Acoustics Australia

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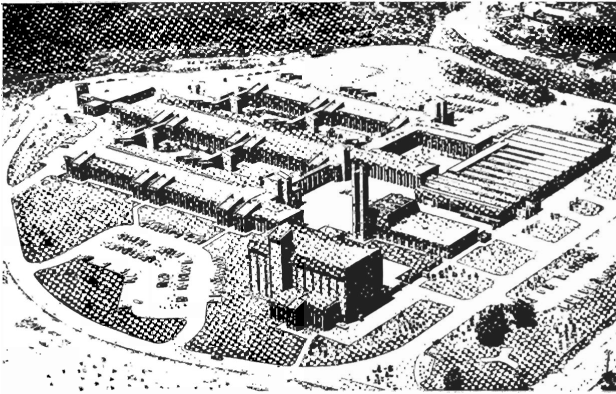

• *Acoustics at The National Measurement Laboratory*

Acoustics Australia

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CONTENTS

COVER . . . The photograph on the cover was taken from a helicopter by Harry Gillette of the National Measurement Laboratory.

NEWS

EDITORIAL

It is with pleasure that we welcome the following additions to our editorial team:

Neville Fletcher, who will be co-ordinating editor for special issues, and

Dennis Gibbings, who will be assistant editor responsible for articles, reports and technical notes from larger institutions and companies.

We also welcome **Mrs Leigh Wallbank,** who has been appointed as our part-time Business Manager. Leigh is the daughter of our printer, Fred Williams, and will include in her responsibilities arrangement of advertising as well as general financial and secretarial work.

This issue features a number of articles by members of the CSIRO Division of Applied Physics at the National Measurement Laboratory in Sydney. We are grateful to **Dr Suszanne Thwaites,** Project Leader, Acoustics and Vibration Standards Project, for co-ordinating and contributing to the set of articles. We hope to feature in future issues similar articles concerning the acoustical and vibrational activities of some of our larger institutions.

Howard Pollard
Chief Editor

LETTER

"Grey" Research

Like many other academics in Australia I am faced with how to maintain a viable research effort when there is a desperate shortage of science and engineering graduates and a government which is charging overseas post-graduate students $15,500 a year for the privilege of acting as slaves.

One possible solution is for me to make use of the "grey power" which is supposed to exist in copious quantities in Australia. If any of your readers who have retired (or are contemplating retirement) would like to exercise their grey matter on their own or my research whilst enjoying the title of Honorary Research Fellow, at Sydney University, I would be delighted to hear from them.

Fergus Fricke
28 Sept 89

13th ICA — Belgrade

The 13th International Congress on Acoustics was held in Belgrade from August 24 to 31, preceded by an associated symposium on musical acoustics in Mittenwald in southern Germany and followed by satellite meetings in Zagreb on electroacoustics, and in Dubrovnik on underwater acoustics. It is not clear just how many Australians were able to attend the Congress — computer system used the same abbreviation for Australians and Austrians — but the total of these two categories was eight, and I recognised three or four other Australians.

Total attendance of 700 was rather disappointing, since the organisers had planned on 1,000 and some other ICA meetings have been considerably larger. There were about 500 papers scheduled for the main Congress, though unfortunately about 50 authors failed to attend. The equipment exhibition was limited to a van from B & K and two or three small tables from other companies. But the spread of countries represented was about as broad as usual and there were many excellent presentations, including 17 plenary lectures. With as many as eight parallel sessions at times, it is difficult to give any overview of the content of the conference, but there was something for everybody. It is possible to scan the proceedings volumes (if you can find someone who attended), but this is recognised as a rather hit-or-miss process, and the International Commission is giving attention to the possibility of publishing future Congress Abstracts in some widely distributed form.

The centre of Belgrade has some old-world charm, but the Congress itself and the hotels were located in New Belgrade, which is flat and architecturally dull, despite the Danube which borders it. For many participants, a welcome break was provided by a two-day visit to the medieval walled city of Dubrovnik, on the Adriatic Sea, during the week-end. There was also an excellent concert of Byzantine choral music and an opportunity to hear the Vienna Boys Choir. The Congress Banquet featured Yugoslavian traditional music played at an uncomfortably high level by an enthusiastic quartet.

The 150 people who attended the Musical Acoustics symposium at the German violin-making School in the charming alpine village of Mittenwald before the Congress certainly enjoyed that experience, and no doubt the same was true of the comparable numbers who attended the two specialist post-Congress meetings.

Yugoslavia is a country few of us had visited before, and our hosts did everything possible to make the Congress pleasant and memorable. Food was unexpectedly cheap and good and the wine quite reasonable. Of course one noticed the inflation — 1,000% in 1988, and currently running at between 2 and 3% per day! The exchange rate for US dollars rose from 25,000 dinars to 30,000 dinars during the week of the Congress! It was interesting to find how the local populace manages with a mix of "spend it now" and a well-developed black market in hard currencies.

The 14th ICA is scheduled for Beijing during 3-10 September 1992, by which time it is hoped that the political situation will have returned to normal, and the 15th ICA for somewhere in Europe in 1995.

Neville Fletcher

Address Changes

Acoustics Australia

The new postal address for correspondence and business matters relating to this publication is

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Something Free

Copies of the volume "The Acoustics of Stringed Musical Instruments", published by the University of Wollongong, may be obtained free of charge by contacting **Abe Segal,** Honorary Visiting Fellow, Acoustics Laboratory, School of Physics, University of New South Wales, PO Box 1, Kensington 2033. Tel: (02) 697 4575.

MEETINGS

Acoustic Emission

The 10th International Symposium on Acoustic Emission will be held in Sendai, Japan, from 22 to 25 October 1990. The purpose of this symposium is to bring together all who have had a significant involvement in applications, research and development and standards for acoustic emission.

The symposium will be followed by two workshops to be held in Kumamoto City from 29 to 31 October 1990. One workshop will be on Acoustic Emission in Civil Engineering and the other will be on Acoustic Emission and Rock Fracture Mechanics.

See listing in Future Events (inside back cover) for the contact addresses.

* * *

Tactile Aids

The 1980s have seen rapid advances in the technical aids provided by profoundly hearing impaired people. The advent of multichannel cochlear implants, improved high powered hearing aids and wearable tactile aids have all led to improvements in the communication potential of the profoundly hearing impaired. Although there have been a number of international conferences on cochlear implants and hearing aids there have been few opportunities for tactile researchers to meet as a group to present their research findings and discuss their work. The National Acoustic Laboratories Central Laboratory invites all those interested in tactile research to attend an International Conference on tactile and other aids for the profoundly hearing impaired in Sydney in 1990. The Conference will run from Tuesday May 1 to Thursday May 3, 1990. The Tactile Aid Confeernce will be restricted to 120 participants. The registration fee will be kept to a minimum to encourage attendance. The Conference has been timed to coincide with the 1990 Audiological Society of Australia Conference which will be held in Thredbo, NSW, from Thursday April 26 to Sunday April 29, 1990. These two Conferences offer participants a unique opportunity to gain an overview of Audiological research in Australia.

Researchers and clinicians working with tactile aids, hearing aids and cochlear implants are invited to submit proposals for presentations at the International Conference. Applicants should send a detailed summary (250-500 words) of the presentation to the Conference Organisers by November 30, 1989. For further information see Future Events listing (inside back cover).

Metropolis '90

Metropolis '90 will have three tiers — plenary, concurrent keynote addresses, and — the heart of the Congress — a tier of seminars, round table meetings, workshops and field trips.

The plenary speakers will set the scene. They will speak from a global perspective and a position of acknowledged authority.

The keynote speakers will cover the following themes:

- Patterns of Growth
- Metropolitan Economy
- Housing and Population
- Environment and Health
- Political and Administrative Organisation of Metropolises
- Transport and Infrastructure
- Australian Metropolitan Development

Metropolis '90 will be held in Melbourne from 15-19 October 1990 and further information is available from the Secretariat, 545 Royal Parade, Parkville, Vic. Tel (03) 387 9955. Fax (03) 387 3120.

AAS ANNUAL CONFERENCES

The 1989 Annual Conference has been postponed because of the airlines dispute and will now be held in Perth on **19-20 April 1990.** The call for papers has now been extended until 31 January 1990. Authors of papers already accepted need not re-apply. Details are given on the Future Events page (inside back cover).

The subsequent Annual Conference has also been postponed. Consequently, the next AAS Annual Conference after Perth will be held in **November 1992** at Ballarat, Victoria. Details of the 1992 Conference will be announced at a later date.

ACT

August Technical Meeting

On 22 August, **Gary Scott** from the Environmental Planning Branch of the National Capital Planning Authority (NCPA) spoke on "Acoustic Control in the ACT — Past, Present and Future". Since the early 1970s, acoustic control for the ACT resided mainly in the planning functions of the National Capital Development Commission (NCDC) and was primarily concerned with traffic noise. More recently the Environment Protection Authority, of the ACT Administration, has entered the field via the 1988 Noise Control Ordinance. Since the introduction of Self Government in the ACT, the planning and control functions have spread even further afield.

Firstly Gary reviewed the role of the NCDC in acoustic studies and control measures associated with town centres and urban areas. Then he spoke about the role of the NCPA regarding acoustic control expressed concern about the future now that the important links between planning and development, which existed in the NCDC, have been broken. There has been a fragmentation of the groups and the specialist knowledge which has been developed over past decades may be lost.

While the number attending the meeting was small, there was a stimulating discussion on the importance of the consideration of noise issues in future planning and on the need for acoustic criteria in the ACT. This discussion continued during the dinner at a nearby Italian restaurant.

October Meetings

Two joint meetings were held in October. One was held in conjunction with the Institution of Engineers,, Mechanical Engineering Branch, on Tuesday 10 October. **Marion Burgess,** from the Acoustics and Vibration Centre at the Department of Mechanical Engineering, Australian Defence Force Academy, spoke on "The Noise from Trains". She commenced with an overview of the acceptable noise levels and the guidelines established by the environmental agencies in Australia and around the world. This was followed by a discussion of the major sources of noise and vibration for railways and the methods available for the reduction of the noise. Reference was made to some typical train noise signatures and to predictions for the proposed Very Fast Train.

The second was held in conjunction with the Australian Institute of Physics on 25 October. **Neville Fletcher,** Chief Research Scientist, CSIRO, and Visiting Fellow at ANU, spoke on "Nonlinearity, Chaos and the Sound of Music". The sounds of musical instruments are usually thought of as being produced by exactly linear processes; indeed the whole of music is built on harmonic relationships — or is it? This talk took a closer look at a few conventional instruments and showed that the sounds they produce contrive to be harmonic only through the intervention of strong nonlinearity. In some instruments, however, particularly in large shallow gongs and cymbals, nonlinear effects go much further than this and produce frequency shifts, energy cascades and vibrational chaos. Neville demonstrated some of these effects and discussed the analysis in terms of limit cycles, bifurcations and strange attractors.

