randwick's Ritz cinema balances drapery with architectural features, meeting modern acoustical recommendations. Nevertheless, such an approach in a large volume theatre such as Mudgee's Regent would need to be done carefully to avoid detracting from the visual appeal of the room. The State Theatre has the fortune of having a large upholstered audience area and a perforated ceiling, and so meets reverberation requirements for a cinema of its size perhaps by coincidence.

The measurements presented in this paper were made in 2003, and the acoustical conditions in the cinemas may have changed in subsequent renovations.

6 ACKNOWLEDGMENTS

The authors are very grateful to Jeff Boltze, Angelo Notaras, Ken Reeve, Des Stibbs, Elizabeth and Bill Suttor, and Jack Ziade for allowing measurements to be made in their cinemas. They are also thankful to those who assisted with the measurements, namely Bill Antram, John Bassett, Young Ji Choi, Ernesto Estivill, Angelo Farina, Fergus Fricke, Megan Kwak, Andy Nguyen, Riduan Osman, Ken Stewart, Jingfeng Xu and the 2003 Audio Systems and Measurement class from the University of Sydney's graduate Audio and Acoustics program.

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IMPROVING THE UPRIGHT PIANO

Martin Keane

Acoustics Research Centre,
University of Auckland, New Zealand

This paper was awarded the **2006 Presidents' Prize** for the best technical paper presented at the Australasian Acoustical Society's Conference, Christchurch, New Zealand. A version was published in the proceedings of that conference, edited by Terrence McMinn.

This paper reports a study of piano vibrations, undertaken to find whether improvements may be achieved by altering the piano case materials. Modal analysis and sound level measurements showed that, because of the manner in which sound is radiated by the piano, the tone does not change significantly when typical materials are used in the case. A method was developed for analysing the spectra of recorded notes; it showed differences in vibrations between upright and grand pianos. A finite element model of a piano suggested that changing one component (the keybed) of the upright would reduce the key vibration level, and make the upright feel more like a grand. These changes were made to one of a pair of pianos, which were subjectively compared by a group of pianists; the results showed that the upright piano had been improved.

INTRODUCTION

This paper gives a (mostly) non-technical overview of the vibrations and radiated sounds of grand and upright pianos. The overall aim was to investigate whether new materials for the case could be found which would bring about an improvement in the subjective evaluation of the piano.

The most important acoustic component of the piano is the soundboard, and many researchers focus solely on this component. The case (and the other components) can affect the vibration of the soundboard, but the degree to which this is important was not known when this project began.

Figure 1 shows the soundboard, frame, action and other important components of a typical upright piano.

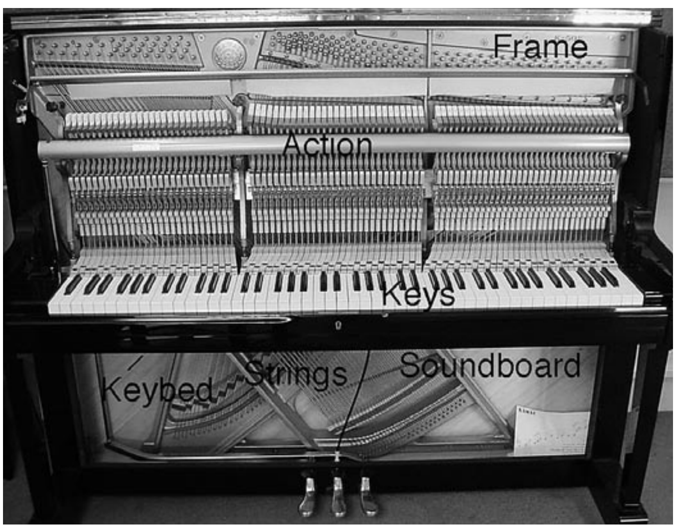

Figure 1. The interior and major components of an upright piano. The keybed, which will be of importance in this paper, is the structure beneath the keys.

At the commencement of the research it was hypothesised that there are three ways in which the case could affect the radiated sound. We will discuss these first. Later a more successful method of influencing the piano performance was discovered, this will be described in the second half of the paper.

The first way in which the case can have an effect is by changing the edge conditions of the soundboard, and thus altering the distribution of modes (the vibrational modes of the soundboard determine its response to the input from the strings). The second is by reflecting the sound radiated by the soundboard (as with the lid of a grand piano) and the third is by direct radiation from the case itself. Each of these methods was investigated in turn.

THE SOUNDBOARD AND CASE

The soundboard is the major sound radiating component in the piano. It is driven by vibration from the strings which is passed through the bridges. The modern soundboard is normally made from Sitka spruce, and is between 6.5 – 9.5 mm thick (Conklin 1990). Ribs are added to the back of the soundboard perpendicular to the grain direction, as shown in Figure 2, in such a way that the stiffness is approximately equal in both directions. Although the soundboard in the grand piano is larger than the upright, the function and basic characteristics of each are the same.

Figure 2. The soundboard of a typical upright piano. Ribs are indicated. The grain direction is perpendicular to the ribs.

The case provides the rigid structure on which all the other components are mounted, as well as edges for the soundboard which attempt to approximate clamped supports. The case is designed, from a vibrational point of view, to prevent the loss of mechanical vibrations from the soundboard. The soundboard is the most efficient radiator, so it is desirable to keep vibrational energy there rather than letting it pass into other components. This is accomplished if the mechanical impedance of the case is much higher than that of the soundboard. High impedances are given by dense, stiff materials such as solid woods, so traditional cases were/are typically made of maple, beech, mahogany or walnut However, modern upright piano cases are often made from medium density fibreboard, as it is cheap and easy to work with, being homogeneous.

The mechanical impedance of the strings is fixed by the string parameters, and is much lower than that of the soundboard. The impedance load imposed by radiation is fixed by the room acoustics. The impedance of the soundboard varies with frequency and is approximately 1000 kg/s, and is essentially fixed by the desire to have notes with slow decay, as lowering the impedance would result in more rapid decay. Therefore the only option left to the piano designer are to limit soundboard damping, which is achieved by using spruce, and to increase the case impedance. Current designs achieve very high case impedance (of the order of 500,000 kg/s) compared to the soundboard, so only incremental further improvements are possible, at the expense of large increases in case mass or material expense.

In a grand piano, the lid is also important, as it is tilted to reflect sound out to the side, to where the audience would be during a performance. This sound field directivity is more pronounced at high frequencies. The major factors affecting this directionality are the angle of the lid and the surface finish used (Fletcher and Rossing, 1991).

RADIATION EXPERIMENTS

Modal analysis

Modal analyses were made of an upright and a grand piano. These were intended to find the soundboard modes and admittance, and to investigate the interaction between the soundboard and the case. Although much previous work has been carried out regarding piano vibrations, this experiment was the first in which the combined motion of the case and soundboard was investigated in both the upright and the grand.

It was found that the upright soundboard deformation always exceeded the case deformation by at least 10 dB, and more typically by 20-30 dB. In the grand, the difference between the soundboard and the case was larger, i.e. the vibrational separation between the soundboard and the case was greater. Some of the soundboard modes were aided by the deformation of case panels. The lowest six soundboard modes are shown in Figure 3. Thus for those modes, in both the upright and grand piano, the frequencies were reduced and the amplitudes increased, but these effects were small, less than 5%. The grand and upright soundboards had impedances of the same order, but it was found that the upright soundboard had the (1,1) mode (at 73 Hz) at unusually high impedance, causing a lack of radiated sound power in the upright bass range. The (1,1) modes of four other uprights were tested and all were found to be at a similarly low amplitude. This may be one of the reasons uprights are considered to sound inferior to grands. The impedance function was found to be smoother throughout in the grand (which is desirable for even playing), this may be due to the irregular shape of the grand soundboard.

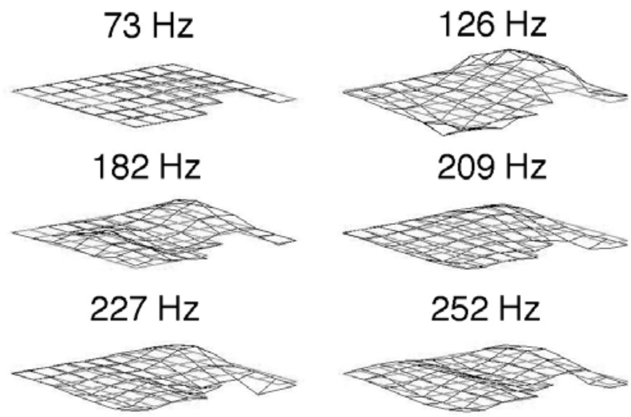

Figure 3. The lowest six vibrational modes of an upright piano soundboard. Note the low amplitude of the (1,1) mode at 73 Hz.

Finite Element Model

Following the modal analysis, a finite element (FE) model of the upright piano was built in ANSYS. This study was intended to assess the errors introduced through the simplifying assumptions that are often used in piano modelling, such as ignoring the case, or assuming an isotropic soundboard.

It was found that including the case in the analysis increased the accuracy of the results, at the expense of greatly increased computation time. Excluding the case from the model gave correct mode shapes, but incorrect frequencies. Using the soundboard with simple supports predicted mode frequencies too low by 5% and clamped supports predicted frequencies too high by 10%. The effect of the soundboard ribs is to make the soundboard approximately isotropic at low frequencies, and modelling the soundboard simply as an isotropic plate can give reasonable results below 250 Hz, and greatly reduces computation time. In both the modal analysis and the FE model, it was clear that as the frequency increased, the simplifying assumptions became less applicable.

Reflection and radiation

The possibility of influencing the radiation or reflection of sound by changing the materials of the case was considered next. Individual case panels were excited to the levels measured during the modal analysis and sound radiation was measured with a sound level meter, and found to be at least 20 dB lower than the radiation from the soundboard. This confirmed that radiation from panels other than the soundboard can be ignored. Also, because the case impedance is so much higher than the impedance of the soundboard and of air, changes to the case materials have very little effect on the reflected sound, since more than 90% of the incident sound is reflected with a normal lid.

Conclusion of radiation experiments

These studies confirmed that, because the case impedance is higher than that of the soundboard and of the radiation load, changes to the case material do not affect the radiation from the piano to a subjectively important degree. However, it was found that another possibility existed: the feedback of vibrations to the pianist through the hands, an important transmission path that does not involve radiated sound or the soundboard, which is affected by the materials of the keybed.

VIBRATION TRANSMISSION EXPERIMENTS

Introduction

When playing, the pianist receives aural and tactile feedback. The measured vibration level of the keys is above the tactile threshold (Askenfelt and Jansson 1992), yet pianists do not seem, in general, to be consciously aware of this feedback path. To date, vibration feedback in pianos has not received extensive study. However, it was found by Galembo (2001) that subjective assessment of a piano was affected more by vibration and touch/feel than by sound.

Tonal and broadband components

It is well known that piano tones consist of a broadband and a tonal component (also known as the BC and TC). The tonal component comes from the strings, and consists of the harmonically related overtone series for that note. The broadband component is by contrast of wide spectrum, with some individual modes at low frequencies but decreasing at a constant rate of 20 dB per octave at higher frequencies, and extending up to around 5 kHz. The spectral differences between these two components allow them to be separated.

Feedback paths are different for the tonal and broadband components. The tonal component originates in the strings, and is transmitted through the bridge and soundboard, then the case and keybed to the keys and to the pianist. The broadband component is composed of vibrations from many parts, but for the pianist the most important is the vibration of the keybed when struck by the falling key. This vibration is transmitted directly back into the keys and to the pianist. Therefore the broadband key vibrations are almost completely determined by the keybed.

