Acoustical Research In Australia

Abstract: A brief review is given of Australian research and development work in a wide range of areas of acoustics. Areas covered include measurement and calibration, human hearing, biological acoustics, musical acoustics, ultrasonics, underwater acoustics, active noise and vibration control, mechanical vibration, building and industrial acoustics, and environmental acoustics.

From time to time it is appropriate to stand back and look at the range of acoustic activity that is going on around Australia. One reason for this is that each of us tends to interact mostly with others in our own particular specialised field, so that we are comparatively ignorant of work in other areas. This is a pity, since techniques are often usefully transferred between apparently quite different areas of research, development and application. Another reason for such a survey is simply one of the interests of the profession. At a time when both science and technology are finding decreasing levels of government support, we all gain by publicising our successes and by showing others the breadth and scope of our activities.

In putting together this survey, the Editors have not attempted an exhaustive compilation of all acoustics-related activity in the country. Rather, we have invited specialists in a wide range of different areas to each write a brief commentary on the things that seem to them to be most interesting among current activities. In this way we hope to have provided a readable and interesting document that conveys the general flavour of acoustical activity in Australia.

There may be areas that have been omitted by falling through the cracks in this approach, and to those people we apologise in advance. Particular topics that have not been treated include Australian noise standards, architectural design, human auditory physiology, and psychoacoustics. We have also not attempted to give a comprehensive account of the widely varied activities undertaken by acoustical consultants. Perhaps we will return to these at another time.

1. MEASUREMENT AND CALIBRATION

Suszanne Thwaites
CSIRO Telecommunications and Industrial Physics
Lindfield, NSW

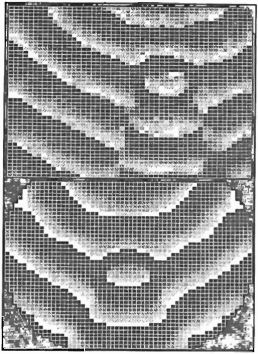
Australia's national standards of measurement are held at the National Measurement Laboratory (NML) in Sydney. NML is actually part of the CSIRO (Commonwealth Scientific and Industrial Research Organisation), a statutory body involved in all areas of scientific R & D and employing some 6000 people Australia wide. The roles of the NML and CSIRO in standards are defined in the National Measurement Act (1960) and essentially encompass the development and maintenance of world class primary standards of measurement and the dissemination of these into the measurement chain via a first level calibration service. At NML the Acoustics Project performs these roles in addition to an involvement with international standards committees and activities in the Asia Pacific region. However, as part of the CSIRO, the project also conducts research and development programs associated with the measurement of acoustic and vibration quantities in industry. In the following we look at these various functions, in the acoustics context, in turn.

Primary Standards

At the foundation of a national measurement system must be a primary, absolutely derived, standard. In acoustics this is achieved, world wide, by the maintenance of sets of three 1-inch capacitor microphones of an agreed design which are calibrated using the principle of coupler reciprocity as laid out in an International Standard (IEC 1094-1,2). At NML such a set is maintained although the implementation of coupler reciprocity is slightly different to the standard one (a 3-port coupler is used instead of a 2-port one) allowing equivalent volume corrections to be made automatically and also making the whole process amenable to automation. Our primary set was established in 1980 and has been calibrated over 700 times since then showing negligible drift over this time. The uncertainty at 95% confidence limits is 10.07 dB and the repeatability in the laboratory is within 0.02 dB.

Dissemination

Dissemination is the second responsibility devolved to NML under the National Measurement Act (see above). This is achieved in two ways; 1) operating a first level calibration service and 2) supporting the activities of the National Association of Testing Authorities (NATA) which accredits testing laboratories and services. As part of the accreditation process a laboratory's technical competence, organisational structure and the traceability of its instrument calibrations to NML are assessed. Frequently the technical assessor is an officer from NML. In addition NATA runs proficiency round robins for various tests, e.g. calibration of a sound level meter, by circulating an artefact amongst accredited laboratories. The NML acoustics group is usually the technical hub for these events and is coordinating a sound level meter round robin at the moment.



Phase map of sonic waves propagating across an aircraft composite panel with a delamination defect. The upper part of the figure shows experimental results. The vibration source is off the top of the figure (the origin of the circular wavefronts) and the defect is located near the centre of the panel. The lower part of the figure shows the results of a theoretical calculation. The size of the imaged section is about 20 cm.

Calibration Service

Any microphones can be calibrated by the acoustics project. If they are standard pattern microphones their absolute sensitivity is established in the 3-port coupler. Otherwise a closed coupler or free field comparison method is used. In a closed coupler a known sound field can be set up using a standard microphone and an insert volts technique. In a free field comparison a substitution method with a free field standard is used eliminating the need for a known sound field.

Frequency response may also be measured with these techniques although, for standard pattern microphones, electrostatic actuation is often a better approach. At low frequencies microphones are calibrated in a pressure and vibration isolation vessel which allows the back vent to be included in the sound field giving a true low frequency response. These techniques give an operating calibration frequency range extending from 10 mHz up to 100 kHz, depending on the microphone, but the usual range is 20 Hz to 20 kHz.

The range of other instruments commonly submitted for calibration includes pistonphones, calibrators, sound level meters, noise loggers and filter sets.

Setting Standards

Australian standards exist for most of the tests mentioned above. It is the general rule that Australian standards follow the international ones so that new or revised IEC standards are used as the basis for new or revised Australian ones. The development of these standards is followed with great interest since the compliance tests contained there-in have to be implemented at NML. In several cases the group has membership on the relevant IEC working group, as the Standards Australia (SA) representative; specifically TC29/WG 4 (calibrators) and 17 (sound level meters) and, beginning this year, 5 (microphones).

Asia-Pacific Metrology Program

The 22 member Asia-pacific Metrology Program (APMP) is a collaboration between national/territorial measurement laboratories in the region. Some of its main objectives are to

- Provide training, advice and consultancy to new laboratories.
- Develop objective technical evidence of measurement traceability and competence as a basis for multi-lateral recognition.
- Support the objectives of the Asia-Pacific Economic Cooperation (APEC).

The APMP is run by an elected regional coordinator and the secretariat is located at the coordinator's institute. For the term 1994-98 the secretariat is at NML. Funding comes from a number of sources including APEC, member governments, the United Nations and the World Bank.

Two activities in which the NML acoustics group is heavily involved are assessment of the needs of developing standards laboratories in the region and training at NML of officers from these laboratories. The group has hosted training visits from and visited groups in many south East Asian countries including Indonesia, Thailand, Philippines and Vietnam. Calibration intercomparisons between APMP members are on going, coordinated by various member institutions. Concomitant with these activities is the stepping up of the membership and development of APLAC, the Asia Pacific Laboratories Accreditation Cooperation, the regional equivalent of NATA. The NML acoustics group is coordinating a calibrator round robin for the APMP and a sound level meter intercomparison for APLAC.

Research and Development

R & D programs in the group vary from year to year. Recent and current activities include NDT of composite materials used in aerospace and marine applications. This, sizeable, project jointly run with Boeing Commercial Airplane Group, has investigated the use of low frequency lamb waves (< 35 kHz) to detect defects in honeycomb-cored composites.

Ultrasonic Transducers

This project worked towards a description of a novel, efficient, air coupled transducer developed at NML for use in gas flow metering. The transducer is air-coupled and operates in the 100 kHz range.

Microphone design

This work, undertaken for a successful small Australian company which manufactures and markets microphones of its own design, involved the development of a good model for the microphone with a view to making design changes in the interests of more efficient manufacture in Australia.