Following the success of these joint meetings it is hoped that more will be arranged in the future.

Marion Burgess

NSW

September Symposium

On 20 September there was a good attendance for a symposium on "Assessment of the effects of aircraft noise on people". This topic is of particular interest in light of the consideration being given to the construction of a third runway at Sydney Airport.

Four speakers presented papers, which were followed by discussion. Professor **Anita Lawrence** (School of the Built Environment, University of New South Wales) began, with some comments on the Draft Guidelines on an Environmental Impact Statement for the proposed third runway at Kingsford-Smith Airport. **Judy Sinclair** (National Acoustic Laboratories) reminded all of the human impact of land use planning with an analysis of recent complaints from Sydney residents about aircraft noise. The third speaker was **Leigh Kenna** (Civil Aviation Authority). Leigh described the method of calculating Australian Noise Exposure Forecast (ANEF) contours for land use planning in the vicinity of airports. Finally, **Rob Bullen** (Renzo Tonin and Associates) presented a discussion of the interpretation of ANEF contours in assessing the impact of aircraft noise on people.

The lively discussion indicated the interest and enthusiasm of the audience.

VICTORIA

AGM and August Meeting

The Annual Meeting of the Victoria Division was held at Gas and Fuel Corporation, Scientific Services Department, Highett, on 31 August 1989. There were 24 members and friends present. Claude Senese and Keith Porter were elected to the committee for the coming year while Simon Leverton and Mike Hartley stood down. Thank you Simon and Mike for your contribution to the Society over the last few years.

The August Technical Meeting, entitled "Sound Intensity — A User's Perspective" followed the AGM. Sound intensity has been promoted with considerable acclaim by the various manufacturers of intensity equipment and we have all wondered whether these claims could possibly be true.

The sound intensity users, **Mike Snell, Dave Hoskins** and **Paul Walsh,** discussed the successes and frustrations encountered during their use of equipment and software. There were many frustrations, particularly in understanding the transmission paths of noise into vehicles. However, the claims for measurement of sound power of sources in-situ and in the presence of background noise appear to be well justified. No other technique allows sound power measurements to be made on appliances installed according to the appliance manufacturer's recommendations.

The draft standards for sound intensity measurement recommend the use of "quality" indicators, generally based on the difference between sound pressure and sound intensity. The use of these indicators should show when measurements are close to the limitations of the measuring equipment. However, the current computer software does not include these indicators.

Sound intensity appears to have offered considerable benefits for those who have worked with it. Development of software with quality indicators and the ability to combine measurements to obtain sound power from large or complicated surfaces will considerably enhance the versatility and reliability of sound intensity measurement.

Mike Snell

SA

1988 Conference

The 1988 Annual Conference of the Australian Acoustical Society was held at Victor Harbour in South Australia between the 24th and 25th of November. It was organised by the S.A. Divisional Committee around the theme of **Noise Into the Nineties.**

The Conference Organising Committee received an overwhelming response to its call for papers with more than 25 being received by the due date. Eventually, 18 papers were selected and poster sessions were offered to the remaining papers. The papers were organised into six sessions over the two days.

The President of the Society, Mr. Bob Boyce, opened the proceedings for more than 70 delegates who then listened to papers ranging from traffic, helicopter and atmospheric sound propagation to hearing loss, intensity measurements and statistics over the two days. All delegates attending the conference appreciated the high standard of the papers presented as well as the excellent hosting of the event by the Apollon Motel.

A limited number of copies of the proceedings are available from the Secretary of the S.A. Division (Bob Williamson) for $35 including postage within Australia.

Bob Williamson

People

John Upton has been appointed Regional Manager for Victoria, Tasmania and South Australia for Bruel and Kjaer Australia.

* * *

Charles Rossiter has recently joined the consulting firm of Ron Carr Associates in Melbourne.

* * *

Congratulations to **Stephen Samuels** on being awarded a PhD for his thesis entitled "The Generation of Road Traffic Noise under Interrupted Flow Conditions".

* * *

New Members

• Admissions

We have pleasure in welcoming the following who have been admitted to the grade of Subscriber while awaiting grading by the Council Standing Committee on Membership.

New South Wales

Mr J Alekna, Mr S Connolly, Mr P J Cordina, Dr K S Jraiw, Mr C McKieth, Mr M Poon, Mr G Tanos.

South Australia

Mr P A Heinze, Dr J Pan.

Victoria

Dr P Alabaster.

• Graded

We welcome the following new members whose gradings have now been approved.

Student

New South Wales

Mr P Karantonis.

Subscriber

New South Wales

Dr J S Lai (ACT).

Member

New South Wales

Mrs J Ablamowicz-Potapowicz (ACT), Ms L A Hudson, Mr D Lindsey, Mr B H Meldrum, Mr Nan Hung Pan.

Queensland

Mr R B Brennan.

Victoria

Dr M Corrigan, Dr A J Cramond, Mr C Senese.

* * *

Student Awards

The Victoria Division has instituted a student award scheme beginning in 1990 to encourage students undertaking acoustical studies in tertiary institutions. The award will be made to a student at each of the selected institutions who has demonstrated excellence in studies in the field of acoustics. The recipients will receive a cash prize of $150, one year's membership to the Society and a certificate.

At present three institutions have accepted participation in the scheme.

The State of Acoustic Standards at the National Measurement Laboratory

Suszanne Thwaites
Division of Applied Physics, CSIRO
P.O. Box 218, Lindfield NSW 2070

ABSTRACT: The past year has been an interesting one for the CSIRO, filled both with uncertainty surrounding its reorganisation and with an unaccustomed prominence in the media associated with the increased level of public debate about scientific issues. Most Divisions have found themselves reformed under new names, with new priorities and new constraints. Surprisingly, the same period has been a time of increased activity in the acoustic and vibration standards area with a number of new and more sophisticated services becoming available. This article looks at the current position of the acoustic standards at the National Measurement Laboratory.

1. INTRODUCTION

According to the Science and Industry Research Act of 1949 it is the responsibility of the CSIRO to establish, develop and maintain standards of measurement for physical quantities, to promote their use and to participate in the development of calibration with respect to them. In the National Measurement Act of 1960 it is further stated that the CSIRO

> "shall maintain, or cause to be maintained, such standards of measurement as are necessary to provide means by which measurements of physical quantities, for which there are Australian legal units of measurement, may be made in terms of those units."

A unit is an "Australian legal unit of measurement" when it is so defined to be by virtue of being mentioned in the regulations to this act [1]. Of immediate interest to the acoustics community is the fact that the regulations under this act were amended in 1985 to include sound pressure level, sound power level and sound intensity level as designated quantities for which there are Australian legal units (dB as it happens). Consequently, the use of these units now implies a traceability to some national standard.

2. STANDARDS POLICY

The Division of Applied Physics, now a division of the Institute of Industrial Technologies, is charged with fulfilling the statutory obligations on the CSIRO contained in these two Acts. It bears the distinction in a revamped CSIRO of being one of only a few Divisions not to experience a name change. It is still located at the National Measurement Laboratory in Sydney with branches in Melbourne and Adelaide and, more importantly given the metamorphoses surrounding the CSIRO in the past year, its interpretation of these obligations remains unchanged. They are

- maintenance of standards
- calibration
- standards research:
  - basic research on primary standards
  - development and updating of standards
  - regional and international intercomparisons
  - improved methods of dissemination of standards
  - industrial measurement research
- representation of Australia as a signatory to the Metric Treaty.

The current group emerged from the reorganisation of 1988 as the Acoustics/Acceleration Standards Project and comprises about four people although the situation tends to be fluid depending on demand. Under the new organisational philosophy, groupings are project-oriented and staff may distribute their time amongst standards and industrial measurement projects according to interest and/or demand.

It is Divisional policy that, in general, only the primary level calibrations be undertaken at the laboratory and that traceability to the national standards, that is, maintenance of the calibration hierarchy in the community be realised via secondary standards held by state authorities. This is provided for in the National Measurement Act. However, it is also recognised that technological developments requiring new calibration services are continually evolving and the Division is also expected, within reason, to develop a new standard or to undertake any secondary level or ad hoc duties should there be the demand.

3. ACOUSTIC STANDARDS

Acoustical measurement begins with a microphone and acoustical activity at the National Measurement Laboratory commenced in 1972 with a project to establish a microphone calibration facility based on the internationally accepted principle of reciprocity. A unique three port coupler was developed, the benefits of which are still being discovered. With this, microphone sensitivity was measured at 250 Hz with an uncertainty believed to be less than 0.05 dB [2]. In 1979 a set of three 1" B&K type 4144 microphones was designated the Primary Standard Set to be maintained as the Australian standards. These are kept in the three port coupler and survive to this day. They are calibrated a good deal more frequently, certainly more quickly and under a greater variety of conditions than ten years ago. This has been possible not the least because of the versatility of the original design.

Outside the reciprocity coupler, microphones are routinely calibrated over the range 100 mHz to 20 kHz by a variety of methods. In each case an auxiliary standard microphone is calibrated by reciprocity firstly, against the primary standards. Then the standard may be transferred to the next level of calibration by comparison with the auxiliary microphone. At the very low frequencies, microphones are compared with a low frequency standard microphone in a vibration isolated vessel. Over the mid range, 16 Hz to 1000 Hz, pressure response may be measured in a microphone comparison

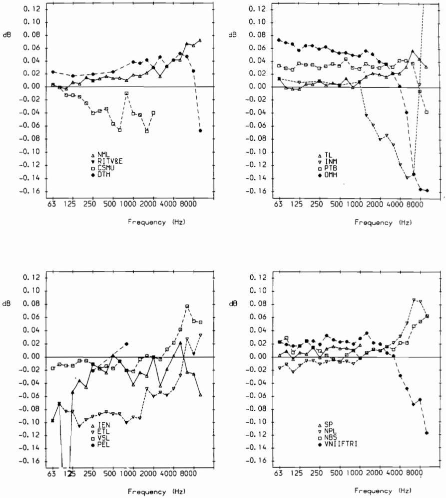

Figure 1: Sensitivities of Bruel and Kjaer type 4160 microphones reported by participating laboratories, plotted relative to the mean difference, at each frequency, between these and the sensitivities determined by NPL (courtesy Torr and Jarvis, private communication). Key: RITV&E—China; CSMU—Czech; DTH—Denmark; TL—Finland; INM—France; PTB—FDR; OMH—Hungary; IEN—Italy; ETL—Japan; VSL—Netherlands; PEL—NZ; SP—Sweden; NPL—UK; NBS—USA; VNIIFTRI—USSR.

coupler. The electrostatic actuator technique measures sensitivity over the range 100 mHz to 20 kHz and free field sensitivity is measured by comparison with a free field standard in an anechoic room from 300 Hz to 20 kHz. Quoted uncertainties range from ±0.5 dB at 100 mHz to ±0.1 dB from comparison coupler and electrostatic actuator measurements up to ±0.5 dB for a free field measurement at 20 kHz. These are conservative uncertainty estimates, that is 99% confidence values.