The keybed

The keybed is the part of the piano on which the keys rest. There are marked differences in keybed construction between upright pianos and grands, leading to differences in transmission of vibrations and radiation of sound. In uprights, the keybed is a solid plate, 45 mm thick and made from plywood. In grands, by contrast, the keybed is a part of the case and about 60 mm thick. Above this there is another, movable frame, called the keyframe, on which the keys rest. The purpose of the movable frame is to accommodate the una corda pedal.

Analysis of piano tones

A new method was developed for splitting recorded piano notes into tonal and broadband components. This method has several advantages over those previously proposed. It is worth going into greater detail to describe the problem and the algorithm used here.

Previous research

The most important previous work concerning the relationship between the components of piano tones is that of Galembo (2003), who investigated the quality of tones in the extreme treble range. Building on the work of Smurzynski (1983) and Revvo (1988), who both removed the tonal component by damping the strings with felt, Galembo used comb filters to remove the harmonics (of which, for extremely high notes, there are typically only two or three) from recorded tones. This method is superior to mechanically damping the strings in that it allows the recovery of the tonal component. However, this method is problematic, as the filter will remove any broadband signal that is within the filter stopbands. Ideally some of the energy in the stopbands should be retained in the broadband signal.

The primary finding of the Galembo study was that "The judged note quality in listening tests increases when the broadband component is less intense, of narrow spectrum, and decays rapidly, while the tonal component is more intense and decays slowly" (Galembo, 2003).

The separation algorithm

A paper describing the technique used to reconstruct the broadband and tonal signals in detail has been accepted for publication in Applied Acoustics, here we will give a précis of the method. The purpose was to create an approximate broadband spectrum from the available data, and then use the inverse Fourier transform to return to the time domain (in the actual program, a series of windowed spectra were used, i.e. a spectrogram). The majority of the broadband spectrum was simply taken from the spectrum of the original signal, however near each harmonic it was the tonal spectrum which dominated. Consequently, in a small frequency range around each harmonic the broadband spectrum was inferred, based on the assumption that it varied linearly over such a small range. A linear interpolation was made across each harmonic peak in the spectrum. Figure 4 illustrates the process for two harmonics of a sample note. Across each harmonic, the broadband spectrum was inferred by interpolating between points on either side of the peak. The shaded area represents the harmonic content that is removed.

Taking the inverse FFT of this approximate spectrum reconstructed the broadband signal (the complex spectral data was used to allow return to the time domain). By subtracting it from the original signal the tonal signal was also recovered. Due to the nature of piano notes, this algorithm was limited to notes between approximately F2 (87 Hz) and C7 (2100 Hz).

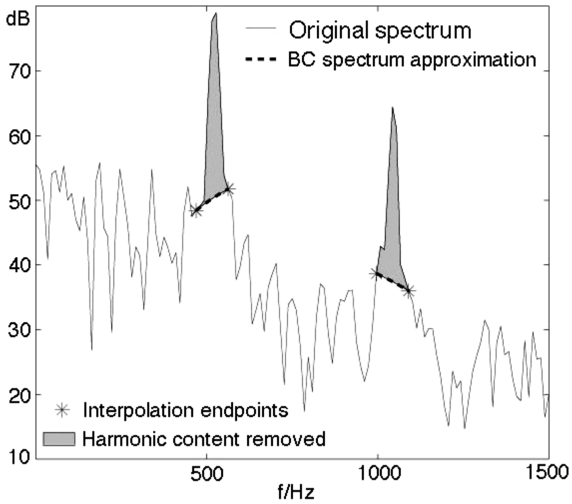

Figure 4. Example removal of spectral peaks. Asterisks mark the endpoints for the interpolation, and the dashed line shows the interpolated spectrum. The shaded area represents the harmonic content which is removed. The decibel scale has an arbitrary reference.

This algorithm was written in Matlab and all parts were automated, including the detection of harmonics and the choice of endpoints, however these tasks could equally have been done by hand. Analysis of a typical note took around 10 seconds on a 3 GHz P4 PC. Also of note was that the algorithm worked equally well whether the input was sound or vibration recorded by an accelerometer.

The broadband to tonal ratio

Recordings were made of radiated sounds and key vibrations (measured with an accelerometer) of four upright and four grand pianos, and analysed with the separation algorithm. The broadband to tonal ratio, which was first used by the authors previously mentioned, Smurzynski (1983), Revvo (1988) and Galembo (2003), was useful when analysing the separated components. The broadband to tonal ratios are twice as large in the measured uprights as in the grands. These differences were not seen in the radiated sound. Hence we concluded that reducing the strength of the broadband acceleration in the upright pianos may lead to an improvement in subjective quality. It was likely that the keybed could be used to moderate the key vibrations as it provides the structure underneath the keys, and so any key vibrations must pass through it.

FE model of the keybed

The ANSYS FE model was again used to investigate the influence of keybed materials on transmitted vibrations in the upright piano. A number of materials were considered, both hypothetical and real. It was shown that, due to the geometry of the piano, broadband vibrations are strongly affected by the impedance of the keybed, while tonal vibrations are not. Thus it was suggested that a material with relatively high impedance would be a suitable replacement material for the keybed. For example, the model predicted that a keybed made from high density fibreboard would reduce the broadband acceleration level by as much as 10 dB, without significantly altering tonal vibrations. Of the readily available materials, this was found to be the most suitable for the subjective experiment detailed below.

Making a new keybed

A replacement keybed was manufactured from high density fibreboard and fitted in the upright piano. The impedance of the new keybed was measured by modal analysis to be on average 10 dB higher than the original (plywood) keybed, yet it had the same speed of sound and thus the modes remained at the same frequencies. Modal analysis and measurements of sound and vibration with the new keybed installed show that the transmitted vibrations were reduced by the modifications: the broadband acceleration level was reduced by an average of 3.2 dB for notes between C3 and C6 (the most heavily used part of the keyboard). This was much less than ANSYS had predicted, however it was greater than the just noticeable difference for tactile vibrations, of 2 dB (Gescheider et. al. 1990). In addition, radiated sound levels were unchanged by the keybed replacement.

The most probable reason for the discrepancy between the ANSYS prediction and the behaviour of the actual keybed is that ANSYS overpredicted the vibration levels in the original keybed. As the impedance of the original keybed was lower, vibrational energy was more easily passed from it to the other parts of the case, which were also of lower impedance. This transmission path was not accurately accounted for in the model. With the higher impedance replacement keybed, this interaction was reduced and so this source of error was less significant.

Subjective assessment of the new keybed

Following these modifications, a subjective experiment was carried out in which two groups of experienced pianists (12 in each) compared two pianos, one of which had the replacement keybed installed, but which were otherwise identical. Both pianos were professionally tuned after the modified keybed was installed. The subjects in the control group, which compared the two pianos before modifications were made, showed no clear preference for either piano. In the experimental group, 10 out of 12 subjects preferred the modified piano and 2 preferred the unmodified piano. This result was significant at the 90% confidence level, thus a clearly sensible improvement was made by using the high density fibreboard keybed. The subjects indicated in their responses that significant differences were found between the timbres of the pianos in the high frequency range, an unexplained result as the tone was not measured to have been significantly modified. In addition, none of the factors such as age or years of playing experience were found to be predictors of preference.

Overall, the subjective results showed that the modifications proposed gave an improved instrument for the pianist, by reducing the acceleration level of the keys.

CONCLUSIONS

The vibration of upright and grand pianos was studied as part of an investigation into the possibility of improving pianos by altering the case. Modal analysis showed that because of the difference in impedance between the case and the soundboard, the tone cannot be altered by changing the case. A new and more accurate method for splitting tones and vibrations into broadband and tonal components was developed. By this method it was found that the magnitude of the broadband vibration component of the keys was twice as large in the four measured upright pianos as in the four grands. Thus, by replacing the keybed with a higher impedance material, it is possible to reduce the broadband vibrations and improve the subjective feel of the upright piano. A high density fibreboard keybed was substituted into one of a pair of pianos, and measurements confirmed that key vibrations were reduced. Comparison of the pianos by groups of 12 experienced pianists confirmed that this resulted in an improved instrument for players.

ACKNOWLEDGEMENTS

This study was carried out at the Centre for Advanced Composite Materials and the Acoustics Research Centre at the University of Auckland, with financial support from the Foundation for Research Science and Technology.

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CLARINET ACOUSTICS: INTRODUCING A COMPENDIUM OF IMPEDANCE AND SOUND SPECTRA

Paul Dickens, Ryan France, John Smith and Joe Wolfe,
School of Physics,

University of New South Wales, Sydney 2052 NSW

J.Wolfe@unsw.edu.au

This paper introduces a web-based database that contains details of the acoustics of the clarinet for all standard fingerings and some others. It includes the acoustic impedance spectra measured at the mouthpiece and sound spectra recorded for each note. The data may be used to explain a number of the playing characteristics of the instrument, both in general and in detail. In this paper we give an overview, and highlight some interesting phenomena. The clarinet has, very approximately, a cylindrical bore, which is acoustically closed at one end and open at the other. Because it is so often used as an example of closed-open pipe, we show several phenomena that can be clarified by comparing measurements on a clarinet with those on a cylinder of equivalent acoustic length. We also compare these data with analogous data for the flute, an example of an open-open pipe.

INTRODUCTION

The acoustic behaviour of wind instruments is largely determined by their acoustic impedance spectrum measured at the embouchure or 'input' to the instrument. The acoustic impedance Z is the ratio of acoustic pressure *p* to acoustic volume flow *U* and its extrema identify the frequencies of resonances and antiresonances due to standing waves in the bore. (For example see [1].)

Backus [2] reports measurements of the acoustic impedance of the clarinet for a small number of fingerings. Advances in measurement technology (reviewed by Dalmont [3] and Dickens *et al*. [4]) have allowed improvements since then. Further, there are advantages in having a rather complete set of data that includes all of the standard fingerings. Detailed information about individual fingerings and the notes they can produce is of obvious interest to players and teachers. It is then helpful to provide, for each fingering, a sound sample and sound spectrum. This paper introduces such a database, available via the internet.

A further important application of such a complete data set is possible. An analogous database [5,6] for the flute was used to develop a computer model for the instrument. This in turn led to a web service for flutists that "knows" many of the playing properties of all 40,000 fingerings for the instrument and uses these to advise musicians on unconventional fingerings for rapid passages, multiphonics, and timbral and pitch variations [7,8]. It is our intention to use the clarinet database reported here in a similar way. Finally, a number of personal communications concerning the flute database convince us that such data bases are of use to researchers studying performance technique either from the acoustical or the musical perspective.