2. HUMAN HEARING

Denis Byrne
National Acoustic Laboratories
Chatswood NSW

Robert Cowan
CRC for Cochlear Implant, Speech & Hearing Research
Melbourne

In addition to physiological research, Australia has a strong record and extensive current programs of research into hearing prostheses. Primarily, this consists of hearing aid research, at the National Acoustic Laboratories (NAL), and research into cochlear implants, electrotactile and other aids at the Bionic Ear Institute, the University of Melbourne, and Cochlear Limited. Much of this work is now being conducted through the Cooperative Research Centre for Cochlear Implant, Speech and Hearing Research, in which the four above institutions are the major partners.

NAL's achievements include the development of prescriptive procedures for fitting hearing aids to suit individual hearing losses. The first procedure was published over 20 years ago and has been succeeded by numerous studies providing refinements, additions and validation data. A 1996 American publication states that the NAL procedure is "Probably the most well-known, widely used, and experimentally verified". The range of procedures includes prescriptions of gain, frequency response and maximum output as well as modifications for severe and profound hearing losses. Current research is extending procedures to the fitting of non-linear amplification and is optimising the design of non-linear hearing aids. It is also examining how amplification needs to be varied, either automatically or by the hearing aid wearer, to suit different acoustic conditions and listening preferences. Other forms of signal processing, for implementation in future digital hearing aids, are also being developed and evaluated. Another research program concerns the design and fitting of hearing aids to optimise auditory localization and possibly other abilities requiring binaural functioning. One aspect of this research has shown that the choice of earmould type, for coupling the hearing aid to the ear, can substantially affect the acoustic information available as cues for sound localization.

Current psychoacoustic research includes investigation of frequency and temporal resolution in hearing-impaired people and, especially, how speech recognition is related to signal audibility and hearing loss characteristics. This has suggested modifications to the Speech Intelligibility Index when using it to predict speech recognition by hearing-impaired listeners. This work has major implications for understanding the amplification requirements of people with severe hearing losses.

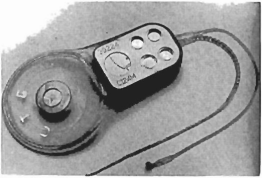
Other research has been concerned with the effects of noise on people and with hearing loss prevention. Currently, otoacoustic emissions are being studied extensively for various purposes which include the early detection of cochlear damage and, hence, a warning of the need for preventative measures. Otoacoustic data are being used to predict future trends in the prevalence of hearing loss in the community. The risk of damage from overamplification by hearing aids, through using "Walkman" devices, and from music, are other strands of hearing loss prevention research. Other research includes the development of hearing impairment tables, for compensation purposes, and the use of otoacoustic emission testing for the screening of hearing loss and identifying aural dysfunctions.

The National Acoustic Laboratories, now 50 years old, recently compiled a complete set of its research publications. These number about 200 on noise and its effects on people and over 400 on hearing and hearing aids.

Since 1978, the University of Melbourne and Cochlear Limited have collaborated in long-term research to develop the Nucleus 22-channel cochlear implant, and to consistently improve its performance capabilities over time, enabling cochlear implant recipients to obtain improved understanding of speech and sound, to engage in telephone conversation, and in the case of children, to develop near-normal speech and language when implanted at an early age.

This research program has been strengthened through the Cooperative Research Centre, which has concentrated efforts on both development of new hardware and speech processing to help the hundreds of thousands of persons in Australia and world-wide who suffer from severe hearing disability. Research is directed at further improvements to the Bionic Ear, so that users obtain improved speech perception and Australia remains foremost in the world market, and so that infants and those with some residual hearing can also gain benefits. The CRC is also directly involved in developing advanced speech processing hearing aids, noise reduction microphones, electrotactile devices, and auditory brainstem implants to extend speech perception benefits to all hearing-impaired persons. The CRC is also involved in research to develop improved tools for use by clinicians, an example being CASALA, or computer-aided speech and language analysis software, which greatly reduced the amount of time required to analyse speech samples.

A recent result of this research was the release of the Nucleus 24 Cochlear Implant System, incorporating an advanced cochlear implant, the CI-24M and two new speech processors, the ESPrit™ ear-level speech processor and the SPRINT™ body-worn speech processor. The new cochlear implant can operate at higher rates of stimulation, enabling implementation of both the current SPEAK coding strategy, and advanced speech processing strategies developed by the CRC. The CI-24M incorporates sophisticated diagnostic neural telemetry functions, simplifying use of the device with infants and young children. CRC biomedical research has also enabled the CI-24M to be specially shaped to enable infants to receive their implant during the critical period of speech and



The C124M™ implanted receiver-stimulator and flexible electrode array which is the heart of the System 24™ cochlear implant hearing system produced by Cochlear. This system is able to provide higher rates of stimulation, monopole stimulation, and a telemetry function.

The Sprint™ advanced speech processor, which is the external part of Cochlear's new System 24™ cochlear implant hearing system.

language learning. The ESPrit ear-level speech processor incorporates all of the features of the present Spectra 22 processor, but in a package similar in size and weight to current behind-the-ear hearing aids. The SPRINT body-worn speech processor is a significant advance, allowing the clinician to choose from a range of advanced speech processing strategies to best meet the needs of each individual user. The Nucleus 24 Cochlear Implant System has been awarded the 1996 Bradfield Award from the Institute of Engineers, and also won the NSW Government Award for Engineering Innovation and an Excellence Award for Engineering Products and Manufacturing.

CRC research is investigating mechanisms to increase the information available from cochlear implants through use of improved electrode arrays, and advanced speech processing strategies designed to take advantage of neural encoding patterns in the auditory system. Speech processing research has resulted in the release of the SPEAK speech processing strategy, and has demonstrated that hearing-impaired adults and children significantly improve speech perception using this strategy, particularly in noisy conditions. Long-term research will also identify cost effectiveness benefits for children receiving cochlear implants. The Speech Processing Hearing Aid program has developed a substantially improved form of directional microphone array to improve speech intelligibility in noise. This may be implemented both as a conference microphone and, after further development, in a hearing aid. A new frequency transposition hearing aid offers the potential for real benefit to people with steeply-sloping hearing losses, who cannot obtain much help from conventional hearing aids. The CRC research program has also produced an enhanced algorithm for selecting the maximum output of hearing aids. The CRC's Tickle Talker™ electrotactile speech processor has been demonstrated to provide significant assistance to lipreading for hearing-impaired adults and children unable to benefit from cochlear implants. The Tickle Talker uses similar speech processing hardware to that employed in the cochlear implant, but delivers this signal through an array of eight electrodes worn in a glove on the fingers of one hand.

The CRC and NAL both publish annual reports which provide summaries of the above mentioned projects and other aspects of hearing research.

3. BIOLOGICAL ACOUSTICS

Alisdair Dawes
Department of Zoology
University of Melbourne

Sounds made by animals are a familiar and pervasive part of the outdoor acoustic environment. Some common examples are the calls of insects, frogs, and birds, which often consist of songs produced by a male in an attempt to attract potential mates. Another example is the biosonar of echolocating bats, which enables bats to hunt at night, and to avoid collisions. As the differential survival and reproduction of individuals underpins evolutionary theory, upon which modern biology is based, it is hardly surprising that the sounds made by animals are of great interest to many biologists.

There are several approaches to the study of bioacoustics, each of which provides valuable information about the use of sound by animals. One strategy takes advantage of the fact that males advertising for a female usually produce songs that are species specific. Hence, these songs can be used to determine the species-identity of an individual, or the species composition of a population. For example, populations of frogs around Australia have been assessed and monitored using the vocalisations of males. This method of population assessment has been used by Margaret Davies and her colleagues, based at the University of Adelaide, Dale Roberts' group at the University of Western Australia, and William Osborne and his colleagues at the University of Canberra. Similarly, researchers at the University of Queensland, led by Mike Ryan, have found that an Australian landbug can be distinguished from its Slovenian conspecifics by differences in vibratory signals. Surveys of the bat fauna of Belair National Park, near Flinders University in South Australia, have been carried out by Ken Sanderson and his research group using the ANABAT system, which detects and records their ultrasonic biosonar. The same research group at Flinders University has also characterised the songs and alarm vocalisations of many bird species.