4. RECENT EVENTS

The results of the latest international intercomparison of microphone sensitivity measurements held by the National Physical Laboratory in the UK are due to appear in Metrologia this year [3]. The intercomparison involved reciprocity calibration of standard microphones for frequencies up to 10 kHz, a rather unusual thing to do. A large number of countries participated and a summary of some of the results, including those from NML, are displayed in Figure 1. In the Asia/Pacific region the laboratory calibrates both the acoustic and vibration standards from New Zealand and vibration standards from Singapore (SISIR). Under the AIDAB scheme it has recently hosted a guest scientist from Malaysia on a three month research program preparatory to setting up an acoustic standard at the Scientific and Industrial Research Institute of Malaysia (SIRIM).

A flurry of activity in the group over the past couple of years has considerably extended the laboratory's capabilities and details of some of these projects will be described in the following articles. The development of a calibration service for the low frequency blast-overpressure microphones attached to ground vibration monitors is an example of this. These microphones can be calibrated down to 100 mHz. Another example is the current research and development program set up to establish a facility to measure output power and beam profile of ultrasonic transducers. Considerable effort has also gone into automating the primary standards calibrations. (Whilst on the subject of new facilities the vibration laboratory can now calibrate accelerometers down to 0.1 Hz. The high frequency end is also extended with the ability to measure oscillatory displacements as low as 2 nm [4]).

Whilst the use of acoustical standards in the community and in industry has always been desirable, the recent changes under the National Measurement Act mean that the CSIRO now ought to extend its responsibility in the "dissemination of standards", that is, the promulgation of the calibration chain relating measurements in the community to the first level standards held by the Division. To this end we have been talking to people in an attempt to find out where acoustical measurement in Australia stands with regard to traceability. The answer has been confusing but the result is that, in conjunction with NATA, it is proposed to hold an Australia-wide "round robin" involving single frequency calibration of some microphones and pistonphones. All interested parties may participate, at a minimal cost, and details will be made available soon. Enquiries may be addressed to B.H. Meldrum, at the National Measurement Laboratory.

Work is continuing on the problems of calibrating of community noise analysers, particularly the statistical analysis features which are now commonly available. Finally, there is the problem of sound power and sound intensity in relation to the National Measurement Act.

REFERENCES

1 National Measurement Act 1960, reprinted as at 30 September 1984.
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3 G.R. Torr and D.R. Jarvis, "A Comparison of National Standards of Sound Pressure." Metrologia (1989) (in press).
4 N.H. Clark, "An Interferometric Method to Measure Oscillatory Displacements, 2 nm to 255 nm." Metrologia, *26*, 127-133, (1989).

Low Frequency Microphone Calibration at the National Measurement Laboratory

B.H. Meldrum and K.J. Hews-Taylor
Division of Applied Physics, CSIRO
P.O. Box 218, Lindfield NSW 2070

ABSTRACT: The need for accurate and traceable calibration of the low frequency microphone channel used in modern Blast monitors has led to the setting up of a facility at the National Measurement Laboratory. With this facility it is possible to calibrate down to frequencies as low as 0.125 Hz, and to check amplitude linearity up to Sound Pressure Levels of 140 dB.

1. INTRODUCTION

Blast overpressure resulting from explosions has been accepted as an important factor in the criteria for predicting and controlling structural damage. Modern Blast Monitors have an acoustic channel as well as channels for measuring 3 orthogonal components of ground motion.

There has been growing community awareness of the need for calibration of the acoustic channel and the possibility of legal challenge to the validity of a blast overpressure measurement. This has led to a number of approaches being made to the National Measurement Laboratory for the setting up of a facility to calibrate the special low frequency microphones used. The following description outlines the facility that has been set up to fill that need.

Amongst the approaches for assistance was one from an Australian manufacturer of monitoring equipment, Micro Innovations Pty Ltd, an export dollar earner with a substantial and growing domestic market. It was felt that such a calibration facility was important, not only as an aid to quality assurance in manufacture, but also to provide a traceable calibration for domestic purposes as well as a recalibration service.

The implications of the National Measurement Act revisions have been elaborated elsewhere in this issue [1] and it seems unwise to use equipment that is not properly calibrated in case of litigation or contentious argument. There has, as a result, been substantial use made of the facility at NML.

2. REQUIREMENTS OF A LOW FREQUENCY CALIBRATION SYSTEM

It was determined that three parameters should be measured during a calibration:

(a) Absolute Sensitivity
(b) Frequency Response
(c) Amplitude Linearity

It is obviously not possible to calibrate at all levels and all frequencies so a compromise was reached. The proposal was to first measure absolute sensitivy at 250 Hz which is regarded as a reference frequency. There were already established procedures at NML for this test for microphones that could not be calibrated directly by reciprocity.

It was then determined that the facility should be able to work from the reference frequency of 250 Hz down to at least 0.1 Hz in order to accurately reproduce the transient nature of an overpressure pulse.

Amplitude linearity is important because a blast monitor is required to operate in a very wide range of conditions. This calls for a very wide dynamic range, perhaps in excess of 80 dB. Up to 140 dB SPL could be encountered in near field measurements.

3. ABSOLUTE SENSITIVITY

This measurement is carried out by comparison at 250 Hz, a frequency used at NML as a standard reference frequency for reciprocity calibration. The first step is a calibration of two auxiliary standard microphones by reciprocity [2]. These are Bruel & Kjaer type 4144 condenser microphones. Next, the test microphone is compared with each standard in turn.

For the comparison, a sound pressure level of 104 dB is used in an acoustic coupler. This device has a cylindrical cavity into which the test and reference microphones are placed facing each other. The microphones are accurately located in O-ring seals and the sound is introduced from a loudspeaker via a central hole. A set of adaptor rings allows the calibration of many different types of microphone including either of the two common low frequency types: the Sennheiser type MKH110/1 or the Cirrus type MK182LF.

The instrumentation used for microphone sensitivity comparison is shown in Figure 1. The signal is introduced to the test channel preamplifier via a dummy microphone matched to simulate the type 4144 microphone reference cartridge. This ensures that the test microphone is compared with the open circuit sensitivity of the reference cartridge, obtained by reciprocity.

A ratio transformer in each channel is adjusted to make the signal the same in each channel. The test microphone sensitivity is then obtained from the "ratio of the ratios" expressed as a difference in dB from the sensitivity of the "cartridge" of the reference microphone.

Typical sensitivities for the common types of low frequency microphones are from 2.5 to 5.0 mV/Pa (-52 to -46 dB re 1 V/Pa). This result can be given with an uncertainty of ± 0.1 dB at 250 Hz.

4. FREQUENCY RESPONSE

Where it is not possible to access the test microphone diaphragm with an electrostatic actuator to directly establish the frequency response, the measurement becomes one of comparison between the test and reference microphones at each frequency. The major problems of arranging a comparison frequency response test down to a frequency of 0.1 Hz are (i) how to generate the sound field? (ii) what to use as a reference microphone with known frequency response to such low frequencies? and (iii) how to accurately measure the RMS voltage of the reference and test microphones?

The generation of the low frequency sound field was accomplished by adapting an existing pressure vessel shown in Figure 2. This vessel has a capacity of 28 litres and is of massive cast steel construction. It is vibration isolated and is normally used for microphone pressure coefficient testing and

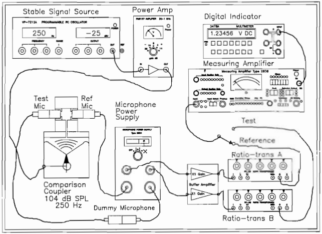

Figure 1: Instrumentation layout used for the absolute sensitivity measurement by comparison of a microphone that cannot be calibrated directly by reciprocity.

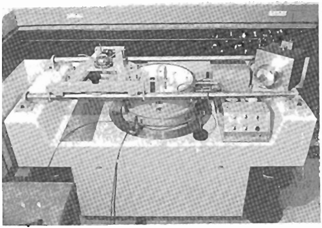

Figure 2: Photograph of the massive cast steel pressure vessel used for the frequency response measurement.

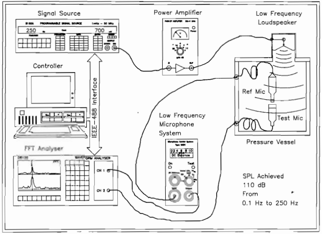

Figure 3: Instrumentation layout used for the determination of the frequency response of low frequency microphones down to 0.125 Hz.

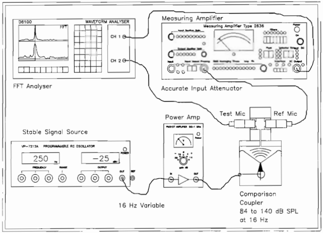

Figure 4: Instrumentation layout for the measurement of the change of absolute sensitivity with sound pressure level.

determinations of the noise floor levels of instruments. Its use brings two very great benefits: *firstly*, that the two microphones are isolated from low frequency pressure fluctuations such as those due to air conditioning, door openings and wind buffeting of the building, and *secondly*, that the whole microphone is subjected to the sound field, thereby more closely simulating the conditions of use. For the comparison, the test and reference microphones are clamped facing each other in the centre of the vessel with a separation of 1 cm.

As the sound field below 250 Hz is essentially a pressure field, a loudspeaker is used as a pump to modulate the pressure in the vessel. The 210 cm diameter roll-surround loudspeaker has been modified to minimise cone porosity, and is mounted in a sealed housing attached to the removable top of the pressure vessel.

For the reference channel, a Bruel & Kjaer type 4147 ½ inch Microphone Cartridge [3] was chosen. The 4147 is a pressure microphone with a lower −3 dB frequency below 0.01 Hz achieved by a long time-constant of the back venting pressure equalisation.

The normal preamplifier is not usable at such low frequencies, so a Bruel & Kjaer type 2631 Carrier System [4] was chosen. The 2631 uses the capacitance of the microphone cartridge as part of the resonant circuit of a frequency modulation detector mounted in the preamplifier case. This is attached to the control unit by a cable. The arrangement allows the head plus microphone to be mounted inside the pressure vessel and the control unit outside where it is accessible.

The frequency response of the 2631 is from zero to 150 kHz. A verification of the low frequency response of the 4147/2631 combination was carried out using an electrostatic actuator.

The usual methods for the measurement of RMS voltage, such as rectifier detector or thermal converter become unusable at such low frequencies. A viable alternative that has become available with the advent of modern digital waveform analysers is to use digital sampling of the waveform and to calculate the RMS voltage from the digital samples. This method is attractive at low frequencies where very accurate analogue to digital converters with wide dynamic range are available.