In this paper, we also report measurements of impedance spectra made on a flute, and on purely cylindrical pipes that have dimensions comparable with those of a clarinet or a flute. These are included for didactic reasons. The clarinet and flute are regularly used as iconic examples of a closed-open and an open-open pipe in acoustics and general physics texts (e.g. [9]) and comparison of

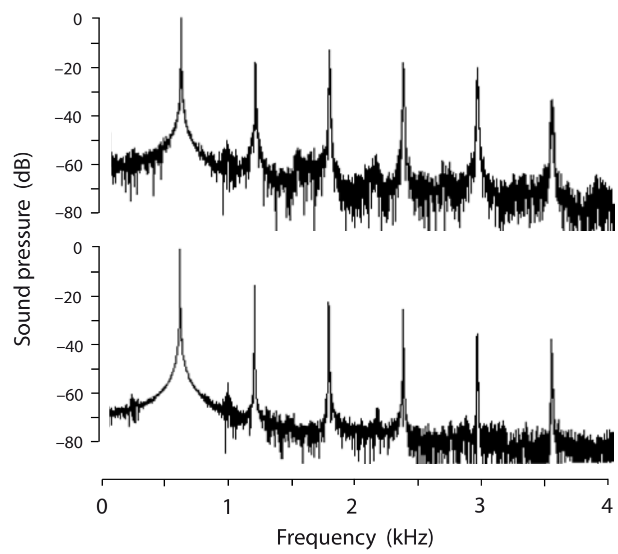

Figure 1. Sound pressure spectra for the note D5 played *mezzoforte* on a flute and on a clarinet, measured near the first open tone hole in each case. Identification of which instrument produced each spectrum is presented at the end of this paper. The 0 dB level was arbitrary and the same for both instruments.

measured acoustic properties can clarify a range of subtle acoustical effects.

For example, the two sound spectra in Fig. 1 are for the note D5 played on a flute and a clarinet under very similar conditions. But which is which? Imagine that, as an acoustician, you are trying to explain this to a musician: Do you find yourself looking for systematically weaker even harmonics?

The clarinet has been used as a model instrument for studying the bore-reed interaction (e.g. [10-15]) and so one might in principle appeal to such studies to begin to answer the question posed by Fig. 1. However, for reasons that we shall see, the spectral envelope of the clarinet varies over the range of the instrument, and even for different fingerings used for the same note. For a simple theory of sound production, or for simple experiments, it is reasonable to connect a clarinet mouthpiece to a simple cylinder with well known acoustical properties. Such a simplification does not, of course, satisfy the clarinettist, for whom the details of each fingering are important.

The database described here has been assembled to provide such details not only as a resource for the musician, but also for the next generation of acoustical models of reed-bore interaction. Further, and for the purposes of this much less detailed article, we select a number of examples so as to answer the general question posed by Fig. 1, and one that might be confronted in the physics or acoustics classroom: When and how can simple arguments about the geometry of these instruments be used to explain their spectra and timbre?

MATERIALS AND METHODS

The clarinet used for most measurements was a Yamaha Custom CX B flat clarinet. A Yamaha Custom CX A clarinet was also measured for some notes, to allow comparisons.

The acoustic impedance was measured using a spectrometer described previously [4]. It uses three microphones, three non-resonant calibration loads and a signal that comprises a sum of sine waves with amplitudes chosen to distribute the errors due to noise and frequency-dependent instrumental sensitivity approximately equally over the frequency range. The three microphones in the impedance heads were located 10, 50 and 250 mm from the reference plane (Fig. 2). With the microphones positioned thus, a singularity occurs at around 4.3 kHz under typical measurement conditions (see [4] for details). At this frequency the smallest microphone separation is equal to half a wavelength, and the impedance cannot be determined. Thus the impedance spectra are measured between 120 Hz and 4 kHz for the clarinet and between 200 Hz and 4 kHz for the flute. These ranges encompass the fundamental frequency of all of the notes on each instrument and include their cut off frequencies.

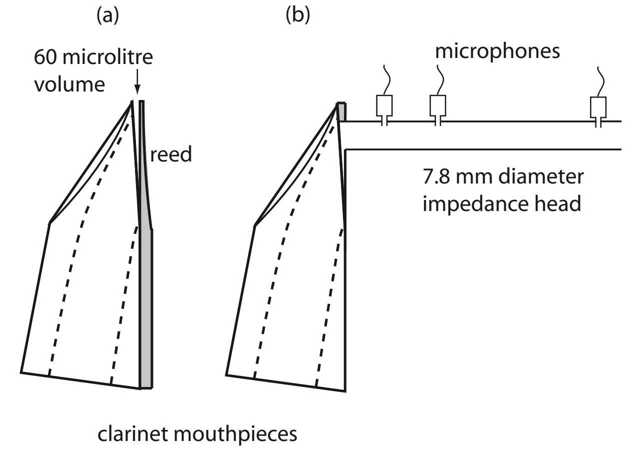

Figure 2. Schematic diagrams of the clarinet mouthpiece and impedance head (not to scale). An arrow in Fig (a) indicates a small volume of about 60 microlitres left between the undeformed reed and the mouthpiece. For measurements, the reed is removed and this volume is enclosed and sealed with a gasket against the impedance head when they are attached – see fig (b). The gasket (shaded in the diagram at right) and the ends of the mouthpiece and impedance head are enclosed in a block of Teflon (not shown) for measurements. The dotted lines show the shape of the bore. During playing, the player's lower lip is pressed against the reed, while the upper teeth and lips touch the slightly curved upper surface of the mouthpiece (top left in the diagram).

The impedance head used for clarinet measurements is shown in Fig. 2. Two geometrical areas are of interest in measurements of the impedance at the clarinet mouthpiece: one is a typical opening between reed and mouthpiece in the mouth and the other is the effective area of the reed upon which pressure variations produce substantial vibrations. To approximate these, a pipe with internal diameter 7.8 mm was used. The same impedance head was used for the few flute measurements reported here. The attachment used to attach the impedance head to the flute was similar to that used previously [5,16]. The flute was a Pearl PF-661 with closed keys and a C foot.

The embouchure apertures of flutes and clarinets are both smaller than their bores, so measurements were also made on cylinders with an internal diameter comparable to the bore. A separate impedance head, with internal diameter 15 mm, was used to measure the impedance spectra of sections of stiff plastic pipe with the same internal diameter. The lengths of such pipe sections were chosen to equal the lengths of the equivalent air column for flute and clarinet resonances, for cases discussed later. The impedance spectra plotted here and in the clarinet database include a compliance corresponding to that of the reed, using the value given by Nederveen [18]. Similarly, an inertance corresponding to the radiation impedance at the embouchure has been added to the impedance curves here and on the flute database [6].

The sound files and the sound spectra available in the database were measured in a recording studio using a condenser microphone positioned one metre in front of the player, at shoulder height. The recording environment reflected typical practice for solo recording in a studio but allows for acoustical properties of the room to influence the spectra. In contrast, the sound files whose spectra are shown in this paper were recorded in a room treated to reduce reverberation, using a microphone positioned 2 cm from the first open hole (for the higher notes) or 2 cm from the bell (for the lowest notes on each instrument). At this distance, room effects and interference effects are negligible. They were played by one of the authors using the same flute and clarinet described above, under very similar conditions for the two instruments.

RESULTS AND DISCUSSION

Simple geometries and the interpretation of impedance spectra.

Before discussing the impedance spectra of the clarinet, with its complicated geometry and consequent complications, it is instructive to look at the impedance spectrum of a simple open pipe. That shown in Fig. 3 is for an open cylinder with length $L = 650$ mm and internal diameter $a = 15$ mm. These dimensions are comparable with those of a clarinet and a flute (the internal diameters of the cylindrical portions of a clarinet and a flute are 15 mm and 19 mm and the lengths of their bores are 660 mm and 615 mm respectively). The impedance spectrum of this cylindrical pipe should thus be helpful in understanding the behaviour of both clarinets and flutes. This pipe is open at the end remote from the measurement head. Should it be considered therefore an open-open or a closed-open pipe? The answer depends on the conditions that are imposed at the proximal end by the valve or jet mechanism used for excitation.

How would this pipe respond if excited by a clarinet reed? Discussions of the interaction of a reed with a pipe are given by a number of researchers, who agree that the system will resonate at frequencies close to impedance maxima of the pipe. (See [1,10-15,17,18].) Qualitatively, one may also say that the pipe is largely closed off by the reed, so the acoustic flow U would be small. The reed would be excited by large variations in the acoustic pressure p. Consequently, the frequencies of the expected playing regimes fall close to those of the maxima in Z ($\equiv p/U$). Hence the observation that a clarinet behaves acoustically as a closed-open pipe, with one end almost sealed by the mouthpiece and reed.

The extrema in Fig. 3 fall at frequencies 130, 261, 392, 524, 655, 787, 919, 1052, 1183, 1315, 1449, 1579, 1711, 1844, 1975, 2107, 2238, 2371, 2502, 2636, 2766, 2900, 3031, 3165, 3296, 3429, 3559, 3692, 3824 and 3957 ± 1 Hz. If n is the number of the extremum, then the mean and standard deviation of f_n/n are 131.5 and 0.5 Hz.

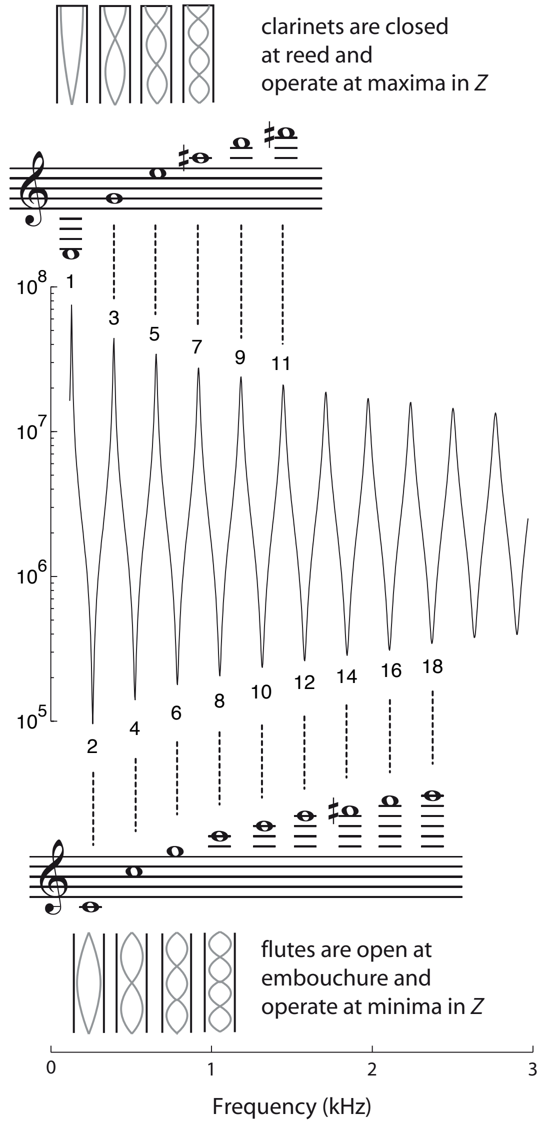

Figure 3. The magnitude of the measured acoustic impedance spectrum of a cylindrical pipe, length 650 mm and diameter 15 mm. The frequencies of several impedance maxima are notated on a musical stave above the spectrum, using the semi-log vertical axis widely used by musicians. The first several notes shown are approximately what would be played by a hypothetical clarinet with this bore, closed at the embouchure by a reed. Similarly, below several impedance minima, are shown the notes that would be played by a hypothetical (end-blown) flute with this bore, open at the embouchure and negligibly baffled by the player's face. The numbers above or below these extrema refer to the harmonics of the lowest note that would be played of the hypothetical cylindrical clarinet. Diagrams indicate the standing waves of pressure associated with some extrema.