Another approach is to study the behaviour of animals to determine the biological function of their acoustic signals. This approach has been used by Stella Crossley and her colleagues at Monash University to study the effects of the courtship song in fruitflies. Leigh Simmons and Win Bailey, at the University of Western Australia, have used a similar approach to study the function of the calling song in bushcrickets, and the way in which the whistling moth defends its territory with sound. A study carried out by Andrew Cooney, at the Australian National University, has investigated the role of female song in superb fairy-wrens. Michelle Hall, also at the Australian National University, is studying the duetting songs of magpie larks. Similarly, the function of song in zebra finches has been studied extensively by Richard Zann at LaTrobe University.

As acoustic communication plays such an important role in the reproduction of many species, it can provide insight into evolutionary processes such as sexual selection and the formation of new species. Murray Littlejohn and Graham Watson, at the University of Melbourne, have looked at the effect of variability in the call of male frogs on the choices made by females, and tested for changes in the song structure of an Australian frog species after its introduction into New Zealand. In a similar vein, Dale Roberts from the University of Western Australia has investigated the effect of hybridisation within a group of closely related frog species on the structure of the male call. Leigh Simmons, at the University of Western Australia, has also tackled evolutionary questions studying insect communication, such as how call structure in crickets is affected by age and parasite load. More recently, he has investigated the effect of asymmetry in the sound production apparatus of male crickets on the calling song, and how this in turn affects female choice.

Biologists are also interested in how animals produce the sounds used in their acoustic communication. Insects have provided valuable models for in-depth study of sound production in biological systems. Studies carried out at the University of Western Australia, by Win Bailey, Leigh Simmons, and others, have investigated the energetics of calling in bushcrickets, illustrating how costly it is for small animals to produce sound. A series of collaborations at the University of Melbourne, involving David Young, Alisdair Daws, and several colleagues, have also investigated sound production in insects. These studies have resulted in acoustic models of sound production in male cicadas, which possess large, hollow abdomens that act as resonant chambers, and male mole crickets, which sing from within a specially constructed singing burrow that is tuned to the song frequency.

Another aspect of biological acoustics is the study of the detection and processing of sounds by animals. The group at the University of Melbourne has studied the way female cicadas receive and process information in the songs of males, and how they use this information when choosing a potential mate. Likewise, the transmission and reception of the song of a desert clicker has been studied by Win Bailey at the University of Western Australia. An intriguing variation on the study of acoustic communication in insects, also carried out by Win Bailey and his colleagues, investigated the way bats localise insect calls when hunting. Hearing in other vertebrates has also come under investigation. Dexter Irvine, Ramesh Rajan, and Lisa Wise, at Monash University, have conducted extensive studies into the neural processing of auditory information in animals such as cats, rats, and guinea pigs. Research on the neural processing of auditory information in cats has also been carried out by Mike Calford and Jack Pettigrew at the University of Queensland. Similarly, Ken Hill at the Australian National University has studied the processing of auditory information in cats and wallabies.

Given the range of acoustic animals native to Australia, and the biological importance of the questions they pose, the study of bioacoustics promises to remain an exciting field with many avenues of research open for investigation.

4. MUSICAL ACOUSTICS

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

Musical acoustics is a field whose boundaries are hard to define. Properly it means the application of science to the study of musical instruments, but this definition shades off into the making and improvement of traditional instruments and the empirical development of new instruments in one direction, and into the study of performance techniques and the psychophysics of musical perception in the other. Some aspects of the development and programming of electronic and computer-based instruments might also be included.

Musical Instrument Making

The art and craft of musical instrument making is well developed in Australia, and instruments made in this country are praised by visiting performers. Only a few makers can be mentioned here, but a much wider survey is given in the recent excellent book by Michael Atherton *(Australian Made... Australian Played...* New South Wales University Press, Sydney 1990). The most visible instrument is probably the wonderful five-manual mechanical-action pipe organ in the Sydney Opera House, built by Ron Sharp, but there are many smaller instruments throughout the country by other builders, and Australian craftsmen maintain and restore notable instruments imported last century, a notable example being the great nineteenth century Hill organ in Sydney Town Hall, with its full-length 64-foot pedal reed rank. On a smaller scale, Fred Morgan's baroque recorders are in demand throughout the world, and we have fine makers of harpsichords, dulcimers, guitars, violins, flutes and oboes, while Hervey Bagot has a scientifically based bell foundry in Adelaide.

Innovative and experimental instruments also have a long and continuing history here, ranging back to Percy Grainger's experiments, at least twenty years before their time, with electronic sound synthesis. His Heath-Robinson-like invention is still on display in the Grainger Museum at Melbourne University. More recently, the Fairlight CMI (Computer Music Instrument) introduced many new concepts in sampled waveform manipulation, and for many years dominated the top-end market for film background music and popular music groups.

Turning to the more strictly scientific aspects of music-instrument acoustics, mention should be made of Graham Caldersmith's development of a family of four guitars, one higher in pitch than the standard guitar and two lower. This development, which pays careful attention to soundboard and body-cavity resonances, closely parallels Carleen Hutchins' development in the US of a family of eight bowed-string instruments based upon the design of a violin by Antonio Stradivari. Graham's guitar family can be heard on the best-selling CD by the Canberra School of Music Group "Guitar Trek", released by the ABC.

Acoustic Investigations

Studies of musical acoustics from a scientific viewpoint are generally undertaken by physicists with a major interest in some other area, so that the field is somewhat fragmented. Nevertheless, a significant number of students have completed higher degrees in the area, though their employment after graduation has been in other acoustics-related fields.

Among those who have worked in this area, and continue to do so, are Joe Wolfe and John Smith (University of NSW) who have developed a new method of measuring acoustic impedance and are applying it to wind instruments, Gordon Troup (Monash University) who has been particularly interested in vocal-tract effects in wind-instrument performance, Hans Gottlieb (Griffith University) who investigated an interesting series of annular drums with quasi-harmonic overtones, Hervey Bagot (Adelaide) and Neil McLachlan (RMIT) who are concerned with bells and gongs, Graham Caldersmith who examined resonances in string instruments, Howard Pollard (University of NSW) who worked on tone quality in organ pipes, and Neville Fletcher (ANU and ADFA) who studies nonlinear effects, particularly in wind instruments, gongs and cymbals.

Musicology

Australia has some significant collections of musical instruments, for example at the Power House Museum in Sydney, and in some University music departments, and the curators of these collections encourage study of their acoustics and performance techniques.

Much of the academic work on musical instruments is devoted to ethnomusicology, with particular emphasis on the didjeridu and other traditional instruments of the Australian aboriginal people, on the gamelan instruments of nearby Indonesia, and on instruments from other Pacific Rim cultures.

Vocal Performance

Over the past year, a new National Voice Centre has been established in the Faculty of Health Sciences at the University of Sydney, thanks to the efforts of Pam Davis. The objectives of this Centre are to apply scientific methods to studying and training the human voice, with particular practical applications to singers, actors, and others to whom the voice is vitally important. The Centre brings together respiratory physiologists, ear nose and throat surgeons, vocal coaches and professional musicians, and offers clinics as well as undertaking research. Many of the approaches vital in singing are also important in the playing of wind instruments, and the Centre initially has research projects related to breath control in flute playing and related areas.

Some of the work mentioned in the previous section is also relevant here, particularly Gordon Troup's interest in vocal-tract effects in reed instrument performance, and Joe Wolfe's equipment that allows real-time measurements of vocal-tract resonances.