For this application a Data Precision DATA-6100 Waveform Analyser was chosen. The instrument was available with an input module that allows simultaneous digital sampling of the test and reference channels with 14 bit (1 in 16348) resolution of full scale ranges of 500 mV and 5 V. For each measurement, 25 to 50 cycles of the two channels are captured simultaneously and stored in input buffers.

A Fast Fourier Transform of the maximum number of complete cycles in the input buffer for each channel is calculated and the ratio of the amplitudes of the same spectral line in each is obtained. From this ratio, the difference between the reference and test microphone sensitivities is obtained. This technique, of coherent sampling and limiting the FFT to the same number of complete cycles, circumvents the inaccuracies arising from the finite frequency resolution of the FFT.

The instrumentation layout used is shown in Figure 3. The measurement is carried out under computer control via an IEEE-488 interface using an "IBM compatible" PC/XT computer as the controller. The control software has been written using the standard GWBASIC interpreter and is currently being rewritten using the TRUE-BASIC compiler system. The frequency response test takes 25 minutes as the data acquisition at the lower frequencies may take up to 250 seconds.

The uncertainty quoted for the measurement is ±0.2 dB for frequencies from 250 Hz down to 16 Hz, rising to ±0.4 dB at the lowest frequency of 0.125 Hz.

5. AMPLITUDE LINEARITY

The acoustic coupler described in Section 3 is also used for the amplitude linearity measurement. A frequency of 16 Hz was chosen for the measurement: this is within the frequency band of interest for an overpressure pulse, and is a frequency at which the conventional loudspeaker used in the acoustic coupler can reach 140 dB SPL with acceptable distortion.

This measurement, using instrumentation shown in Figure 4, is a comparison between the test microphone and a reference B&K type 4144 microphone of known amplitude linearity. The B&K reference microphone preamplifier type 2639 is taken directly to the "pre-amp" input of a B&K type 2636 Measuring Amplifier.

The attenuator of the 2636 has been well calibrated and allows the 2636 full scale range to be stepped in known 10 dB increments. The sound pressure level is increased in 10 dB steps from 74 dB SPL to 134 dB SPL, then a 6 dB step takes the level to the maximum of 140 dB. This technique allows the reference channel of the measurement system to have a nearly constant reference voltage, which is measured at the AC output of the 2636. The only variation is due to small errors in the drive system attenuator, or due to the step from 134 dB to 140 dB where the 2636 range remains untouched.

The comparison of the reference voltage output from the 2636 and the output from the test microphone is made using the DATA-6100 waveform analyser and the technique described above in Section 4. Thus by incrementing the SPL drive level in 10 dB steps; increasing the full scale range on the 2636 measuring amplifier and comparing its AC output signal with that of the microphone under test, it is possible to determine how the test microphone sensitivity varies with amplitude (see Figure 6).

At the time of writing, software is being written to allow the linearity test also to be carried out under computer control. The uncertainty of measurement for this test currently ranges from ±0.2 dB to ±0.3 dB.

6. SOME TYPICAL TEST RESULTS

The need for frequency response measurements is amply demonstrated in Figure 5 where the results of the calibration of five different microphones of the same type are shown. These results show the extremes of the variation in frequency response observed: a maximum variation of ±10 dB from an ideal response at 0.125 Hz, and a variation of +1 to −3 dB at 1 Hz. Without knowledge of or compensation for these variations, a measurement could be considerably in error depending on the frequency content of the overpressure pulse.

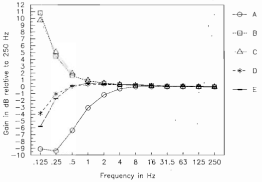

Figure 5: The frequency response of five sample low frequency microphones between 250 Hz and 0.125 Hz.

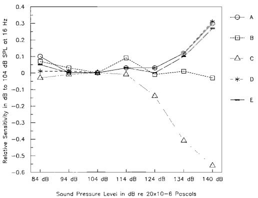

Figure 6: The variation of the absolute sensitivity of five sample microphones as the sound pressure level is increased from 84 dB to 140 dB.

An amplitude linearity measurement for the same five microphones is shown in Figure 6. This shows that the sensitivity of some individual samples can vary by as much as +0.3 to −0.5 dB as the amplitude of the sound field increases to 140 dB SPL. Whilst these errors are not as great in magnitude as those observed in the frequency response tests, the measurement does give an assurance that the microphone does not become highly nonlinear or start to "clip" as maximum expected levels are reached. A performance such as that of Sample "C" shown in Figure 6 should be investigated further before the microphone is used.

In the three years since the facility was set up, some 40 microphones have been calibrated thus suggesting fair demand. It is known that there are more than this number of Blast Monitors in use in Australia so we must conclude that there are some that are either uncalibrated or have calibrations that are not traceable to Australian Standards. This leaves the measurements made with these instruments open to challenge in cases involving litigation.

The service has not been in operation long enough for us to see many recalibrations of microphones. It will be informative to monitor these microphones as they are recalibrated to determine how the aging process affects their performance. The facility is being further developed as time permits, and it is expected that the uncertainties of the frequency response and amplitude linearity measurements will be lowered.

7. CONCLUDING REMARKS

By responding to expressed community needs with regard to calibration services, the National Measurement Laboratory is able to contribute to the advancement of Australian measurement technology. By using the system described above, practitioners of blast effect measurement can be assured that the microphones used with their blast monitors are performing correctly and that results quoted are more likely to stand up to expert scrutiny if technical argument ensues.

As has been illustrated, the characteristics of some low frequency microphones of the types commonly in use can vary widely and the only assurance possible for a user is to have the device calibrated as a matter of course.

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Obituary

J F M Bryant

BE, BA, Grad Dip Psych

James Bryant was born at Cottesloe, Western Australia, in 1919. After graduating in Electrical and Mechanical Engineering at the University of Western Australia, he spent six years in the Army as a telecommunications and radar officer with the Royal Australian Engineers. He served in the United Kingdom, the Islands, and finally in Japan.

After the war, Jim obtained a mathematics degree at the University of Melbourne. He then joined the Postmaster-General's Department where, until 1965, he worked in the PMG Research Laboratories, specialising in electro-acoustics, room acoustics, information theory and the human factors associated with telephone communications.

In 1965 Jim became a Research Fellow in Psychology at the Australian National University, after which he joined the Australian Road Research Board as a Principal Research Scientist, and Group Leader of the Human Factors Group. This group studied the relationship between personality and driving performance and the design of traffic lanes, warning signs, traffic control signals and street lighting for optimum performance in human engineering terms.

Jim joined the Acoustic Society at the time of the Victorian inaugural meeting on 16 November 1964. Those associated with him in the years leading up to the Society's incorporation as a federal body in 1971 will recall his great contribution to the committee and, in particular, the monumental effort he put into the preparation of the constitution. On this he worked with Ron Barden and Paul Dubout in Victoria and with those committee members in New South Wales undertaking a similar responsibility.

His death in August 1989 was not only a great loss to his wife and family and friends, but to all those who had the good fortune to be associated with him.

The Society expresses its sympathy to his wife Phyllis, until recently Principal of Sandringham House, Firbank Junior School, and to his three sons, Ian, David and Evan.

GERALD A B RILEY

Accelerometer Calibrations —Who Needs Them?

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ABSTRACT: When assessing the uncertainty of a measurement made with an accelerometer, the contribution which calibration error makes to systematic error may not be known. The present paper gives some guidance on this, with reference to recent round-robin calibrations, and outlines some calibration services at the National Measurement Laboratory.

1. INTRODUCTION

Accelerometers have almost completely supplanted other types of transducer for measurements of vibration. Exceptions to this include special uses of relative-motion displacement transducers, and very sensitive seismometers. In some applications, users are not interested in the absolute value of acceleration measurements, for example when dominant components of a vibration spectrum are sought, or when seeking a qualitative evaluation of "is A much greater than B?", both being measured with the same instrument.

There are many cases, however, where it is not only useful, but crucial, that the absolute value is known within calculable limits of uncertainty ("fiducial limits"). This will be so, for example, where it must be shown that a legal limit has not been exceeded, or where small changes of vibration over time must be distinguished from possible transducer drift.

In calculating uncertainty limits, systematic error is often the most difficult to assess, particularly the error component due to calibration error. The accelerometer and other components of a measuring system may have been calibrated by the manufacturer, but eventually it will be necessary to recalibrate.

2. CALIBRATION

For calibration in the field, one of the easiest acceleration references to use is the earth's gravitation. If an accelerometer has frequency response extending down to zero frequency (i.e. infinite time-constant), it can be calibrated by simply standing it on a surface with its sensitive axis vertically up, for a +1 g input. Then it can be inverted, for a −1 g input. Servo-accelerometers and some strain-gauge types, for example, can be calibrated in this way, and the results extrapolated at least up to low frequencies with maybe two percent uncertainty.

Also in common use are portable calibrators with which an acceleration measuring system can be checked at one amplitude, at a fixed frequency. These useful devices, analogous to the familiar portable calibrator for sound level meters, must in turn be checked periodically to ensure that the amplitude is what the user thinks it is. Generally these calibrators can be relied on to within about five percent.

Organisations which use many accelerometers often find it convenient to set up their own comparison calibration systems. Such systems commonly include an electrodynamic shaker, drive amplifier and oscillator, with possibly a compressor or other controls, a reference transducer and some means of measuring voltage ratios. Often these organisations also provide a commercial calibration service to other users of accelerometers, maybe with NATA accreditation (in Australia). The reference transducers of such systems are recalibrated at regular intervals by some standards laboratory, which in Australia is the National Measurement Laboratory (NML).

3. THE AUSTRALIAN ROUND-ROBIN

In 1988 NML and NATA conducted a round-robin of accelerometer comparison calibrations, using two donated working-grade accelerometers and two charge amplifiers. Five of the nine participating laboratories were registered with NATA for calibration of vibration transducers, and for these the round-robin was part of the NATA proficiency testing program. For NML, the main interest lay in obtaining realistic estimates of the uncertainty at this link of the calibration chain.

Participants were asked to calibrate each accelerometer/preamplifier set for voltage sensitivity, by comparison with their own reference accelerometer sets. Two laboratories also chose to calibrate the accelerometers alone, for charge sensitivity. Between each of the laboratories, the sets were sent to NML and recalibrated, as a stability check. Laboratories were identified only by numbers, in analysing the results.

Figure 1 shows individual results in mV/m.s^{-2} from six of the laboratories, for one of the accelerometers. The solid line is fitted to their mean at each frequency, the dashed line represents the means of the NML calibrations.

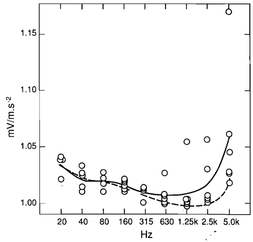

Figure 1: Australian Round Robin results from six laboratories, and their mean (solid line). The dashed line represents the NML calibrations.