The maxima in Fig. 3 thus fall almost exactly at frequencies corresponding to wavelengths of $4L/n$, where n is an odd integer. (Small differences are expected due to the radiation impedance at the open end, which has a small frequency dependence [1].) A clarinet with a purely cylindrical bore of these dimensions and with all tone holes closed might then be expected to play approximately the pitches indicated in Fig. 3. These correspond to the note C3 (one octave below middle C, with nominal frequency f_1 = 131 Hz) and its odd harmonics with frequencies in the ratio 1:3:5 etc, i.e. frequencies nf_1 Hz, where n is an odd integer. Sketches representing standing waves are included on the figure.

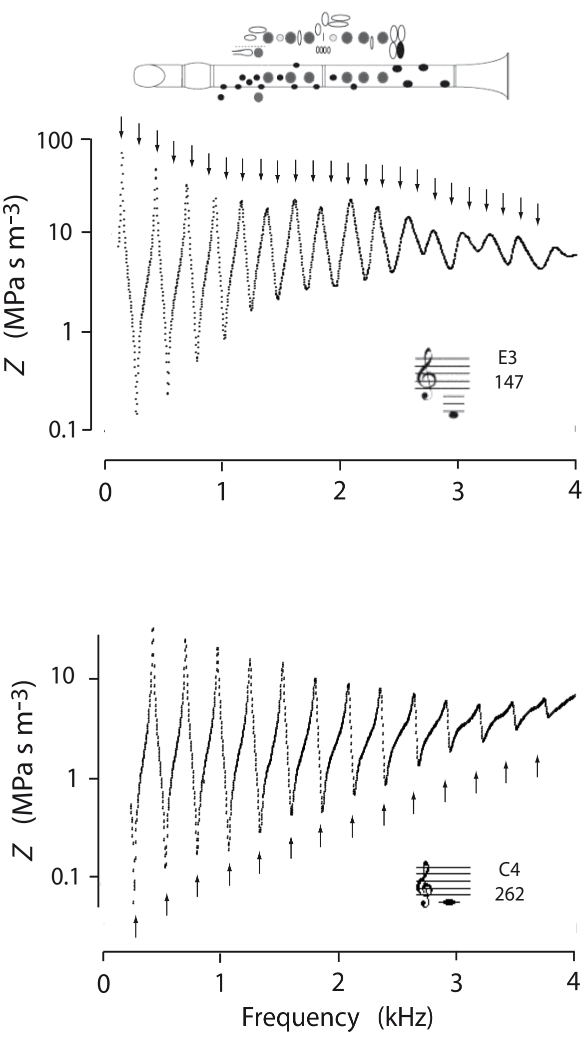

Figure 4. The magnitude of the measured impedance curves for the lowest notes on the clarinet (upper) and flute (lower). The lowest note on the clarinet is D3 (called E3 on the clarinet, a transposing instrument) and can be produced by closing all tone holes, as indicated on the schematic located above the spectrum. There are two other fingerings (not shown) that will also close all tone holes – alternatives are required because the clarinet overblows at a musical twelfth, and twelve tone holes exceeds the number of fingers available to standard players. The lowest note on the flute with a C foot is C4, which is produced by closing all tone holes (see schematic) and is nearly an octave above the lowest note on the clarinet. The vertical arrows indicate the harmonics of the note that would be played.

In contrast, the bore of a flute is open to the air at both ends so, with all tone holes closed, it is acoustically an open-open pipe. A model of the excitation of a pipe by an air jet is given by Fletcher and Rossing [1]. Here however we can make the following simple argument: Because the flute is excited by volume flow at the embouchure, which is open to the outside air, one might expect to find, near the embouchure, a minimum in p and a maximum in U. Consequently, a simple cylindrical pipe played as an end-blown flute is expected to play at frequencies near those of the impedance minima in the curve in Fig. 3. This idealised open-open pipe has resonances with frequencies in the ratio 1:2:3 etc, whose modes are shown in the sketches in Fig. 3. For the pipe shown, this is the note C4 (middle C, nominally 262 Hz) and its harmonics are both odd and even. Animations that represent standing waves in closed and open pipes in the time domain are shown on www.phys.unsw.edu.au/jw/flutes.v.clarinets.html

In practice, the lowest notes on a clarinet are either D3, for a Bb instrument, or C#3, for an A clarinet. (The clarinet is a transposing instrument, meaning that although the aforementioned notes are sounded, they are written as E3 for both instruments in the printed parts, and fingered the same on the two instruments, the A clarinet being just 6% longer and thus one semitone lower.) That the 660 mm B flat clarinet has a lowest note that is a tone higher than the first resonance of the 650 mm cylindrical tube may be explained by the fact that the clarinet is flared in the lower half and has a bell, both of which reduce the effective length. That the 615 mm C flute has a lowest note (C4) at the frequency of the 650 mm cylinder is explained by the constriction at one of its open ends (the embouchure) that lowers the frequency of modes that have a flow antinode at this end [19].

Impedance spectra of a clarinet.

The upper part of Fig. 4 shows the impedance spectrum for the lowest note on a B flat clarinet, measured at room temperature. The first maximum occurs at f_1 = 148 Hz, which is close to the sounding pitch of the lowest note on the clarinet (D3 has a nominal frequency of 147 Hz). The upper part of Fig. 5 shows sound spectra recorded close to the bell of the clarinet for this note.

Fig. 3 shows that, for the cylindrical pipe, the frequencies of the first several maxima occur at odd integral multiples of that of the lowest. In contrast, Fig. 4 shows that, while the second maximum occurs at a frequency only a little less than 3 f_1, the frequencies of the next several subsequent peaks occur at frequencies successively less than odd multiples of this frequency, as is indicated by arrows in the figure. The frequencies of the maxima shown here are 148, 435, 699, 938, 1159, 1380, 1612, 1837, 2088, 2318, 2576, 2795, 3039, 3269, 3513 and 3820 Hz. If n is the number of the maximum, then the mean and standard deviation of $f_n/(2_n-1)$ are 127.7 and 9.0 Hz, so they are rather more closely spaced, on average, than f_1. The primary cause of this is the bell, which gives the instrument an effective length that increases with frequency: the effective point of reflection for waves travelling down the bore is more distant for higher frequencies.

Sometimes, a maximum will occur with a frequency close to an even harmonic of the lowest maximum, e.g., the fifth maximum coincides with $8f_1$. The effect of a small difference in frequency between an impedance peak and a harmonic is shown in the sound spectrum in Fig. 5: the first and third harmonics are very much stronger than the second and fourth. The fifth to seventh harmonics decrease regularly, however, while the eighth harmonic is stronger than its neighbours.

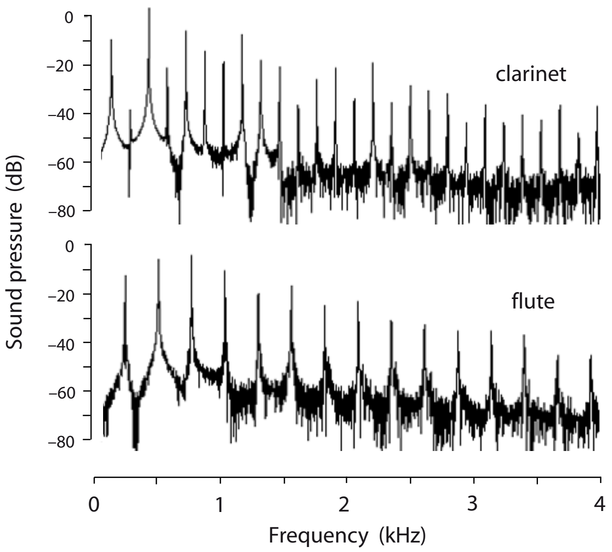

Figure 5. Sound pressure spectra for the notes played *mezzoforte* with all tone holes closed on a B flat clarinet and on a flute. See Fig. 4 for more details. Here, in contrast with Fig 1, the first two even harmonics of the clarinet sound spectrum are weaker than their neighbours. The 0 dB level was arbitrary and the same for both instruments.

Further clear differences between the clarinet impedance spectrum and that shown in Fig. 3 for a cylinder are also due to the clarinet's bell. The amplitude of the maxima and minima decrease with increasing frequency at a rate greater than that for the simple cylinder. One function of the bell is to radiate high frequencies (i.e. wavelengths that are not long compared with its dimensions). Increased radiation means less reflection at high frequencies, and so weaker standing waves or resonances. Second, the geometrical mean of the clarinet impedance increases overall with frequency. This is due to the shape of the mouthpiece: its cross-sectional area, which increases with distance from the embouchure and measuring point, can be considered as an impedance matcher that operates at sufficiently high frequencies. Impedance spectra may be calculated with a simple waveguide model, and the respective effects of mouthpiece and bell may be illustrated [20].

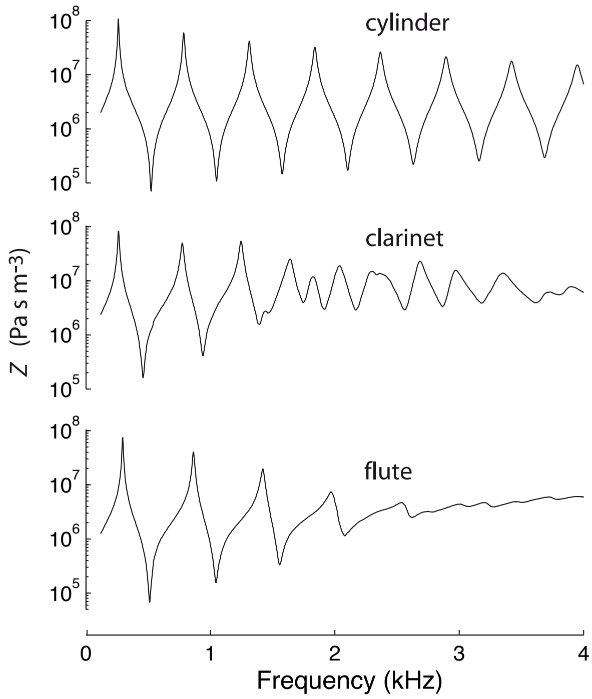

Figure 6. The magnitude of the measured impedance spectra of a cylinder (top), a B flat clarinet fingered to play the note C4 or 'middle C' and a flute fingered to play the note C5 (bottom), each with the same effective length. (C4 is called D4 on the B flat clarinet, a transposing instrument.)

Impedance spectra of a flute.

Figs. 4 and 5 also show, for comparison, the impedance spectrum and sound spectrum for the lowest note on a flute (C4, nominally 262 Hz). The first *minimum* in Z falls at 259 Hz, close to the frequency at which it plays. As discussed above, the open embouchure of the flute means that it plays at minima in impedance. The minima shown in this figure fall at the frequencies 259, 525, 790, 1059, 1326, 1590, 1856, 2124, 2390, 2671, 2938, 3217, 3500 and 3771 Hz. These are approximately integral multiples (both even and odd) of this frequency: if n is the number of the minimum, then the mean and standard deviation of f_n/n are 265.4 and 2.7 Hz. The flute will play at eight or more of these minima. Sound files illustrating the notes obtained by overblowing the lowest note fingerings of the flute and clarinet are at www.phys.unsw.edu.au/jw/flutes.v.clarinets.html. These files show that, while the first several flute resonances play notes in nearly harmonic ratios, only the first two clarinet notes are in harmonic ratios.

Comparison with the simple cylinder shows several differences. The decrease in the magnitude of the extrema with increasing frequency in this case has a different explanation. The bore is in series with the air in the downpipe, which increases the impedance over the range shown. Further, the embouchure end of the flute includes a Helmholtz resonator, of which the mass is the air in the small downpipe or chimney into which the player blows, and the 'spring' is the volume of air between the chimney and the cork in one end. The combined effect attenuates the resonances over the high end of the frequency range shown. More detail on these and other effects is given elsewhere [5,21].