5. ULTRASONICS

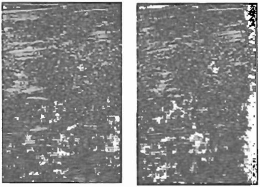
George Kossoff
Ultrasonics Laboratory
CSIRO Telecommunications and Industrial Physics
Chatswood, NSW

Research into ultrasonics in Australia is undertaken primarily by statutory authorities and government organisations. Often this research is performed on behalf of or in collaboration with a commercial partner. The applications include medical ultrasound, high resolution underwater imaging, measurement of flow in fluids and non destructive evaluation.

Medical Ultrasound

Research into medical ultrasound is undertaken by the Ultrasonics Laboratory of the CSIRO Division of Telecommunications and Industrial Physics.

Decision support analysis methods are being developed to allow accurate identification of high risk pregnancies. This will allow a more targeted utilisation of diagnostic ultrasound and a more cost effective provision of health services.



original corrected

Original and corrected ultrasonic image of a phantom containing a cyst. An aberrator simulating overlying subcutaneous tissues has been placed on the surface of the phantom. The corrected image has been processed using the near field redundancy algorithm. The portrayal of the cyst has been significantly improved.

Comparison of images obtained with transducers applied externally on the patient with those obtained with internal probes dramatically demonstrates the degradation in image quality incurred by propagation through the overlying subcutaneous tissues. Forward and inverse propagation compensation methods are being investigated and impressive improvements have been obtained on clinical images acquired on the Laboratory's array research synthetic aperture equipment.

Research into bioeffects has shown that, in some modes of operation, current equipment can cause significant temperature elevation in the foetal brain. Studies are being conducted to elucidate the various factors responsible for the effect with view to develop safe operational criteria.

High Resolution Underwater Imaging

Many of the coastal waters of Australia are muddy and this precludes conventional visual imaging of submerged objects.

The Ultrasonics Laboratory, in collaboration with Thomson Marconi Sonar, is developing a high resolution 3-D underwater imaging equipment suitable for mounting on a remote control operational vehicle. The aim is to provide resolution of the order of a few mm over a depth of several metres. The project is funded by the Department of Defence and is being undertaken in collaboration with DSTO.

Measurement of Flow in Fluids

Research into measurement of flow in gases and liquids is carried out in the CSIRO Division of Telecommunications and Industrial Physics (formerly Applied Physics).

A piezoelectric polymer foil transducer is used to generate ultrasound into gas and flow is measured by noting the difference in the speed of ultrasound between two opposing transducers. A domestic gas meter is being developed in association with the Australian Gas Light Company to measure flow rates to an accuracy of ~ 1%, over a range of flow rates from 40 l/hour to 6000 l/hour which corresponds to flow velocities from ~ 10 mm/s to 1500 mm/s. It is designed to operate satisfactorily in temperatures from -20° C to +60° C, and have a battery life of at least 10 years. The advantages of an ultrasonic meter are small size, lack of moving parts and adaptability to electronic remote meter reading.

Another group is working on the development of liquid meters, using similar techniques. The research problems involve the fluid dynamics of flow along a tube, within which the transducers are mounted. The flow patterns are complicated, changing from laminar at low flow to fully turbulent at higher velocities. The flow profile is also a function of the mean velocity and the position along the tube, and depends on pipe geometries upstream from the meter. Other research issues concern the propagation of ultrasound in a non-uniform flow profile and the measurement of time differences of a few tens of picoseconds.

Non-Destructive Evaluation

ANSTO

The Australian Nuclear Science and Technology Organisation conducts research into acoustic imaging in support of safe reactor operation.

The work on remote ultrasonic inspection of the HIFAR reactor has led to research into 2D arrays for high resolution imaging in heavy steel and aluminium sections. Studies are currently directed at developing a 3D bi-static imaging system based on a passive 2D PVDF receiving array and separate conventional piezo-ceramic transmitter. The emphasis is on achieving focussing entirely in reception, by using a combination of general purpose and DSP hardware.

The 2D array incorporates a single edge-connected PVDF film element with four sets orthogonal strip electrodes on each face. The orthogonal electrode pattern samples the 2D pressure field incident on the array, yielding Fourier coefficients for spatial frequencies in the X and Y directions. The result is that the array is sparse in the spatial frequency domain, unlike arrays which are sparse in the spatial domain. A single set of orthogonal Fourier coefficients is not sufficient for 3D image reconstruction. However simultaneous reconstruction with coefficients sampled from four quadrants of the array has been shown to yield a unique solution, provided imaging is conducted in the near field. A regularising operator is used to yield results comparable to a conventional filled array, while allowing a degree of super-resolution relative to linear reconstruction algorithms. The use of a non-linear reconstruction algorithm requires considerable computation , and imaging times are presently 15-30 mins for 3D images of 32×32×32 pixels.

CSIRO

Materials characterisation and non-destructive testing is a significant area of ultrasonics activity in the CSIRO.

Research, in collaboration with Boeing Airplane Group, is concentrated on the study of ultrasonic modes that propagate along multilayered plate structures. These are sensitive to material properties and to boundary conditions provided by adhesive bonding, to detect defects within a composite laminate and to disbonds. Current work is directed towards measurement of the strength of adhesive bonds which may be reduced by improper curing, inadequate surface preparation, water absorption, microcracking, etc.

Optical techniques, whereby a high power pulsed laser is used to generate ultrasound and a sensitive optical interferometer is used to measure surface vibrations, is being applied to the inspection of hot steel products, in collaboration with AEA Technology, Harwell, UK. Ultrasound is used to detect defects in the materials, to monitor microstructural changes and phase transformation kinetics, and to measure internal temperatures in large steel billets.

DSTO

DSTO ultrasonics program involves the development of improved methods to quantify corrosion in ageing aircraft, the detection of weld cracking, the disbonding of tiles on submarines, and the assessment thick-section glass-epoxy composite ship structure.

While much of the research involves conventional transducers, laser ultrasonics is also being evaluated. Modelling of laser generation has been carried out and laser ultrasonics is used to detect surface crack sizing in aluminium alloys, in one-sided measurement of elastic constant in composites, and for the development of Lamb waves for large-area scanning for early detection of corrosion in aircraft skins.

Considerable effort is presently being directed towards the reliable examination of boron-epoxy composite repair technology where it is used to validate reinforcement bond durability and to monitor cracks in non-standard configurations. Carbon-epoxy composite are also being examined to assess the minimum detectability of service-incurred damage to carbon reinforcement, both in the form of delaminations within the reinforcement and the reinforcement disbonding.

6. UNDERWATER ACOUSTICS

Douglas H. Cato
Defence Science and Technology Organisation
Pyrmont, NSW

Much of the underwater acoustics research in Australia is related to sonar, since sound is the most effective means of transmitting information through the ocean, though there is also significant interest in the extensive use of sound by marine animals. Most work is concentrated at the Salisbury and Sydney branches of the Maritime Operations Division of the Defence Science and Technology Organisation (DSTO), at the University of Sydney and at Curtin University of Technology in Perth. Australian underwater acoustics research covers the frequency range 0.1 Hz to 3 MHz.

The acoustic environment of the ocean is complex and variable and causes wide variation in sonar performance. Understanding the environment is an important input to sonar design and optimisation of performance. The same factors impact on the use of sound by marine animals. The Australian ocean environment differs significantly from the colder waters around North America and Europe which have provided most of our knowledge of underwater acoustics, so is a fertile field for research.

Transmission of sound in the ocean is complicated by sound speed variation, particularly vertically as a result of horizontal layering of water masses. This results in significant refraction, so that transmission in shallow waters (depths < 200 m) involves many boundary reflections. Transmission loss varies in both space and time, since it depends on the water temperature profile (through the sound speed), the sea surface roughness and the acoustics of the bottom. Prediction of transmission loss requires computational models and adequate knowledge of the environmental parameters for input to the models.