The round-robin report [1] concludes that the uncertainty for a calibration of this type can be expected to be "... of the order of ±3%, from 40 Hz to 5 kHz for instruments of quality comparable to those in this series (see Appendix E). At smaller accelerations (10 $m.s^{-2}$) and at lower frequencies (20 Hz) an increase in uncertainty of anything up to 10% can be expected. However, it has also been demonstrated that, where due care has not been taken, it is possible to be in error by as much as 500%".

The "due care" mainly refers to gross mistakes with instrumentation or documentation, which occurred more frequently than expected by the organisers. These mistakes were responsible for a few very large errors. Apart from these cases (excluded from Figure 1), results generally were within the above uncertainties, and within the participants' own estimates of uncertainty except at the higher frequencies. The nature of deviations in the latter cases suggested that sufficient care had not been exercised in ensuring close coupling between the test accelerometer and the reference accelerometer. It is worth noting that similarly large errors in high frequency components could be expected when making field measurements, if close attention is not paid to mounting conditions.

4. CALIBRATION SERVICES AT NML

At NML several reference accelerometers are maintained as standards. These are frequently intercompared, and are regularly recalibrated at the laboratory by methods using optical interferometry. These are referred to as "absolute" calibrations, in which strict traceability is maintained to the primary standards of length, time and voltage. Each standard accelerometer is used always with its committed preamplifier, and the combination is calibrated in terms of volts per meter per second per second, at each of a number of amplitudes and frequencies which span the operating range [2].

Three of the NML standards are calibrated over the frequency range 20 Hz to 10 kHz, with amplitudes from 10 $m.s^{-2}$ to 5000 $m.s^{-2}$. Another four are calibrated from 2 Hz to 80 Hz, with amplitudes from 0.4 $m.s^{-2}$ to 5 $m.s^{-2}$. The uncertainty at the ISO reference frequency of 160 Hz is about 0.25%, and about 0.5% over the rest of the range.

Accelerometers submitted to NML, complete with their amplifiers, are calibrated by comparison with one or more of the above standards. Generally the least uncertainty quoted is 0.6% for most of the range. Velocity transducers can also be calibrated in a similar way. At frequencies from 20 Hz down to about 0.1 Hz, accelerometers are calibrated by rotation in a vertical plane, using as a standard the local value of "g", which is known with an uncertainty of about 5 parts per million. The uncertainty of these very low frequency calibrations is about 0.5% or more, depending on accelerometer sensitivity.

5. INTERNATIONAL INTERCOMPARISONS

Australia conducted possibly the first international intercomparison of absolute accelerometer calibrations in 1976, with PTB (the German standards laboratory). Over the frequency range 120 Hz to 1.2 kHz the results agreed within the uncertainty of 0.5% claimed by each of the two laboratories. Since then the range and accuracy of NML absolute calibrations have been improved by new techniques developed in the laboratory [3,4].

Since 1984, NML has been participating in an international round-robin of absolute calibrations, which involves 14 accelerometers and 22 laboratories in 19 countries. This has been organised on behalf of the ISO by R.M. Serbyn of NBS (the USA standards laboratory, now NIST). The third status report [5] indicates that, so far, "... 86% of all values fall within ±1% of median. The percentage within the ±0.5% limits is also very high, 73%". Most laboratories claimed about 0.5% uncertainty, but it is not clear whether these were all at the same confidence level. From what data we have been able to get, it seems that the calibration factors obtained at NML are consistently near the median.

6. THE FUTURE?

Many current applications of accelerometers could more suitably be tackled using Doppler velocimeters, which are apparently becoming cheaper and better and which may not require frequent recalibration.

Much cheaper accelerometers have recently come on the market, using piezoelectric polymers. These make multichannel instrumentation more practical, but as they seem to lack the stability of piezoceramics, more frequent recalibration may be necessary.

The calibration of accelerometers which are used for measuring impacts is not always satisfactory, in that it is difficult to assign uncertainty limits. Current practice is to determine the sensitivity and the frequency response using steady-state sinusoidal excitation. If the amplitude range required exceeds that which can be provided in this way, the linearity extrapolation is done using haversine excitation from impacts, with the relative acceleration found from the total velocity change. A method currently being developed at NML seeks to provide a more direct calibration using haversine excitation only, supplemented by a low frequency response test.

7. CONCLUSION

The above review should serve as a guide to users of accelerometers, in assessing the contribution which calibration error can make to uncertainty of measurement. Even broad estimates ("...oh, let's say plus or minus 30 percent, to be on the safe side...") may have to be backed up by calibration traceable to standards, particularly if there is the possibility of a legal challenge. Of course, it is recognised that there are still a great number of applications where calibration may be of no interest at all to the user.

It should be mentioned that the uncertainties quoted throughout this discussion are at the 99 percent level of confidence, which is usual for standards work.

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The Pistonphone as a Portable Reference

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ABSTRACT: The Pistonphone now in common use as a portable single frequency reference for Sound Pressure level calibration is a cost effective and efficient means of maintaining traceability to National Standards. Where the ½ inch microphone is used, there is potential error if the pistonphone has not been calibrated for the ½ inch adaptor. The discussion relates experience at the National Measurement Laboratory of the possible errors involved.

1. INTRODUCTION

The Pistonphone, or Reference Sound Pressure Level Calibrator, has been increasingly used over the last few decades as a means of maintaining an "Internal Standard" for Sound Pressure Level at one frequency in many organisations where Sound Level Meters are in use. Three factors have brought to light a potential source of error in one mode of the use of the pistonphone.

The first is the increasing emphasis on the need for a "traceable calibration" by users who have realised the implications of the revisions to the National Measurement Act as discussed in the publication [1] elsewhere in this issue. This has led to an increasing demand for calibrations at NML. The second factor is the increasing use of the ½ inch microphone as a transfer standard, and also as a working microphone on many modern SLMs. The third factor is the decreased uncertainty in pistonphone calibration at NML associated with decreased uncertainties in the reciprocity calibration of the microphones used as the transfer standards during a pistonphone calibration.

2. PRINCIPLES OF OPERATION

The critical element for this discussion of the pistonphone is the volume of the cavity. This cylindrical cavity is sealed except for four openings. The first is an axial port on one end of the instrument into which the microphone is inserted to be sealed by an O-ring and to locate against a shoulder thus accurately determining the position of the diaphragm when a B&K pattern microphone is used. The second is a long-time constant-bleed that allows the pressure to equalise to ambient after a microphone has been inserted.

The other two openings are cylindrical holes located radially near the base of the cavity and having in them small teflon pistons which are spring loaded inwards against a camshaft on the end of a small motor lying on the axis of the instrument, but outside the cavity. As the camshaft turns, the lobes move the pistons in a sinusoidal motion in antiphase against the spring, and the volume of the cavity is thereby modulated by the swept volume of the pistons. The SPL resulting from the pressure variation is determined by the ratio of this swept volume to the total volume.

3. SOURCES OF ERROR

The variables that determine the SPL output are, in the main, controllable or can be corrected for, such as air density due to atmospheric pressure, for which the maker will usually supply a small aneroid barometer marked in output correction versus local atmosphric pressure. The other variables, such as cavity volume, adaptors which compensate for change of volume due to different microphones and camshaft stroke, are the province of the manufacturer but can be "calibrated out" after manufacture by determining the correction necessary. The latter factor should remain constant if sufficient care is taken in design, and the instrument is properly maintained.

Two other variables that are not carefully controlled by many users are the health of the O-ring seals which, if allowed to harden or deform, can allow leakage past the microphone or adaptor thereby lowering the output by an undetermined amount, and when in use, the correct insertion of the microphone into the output port so that it locates firmly on the metal lip.

4. UNCERTAINTIES

Past practice has seen most pistonphones calibrated only with a 1 inch microphone in order to check the maker's figure for output SPL, and then used with the adaptor supplied with the instrument when the need arises to calibrate a ½ inch microphone. For the Bruel & Kjaer type 4220 pistonphone, shown in Figure 1, which appears to predominate in Australia, the maker states on the calibration card inside the box lid an uncertainty of ±.2 dB for *correct calibration*.

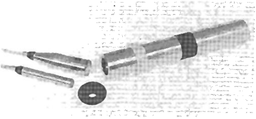

Figure 1: A Bruel & Kjaer type 4220 Pistonphone shown with a 1 inch and ½ inch microphone together with its adaptor.

In the literature supplied [2,3] with the pistonphone, mention is made that (a) the calibration uncertainty is ±0.2 dB (±0.15 dB in recent literature) in output SPL, and that (b) for B&K pattern microphones, the supplied adaptors are made to correct for change of *front volume* when a smaller microphone is used. The term *front volume* is defined to include both the air volume between the protective grid and the diaphragm, and the component due to the *equivalent volume*. The effect of change of *equivalent volume* will be discussed below.

The 0.2 dB figure is conservative, as the science of reciprocity calibration has marched on and increased accuracy has lowered the uncertainty in the sensitivity of microphones calibrated by this method [4]; we quote ±0.02 dB at NML for in-house calibration of our own microphones. Thus the uncertainty with which the pistonphone output can be calibrated at NML has been calculated to be ±0.05 dB at the 99% confidence level.

This lowering of stated uncertainty from the maker's figure has uncovered an inconsistency arising from (b) above, whereby a pistonphone calibrated to an uncertainty of ±0.05 dB with a 1 inch microphone and then used with the adaptor supplied for a ½ inch microphone may have an output SPL different by, in some cases, in excess of three times the uncertainty stated. Clearly in these cases the claimed uncertainty cannot be attained.

5. CALIBRATION OF PISTONPHONES AT NML

At NML an "insert voltage technique" uses the calibrated microphone cartridge sensitivity by inserting an accurately measured AC voltage into the microphone preamplifier earth circuit in such a way as to simulate the output of the microphone cartridge. This has the advantage that the preamplifier gain and loading due to the microphone cartridge are accounted for and the uncertainties remain the same for all microphone sizes.

The method used is to first calibrate a set of microphones by reciprocity (both 1 inch and ½ inch to ±0.02 dB uncertainty) and by using at least two of our own pistonphones, conduct a round-robin with the test pistonphone. The calibration sequence is then to measure the output of all pistonphones in combination with all microphones, and with the pistonphone vertical, facing both up and down. Using this method we can provide an uncertainty of ±0.05 dB in stated output SPL as there are at least four measurements per pistonphone/microphone combination for a given microphone size.

As a testimony to the practicality of such accurate calibration, records of the calibration of two pistonphones over a considerable time period, taken from our files, are shown in Table 1. The stability in output level needs no further comment.

To illustrate the point about the difference between 1 inch and ½ inch calibrations we have shown in Table 2 the results of recent calibrations of a number of Bruel & Kjaer type 4220 pistonphones at NML where the pistonphone was calibrated for both. The data suggests that the differences in output have a small systematic component of up to −0.17 dB.