Comparing clarinet and flute with all holes closed

Qualitatively, the impedance spectra of both flute and clarinet are somewhat similar to those of the cylindrical pipe for their lowest note (i.e. with all holes closed). Further, the sound spectra of the lowest notes shown in Fig. 5 reflect this similarity: the first few odd harmonics of the clarinet sound are relatively strong, because they excite corresponding resonances in the bore, whereas the low frequency even harmonics do not coincide with resonances.In contrast, the flute's sound spectrum exhibits no systematic difference between odd and even harmonics. For all notes other than the lowest, however, there will be open tone holes and/or register holes. These are responsible for some of the complications suggested by Fig. 1.

Comparing clarinet and flute with open holes

Fig. 6 shows three impedance spectra. The first is for a cylindrical pipe, 15 mm in diameter and 325 mm in length. Its length was chosen so that its first impedance maximum corresponds to the note C4 and the first minimum to C5. Simplistically, we should expect it to play these notes respectively if excited by a reed (making it an open-closed pipe) or an air jet (making it open-open).

Fig. 6 also shows the impedance spectrum of a clarinet with the fingering to play the note C4. In this configuration, most of the keys on the lower half of the instrument are open, so we could simplistically say that its effective length is the same as that of the cylindrical pipe. At low frequencies, this simplistic picture is adequate: the first three maxima correspond closely to those of the pipe and the instrument will play notes near these frequencies. The minima are displaced in frequency, because of the mouthpiece constriction mentioned earlier.

Above about 1.5 kHz, however, the behaviour is qualitatively different. This is due to the cut-off frequency of the array of open tone holes. At sufficiently high frequency, the force required to accelerate the mass of air in and near the open hole is sufficiently great that there is little radiation from the hole [22, 23]. The array of open tone holes and the short sections of bore connecting them thus behave like inertances and compliances in a finite element transmission line. Benade [23] derives a theoretical expression for the cut off frequency of a continuous waveguide approximating this situation. Wolfe and Smith [21] give an explicit derivation for an infinite tone hole array. The cut off frequency for the clarinet is about 1.5 kHz. (Because the holes on a clarinet are neither uniformly sized nor uniformly spaced, the cut off frequency varies for different fingerings. For this fingering, using the average value of parameters for the next five tone holes, the calculated value is 1.5 kHz.)

Below 1.5 kHz, the average spacing between impedance maxima is about 500 Hz, as expected for a pipe with effective length 330 mm, i.e. a length roughly equal to the length of bore down to the first open tone hole. Above 1.5 kHz, however, the average spacing is about 280 Hz, corresponding to an effective length equal to that of the *whole* bore of the clarinet. At frequencies above the cut off, the sound waves 'do not notice' the open holes, the air masses in which have sufficiently large inertia that they effectively seal the bore.

Fig. 6 also shows the impedance spectrum for a flute fingered to play the note C5, one octave above its lowest note. For this fingering, most of the tone holes in the downstream half of the instrument are open. At low frequencies, it also behaves somewhat like the simple cylinder that has the same effective length. The frequencies of the three first minima have harmonic ratios, and each of these minima may be played as a note. Above about 3 kHz, very few features are seen, because of the Helmholtz resonator mentioned above. The cut off frequency for the flute is higher than that for the clarinet, because the holes are considerably larger. The Boehm mechanism of the flute also opens a larger proportion of the tone holes, reducing the average distance between open tone holes for this example. However, the effect of the cut off frequency can be seen on the flute at frequencies above that of the Helmholtz resonance, typically above 7 kHz [21]. In this high frequency range, the effective length of the flute is close to that of the complete instrument, in spite of the open tone holes.

Fig. 6 shows that, once a number of tone holes are open, treating the clarinet as a closed-open cylinder and the flute as an open-open one is an appropriate approximation only at low frequencies. This explains the difficulty of the question posed in Fig. 1: at frequencies above the cut off, the resonances do not match the frequencies of the harmonics. For the flute, the Helmholtz resonance also reduces the magnitude of the extrema in the impedance. Thus, in the high frequency range, the spectral envelope depends on features of the reed and air jet operation and less strongly on features of the bore.

Fig. 7 shows the acoustic impedance spectra for the two notes whose sound spectra are shown in Fig. 1, measured on the same instruments. These impedance spectra also show another interesting feature, because both use register keys. A register key is usually a small key, located well away from the open end of the bore, whose purpose is to weaken and/or to detune the lowest resonance(s), so that the instrument will more easily play a note whose fundamental coincides with one of the higher resonances. Arrows on the insets of Fig. 7 indicate the register keys, whose effects may be seen by comparing the low frequency extrema in Fig. 7 with those in Figs. 3 and 6.

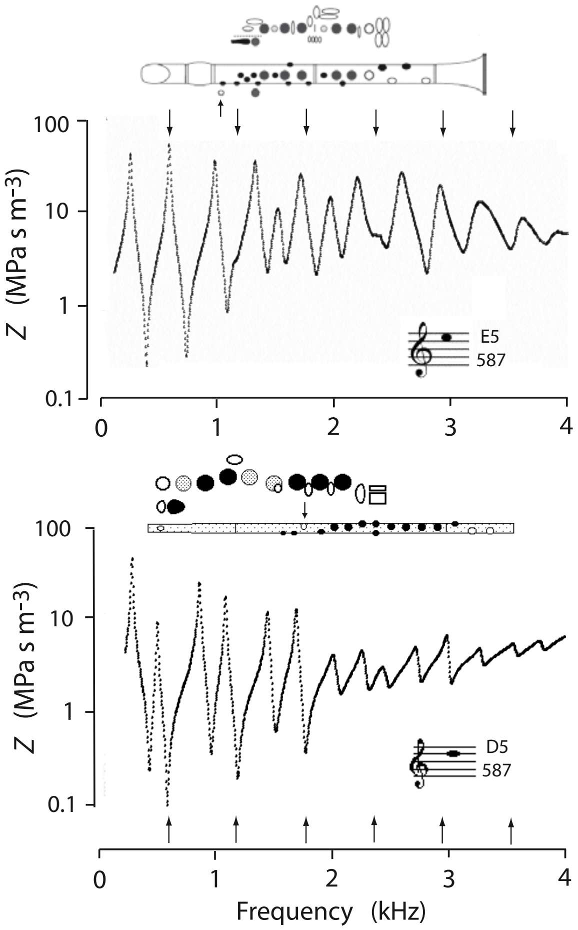

Figure 7. The magnitude of the measured impedance curves for the clarinet (upper) and flute (lower) for the fingerings used to play the note D5, whose spectra are shown in Fig. 1. The fingerings used are indicated by the schematics above each spectrum. The vertical arrows on the spectra indicate the harmonics of the note played. The arrows on the instrument schematics show holes opened to act as register holes, whose function is to weaken the lowest resonance(s), as is evident in the impedance spectra. (D5 is called E5 on the clarinet, a transposing instrument.)

It is tempting to extend this discussion to consider further subtleties of the acoustics of the clarinet. However, these are mainly of interest to clarinet players and researchers. So we have added such discussions to each of the pages in the clarinet acoustics database reported here. (Similarly, such comments appear on each page of the flute acoustics database.) Sound files are also provided.

We return, however, to the question posed by Fig. 1, to which the answer is printed below. Can one, in general, tell a clarinet from a flute simply from looking at the sound spectrum of a sustained note? Sometimes this is possible: in the Western classical and romantic tradition, clarinets are played without vibrato, while flutes are often played with considerable vibrato. In such cases, this difference may be distinguished by the width of the spectral peaks produced by the harmonics. Further, depending on the style of playing and the level of background noise, it may be possible to see, in the spectrum, the broad band noise associated with the jet of the flute, as is the case here.

In the notes of the lowest register of the clarinet (including, of course, the lowest note – Figs. 4 and 5), at least a few harmonics fall below the cut off frequency. Further, the presence of the bell produces only weak frequency dependence of the effective length. Consequently, for the first few harmonics at least, the clarinet's sound spectrum exhibits even harmonics that are weaker than their neighbours. However, this does not extend beyond the second resonance.

Further, one cannot, in general, rely on the spectral envelope, even at low frequencies. In Fig. 7, vertical arrows indicate the harmonics of the played notes. The fundamental of the clarinet note is largely determined by the frequency of the first impedance peak. The next few higher harmonics do not systematically coincide with impedance peaks and so do not systematically benefit from the impedance matching. Their relative amplitudes depend, in part, on the nonlinearity of the reed vibration and thus to some extent on how loudly the instrument is played. At high frequencies, the bell is acting as an efficient radiator of all frequencies.

For the flute, which has a higher cutoff frequency, the first three harmonics all fall close to impedance minima. At higher frequencies, one might argue that there is little need for an impedance matcher, as the impedance of the radiation field doubles with each octave in frequency. So, again, the sound spectrum depends in part on nonlinearities in the behaviour of the jet.

Many further examples are given in the database, which is at www.phys.unsw.edu.au/music/clarinet

ANSWER TO THE INTRODUCTORY QUESTION

The clarinet is the lower spectrum

ACKNOWLEDGMENTS

We thank the Australian Research Council for support, Yamaha Australia for supplying the clarinets, The Woodwind Group for supplying the flute, John Tann and Catherine Young for assistance and John Coltman for helpful suggestions on an earlier version of this manuscript.

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ICA 2010

This is the sixth in a series of regular items in the lead up to ICA in Sydney in 2010.

ICA 2007

Madrid 2 -7 September 2007

ACOUSTICS FOR THE 21ST CENTURY

The 2007 International Congress on Acoustics (ICA) is to be held in Madrid 2-7 September. This Congress will be held at the Municipal Congress Centre of Madrid (Palacio Municipal de Congresos) which is an iconic building, located at the "Campo de las Naciones", a new exhibition and financial area in the city of Madrid. The feature of an ICA that distinguishes it from other international conferences is that it is a true congress with technical sessions on all topics in acoustics. The topics include Bioacoustics, Computational Acoustics, Electro-acoustics and Audio Engineering, Environmental Acoustics, Musical Acoustics, Noise, Non-linear Acoustics, Physical Acoustics, Physiological Acoustics, Psychological Acoustics, Room and Building Acoustics, Speech and Communication Acoustics, Structural Acoustics and Vibration, Ultrasonics and Underwater Acoustics.

The plenary and distinguished lectures are specially selected to provide the opportunity for all participants to learn about recent advances in the range of topics. Thus the registrants have the opportunity broadening their knowledge in acoustics by learning about other fields as well as participating in the technical sessions in their particular field.

Attendance at ICA 2007 offers a great opportunity to blend your interest in acoustics with an opportunity to visit the exciting and historic city of Madrid and travel in Spain and Europe. Information on the conference is available from www.ica2007madrid.org

SYMPOSIUM ON MUSICAL ACOUSTICS ISMA2007

Barcelona 9 to 12 September 2007

ISMA 2007 to be held in Barcelona will be organized by the Department of Mechanical Engineering of the Universitat Politécnica de Catalunya; Sociedad Española de Acústica, SEA; Instituto de Acústica, CSIC, IA. Information from www.isma2007.org

SYMPOSIUM ON ROOM ACOUSTICS ISRA 2007

Sevilla 9 to 12 September 2007

ISRA2007 will be organized by the Instituto Universitario de Ciencias de la Construcción, IUCC; Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, ETSAS; Sociedad Española de Acústica, SEA; Instituto de Acústica, CSIC, IA. Information from: www.isra2007.org

This is the sixth in a series of regular items in the lead up to ICA in Sydney in 2010.