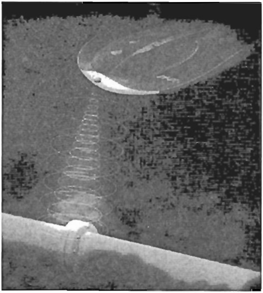
A number of computational models are available, including STOKES developed at DSTO (M.V. Hall). All are limited in their domains of validity, but between them cover most conditions of interest. DSTO research has assessed these domains for various models against benchmarks (S. Tavener, A.I. Larsson and M.V. Hall). Generally, the main limitation in accuracy is inadequate knowledge of the environment, particularly the acoustics of the bottom.

Shallow water transmission loss measurements around Australia have shown wide variation, prompting effort to determine the acoustic properties of the bottom (available geological data have not proved to be useful in this respect). Current research is aimed at developing and implementing techniques of inverting received signals from impulsive sources to determine the characteristics of the bottom acoustics (M.V. Hall, D.N. Mathews, G. Furnell and A.I. Larsson), in conjunction with laboratory measurements of bottom samples (J.I. Dunlop, University of NSW).

Interference patterns from multipath transmission provide complicated sound fields, reducing the coherence and detectability of signals. DSTO is studying the spatial, temporal and spectral statistics of the signal sound field, including measurements of amplitude and phase, and modelling of the times series, to allow signal processing to be optimised (A. Jones, A. Larsson).

Ambient sea noise provides a basic limitation on the detection of signals. It results from a variety of sources and temporal and spatial variation in Australian waters in excess of 20 dB is common. A major component results from motion of the sea surface, particularly breaking waves. DSTO has a long term project to understand the mechanisms of noise generation and the development of the noise field and its directionality (D.H. Cato, I.S.F. Jones, and S. Tavener). This has included theoretical modelling of mechanisms and experimental verification, including an extensive series of measurements of noise and its dependence on wind speed, wave height and white cap coverage.

There is continuing research on biological noise, which is widespread around Australia and is often the main component in tropical waters (D.H. Cato and R.D. McCauley). Biological choruses from large numbers of animals are show considerable



"Acoustics Vision" is an important aspect of marine acoustics that is being investigated at DSTO laboratories.

diurnal and seasonal patterns, commonly increasing noise levels by more than 20 dB in the audio frequency range, though shrimp noise extends more than 300 kHz. Whale sounds are becoming more evident as numbers increase. The intense and variable sounds of humpback whales are transient signals that must be discriminated by sonars.

In active sonar, scattering of the sonar signal from objects (e.g. fish) in the ocean or from the boundaries provides "reverberation" that limits the detection of the signal reflected from the target. Research on scattering includes measurement, particularly of bottom scattering and reflectivity at low grazing angles (G. Furnell and S. Taylor, DSTO) and general theoretical research on scattering from rough surfaces (C. Macaskill and P. Cao, Sydney University).

There is considerable effort in DSTO in assessing and improving the performance of sonar systems, including work on environment effects, sonar technology, and signal processing. The emphasis of current work is towards multistatic and combined active-passive operation for detecting vessels, including evaluation in Australian conditions of a low frequency active-passive sonar to be acquired by the Navy (S. Taylor, L. Kelly, I. Cox, J. Marwood and H. Lew). There is a continuing research on the tracking and classification of targets by multi-element systems, and on mine hunting sonars (B. Ferguson G. Speechley, D. McMahon and J. Riley). Some techniques are being applied to detection in air for Army operations. There is significant involvement by industry in sonar technology research (Tompson Marconi Sonar, Nautronix, R.J. Wyber).

DSTO projects are also concerned with the protecting vessels against sonar detection. This includes studies of their target strengths and their radiated noise (M.J. Bell, and G. Furnell). Reduction and control of vessel acoustic signatures, has addressed sources and acoustic paths to the water, and includes work on passive isolators, active noise control and modelling (C. Norwood).

Scattering of sound can be useful if it shows the environment in a way that aids detection of a target. Detection of mines on the sea floor is enhanced by the contrasting image of the sediment and the presence of the acoustic shadow. DSTO's current research includes measurement of scattering from a patch of sediment at precisely determined angles of incidence, using specially designed instrumentation, and imaging using side scan sonars (S. Anstee, A. Parkinson, R. Neill).

Scattering is also being applied to measure the thickness of Antarctic ice, the abundance of krill biomass, and fish stocks (A. J. Duncan, J.D. Penrose, G. Bush and P. Siwebessy of Curtin and T.J. Pauly, Antarctic Division).

When acoustic mines are investigated by divers or remotely operated vehicles as part of the clearance process, the noise they generate must be carefully controlled to avoid triggering the mines. DSTO is investigating the noise of divers and vehicles under operational conditions to minimise their vulnerability (B. Jessup, S. Bocquet, J. Barnes, D. Mathews, J. Mentjox, N. Capps and). DSTO is working with Australian Defence Industries to develop a new underwater noise source which would emulate ship signatures for mine sweeping (B. Castles and S. Page).

Fine scale imaging of mines is important in identification, but optical methods are ineffective in the turbid waters that are common around Australia. A research project on "acoustic vision" by DSTO and the former Ultrasonics Institute has shown the potential for innovation in underwater imaging by sound (I.S.F. Jones, D.G. Blair and D.E. Robertson). This has demonstrated that the ocean medium can support imaging of millimetre resolution at ranges of several metres, using frequencies of a few megahertz with sparse, random array technology. The project is now in the development phase with Thomson Marconi Sonar (A. Madry). Research continues on the effectiveness of the medium to support transmission at megahertz frequencies, including the scattering of sound by fine scale fluctuations in temperature and water flow, and by fine particles, and transmission through bubbly water (R.A. Thuraisingham).

"Acoustic Daylight" is a new sonar concept developed by Scripps Institution of Oceanography, California (M.J. Buckingham) that uses ambient noise to image objects in the ocean. DSTO is collaborating in further development and application to Australian conditions, particularly exploiting snapping shrimp noise (M. Readhead).

The University of Sydney has an active an active postgraduate research program in marine bioacoustics in conjunction with Taronga Zoo and DSTO (T. Rogers, K. Schultz, M. Noad, D.H. Cato and M.M. Bryden). Studies of the sounds of leopard seals in captivity and in the Antarctic have distinguished between local sounds of close range interaction between individuals and sounds broadcast by isolated individuals (both male and female) over long distances associated with breeding activity. Studies of communication sounds of three species of dolphin have related the characteristics to differing behavioural requirements of the species. Current research with humpback whales involves both acoustic and visual tracking of the whales to improve our understanding of the function of their long and complex song.

The impact on marine animals of noise from human activities is also an area of investigation (R.D. McCauley, D.H. Cato, J.D. Penrose and A.F. Jeffery). A study of the impact of whale watching on the humpback whales in Hervy Bay, Queensland has lead to guidelines on design and operation of whale watch vessels. A project at Curtin University is investigating the impact of air guns used in seismic surveys for the oil industry on a wide range of animals and includes modelling and measurement of sound propagation and ambient noise.

7. ACTIVE NOISE AND VIBRATION CONTROL

Colin Hansen
Department of Mechanical Engineering
University of Adelaide

There are a number of groups in Australia currently undertaking research in the active control of sound and vibration. Although much of the work is being funded by the Australian Research Council (ARC), a number of groups are receiving funding from industry and one group is supported entirely by the Defence Science Technology Organisation (DSTO).

University of Adelaide

At The University of Adelaide in The Department of Mechanical Engineering, the Active Noise and Vibration Control Group, led by Colin Hansen and Scott Snyder with a team of 12 postgraduate students, a Post Doctoral Research Fellow and a Research Officer, is undertaking research in a number of areas as follows.

Sound transmission into irregularly shaped enclosures

This project, funded by the Sir Ross and Sir Keith Smith Fund and The Australian Research Council, is concerned with the active control of sound transmission into enclosures of irregular shape such as aircraft cabins and motor vehicles. The project is concerned with a number of physical acoustics issues such as optimum location and type (vibration or acoustic) of sensors and actuators using genetic algorithms and the description of the vibration response of the enclosure bounding surface in terms of orthogonal acoustic radiation modes rather than normal vibration modes. Signal processing and controller issues being addressed include short-cut ways of performing on-line cancellation path identification for systems with many control channels, the development of a high-speed multi-channel floating point controller with a windows menu system for optimising the controller parameters.