Table 1—
Calibration history of two type 4220 Pistonphones

Calibration Date	SPL Output (dB)
Pistonphone E	
21/06/76	123.94
01/11/78	123.96
24/11/88	123.93
Pistonphone A	
26/02/81	123.97
11/03/83	123.98
14/02/85	123.97
01/05/87	123.97
11/06/89	123.95

Table 2—
Differences in SPL output for 1 inch and ½ inch

Pistonphone	1 inch SPL dB	½ inch SPL dB	Difference dB
NML#668490	123.85	123.74	−0.11
NML#893591	124.00	123.83	−0.17
Pistonphone A	123.95	123.88	−0.07
Pistonphone B	123.77	123.62	−0.15
Pistonphone C	123.93	123.80	−0.13
Pistonphone D	123.93	123.76	−0.17

6. IN SEARCH OF THE DIFFERENCE

There are several potential sources of the difference. The first is that causd by the difference in *equivalent volume* between the 1 inch and ½ inch microphones. The *equivalent volume* or acoustic impedance is the compliance of the diaphragm under dynamic pressures which will change the effective cavity volume. From the B&K microphone handbook [5] the *equivalent volume* V_{eq} of a typical 1 inch microphone and two types of ½ inch microphone are shown in Table 3

Table 3—
Equivalent Volume effects on Output SPL

Type	V_{eq} cm^3	ΔSPL dB	Difference dB
4144 (1 inch)	0.148	−0.0653	0 (ref)
4165 (½ inch)	0.04	−0.0177	+0.048
4133 (½ inch)	0.01	−0.0043	+0.061

in which ΔSPL is calculated from

$$\Delta SPL = 20 \log_{10}[V/(V + \Delta V)]$$

where V is the stated [3] cavity volume of 19.6 cm³.

It is clear that these positive differences do not explain the apparent negative differences of Table 2. It may be noted in passing that the type 4165 has a higher sensitivity than the type 4133 and this is reflected in the higher V_{eq} and implies a more flexible diaphragm.

These calculations show us (i) that the effect due to equivalent volume alone should be an increase in output rather than the observed decrease, and (ii) that the output SPL for a pistonphone calibrated with the higher sensitivity 4165 would be higher by 0.013 dB when used to calibrate the lower sensitivity 4133 due to the lower V_{eq}.

The second possible cause of the difference between the 1 inch and ½ inch outputs may be errors in the volume change introduced by the adaptor. The manufacturer supplies the adaptor to compensate for the *front volume* change introduced when a smaller microphone type is calibrated. However, as shown in Table 2, there is a 0.1 dB variation in this difference between the sample of six pistonphone/adaptor combinations measured.

To try to come to terms with this variation we carried out a series of round-robin calibrations by our normal method, but using one ½ inch microphone, one pistonphone and 5 different 1 inch to ½ inch adaptors. The results, in Table 4, show a standard deviation of 0.025 dB from the mean; certainly not enough to explain the differences of Table 2.

Experience has shown us that the health of the O-ring seals play a major part in unexplained variation, and that the variation in 1 inch to ½ inch output between pistonphone and adaptor combinations should be documented by proper calibration.

Table 4—
Variation in SPL output between Adaptor Rings

Adaptor #	Output SPL (dB)
1	123.92
2	123.97
3	123.92
4	123.97
5	123.94

7. CONCLUDING REMARKS

A pistonphone of the type tested in this exercise is shown to be a stable and effective single frequency Sound Pressure Level reference if used and maintained with care. The cause of the variation in output between the pistonphone when used with a 1 inch microphone, and that when used with the adaptor for ½ inch microphones remains unexplained, as does the variation between individual pistonphone adaptor combinations.

However, one important finding emerges: that if the low uncertainty in the NML calibration of a pistonphone is to be effectively used with other than a 1 inch microphone, then the pistonphone should also be calibrated with the appropriate adaptor ring that will be used during the microphone calibration.

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REPORT

Traffic Noise Barrier Development

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Kew Victoria 3101

Traffic noise amelioration has become a major component of new arterial road costs. The community directly influenced by a road proposal expects the construction authority to provide noise barriers of some form to protect their residences from the anticipated traffic noise.

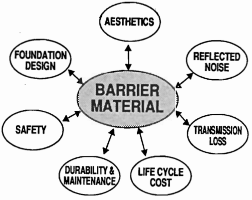
The Roads Corporation, in Victoria, previously built noise barriers using treated timber, but these barriers have limited application and life span. The need for a fresh approach to barrier design came about when it was necessary to ameliorate noise along a new road, the South Eastern Arterial, by installing barriers adjacent to the carriageway as well as at the right-of-way boundary and along bridge structures. It was necessary to consider three major inputs to barrier design . . .

- Acoustic performance;
- Barrier material;
- Aesthetics.

It was also necessary to consider from an aesthetic point of view . . .

- Road users' perception;
- Residents' perception;
- Landscaping opportunities.

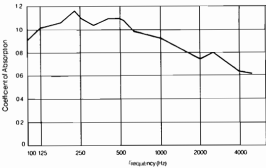
A reasonable approach to material choice is detailed below, and closely follows the process that developed for the choice of barrier along the South Eastern Arterial.



The barrier material finally chosen was glass-fibre reinforced cement, GRC. This material is compatible with other concrete structures, like bridge parapets and New Jersey crash barriers, while also being moulded into acoustically useful designs.

The planned road, through a creek valley, with adjacent residential areas, made it necessary to consider installing absorption as well as reflective barriers. The reflective barriers would be made from GRC, although an initial section of barriers was made from treated timber. Investigations of absorption barriers manufactured locally and overseas indicated that most barriers did not meet some criteria, although this was expected, while most proved to be excessively expensive.

Development of the absorption barriers was basically aimed at achieving the best acoustic performance while using GRC for the panel support material. Acoustic consultants were engaged early on to design the basic absorption components. These were tested initially in an impedence tube then in the 605 m³ reverberation chamber at CSIRO's Building, Construction and Engineering Division, Highett, Victoria. In all, a dozen tests were completed to obtain the optimum absorption coefficients at various frequencies by varying the absorption components. Also, tests were conducted to obtain the barrier transmission loss. The following graphs give the absorption coefficients and sound transmission loss from the CSIRO laboratory tests.



SOUND ABSORPTION COEFFICIENT FOR THE BLOCK WALL BACK ABSORPTION BARRIER.

(Continued on page 73)

Program for Determining the Effectiveness of Hearing Protectors in a Given Noise Environment

Dr Greg Ash
GPO Box 2683
Canberra 2601

Introduction

There are two accepted ways of determining the performance of a given hearing protector. The first uses the SLC_{80} method,[1] and the second uses octave band measurements.[2]

The SLC_{80} method requires measurement of the noise environment in dBC, and reference to the SLC_{80} values published by the National Acoustic Laboratories (NAL),[3] or supplied by the manufacturer. Subtracting the SLC_{80} value from the dBC level gives the expected in-ear level in dBA for that protector.

The advantage of this method is that it only requires a single sound level measurement. The major disadvantage is that the SLC_{80} method uses an average spectrum, and if the noise source under investigation varies significantly from this, the result will be inaccurate. Obviously, a sound level meter capable of measuring dBC must also be used.

Another disadvantage is that some occupational health and safety officers erroneously believe that those protectors with the highest SLC_{80} rating must be the best for their application. This can lead to "overprotection", which can severely compromise user acceptance of wearing hearing protection.

The octave band method requires measurement of the noise environment in octave bands, and use of the attenuation figures supplied by NAL or the manufacturer. This method provides a more accurate assessment of protector performance. Unfortunately, there are many calculation steps which must be repeated for each selected protector.

This report describes a program, designed to run on an IBM (or compatible) personal computer, which automates the process of using the octave band method as described in the NAL publication.

Program Overview

The program requires the user to input the measured octave band levels for the noise environment under consideration.

The program then prompts you to input either your own hearing protector data, or to use a search procedure which automatically checks the more than 200 protectors listed in the NAL publication against the measured spectrum.

Individual Hearing Protectors

If the option to input individual data for hearing protectors is chosen, the user is prompted to input the appropriate attenuation data. The expected in-ear dBA level is calculated, as well as the dBA noise reduction and the SLC_{80} for that protector.

Search Procedure

If the Search Procedure is specified the program then prompts you for the type of hearing protector required:

1. *Ear muffs only.*
2. *Ear plugs only.*
3. *Helmet mounted muffs only.*
4. *Combination muff and plug only.*
5. *Communication headset only.*
6. *All devices.*

Finally the program asks for the level in dBA below which protection is not desired. For example, the desired in-ear level might be 75 dBA. This step can help eliminate "overprotection".

The program then tests each individual protector listed in the NAL publication against the given spectrum, ranks the 10 best performing hearing protectors against the selected criterion, calculates the expected in-ear dBA for each protector and also calculates the overall dBA level associated with the selected spectrum.

The program in operation

To demonstrate the effectiveness of the program, the following sound spectrum, which was measured during the operation of an angle grinder, was used to compare the two methods of assessing hearing protectors.

63 Hz?	60
125 Hz?	67
250 Hz?	71
500 Hz?	82
1000 Hz?	95
2000 Hz?	97
4000 Hz?	101
8000 Hz?	110

Using this spectrum, the top ten ear muffs as determined by the program, together with the calculated in-ear levels using both methods, and the difference in dBA between the methods, are presented below.

Protector	Oct	SLC_{80}	Diff
Bilsom 2452	76.9	84.8	—7.9
Hellberg 26047	77.6	79.8	—2.2
Bilsom Comfort 2424 Mk III	77.6	84.8	—7.2
Bilsom Viking 2421 Mk III	77.7	79.8	—2.1
Bilsom 2461	77.9	83.8	—5.9
Gardwel Centurion	78.1	84.8	—6.7
Bilsom Viking 2318 Mk II	78.6	79.8	—1.2
Bilsom Blue 2457	79.4	84.8	—5.4
Goffin Ausmuff 300	79.4	89.8	—10.4
Bilsom Blue 2308	79.5	84.8	—5.3

As can be seen the octave band method produces results that are more accurate, by more than 10 dBA in one case.

Fortunately, this example shows that all tested muffs were underrated using the SLC_{80} method. It is just as likely, and of more consequence, if the SLC_{80} overrates the performance of protectors. In this case the protection provided would be less than expected.

An example of this uses noise measured in the engine room of a small ocean-going vessel.