AAS News

Termites get the vibe on what tastes good

Researchers from CSIRO and UNSW@ ADFA have shown that termites can tell what sort of material their food is made of, without having to actually touch it. The findings may lead to improvements in the control of feeding termites. By offering them a choice between normal wooden blocks and specially designed blocks made of wood and other materials, the researchers found that the termites always preferred the blocks containing the most wood – even though they could not touch or see the other materials. The results are published in the Journal of the Royal Society Interface ("Termites live in a material world: exploration of their ability to differentiate between food sources" by Mr Ra Inta, Professor JCS Lai, Mr EW Fu and Dr T Evans (doi: 10.1098/rsif.2007.0223)).

Ra Inta, from UNSW@ADFA and CSIRO Entomology, says the ability to differentiate between food sources is based on the vibrations of the food that the termites are eating, although the exact mechanism for this ability is yet to be explored. "Scientists have known for some time that termites are receptive to vibrations," Ra says. "But these results demonstrate that termites' methods of food assessment are much more sophisticated that previously thought. "When offered a choice between blocks of their normal wooden food, and specially engineered blocks made of wood and other materials, they could tell when there was another material attached and always chose the blocks that contained the most wood."

The researchers are designing further experiments to test termites' assessment methods in an attempt to determine precisely what aspect of the vibrations termites are responding to in assessing food. "If we understand how they use vibrations to assess their food, we might be able to exploit this to manipulate their feeding habits, and address the very significant problem of termite damage in buildings and other structures," Ra says.

This research is a partnership between CSIRO and the University of New South Wales and is funded as an Australian Research Council Discovery project. http://www.scienceimage.csiro.au/mediarealease/mr07-termites.html

Acoustics Education program underway

The lack of suitable opportunities for education in acoustics was identified as a major problem for the acoustic consulting firms. The AAS and the AAAC have cooperated to support the establishment of a program based on the Diploma in Acoustics managed by the UK Inst of Acoustics (IOA). The essential criteria was that it must be able to be undertaken fully in distance mode. Following negotiations with the IOA, the program material for the first module, General Principles of Acoustics has been received. This material has required considerable updating in addition to referring to Australian standards. The IOA has provided the test and assignments for the first offering of the module to ensure maintenance of standards.

This first module is now available via the Short Course program of the University of New South Wales at the Australian Defence Force Academy. The registrants come from all states of Australia. The next stage will be to provide additional modules covering community and occupational noise, building acoustics, vibration, legal aspects etc based on the IOA program but further updated to meet Australian requirements. In the longer term the necessary steps will be taken to ensure that successful completion of these units will be considered for advanced standing for students seeking to undertake a formal post graduate University course. Anyone interested should contact avunit@adfa.edu.au for more information.

New phone number for Davidson Measurement

Davidson Measurement to have one telephone number Australia wide. 1-300-SENSOR (736-767). The old Melbourne office number (will be disconnected soon, so please update your records.

NEW Products

DecorBond: Experience flat clean lines with the latest in aluminium composite internal acoustic panelling.

Available in any colour, it is rigid and able to be formed into many shapes to suit any design requirement. This lightweight panel is produced under stringent manufacturing processes thus protecting Decor Systems long-standing reputation for quality and optimum performance. DecorBond is available with short lead times, in any colour, with no minimum quantity, at a very competitive price.

Product features: Can be slotted or perforated in range of modules, Versatile and flexible, Short lead times, Available in any custom colour, Lightweight, Ultra long-life coating technology, Impact resistant acoustic panel, Can be folded 90° without flaking

for more information on Décor Systems p: +61 2 9748 1800

Barn Owl Update

SoundScience is pleased to announce Version 4 of its award winning BarnOwl system is now available. This new software version includes some product enhancements and also now uses Sinus Soundbook technology (which incorporates a Panasonic Toughbook) enabling BarnOwl to operate without mains power. First used by BHPBilliton in 2002, to provide real time fully directional noise monitoring this important new development means BarnOwl is now based on a highly portable and well proven off-the-shelf hardware solution.

For customers requiring permanent systems, with appropriate solar panels and batteries, the unit will now be able to operate continuously in a remote environment. More importantly for customers needing a mobile system i.e. regulatory authorities, acoustic consultants or clients using it more as a diagnostic tool the system can operate for several hours on the battery and is now extremely lightweight and portable.

For heavy industry such as mines, quarries or industrial facilities BarnOwl will allow you to differentiate multiple noise sources from any direction and unambiguously determine the noise contribution from each source.

To take advantage of BarnOwl's new portable solution we will make the Soundbook version available for daily hire for $400 excl GST. However, for an introductory period it will be available first time to each user for $200 per day excl GST.

If you would like to find out more about the system features and benefits, and information about some of our existing customers, then please follow this link to our website www.soundscience.com.au or call Neil Gross to discuss your needs.

Phone: +61 2 8116 6118.
Fax: +61 2 9437 4393
email: neilg@soundscience.com.au.
Internet: www.soundscience.com.au

Future Meetings

ICSV 14 incorporating AAS Annual Conference

9-12 July 2007, Cairns

The 14th International Congress on Sound and Vibration (ICSV14), sponsored by the International Institute of Acoustics and Vibration (IIAV) and the Australian Acoustical Society (AAS), will be held at the Cairns Convention Centre in Cairns, Australia, 9-12 July, 2007. The key note papers will be presented by

Professor Jeremy Astley, ISVR, University of Southampton, UK, 'Predicting and reducing aircraft noise'

Professor Ilene Busch-Vishniac, Johns Hopkins University, US, 'The challenges of noise control in hospitals'

Associate Professor Svante Finnveden, MWL, Royal Institute of Technology, Sweden, 'Two observations on the wave approach to SEA'

Professor Colin Hansen, The University of Adelaide, Australia, 'Optimisation of active and semi-active noise and vibration systems'

Professor Jeong-Guon Ih, Korea Advanced Institute of Science and Technology (KAIST), Korea, 'Acoustic holography based on the inverse-BEM for the source identification of machinery noise'

Associate Professor Kimihiro Sakagami, Kobe University, Japan, 'Recent developments in applications of microperforated panel absorbers'

Professor David Thompson, ISVR, University of Southampton, UK, 'But are the trains getting any quieter?'

The details of the technical program with contributed papers and structured sessions will be available from the web page. The exhibition and the social program will complement the technical program to provide an excellent conference.

For further information on the conference go to http://www.icsv14.com/

19th ICA, Madrid

2-7 September

The 19th International Congress on Acoustics is organized under the auspices of the International Commission for Acoustics, ICA. The Congress Program will consist in the presentation of Plenary Lectures, Invited Papers and Contributed Papers in Structured Sessions. The unique feature of an ICA congress is that it comprises sessions on all aspects of acoustics. The extensive range of fields can be seen from the ICA web page, www.ica2007madrid.org.

The Congress will be held at the Municipal Congress Centre of Madrid (Palacio Municipal de Congresos). This is an iconic building, located at the “Campo de las Naciones”, a new exhibition and financial area in the city of Madrid. It is very easily accessed both from the city centre and the Barajas International Airport.

During the week of the ICA 2007 MADRID an International Technical Exhibition of Products and Services in Acoustics EXPOACÚSTICA® 2007 will be held. The participation of the most prestigious companies in the field is expected.

ISMA 2007, Symposium on Musical Acoustics will be held in Barcelona from 9 - 12th September 2007. This will be organized by the Department of Mechanical Engineering of the Universitat Politécnica de Catalunya; Sociedad Española de Acústica, SEA; Instituto de Acústica, CSIC, IA. Details from www.isma2007.org

ISRA 2007 Symposium on Room Acoustics will be held in Sevilla from 9 - 12th September 2007. This will be organized by the Instituto Universitario de Ciencias de la Construcción, IUCC; Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, ETSAS; Sociedad Española de Acústica, SEA; Instituto de Acústica, CSIC, IA. Details from: www.isra2007.org

INTER-NOISE 2007, Istanbul

28-31 August

Inter-noise 2007 will be held at the Convention and Exhibition Centre in Istanbul. From the centre there is convenient access to the scenic and historic aspects of Turkey. The city may be even more lively than usual as the Turkey Grand Prix will be in Istanbul on the preceding weekend.

The theme of Inter-Noise 2007 Congress is "Global Approaches to Noise Control" and papers of specific relevance to this theme are especially encouraged. Technical papers in all areas of noise control may be submitted for inclusion in the technical program. Special structured sessions covering a wide range of relevant topics are being organized. Three plenary lectures will be presented and there will be a technical exhibition during the time of the conference. The social program will include opportunities for viewing some of the sights of Istanbul.

More details from www.internoise2007.org.tr/

VibroAcoustics Optimisation, Ontario

August

For those interested in the application of industrial strength optimisation in vibro-acoustic applications, Rick Morgans from Adelaide Uni is organising a Mini-Symposium on "Optimisation in Vibro-Acoustics". This will discuss the implementation of different optimisation methods to various practical applications in vibrations and acoustics. The symposium would be part of the "Engineering Optimisation" stream in ICCOPT II, Second Mathematical Programming Society International Conference on Continuous Optimization, http://iccopt-mopta.mcmaster.ca/index.html. The main congress is organised by Natalia Alexandrov from NASA Langley and will take place in August 2007 in Ontario, Canada. For more information on the optimisation symposium contact Rick on rmorgans@mecheng.adelaide.edu.au.

Wind Turbine Noise 2007, Lyon, France 20 - 21 September 2007

A reminder that the final date for submission of Abstracts for WTN2007 is approaching. If you think you may be able to present a paper, please see http://www.windturbinenoise2007.org/ for further information.

AUSTRALIAN ACOUSTICAL SOCIETY

EDUCATION GRANT 2007

The AAS Education Grant is awarded annually to promote research and education in acoustics in Australia.

The total grant of $15,000 may be split between several projects.

Submissions close on 31 July 2007. Details are available from: www.acoustics.asn.edu

Standards Australia

Moves

Following an extensive appraisal of alternative office premises, Standards Australia has entered a long term lease at Exchange Centre, 20 Bridge Street, Sydney. This contemporary building, which is located on the corner of Bridge and Pitt Streets, is the home of the Australian Securities Exchange (ASX).

This relocation provides a further opportunity for Standards Australia to position ourselves independently from our former subsidiary, SAI Global. This move represents a significant event in Standards Australia"s long history and it is an important and exciting step towards a robust and invigorated Standards Australia. From Standards Australia enews March 2007.

New Standards

A number of standards relating to audiometric equipment and hearing aids have been released.