Electric power transformer noise

This project is concerned with the active control of electric power transformer noise and is funded jointly by The Australian Research Council and the Electricity Supply Industry. The need for the work has arisen from the presence of substations in residential areas, usually as a result of houses being built around existing substations rather than vice versa. Problems which are being addressed by the research include control system instability resulting from many channels of control coupled with large distances between the control sources and error sensors. This problem is being tackled by using near field error sensing and fewer large control sources (cavity backed curved panels driven with piezoelectric actuators). Piezoelectric patches on the transformer tank are being considered for control of the 400Hz and partly the 200Hz tones. Near field acoustic error sensing poses some interesting problems in that only the propagating part of the field must be present in the error signal used by the controller. Other problems being addressed in the project are associated with the large number of controller channels required and associated techniques for optimising controller set-up procedures, practical installation of a system which must function for an extended time outdoors in a hostile electromagnetic environment.

Active vibration isolation

A third large project currently being undertaken at The University of Adelaide is concerned with a thorough fundamental study of the physics of active vibration isolation. The work is currently being funded by The Australian Research Council and includes the development of a 6-axis active vibration isolation system, consisting of 6-axis sensors and actuators. Error signal cost functions for minimisation which are being considered include force, acceleration and power transmission at the base of each mount. It is considered impractical to use distributed accelerometers to minimise the kinetic energy of the support structure.

Controller optimisation

Two projects are on-going in this area. One is concerned with the effect of parametric uncertainty on the performance of feedback control systems and how this may be compensated for. The other is concerned with the optimisation of algorithm parameters for feedforward control.

Other work at The University of Adelaide is concerned with a fundamental analysis of the use of shaped sensors for providing a signal proportional to sound radiated by arbitrarily shaped structures, optimisation of sensing systems and the development of a novel active vibration absorber.

The work at the University of Adelaide has led to the development and commercialisation of a low-cost multi-channel active noise and vibration control system (for both tonal and random noise) which is currently being marketed by Causal Systems.

University of Western Australia

At the University of Western Australia, there is a very active group led by Jie Pan undertaking research on a number of important theoretical and experimental projects. In addition to Dr Pan, the group consists of 4 postgraduate students and 1.5 post Doctoral Research Fellows. Projects currently being undertaken by this group include the following.

Active ear defenders

Systems being investigated include digital feedforward and feedback as well as analogue feedback. The project has received funding from the Western Australian mining industry and also involves the construction of prototype units.

Sound through walls

This project involves an investigation of the coupling and control mechanisms associated with the transmission of sound through double walls with application to the reduction of low frequency transmission of sound into an enclosure.

Pipeline noise transmission

This project is concerned with the investigation of an integrated active/passive system for the control of the transmission of structure-borne and fluid-borne acoustical energy in piping systems. Of special interest is the interaction between the pipe wall vibration and the internal and external sound fields, the interaction between passive and active control elements and the excitation mechanisms responsible for the acoustical energy.

Barriers

This project is concerned with the use of active noise cancellation to improve the low frequency performance of acoustical barriers. Issues being investigated include the effect of the ground on the performance, characterisation of the extent of influence of active control and the optimum design of the controller.

Other projects being undertaken by the group in the University of Western Australia include: active control of non-linear vibration in flexible structures, and active control of vibration in ribbed structures with fluid loading.

Australian Defence Force Academy

At the Defence Force Academy, School of Electrical and Electronic Engineering, University of New South Wales, a research group consisting of two Academic staff (Hemanshu Pota and Ian Petersen) and a Post Doctoral Research Fellow are working on an ARC funded project involving the application of H-infinity and LQG feedback control techniques to the distributed control of vibrations in a flexible structure. Control actuators and sensors being considered are piezo-electric patches and films.

University of Sydney

At Sydney University, Fergus Fricke and one of his graduate students is investigating a novel active noise control approach to reducing the transmission of intermittent noise (such as aircraft noise) into buildings. The work involves the development of a control system which shuts windows when an undesirable noise (such as a truck or plane) approaches. A large part of the work is associated with the classification of unwanted noise types and training the control system to only react to these.

University of Technology, Sydney

In the Faculty of Engineering at The University of Technology, Sydney, Guang Hong and David Eager are investigating the active control of vehicle exhaust noise; at the DSTO Aeronautical and Materials Research Laboratories, Ross Juniper and Chris Norwood are investigating the active control of fluid-borne pulsations in liquid filled pipes and with John Dickens are beginning investigations on the development of practical active/passive vibration isolation systems suitable for isolating propulsion and service equipment from the hulls of ships and submarines.

8. MECHANICAL VIBRATIONS

Len Koss
Department of Mechanical Engineering
Monash University

This section outlines vibrative and acoustic investigations which fall in to the general category of Mechanical Vibrations with or without acoustic radiation. The spectrum of research varies from heart sounds to acoustic fatigue of pipelines, however, the principles of measurement and analysis which underlie the investigations fall into the area of vibrations.

I am grateful to Bob Hooker and Samuel Asokanthan (University of Queensland), Michael Norton (University of Western Australia), Bob Randall (University of New South Wales) and Joseph Lai (Australian Defence Force Academy) for help in the preparation of this report.

University of Queensland

Transmission Line Dampers

Overhead electrical transmission lines experience Aeolian (wind-induced) vibrations which can lead to fatigue failure of conductor strands. Similar problems can arise in suspension and cable-stayed bridges.

Loudspeakers

Two loudspeaker applications are being investigated. One of the use of loudspeakers as passive absorbing devices—they can be used as narrow frequency band absorbing devices. The other concerns a more common situation, the measurement of insertion loss. A measured insertion loss can be dependent on the properties of the source loudspeaker used and the studies concern the extent of that dependence and the conditions necessary to minimise it.

Impact Noise through Floors

The project deals with sports noises—'soft' impacts such as from basketball bouncing and athletes running and jumping. These activities often operate on lightweight floors and noise is transmitted to occupied spaces beneath the sports area. The nature of the impacts, the transmission behaviour and the radiation are being modelled with a view to ensuring floor designs of adequate performance.

Dynamic Stability and Control

Several projects are in progress related to spatially distributed actuators and the optimal dynamic control of flexible systems. Some of the research is at the fundamental level, and some has been developed in the specific context of control of aerospace vehicles, and particularly of flexible components of these, such as deployable solar panels. At a more down-to-earth level, similar techniques, particularly in relation to torsional motion, are being applied to railway rolling stock in collaboration with Queensland Rail.

University of Western Australia

Research interests include noise and vibration control, flow-induced vibration and sound, the effects of dynamic stress on fatigue, unsteady boundary layer, acoustics and stability, statistical energy analysis, and noise and vibration, a diagnostic tool.

Current major research projects include vibration and strain analysis on wellhead flowlines and associated small bore piping, flare piping, vessel bore piping, major structural members, dynamic stress prediction and fatigue flowlines and small bore piping, development of dynamic stress and vibration acceptability criteria, and flow induced vibration and dynamic stress effects on industrial gas turbines. Current research projects include:

- the effects of dynamic stress on fatigue life of piping systems;
- the prediction of stress distribution in structures subjected to random excitation;
- flow-induced noise and vibration in gas pipeline systems;
- industrial and environmental noise pollution and noise control studies;
- development of adaptive-based active noise control ear defenders;
- high voltage transformer noise control;
- high temperature strain gauging and analysis;
- quantification of acoustic and hydrodynamic fields in flow duct systems;
- development of environmental noise prediction models;
- maximum entropy approach to fatigue life distribution; and
- fatigue under cyclic stressing with non-zero means.