63 Hz?	111.3
125 Hz?	115.0
250 Hz?	124.0
500 Hz?	106.8
1000 Hz?	110.5
2000 Hz?	108.6
4000 Hz?	103.6
8000 Hz?	94.7

Protector	Oct	SLC_{80}	Diff
Racal Safety Sonomuff	95.1	94.0	1.1
Protector EMH 12	96.0	95.0	1.0
Racal Amplivox—Amplivox	96.1	96.0	0.1
EAR 3000	97.7	95.0	2.7
Bilsom Viking 2318 Mk II	97.9	94.0	3.9
Exel OY Eilenta Super	98.1	96.0	2.1
Bilsom Viking 2421 Mk III	98.8	94.0	4.8
Protector EMM 11	98.8	97.0	1.8
Bilsom Com-Impact Viking Stereo 2392	99.6	94.0	5.6
Hellberg 26047	99.6	99.0	0.6

In this case the SLC_{80} method overestimates the protection level in every case for the top 10 ear muffs selected by the program. In one case the difference in the values was 5.6 dBA. Significantly, this was for one of the protectors that the SLC_{80} method predicted would be a good performer in this noise environment.

Conclusion

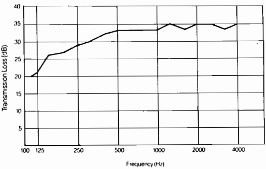
The octave band method provides a more reliable estimate of the performance of hearing protectors in a given environment. The program described automates the most tedious parts of the calculation, and has the benefits of speed, accuracy and flexibility.

The program is available from the author at a special price for members of the Australian Acoustical Society.

References

1. Waugh, R., Investigation of Sound Level Conversion as a means of rating ear protector performance, *Amer Ind Hyg Assoc J* **37**, 239-245, 1976.
2. National Acoustic Laboratories, Attenuation of Hearing Protectors (5th Edition), AGPS, 1987.
3. Ibid.

<u>*WEST . . .*</u>



SOUND TRANSMISSION LOSS FOR THE DISPERSIVE BACKED ABSORPTION BARRIER.

It is worth noting that the absorption coefficients are > 1.0 in the lower frequencies, which was a design feature, and far greater than other barriers available on the market. The high absorption coefficients between 100 Hz to 1200 Hz corresponds well with the traffic noise spectrum. Also, the sound transmission loss spectrum indicates an adequate noise reduction which would be expected to improve in actual usage as the barrier would be sealed at joins for its permanent fixture.

Further experiments were conducted, in the field, along a section of the heavily trafficked Tullamarine Freeway, using GRC reflective and absorption barriers. Initial results have indicated that . . .

- There is a barrier insertion loss degradation due to parallel reflective barriers, compared to a single barrier.
- Parallel absorption barriers give a higher insertion loss compared to parallel reflective barriers.
- A single absorption barrier gives a greater insertion loss than a single reflective barrier, due to the barrier construction.

The mountain of data obtained from the various tests has not been analysed entirely. Further papers will appear in journals detailing the tests and results of these unique (to Australia) trials.

Publications by Australians

We are grateful to Dr Richard Rosenberger, University of NSW, for this updating of publications by Australian authors. Within each year the listing is alphabetical by first author.

1988

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(1) R J ALFREDSON.
(2) I J PHELAN.
(1) Dept of Mechanical Eng, Monash University, Clayton, Vic 3168.
Appl Ac **23 (4)**, 281-296 (1988).

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W J BAILEY et al.
The University of Western Australia, Nedlands, WA 6009.
J Acoust Soc Am **83 (5)**, 1828-1832 (1988).

Specific Acoustic Impedances of Piezo-Electric Ceramic and Polymer Composites used in Medical Applications
(1) T BUI.
(2) H L W CHAN, J UNSWORTH.
(1) Ausonics Pty Ltd, 16 Mars Road, Lane Cove, NSW 2056.
J Acoust Soc Am **83 (6)**, 2416-2421 (1988).

Sealed, Close-Fitting, Machine-Mounted Acoustic Enclosure with Predictable Performance
K P BYRNE et al.
School of Mechanical and Industrial Engineering, The University of New South Wales, PO Box 1, Kensington, NSW 2033.
Noise C Eng J **31 (1)**, 7-15 (1988).

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K. P. BYRNE.
School of Mechanical and Industrial Engineering, The University of New South Wales, PO Box 1, Kensington, NSW 2033.
J Sound Vib **123 (3)**, 423-435 (1988).

Cochannel Interference between Point-to-Point Urban Microwave Radio Systems
(1) W E DAVIES.
(2) D WENDE.
(1) Telecom Australia Res Dept, Clayton N 3168.
IEE Proceedings — F Comm, Radar and Sign Proc **136 (3)**, 225-232 (1988).

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J L DAVY.
Div of Building Research, CSIRO, PO Box 56, Highett, Vic 3190.
Appl Ac **23 (1)**, 63-79 (1988).

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(1) L C GODARA.
(2) D A GRAY.
(1) Dept of El and Electronic Eng, Australian Defence Force Academy, Northcott Drive, Campbell, ACT 2600.
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H P W GOTTLIEB.
School of Science, Griffith University, Nathan, Qld 4111.
J Sound Vib **120 (1)**, 167-173 (1988).

An Experimental Investigation into the Interaction between a Sound Field and its Boundaries
P JIE, D A BIES.
Dept of Mech Eng, University of Adelaide, SA 5001.
J Acoust Soc Am **83 (4)**, 1436-1444 (1988).

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R F S JOB.
Dept of Psychology, University of Sydney, NSW 2006.
J Acoust Soc Am **83 (3)**, 991-1001 (1988).

The Attenuation of Acoustic Signals by Aqueous and Particulate Foams.
N T MOXON, A C TORRANCE, S B RICHARDSON.
Central Res Lab, BHP, PO Box 188, Wallsend, NSW 2287.
Appl Ac **24 (3)**, 193-209 (1988).

Continued on page 79

BOOK REVIEWS

AN INTRODUCTION TO THE PHYSIOLOGY OF HEARING — 2nd Edition

James Pickles

Academic Press, London, 1988, pp 367, ISBN 0-12-554753-6, Australian Distributor: Academic Press, PO Box 300, North Ryde, NSW 2113, Price $(A)101

In presenting his first edition of *An Introduction to the Physiology of Hearing*, Jim Pickles succeeded in counteracting what could loosely be described as a deafening silence in readable introductory literature on this complex central sense. Any advantages we may have gained from the first edition, and there were many, have been well surpassed in this new, substantially revised and updated work.

The overall plan of Pickle's second edition is the same as his first, namely a discussion in the first half of the book of the physics of sound, the outer and middle ears, the cochlea, and the auditory nerve. The second half of the book is devoted to discussions of the auditory brainstem nuclei, the auditory cortex, the centrifugal pathways, auditory psychophysics and sensorineural hearing loss. From my own perspective I found these proportions to be a little unbalanced insofar as the cochlea is dealt with in far greater detail than the neurophysiology of central processing. However, this is an introductory text and as such the reader is well served with information at all levels of the system.

There are several features of Pickles' book that deserve high praise. The first is its literary style. As a text for undergraduate or postgraduate students, lecturers and professionals, this book is exemplary. Each chapter is prefaced by a brief description of its aims and is suffixed by a summary and recommendations for further reading. The text is very easily read and all arguments are put with clarity. The evidence that has led to the formulation of theories and hypotheses is well described and the original data has been presented where relevant. At several points in the text well developed principles or sequences of events in complex processes are presented in numerated paragraphs that leave no misunderstanding of the logic in the arguments. The gentle, guiding hand of an educator is also evident in parts of the text where phrases such as "If we add . . ." and "Once we have obtained . . ." are used.

The book is also characterized by a large number of original diagrams and explanatory figures. Rarely is one faced with two pages without a figure! All of the figures are important and in the main they are clear. There are perhaps just two or three figures that would benefit from an expanded format.

The most outstanding feature of this introductory text is its bibliography. The number of references in this second edition appears to be about 30% higher than in the first edition published in 1982. By far the majority of the additional references have been published between 1986 and 1988. We are in debt to Pickles' diligence and enthusiasm in producing such a modern text.

Above all, this book has been written by an expert in auditory physiology. His leadership in the area of cochlear physiology and its implications in auditory psychophysics is a very firm base upon which the book is founded. The combination of expertise, attention to detail and easy literary style make this book essential reading for all who have an academic, experimental or professional interest in the auditory system.

Alan Pettigrew

NOISE CONTROL IN BUILDING SERVICES

Alan Fry (Editor)

Pergamon Press, 1988, pp 441, Hard Cover, ISBN 0-08-034067-9. Australian Distributor: Pergamon Press (Aust) Pty Ltd, PO Box 544, Potts Point, NSW 2011. Price $(A)105.

This book has been written by the Engineering Staff at Sound Research Laboratories (SRL) in the UK and is aimed at consultants and engineers who have a need to be involved with, or to be conversant with, noise and vibration control. The practical approach to the topics makes it a very readable book and shows the wealth of experience of the 10 contributing authors.

The first four chapters cover the basic concepts of sound, noise and hearing. Chapters five and six deal with sound insulation and vibration isolation. While this type of information is included in many other books on noise, the examples used by the authors relate to real problems which may be encountered in plant rooms or other building services applications.

Chapters seven to nine cover the three aspects of ductborne noise, i.e., transmission, flow generation and breakout. Plenty of charts, diagrams and graphs are used in the step-by-step explanations of the calculations. A blank SRL calculation chart and examples of its use are given. Noise from the room units is dealt with in chapter 10, which concludes with a trouble-shooting flow chart and supplementary notes.

Noise to the exterior is covered in the next chapter and includes the effects of barriers (including unwanted reflections) and the atmosphere. In chapter 11 the control of noise and vibration on building sites is discussed. This initially appears out of place but as well as giving guidelines for approaches to the control of various types of sources it provides reinforcement of the techniques introduced in the previous chapters.

The chapter on laboratory testing covers the normal range of acoustic and vibration tests which can be undertaken and, where appropriate, outlines the standard test procedures (primarily British Standards with some references to ISO, ASHRAE and Eurovent). Photographs of tests being undertaken in the SRL facilities complement the sketches and diagrams. The final chapter covers, in brief, other building services plant, including lifts, elevators, cooling towers, etc.

This book certainly contains a wealth of material and meets the expectations of the Editor of being *a reference book of useful engineering guidance and data*. The extensive use of photographs assists the reader in understanding the points made in the text. However, there is unnecessary replication of some material. Two examples are: the NC, NR and PNC curves are dealt with in some detail in two chapters (two and four); the same diagram for directivity factor is used in chapters three and 11. Cross referencing within the text would have avoided such repetitions and encouraged the reader to go back over some of the earlier, basic concepts. Tables of Sound Reduction Indices are given in chapter five and 13 with duplication of many items but in both tables the data is only provided in terms of octave bands. The editor explains, and apologises to readers who may be annoyed, that a conscious decision was made to provide a list of further reading and not specific references. A preferable compromise may have been the inclusion of a reading list for each chapter rather than a general reading list for the book as a whole. In that way a reader seeking further information on a particular topic could consult books most likely to be relevant.

This is certainly a valuable reference book for all consultants and those who may be involved with noise and vibration control in building services. It is also an essential addition for engineering libraries, in particular those associated with educational institutions.