AS ISO 389.1-2007 Acoustics - Reference zero for the calibration of audiometric equipment - Reference equivalent threshold sound pressure levels for pure tones and supra-aural earphones

AS ISO 389.2-2007 Acoustics - Reference zero for the calibration of audiometric equipment - Reference equivalent threshold sound pressure levels for pure tones and insert earphones

AS ISO 389.3-2007 Acoustics - Reference zero for the calibration of audiometric equipment - Reference equivalent threshold force levels for pure tones and bone vibrators

AS 60118.0-2007 Hearing aids - Measurement of electroacoustical characteristics

AS 60118.1-2007 Hearing aids - Hearing aids with induction pick-up coil input

AS 60118.12-2007 Hearing aids - Dimensions of electrical connector systems

AS 60118.14-2007 Hearing aids - Specification of a digital interface device

AS 60118.2-2007 Hearing aids - Hearing aids with automatic gain control circuits

AS 60118.4-2007 Hearing aids - Magnetic field strength in audio-frequency induction loops for hearing aid purposes

AS 60118.6-2007 Hearing aids - Characteristics of electrical input circuits for hearing aids

AS 60118.7-2007 Hearing aids - Measurement of the performance characteristics of hearing aids for production,supply and delivery quality assurance purposes

AS 60118.8-2007 Hearing aids - Methods of measurement of performance characteristics of hearing aids under simulated in situ working conditions

AS 60118.9-2007 Hearing aids - Methods of measurement of characteristics of hearing aids with bone vibrator output

Meetings Reports

Victorian Division

The meeting on apr-06 was a combined meeting with the ANCE held at Sinclair Knight Merz, Armadale at which Stephen Spicer, BEE [hons] and formerly of Telstra Research Laboratories, spoke on, and gave audio demonstrations of Sound Reproduction: an historical perspective. There were 22 present.

The first group of recorded examples covered the period from Edison's 1877 tin foil phonograph using an acoustical horn process to produce a "hill and dale" groove on a cylinder rotating at 60 rev/min, through Frank Lambert's 1878 recording on lead [the oldest playable audio], Edison's 90 rev/min wax cylinders, Berliner's 1897 disks with lateral cut grooves, de Forest's 1922 recording on film, to the first electrical recordings of 1925, Harry Olson's 1929 RCA PB90 ribbon microphone, and the 1931 Bell Labs' stereo recording experiments by Leopold Stokowski and Harvey Fletcher on vinyl [not shellac] disks.

The second group of recorded examples began with an acoustic replay of an electric 78 rev/min recording [thus retaining the 'acoustic' sound], an electrical recording used by the BBC for test purposes, the 1930s early tests with magnetic recording on steel wire [the Blattnerphone], the BASF Fe2O3 on tape and the 1945 German Fe2O3 on polyester tape, the multi-track recording and "surround sound" for the 1940 Stokowski/Disney film, Fantasia, the H J Leak [1945] and D T N Williamson [1947] high fidelity valve amplifiers using push-pull output triodes [KT66s] with 26 or 20 dB of negative feedback, and the high quality Tannoy loudspeakers.

It continued with examples of the 1945 direct-to-disk Capitol recordings and 1949 Ampex tapes [both with good, but perhaps too obvious high frequency response], the first long-playing 33,3 and 45 rev/min vinyl disks of 1949, the 1950s change from RCA ribbon to Neumann capacitor ["condenser"] microphones, the RCA "living stereo" on tape [1954] and disk [1958], the 1963 Philips compact cassette, the introduction in c. 1970 of the Dolby frequency compensation response, further direct-to-disk recordings from 1968 through the 1970s, and concluding with the introduction in 1983 of DDD compact disk recordings. He also discussed and demonstrated several types of audio masking effects, some of which have been recently applied in MP3 players to minimize background noise.

At the end of the meeting, Norm Broner thanked Stephen Spicer for a most interesting talk and demonstration, carried with applause.

The technical meeting held on jun-06, at which 14 were present, was an ANCE meeting to which AAS members were invited, and was an information night at the Eastlink Display Centre, Brandon Park. The speakers, Bruno Aleksic and Liz Iser, described, by means of maps and numerous illustrations, the main features of the 40km long Eastlink Tollway from Mitcham to Frankston --- currently being built at an average cost of 62 million $/km. Of acoustical interest was that the design of noise barrier walls would be such that in noise-sensitive areas such as residential areas, vehicle noise would be limited to a maximum of $L_{10.18h}$ = 63dB(A). At the close, John Upton thanked the speakers on behalf of all present.

SYMPOSIUM :
New Uniform Expert Evidence Rules (NSW) 2006

The Faculty of Law, University of Sydney and Expert Witness Institute of Australia presented a Symposium: ”New Uniform Expert Evidence Rules (NSW) 2006”, which was opened by Professor Ron McCallum AO, Dean, Faculty of Law. Keynote speaker was The Honourable Justice Peter McClellan, and Panel Chair: The Honourable James Wood AO QC

The Symposium discussed the operation of the new Uniform Civil Procedure Rules of Court in relation to expert evidence that implement recommendations of the NSW Law Reform Commission’s Report 109 on Expert Witnesses and the report of the NSW Attorney General’s Working Party on Civil Procedure

The new Rules are detailed in “Uniform Civil Procedure Rules (Amendment No. 12), 2006 under the Civil Procedure Act 2005 (NSW). The Uniform Rules Committee made these Rules of Court on 4 December 2006, which replace the existing rules concerning the appointment and engagement of expert witnesses and replace the existing code of conduct for expert witnesses.

The narrow traditional use of scientific evidence in litigation was applied to such as ballistics, finger printing and blood analysis. With the proliferation and evolution of new science, applied science, technical endeavour, and a wide range of specialised matters, there are increased possibilities for expert opinion. The CCH Subscription Service for Expert Evidence by Dr. Ian Freckelton and Mr Hugh Selby, now in six volumes, illustrates this expansion. Of interest to acousticians is Ch. 114 of the series, "Noise Analysis", by Barry Murray.

The involvement of expert witnesses is becoming increasingly important for all types of cases. For many of our membership who frequently present opinion evidence in acoustics and related matters, and others, you are advised of a four day intensive course in expert evidence to be offered by the University of Sydney Law School's Legal Professional Development Program on August 3, 4, 6, & 7 from 9.00 - 5.00 pm. It is possible to enrol on an "Attendance Only" basis. The course will be conducted by Professor Ian Freckelton, who is author together with Mr. Hugh Selby, "Expert Evidence: Law Practice, Procedure & Advocacy", 3rd Edition, 2005. Limited spaces are available for this course. Further details of course coverage can be obtained from Val Carey, Sydney Law School, Phone: (61-2) 9351 0238, email: v.carey@usyd.edu.au OR check website: http://www.law.usyd.edu.au/CLE/

Donald Woolford MAAS

FASTS

ABS Codes revision

FASTS successfully lobbied for a revision of the ABS codes for R&D (currently called the Australian Standard Research Classification – ASRC). DEST are funding the project and FASTS is represented on the reference group alongside CSIRO, NZ Stats, ARC and AVCC. The intent is to try and maintain the 2 and 4 digit codes in their current form, where possible, to ensure reasonably robust longitudinal data. However, there is scope for non-trivial, pragmatic revision of 6 digit codes including new codes for emerging fields and deletion of existing codes that attract little investment.

Over recent years, on behalf of the Australian Acoustical Society, Colin Hansen has sought the inclusion of codes specifically related to acoustics. This would make it possible to more effectively track the value of acoustics related research. This would also enhance the reputation of acoustics as a field of study. The AAS will take this opportunity to again seek inclusion of appropriate codes.

Science and gender

A media release from Melbourne Uni on 9 January 2007 (http://uninews.unimelb.edu.au/articleid_3965.html) states from a new study that women scientists produce higher quality work, but men produce more early in their careers. An international study led by the University of Melbourne reveals that, while female scientists produce better quality science, they are less productive early in their careers, and thus have to play catch-up to their male counterparts. The study, conducted by Dr Matthew Symonds from the Department of Zoology at the University of Melbourne with colleagues from Australia and New Zealand followed 168 biologists from British and Australian universities, all of whose careers began in the early 1990s. Results showed that the men in the study published 40 percent more papers than women, but that women's work is cited relatively more often by other scientists, a key indicator of quality. The study also revealed that the differences in male and female productivity arise surprisingly early in their careers. "Why men publish more papers than women, known as the "Productivity Puzzle" has long been debated, "said Dr Symonds. "There is not one obvious explanatory factor, but we now have a better idea of when key problems for women arise," he said.

Science in mainstream media?

The Australian Science media centre have distributed a report from media monitors comparing the coverage of scientific research and policy in the 3 month period ending October 2006 with the corresponding period in 2005. The report only uses 12 key words such as water, climate change, cloning, stem cells but does show a significant overall jump from 3,800 items for the key words in 2005 to 10,300 items in 2006. Water increased from 124 to 2076 articles, climate from 561 to 1939 and nuclear 395 to 1157. Bird flu, on the other hand, fell from 1534 to 230. In terms of 'market share' bird flu dropped from a staggering 40.3% to 2.2% whereas in 2006 the main areas were cloning 22.2%, stem cell research 21.8%, water resources, 20.2% and climate 18.7%. FASTS Executive Director comments that " I wouldn't want to over determine any of this but a couple of observations: The increase in volume highlight that odd space we are in at the moment whereby science is completely pervasive but remains – in a policy sense - almost invisible, and it is the politics that drives stories not the intrinsic importance or interest of the science per se."

More info can be found at http://www.aussmc.org/A_recent_snapshot.php

RQF Panels

As part of the process to assess the quality and impact of research in Australia the Australian Government is proceeding with the Research Quality Framework (RQF). Within the University sectors there is considerable concern about the value of this process and it has been high on the agenda for FASTS actions. However the process is continuing and recently the government announced the chairs of the 13 Assessment Panels. The subject areas of these panels are based on the RFCD codes. FASTS has advised of the call for nominations for membership of each panel and encouraged each Society to pursue this with their members. The AAS Council has followed up and encouraged members who may have the requirements for these panels to consider nominating. It will be most valuable for the future of acoustics in Australia to have a member on the relevant panels.

Book Reviews

Worship, Acoustics and Architecture

Ettore Cirillo and Francesco Martellota

Multi-Science Publishing 2006, 218 pp soft cover ISBN 0 906522 44 7. List price £32.50

Churches and places of worship have always had a fundamental importance in our social life because, although they are specifically designed for prayer, they are frequently used for different purposes including speeches and instrumental and choral music. As the acoustics of theatre and concert halls had been investigated in great detail, the authors were induced to investigate the complex relationship between music, worship, architecture and acoustics in places of worship. This book reviews the history of church architectural development and the associated acoustic perspective.

The book includes the review of 34 Italian churches spanning from Early-Christian to Contemporary. The Contemporary churches have been given great considerations because of the dramatic change in the acoustic conditions required by the Second Vatican Council with the introduction of the use of common language and the call for community participation. The renovated role of spoken word implied the need for good speech intelligibility, a requirement that must be taken into account from the beginning of the design process.

The book is organised into five chapters: The first introduces the complex relationships between music and architecture. The second briefly summarises the evolution of the Christian liturgy and its implications in architectural and acoustic terms. The third presents an outline of the evolution of the sacred music. The fourth illustrates the subjective and objective criteria used to assess performance of a space. The fifth chapter presents the results of the survey of the 34 churches using up to date techniques in agreement with current international standards.

It is an attractive book and whets the appetite to undertake a hand clapping study tour of similar facilities around the world. Although it is not very applicable to every day consulting work, it an interesting foray into the detail of architecture meets acoustic works of the past.

Gillian Adams is a Director and Senior Engineer in acoustics at ASK Consulting Engineers. She has provided acoustic design advice for a number of places of worship including St Stephens Cathedral and Francis Rush Building in Brisbane.

Spaces Speak, Are You Listening? Experiencing Aural Architecture

Barry Blesser and Linda-Ruth Salter

The MIT Press, Cambridge Mass., 2007, 437pp, hard cover: ISBN-13: 978-0-262-02605-5; ISBN-10: 0-262-02605-8, approx A$67

Barry Blesser is a former professor at MIT and has been heavily involved in the establishment of digital radio. For the past 40 years he has worked at the junction of acoustics, auditory perception, and cognitive psychology. Linda-Ruth Salter is an independent scholar with interests in the interdisciplinary relationships among art, space, culture and technology. She and Barry Blesser are married and worked on this book together.