University of New South Wales

Most of the research is in machine diagnostics, and in four main areas:

- Rolling element bearing diagnostics, including cases where the bearing (eg. helicopter gearboxes) and rail vehicle bearing diagnostics using an array accelerometers along the rail. The helicopter gearbox bearing diagnostic is the main focus so far of the work supported by AMRL under the 'Centre of Expertise' scheme. In particular, we have developed techniques to enhance envelope analysis by improving the signal/noise ratio of bearing to background noise. In particular, where the latter is dominated by gear vibrations, we developed self-adaptive noise cancellation techniques to remove it. We have developed techniques to deal with the short signals limited by the passage of the bearing past the transducer(s).
- Gear transmission error simulation and measurement with applications to gear noise studies and diagnostics. One developed method was measuring TE down to fractions of an arc second using shaft encoders mount each shaft, and also developed a simulation method which gave very good correspondence with measurement on automotive quality gears. A further development includes techniques to eliminate encoder error (thus allowing the use of much cheaper encoders) and has improved the simulation model to cover cases where the tooth deflection is a more significant part of the TE. Good agreement was obtained using nylon gears and the method should extend to precision gears. The original method was applied to quasistatic TE, but it has now been extended to include the dynamics of the gear train.
- Diesel engine diagnostics, using externally measurable signals such as accelerometers, and crankshaft torsional vibration. Part of this work is an attempt to reconstruct cylinder pressure from these externally measured sources and another part is to develop methods to recognise faults using time/frequency.
- One of the techniques being investigated for diesel engine cylinder pressure reconstitution is based on the cepstral techniques mentioned earlier. The method being developed more generally, in particular as a means of adjusting modal models, possibly measured under ideal conditions in the laboratory, to actual conditions in operation, using response measurements only, though having knowledge of the characteristics of the dominant force. A tentative conclusion from my work at KU Leuven is that as long as the largest force is bigger by a factor of at least 4 than the next largest, then principal components analysis can be used to obtain updated FRFs from those force to all measurement conditions. It is also hoped that the same techniques will be able to be used to adjust a modal model obtained on one object to all others of the same meaning that only one has to be fully instrumented and measured in the laboratory.

Monash University

Short impulses of sound, such as gunshot, have been used by a small group in the Physics Department, as a probe to investigate a number of environmental problems. These include the propagation of sound through the atmosphere, with a particular interest in the behaviour of the sound in the presence of wind and temperature gradients. More recently, this has led to a study of the way turbulence alters the shape of a pulse as it passes through the atmosphere. Simultaneously, the local meteorological conditions and the wavefonns of many hundreds of individual pulses have been recorded to study the relation between wind gusts and changes to the wave shape.

Other areas investigated have included the behaviour of cracks in acoustic barriers, where the timing between various components passing through the gap can be used to identify the path taken by the sound. The properties of soils have also been investigated using pulses of sound. By observing the change in waveshape when a pulse is reflected from a surface, the complex impedance of the reflecting material can be deduced. Similarly, the propagating constants of foams and wet soils have been deduced from the changes occurring when pulses travel in the medium. These latter studies have led to the development of an acoustic detector of buried objects, such as land mines. The fact that reflection of the pulse depends on there being an impedance discontinuity means that such a detector works equally well with plastic and metal objects.

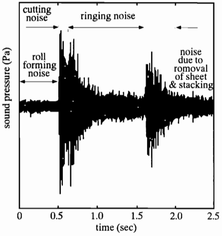
Investigation in the Mechanical Engineering Department include the development of 'frequency shifting techniques' for development of low frequency vibration, unconstrained and constrained layer damping treatments, impact vibration absorbers, motion sickness on high speed vessels and pre-natal heart sounds. The Centre for Machine Condition Monitoring uses vibration as a diagnostic tool in their investigations.

Australian Defence Force Academy

The following research projects are undertaken at the Acoustics and Vibration Unit located within the School of Aerospace and Mechanical Engineering at the University College, the University of New South Wales, Australian Defence Force Academy in Canberra:

Machinery noise

Collaborative projects with BHP Building Products have included noise reduction in the sheet metal industry and the reduction of noise in friction saws. This work has been sponsored by Worksafe Australia.



Noise signature due to shearing a corrugated metal sheet in a roll-forming production line.

Vibration Isolation

Several academics are carrying out a collaborative research program on vibration isolation with DSTO. The thrust of the program is to understand and ultimately optimise the design of machinery foundations in ships and submarines.

Human Vibration

Further, several academics have been developing instrumentation in collaboration with Worksafe Australia for the evaluation of the effects of vehicle vibrations in underground mining. Evaluation of the effects of vibrations on people is a field where standards and methods of measurement are rapidly evolving.

9. BUILDING ACOUSTICS

P. P. Narang
CSIRO Division of Building, Construction and Engineering
North Ryde, NSW

The CSIRO has a long history of scientific and industrial involvement in the building and industrial acoustics fields. The Division of Building, Construction and Engineering has two acoustics laboratories—one located at North Ryde in Sydney, and the other located at Highett in Melbourne—which are used for both research work and commercial activities. Both laboratories have reverberation chambers, and the Highett laboratory also has a vertical pair of chambers which can be used for measuring the sound insulation performance of floor systems. Areas of work covered by the two laboratories include sound transmission, sound absorption, impact sound, sound power level determination, noise emission from appliances and equipment used in water supply installations, and noise generation by mechanical ventilation equipment.

As part of the redevelopment of the North Ryde site, the acoustics laboratory was rebuilt in 1997. The new laboratory consists of two large reverberation chambers located side-by-side with a 3.6m wide by 3.0m high opening for the installation of test specimens. The two chambers are housed inside a building of conventional design which provides space for the storage of materials as well as a control room and an office area. The volume of both rooms is slightly in excess of 200 m^3 and the two volumes differ by at least 10%, in line with the recommendation of the Australian Standard 1191-1985. The concrete floor slab of each reverberation room rests on resilient vibration isolation pads and specially prepared footings. Both rooms have non-parallel surfaces and the walls are rendered and painted. The walls and roof of each room comprise double-leafed concrete and masonry construction, fully supported on the edges of the floating floor slabs. A 1.2m by 1.2m removable hatchway has also been built in one side wall for possible future work on the insertion loss measurements of mechanical equipment.

Some recent acoustics projects undertaken by the CSIRO are briefly described below.

Noise radiation by different pipe materials (including copper) attached to domestic-type wall construction, and the effectiveness of different methods of fixing pipes to the wall was investigated. The water-hammer problem and the extent to which it can be mitigated by the use of pressure limiting valves or by the installation of an air chamber in the system was studied.

Rain noise, particularly on uninsulated roofs, can be a source of significant noise annoyance. The CSIRO has been involved in the measurement of rain noise on different roof systems with real rain as well as using a mechanical simulator designed to generate spectra similar to that produced by real rain on metal roofs.

The acoustic performance of windows depends not only on the glass thickness and type, but also on the window size and type (e.g. double-hung, casement, sliding or awning), window frame, method used to mount glass, and the quality, location and type of seals used. A series of acoustic tests on single-glazed window systems of a given glass thickness showed significant variations in the sound insulation characteristics of the window units.

The opening of the third runway at the Sydney airport generated widespread community concern about aircraft noise, and as a result the Commonwealth Government decided to provide sound insulation upgrading to the worst-affected properties subject to certain financial constraints. The CSIRO has provided its technical expertise and review services for this work and has also carried out aircraft noise reduction measurements on some of the affected properties before and after sound insulation upgrading work.

Commercial work done in the acoustics area have also included: measurements of the acoustic performance of various floor underlay systems; evaluation of the performance of absorptive roadside noise barriers; and assistance to a door manufacturer to develop high performance acoustic doors with matching seals.

Sydney University

Architectural acoustics research at Sydney University covers the following areas.

Ventilation Openings

The growing movement to design "greener" buildings requires increased use of natural ventilation, which brings with it problems of noise ingress. The current research involves both passive methods, which use optimised openings and arrays of resonators, while the active system uses an "intelligent" window which opens and closes depending upon external noise conditions, such as aircraft flyover. The passive system can reduce noise levels by 10 dB(A) and the active system by as much as 20 dB(A).

Auditoria

This research is based upon neural network analysis of existing auditoria. Predictions of reverberation time using this technique are better than those using classical reverberation equations and ray-tracing software, while correlation coefficients of about 0.9 have been achieved for prediction of overall acoustic quality.

Sound in Small Rooms

Several projects are investigating the recording and reproduction of sound in small rooms. Preferences are linked to objective tests and to the physical dimensions of the rooms, and methods are being investigated to increase apparent reverberation time.

National Acoustic Laboratories

NAL has excellent acoustical measurement and testing facilities that are being used increasingly for tasks related to building acoustics. There has been particular interest in testing of windows, all types of secondary glazing, acrylic window barriers, and heavy single-glazed units for the upgrading of hotels and other community facilities.

Other tests have encompassed the behaviour of lagging and noise barriers, together with materials such as fibreglass, rockwool, polyester and cellulose fibre. There has also been testing of extruded plaster and concrete products and heavy walls and windows.

10. ENVIRONMENTAL ACOUSTICS

Renzo Tonin
Renzo Tonin & Associates Pty Ltd
Sydney

Power Industry

Colin Hansen from Department of Mechanical Engineering, Adelaide University SA is doing research on active control of electrical transformer noise. Funded under a collaborative ARC grant with Transgrid, ETSA, SEQB, United Energy, Integral Energy, Energy Australia, Powerlink QLD and AESIRB. The Project began in 1996 and is scheduled for completion in 1998. Its aim is to have a demonstration system in operation at a transformer installation by the end of the project. Research is focussed on effective sound sources, use of near field error sensors to control far field noise, use of tank vibration control, weatherproofing microphones and sound sources, effects of electromagnetic fields on system performance, development of a controller with a large number of interacting channels and solution of practical problems associated with on-site installation.

Mike Norton and Jie Pan from the Department of Mechanical and Materials Engineering at the University of Western Australia, Nedlands are also working on the development of practical techniques to control noise from existing power transformers, funded by Western Power.

Road Noise

Lex Brown and Joseph Affum at the School of Environmental Planning Griffith University, Nathan, Brisbane are working on integrating environmental noise evaluation directly into transport demand modelling. This research looks to integrate the output of travel forecasting procedures with land information systems, to provide an "automatic" assessment of the noise consequences of different scenarios in transport systems design.

Lex is also working on the development of a windows based user friendly model for traffic noise to evaluate different barrier positions, heights and window heights for use by architects, planners and students.

A significant proportion of Stephen Samuel's effort at the University of New South Wales, School of Civil Engineering, Department of Transport Engineering in Sydney is devoted to evaluating the noise characteristics of various rigid pavement surfaces. This ongoing work is assisting in the design and development of low noise pavements that also provide optimum drainage and skid resistance properties. Stephen is also studying the acoustic attributes of traffic speed control devices used in Local Area Traffic Management schemes.

Most of us are familiar with Stephen's interrupted traffic flow model he developed whilst at the Australian Road Research Board. He is proceeding, albeit at a low level, on enhancing this model. Stephen has also just about completed research on the fuel consumption characteristics of Australian Defence Force trucks. Outcomes of this work will include fuel saving recommendations and management plans that include issues such as the adoption of alternative fuels.

Jie Pan from the Department of Mechanical and Materials Engineering at the University of Western Australia, Nedlands, is supervising J.N. Guo, a PhD student who is working on active noise control of traffic barriers. They recently published promising results at the AAS 1996 annual conference in Brisbane.

Robin Alfredson Dept of Mechanical Engineering at Monash University, Clayton is preparing a paper for the WESTPRAC conference later this year in Hong Kong in which he will investigate the influence of surface impedance on the effectiveness of noise barriers for road traffic. The objective is to optimise that impedance and compare that effect with the effect of two other variables that can be easily be varied, namely barrier height and barrier shape.

Marion Burgess at the Acoustics and Vibration Unit at the Australian Defence Force Academy in Canberra is investigating new noise limit guidelines, in particular for Canberra which differs from other cities.

Peter Karantonis from Renzo Tonin & Associates Pty Ltd in Sydney has just completed a research study for the NSW RTA involving the measurement of service brake parameters in large road haulers typically used in the transportation industry. The aim of the exercise was to determine whether a ban on exhaust brake usage near populated areas, permitting only service brakes to be used, would compromise safety in respect of generating high brake pad temperature and wear. The study found that safety would not be compromised and reports the costs associated with additional brake pad wear. Therefore, the issue becomes one of whether industry or the community is willing to pay for the additional costs imposed. The results will be published later this year at the AAS annual conference in Adelaide.

Community Response

Fergus Fricke from the Department of Architectural and Design Science at the University of Sydney is studying annoyance predictions using neural network analysis. This work involves taking the results from a number of environmental noise annoyance surveys, such as the Bullen and Hede one on aircraft noise in the early 80's, and predicting the overall noise annoyance from the answers to individual questions in the surveys. The work is aimed at finding out whether the relationship between various factors is linear.

Renzo Tonin from RTA Technology Pty Ltd in Sydney has just completed two years research and development into developing a multi-media system for the visualisation and auralisation of EIS projects (road, rail, aircraft, mining etc) to the community. His first completed project was a multi-media display simulating the effects of the proposed long term operating plan for Kingsford Smith Airport announced by the Minister for Transport and Regional Development, John Sharp, as it affects the Hurstville community in Sydney. In the first four weeks, over 1000 people viewed the display and provided comments. This presentation method looks like it will be an important component of future EISs. Renzo is currently working on a traffic noise display for the M5 East. He has just spun off a new company called RTA Techvision Pty Ltd to promote the venture.

Aircraft Noise

Karl Mezgailis from the Federal Airports Corporation in Sydney is co-ordinating various projects primarily as a result of the DASETT recommendations for the Third Runway, the Sydney (Kingsford Smith) Airport. These studies focus on the effects of aircraft noise on human health. They are being undertaken by Norm Carter from the National Acoustic Laboratories and the University of Sydney, and include an evaluation of Airservices Australia's Noise and Flight Path Monitoring System, a study of the mental health and human reaction to aircraft noise and a study of the effects of aircraft noise on the blood pressure of primary school children.

Marion Burgess at the Acoustics and Vibration Unit at the Australian Defence Force Academy in Canberra is working on amelioration measures for residents exposed to high levels of aircraft noise. A current study on this topic involves an assessment of the effectiveness of the house insulation program for homes around Sydney Airport.

11. OTHER TOPICS

Because this review has been organised along sub-discipline lines, there are inevitably many topics that have not been included. We mention just a few of these here, to show the breadth of Australian interest in acoustics.

At the Australian National University there are several diverse projects in the acoustics area. Bob Williamson and Rod Kennedy are investigating microphone arrays and have developed signal-processing techniques that allow broad-band beam forming. These techniques are useful for speaker tracking, reverberation control and noise reduction in complex environments. A group working with Bruce Millar is concerned with computer speech recognition from both fundamental and applied points of view. This work can be applied both to speaker recognition and to the recovery of spoken information.

Elizabeth Lindqvist, with her group at RMIT, is investigating the propagation of sound through porous and fibrous materials and the applicability of the Biot model. Other projects involve the effects of low-frequency sound on fluidised beds and wind-induced turbulence noise in motor vehicles.

Other areas of interest include subjects as diverse as the acoustic properties of Australian natural timbers and phonon spectroscopy at liquid helium temperatures. Some of these more exotic fields will be the subject of another review.