The general theme of the book is explained as being "aural architecture", which relates to human perception of sound and the message it conveys in diverse surroundings ranging from caves through cathedrals and concert halls to cafes and sports arenas. This is rather different from the usual concerns of architects and acousticians, and leads to a book that is very different as well. It provides a general "discourse" covering all these areas in considerable detail and avoids becoming technical about any of them except in the sense used by art critics and scholars in the humanities. It is, however, an easy book to read and makes one think about the topic in a slightly different manner from usual.

After a short introduction to aural architecture, the book moves on to discuss auditory spatial awareness, the ability of many blind people to find their way around using auditory cues, and the fact that all of us can detect much about our surroundings from listening to incidental background noise. We can sense the opening to a cave, the fact that we have entered a cathedral, or even an open door without using our eyes. These sensual experiences – the spaces "speaking" – probably influenced neolithic cave painters as well as later priests of many religions because they felt that somehow they were hearing "the voice of God" in these sacred places. There are also many symbolic sounds such as bells or gongs that the authors call "earcons" by analogy with visual "icons"! Another interesting idea is the "acoustic arena", which is the area surrounding each individual inside which they can communicate with other individuals and whose space they somehow own, so that they resent intrusion. The third chapter of the book, "Aural spaces from prehistory to the present", examines all these matters in their historical settings, including discussion of some famous venues ranging from Roman arenas to Boston Symphony Hall. The discussion is once again in very general terms with the emphasis being on audience perceptions.

Two chapters then deal specifically with musical performance spaces, with specific reference to "new conceptualizations" involving "meta-" and "proto-instruments", terms that I have not really absorbed the meaning of! There is then a long chapter on "Scientific perspectives on spatial acoustics", which I did not find very illuminating, since it substituted rhetoric for quantitative statements. The two final chapters are on "Spatial innovators and their private agendas" and "Auditory spatial awareness as evolutionary artifact" – these titles give the general flavour and the content ranges from biology and evolution to politics and business. The book concludes with 36 pages of references and a detailed index filling another 33 pages.

All in all this is a well written book and a pleasant read, but I felt it could have been condensed into a much shorter span with advantage. It is clearly designed to be read by non-technical people, or perhaps by cognitive psychologists, rather than by those with a background in science and in acoustics in particular. It will also convey a valuable message to any architects who read it. If you come across the book in the library, I recommend Chapter 3 – the historical one – as well worth your attention.

Neville Fletcher

Neville Fletcher is Visiting Fellow in the Research School of Physical Sciences of the Australian National University. He has written widely on many aspects of acoustics.

Predicting Outdoor Sound

Keith Attenborough, Kai Ming Li and Kirill Horoshenkov

Taylor and Francis, 15/11/2006, 456 Pages (Hard Cover); 100 line illustrations, 6 black and white photos, 20 tables

List Price: £75.00 www.tandfbuiltenvironment.com

ISBN: 9780419235101

ISBN-10: 0419235108

Predicting outdoor sound or noise levels for major projects over long distances is probably one of the most complex tasks that the acoustical consultant need to carry out. This is because of the many variables that are required to be taken into account. There is, of course, a variety of software programs which carry out the complex calculations and provide noise contour maps. However relying on software programs without a true understanding of the subject is precarious. This book provides a practical yet mathematically rigorous reference for acoustical consultants, engineers and academics.

There are many technical articles but few textbooks that offer guidance in the field of noise propagation and prediction. This book offers a comprehensive reference about outdoor sound by critically comparing old and new mathematical theories with field measurement data. It then provides a basis for deciding which model or scheme to use in a given situation. Both numerical and empirical methods for predicting the various influences on outdoor sound are provided.

Topics include ground impedance models and data, methods of measuring ground impedance, ground effects in homogeneous atmospheres, sound propagation in refracting and turbulent atmospheres, sound propagation from moving sources, the performance of outdoor noise barriers and the effects of tall vegetation.

One chapter is devoted to a critic of the sound propagation prediction schemes commonly use in Australia such as those given in ISO9613-2, Concawe, CTRN, CRN, NORD200 and HARMONOISE. The final chapter cover predicting sound in the urban environment including noise propagation tunnels, acoustic effect of a single building faced with balconies and sound propagation in street.

'Predicting Outdoor Sound' is an essential read for the acoustical consultant or researcher who needs to gain an appreciation of sound propagation over long distances.

Ken Scannell

Ken Scannell is a Partner and Senior Consultant with Noise and Sound Services, Sydney. Ken holds a Masters Degree in Environmental Acoustics and has over 25 years experience within the acoustics profession.

The effects of low-frequency noise and vibration on people

Editor Colin Hansen

Multi-Science Publishing Co Ltd, 2007, 416pp, soft cover, ISBN 0906522 45 5, approx cost hard cover A$136

Low frequency noise and vibration on people is of concern to people who experience the effects and for authorities charged with the responsibility for establishing acceptable criteria limits. While many books on environmental noise will include some reference to low frequency sounds, this topic is not dealt with to any great depth and there is no clear statement of guidelines. There are a number of research groups throughout the world that are actively researching the effects of low frequency noise and vibration. Their findings are published in various research journals. This book brings together in one volume over thirty papers on this topic that have been published over the period 2000 to 2005 in the Journal of Low Frequency Noise and Vibration and Active Control.

Its important to realise that this is not intended to be a text book or a handbook on the topic but is a compendium of research papers. Consequently the contents is a listing of the titles of the papers and there is no index to the book as a whole. The editor has provided some structure by grouping the papers under five chapters:

- Perception thresholds for low frequency noise – 4 papers
- Effect of low frequency noise on people in terms of annoyance and sleep deprivation – 16 papers
- Physiological effects of low frequency noise - 7 papers
- Perception thresholds for low frequency vibration and the effect of low frequency vibration on people in terms of comfort and annoyance – 2 papers
- Physiological and health effects of low frequency vibration –3 papers

Each chapter commences with one or more pages with a listing of the paper headings, authors and 3 or 4 sentences extracted from the abstract for that paper. This also helps the reader to decide which papers are of most interest. Each paper is well written with an appropriate reference listing. They have all gone through a review process for the journal publication and some have been further revised prior to inclusion in this book.

While this book does not include new material as such, it clearly represents a valuable contribution to the knowledge in this area as it brings together relevant and related papers. Thus the book will provide an essential reference for researchers investigating this topic and for new researchers entering this field. It will also provide a valuable reference for anyone seeking to gain an understanding of the field or seeking background knowledge on the area as a whole. But a reader seeking guidance on what are suitable criteria may not find the answers in this book. This highlights that the topic area is still a multidisciplinary research field.

Marion Burgess

Marion Burgess is a research officer at the Acoustics and Vibration Unit of the University of NSW at the Australian Defence Force Academy.

Diary

2007

16 - 20 May, Honolulu,
IEEE Int Conf on Acoustics, Speech & Signal Processing (IEEE ICASSP 2007)
www.icassp2007.org

03 - 07 June, Bologna
11th Int Conf on Hand-Arm Vibration.
www.sociazioneitalianadiacustica.it/HAV2007/index.htm

18 - 21 June, Aberdeen
Oceans07 Conf.
www.oceans07ieeeaberdeen.org

25 - 29 June, Heraklion
2nd Int Conf Underwater Acoustic Measurements: Technologies and Results.
www.uam2007.gr

3 - 5 July, Lille
First European Forum on Effective Solutions for Managing Occupational Noise Risks
www.noiseatwork.eu/default.html

9-12 July, Cairns
ICSV14 incorporating AAS Annual Conference
www.icsv14.com

August 2007, Ontario
Mini-conference on 'Optimisation in Vibro-Acoustics'
contact rmorgans@mecheng.adelaide.edu.au.

26 - 29 August, Istanbul
Inter-noise 2007.
http://www.internoise2007.org.tr

27-31 August, Antwerp
INTERSPEECH 2007.
conf@isca-speech.org

2-7 September, Madrid
ICA2007
www.ica2007madrid.org

9-12 September, Barcelona
Symposium on Musical Acoustics (ISMA2007)
www.ica2007madrid.org

9 - 12 September, Sevilla
Symposium on Room Acoustics
www.ica2007madrid.org

17-19 September, Lyon
Fan noise 2007
www.fannoise2007.org

28 - 31 October, New York
IEEE Int Ultrasonics Symposium.
www.ieee-uffc.org/ulmain.asp?page=symposia

2008

20 - 23rd May, Canberra
Audiological Society Australia Annual Conference
www.audiology.asn.au/

30 June - 4 July, Paris
Acoustis'08 Paris
http://www.acoustics08-Paris.org

07 - 10 July, Stockholm
ISNA18. 18th International Symposium on Nonlinear Acoustics
http://www.congrex.com/18th_isna/

28 July - 1 August, Mashantucket
ICBEN 9 Int Cong Noise as a Public Health Problem.
www.icben.org

22 - 26 September, Brisbane
INTERSPEECH 2008 - 10th Intl Conf on Spoken Language Processing (ICSLP)
www.interspeech2008.org

26 - 29 October, Shanghai
Internoise 2008
www.internoise2008.org

2009

6 - 10 September, Brighton
Interspeech 2009 Conference
www.interspeech2009.org

2010

23-27 August, Sydney
ICA2010
http://www.ica2010sydney.org/

Meeting dates can change so please ensure you read the www pages. Meeting Calendars are available on http://www.icacommission.org/calendar.html

New Members

Daniel Weston (NSW)
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Jessica Gouthro (Vic)
Phil West (Vic)
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Jackson Yu (Qld)
Benjamin Farrrell (WA)
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Saskia Gerlach (QLD)
Alexander Dundon (SA)
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Hugo Waibel (NSW)
Rohan Barnes (vic)
Carolyn Decock (Qld)
Stuart Baker (NSW)

Student
David Steinfeld (Qld)
Bernard Hannemann (Qld)

Obituary

HENNING VON GIERKE

Those who work in the area of noise and its perception will be saddened to hear of the death of Henning Von Gierke on March 11. He had been battling emphysema for some time but still maintained an active involvement in acoustics. His work over more than five decades has covered the transmission, action, and human perception of all types of mechanical energy from infrasound, vibration, impact, and blast through the audio spectrum to ultrasound in air as well as in tissue. Just one of the many recognitions of his outstanding achievements has been the award of the Gold Medal of the Acoustical Society of America in 1999 and the citation on http://asa.aip.org/encomia/gold/vongierke.html provides a small summary of his achievements.

Marion Burgess

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* Proceedings of annual conferences

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AAS - Queensland Division
PO Box 760
Spring Hill Qld 4004
Sec: Richard Devereux
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rdevereux@acran.com.au

AAS - SA Division
Department of Mech Eng
University of Adelaide
SOUTH AUSTRALIA 5005
Sec: Anthony Zander
Tel: (08) 8303 5461
Fax: (08) 8303 4367
azander@mecheng.
adelaide.edu.au

AAS - Victoria Division
PO Box 417
Collins St. West
PO MELBOURNE 8007
Sec: Jim Antonopoulos
Tel (03) 9526 8450
Fax (03) 9526 8472
jim.antonopoulos@
heggies.com.au

AAS–WA Division
Unit 3
2 Hardy Street,
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