Marion Burgess

ENGINEERING NOISE CONTROL

D A Bies and C H Hansen

Allen & Unwin Aust, 1989, 414 pp, ISBN 0-04-620022-3;
Distributor: Allen & Unwin, PO Box 764, Napier Street, North Sydney, NSW 2059, Paperback, Price $49.95.
(This review first appeared in Engineers Australia, June 1989)

Engineering Noise Control was primarily written as a textbook for undergraduate and post-graduate courses in engineering and applied physics. David Bies is a reader in mechanical engineering at Adelaide University and was my course tutor and post-graduate supervisor. He was formerly with BBN and is one of the contributing authors in Beranek's *Noise and Vibration Control* (the purple bible). Since the late 1970s he has single-handedly moulded the acoustics group in Adelaide into one of the world's best. Colin Hansen was one of his students and, I'm proud to say, my room-mate at the university up until 1978.

The authors have unique inquisitive minds and are expert at discovering the engineering reason for what makes things happen. I can recall David telling me of some of his latest work in the coupling of acoustic and structural modes in a reverberation room — the ideology was fresh and controversial. I can't remember the number of times that Colin has told me "you're wrong Renzo" because of this or the other. And so, this book reminds me of these discussions.

Chapter 1 discusses the now obligatory fundamentals — planar and spherical propagation of sound. The philosophical chat-like approach is refreshing, departing from the usual textbook rigour which can be like munching Jatz biscuits without a drink. For example, it is nice to see the comparison of plane and spherical waves from the point of view of the ratio p/u and the propagated sound intensity. Too bad the authors didn't do something new with explaining the addition of dBs (yawn).

The discussion on the mechanics of the human ear in chapter 2 from a mechanical engineer's point of view is certainly unusual and interesting. On the other hand, the subsequent treatment of the measurement of loudness is only likely to interest Zwicker's devotees. It is not likely to be of interest to professionals.

Chapter 3 gives a general view of the type of instrumentation available for measuring, recording and analysing noise.

The highlight of chapter 4's discussion on criteria is the presentation of the author's recent research into hearing risk criteria which concludes that the 3 dB trade-off rule used in Australia and Europe is conservative and that the 5 dB used in the US is closer to the mark. A summary of impulse and broadband noise criteria for both internal and external environments presented in this chapter is a useful compilation of Australian and US standards.

Chapter 5 includes an extensive collation of sound radiation from many types of idealised sources as well as sound propagation in the atmosphere. The description of the ground effect is particularly well done.

Chapter 6 is a thorough compilation of the measurement of sound power of sources in a diverse range of environments. The sound intensity method is not covered at all due to lack of suitable standards — I'm sure this will be rectified in the next edition.

Sound in enclosed areas is handled in textbook fashion — a typical treatment of room modes, absorption, reverberation and material properties. David's interest in porous materials shows through here — in fact an appendix is devoted to acoustic properties of porous materials. Sound transmission through panels (including composite panels) and the attenuation provided by enclosures and barriers is presented in detail. This material is a compilation of current methodology. The topics in these chapters are essentially the bread and butter of acoustic consultants. It would be wonderful if more effort could be devoted here.

Colin is an expert in sound radiation from panels — it's a pity this subject didn't get a thorough airing. Structure-borne sound is one of the least understood topics in the professional field of acoustics. Also, a lot of research effort in Adelaide was devoted to sound radiation from pipes (Rennison & Norton) and this would have been a handy inclusion.

Reactive mufflers are analysed in terms of lumped elements — a single- and a 2-chamber muffler are studied in detail. Practical design curves for dissipative lined ducts are presented and include the effects of flow and liner flow resistivity. If the curves are accurate (no experimental data is provided), and if they can be used for both ducts and short silencers, this presentation could be extremely useful for the practising acoustic consultant. It's noted that work by Fuller and Jones (also from Adelaide) is not included — maybe it's too complicated.

The chapter on vibration control includes the customary single degree of freedom system and treatment of isolation of a rigid mass. A discussion of types of isolators and the effect of dampnig treatments follows. These topics are not discussed in depth but would suit the student.

Chapter 11 is a compilation of useful formulae for prediction of sound power levels of a variety of sources — fans, motors, pipe noise, gears, etc. This is good data if one is caught with no proprietary information.

The final chapter is a survey of mathematical techniques which are likely to lead the way in source noise prediction schemes in the future. More of a philosophical presentation, the reader is referred for more details to the relevant reference.

A set of problems for each chapter is presented in an appendix. The questions are thoughtful and practical and obviously ideal for course work.

In summary, this is an excellent textbook for use in undergraduate and post-graduate coursework, having just the right level of complexity and a good mix of theoretical and practical topics. While the book may not be specialised enough and does not contain lots of experimental data for the practising acoustic consultant, its price makes it an attractive purchase regardless. I must confess, in the short time I've had it for this review, I've had occasion to refer to it. Highly recommended.

Renzo Tonin

ULTRASONICS FUNDAMENTALS, TECHNOLOGY, APPLICATIONS

2nd Edition

Dale Ensminger

Marcel Dekker Inc, New York, 1988, pp 580, Hard Cover, ISBN 0-8247-7659-3.
Australian Distributor: DA Books (Aust) Pty Ltd, 11 Station Street, Mitcham, Vic 3132. Price $(A)158.

This second edition of Ultrasonics has much to recommend it to anyone needing an introduction to any of the many and various aspects and applications of ultrasound. As a general reference it seeks to cover both the theory and practice of generation, propagation and detection with a special emphasis on

Continued on page 77

NEW PRODUCTS

Vipac

Techstations — Data Logger Spectrum Analyser 8386 Laptop Combined

The Techstation is the first instrument that incorporates the functions of data logging, spectrum analysis and a full function 386 computer into a machine that weighs only 7 kilograms.

The functions are fully integrated by Onsite's menu driven software and an 80186 AT class microprocessor allows users to collect, analyse and plot data without programming. The second microprocessor, an 80386 in Techstation, contains full mathematical software that makes data reduction quick and easy.

Features include: 16, 32 or more input channels, battery operated, sample rates selected by channel, analog anti-aliasing filters, rugged Mil-Spec construction, 80387 PC, 100% IBM compatible, Real Time display of data and dual microprocessors.

Further information: Vipac Pty Ltd, 275 Normanby Road, Port Melbourne, Vic 3207. Tel (03) 647 9700.

Bruel & Kjaer

Noise Monitoring Systems

Bruel & Kjaer introduces an entirely new concept in environmental noise monitoring with two new systems it has recently developed. Data processing now takes place *in situ* by outdoor Noise Monitoring Terminals. The former costs of a central computer and telephone line renalts have been reduced respectively to 10% and 2%. Both systems make use of intelligent outdoor Noise Monitoring Terminals Type 3543 whose major components are a Noise Level Analyzer Type 4435 and a Modem ZM 0066, housed in a Weatherproof Cabinet with internal climatic control, and a Weatherproof Microphone Unit Type 4184.

The Noise Monitoring Terminals, placed around airports, motorways, industrial sites, residential areas or any other noise-sensitive spots, measure noise levels accurately and process them *in situ.* These data are then transferred routinely to a central IBM PS/2 series PC for further processing and management by Bruel & Kjaer software.

The two systems differ mainly in the way the software expects the computer to receive the noise data. For this two corresponding software packages are available, viz, the Type 7617 for Noise Monitoring Terminals moved from site to site and the Type 7618 for Noise Monitoring Terminals placed at permanent sites.

The Type 7617 software receives the data from a diskette via the computer's floppy disk drive; the diskette was previously used in a portable computer to gather data manually from each Noise Monitoring Terminal.

The Type 7618 software receives data via the computer's modem interface which is the first stage in a direct link with the Noise Monitoring Terminals via standard modems and public telephone lines. This link is established automatically *only* while data are being transferred, i.e., once per day, which keeps telephone rental costs down to a minimum.

Once in the computer, the data are sorted out and stored logically in a database, ready for immediate access by the user. The contents of the database cover *Noise Events, Calibration Reports, Periodic Statistical Reports* based on fixed intervals of 1 hour, 24 hours and 1 month as well as on seven more user-definable intervals.

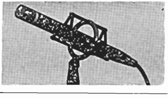
* * *

Cardioid Microphone

Bruel & Kjaer's Type 4012 Studio Microphone is a prepolarized condenser-microphone with a first-order directional pattern, and is powered from Bruel & Kjaer Dual-channel Power Supply Type 2812. Type 2812 supplies 130 V to the preamplifier of the Type 4012, which enables the microphone to handle up to 168 dB SPL before clipping occurs.

Nor have other performance parameters of the 4012 been neglected. The on-axis frequency response measured at 30 cm distance is flat from 40 Hz to 20 kHz (+1, —2 dB), and the combination of this with smooth off-axis responses gives a microphone of the highest fidelity. Each microphone is individually calibrated to ensure excellent agreement and continuity with the impressive published specifications.

As well as increased headroom, the 4012/2812 combination offers other advantages over traditional phantom-powered microphones. It has a high output level (allowing the signal path to be kept as simple as possible by direct connection to the recording medium) and the ability to drive very long cables without noticeable deterioration of the signal. The Power Supply Type 2812 is also used with omnidirectional microphones Types 4003 and 4004, established members of the Series 4000 range.



Room Acoustic Module for 2231

Bruel & Kjaer's Room-acoustics Module BZ7109 supplements the range of application modules already available for Modular Precision Sound Level Meter Type 2231. It is an advanced version of Reverberation Processor Module BZ7104. The addition of dedicated computer software adds flexibility by enabling data to be transferred to a computer for calculation of room-acoustic parameters and storage of decays and results on disk. This makes it particularly suitable for applications such as measurements in auditoria and concert halls.

The module uses the Schroeder Method to calculate the reverberation times EDT, T (20) and T (30) in 1/1- or 1/3-octave bandwidths, thus giving highly reproducible results in a short measurement time. In addition to the fully annotated decays and tabular results, several important room-acoustic parameters — Early-to-late Sound Index (Clarity), 50 ms Early Energy Fraction (Deutlichkeit), Centre Time and Total Sound Level — can also be calculated.

All results and decays can be displayed on the computer screen. An averaging routine in the application software enables results from a series of points in an enclosure to be averaged together. The application software also enables hard-copies to be taken of all graphs and tables of results on a standard dot-matrix printer.

* * *

Underwater Accelerometer

All watery environments are the natural habitat of Underwater Accelerometer Type 8319, the latest accelerometer from Bruel & Kjaer. Constructed in UHB 904L stainless steel and encased in polychloroprene rubber with all joints either welded or moulded, the Type 8319 is not just water-resistant — it's *waterproof.* With its integral cable, protected by a polyurethane jacket, Type 8319 can operate for extended periods under water — and that includes sea water — to a depth of 400 metres.

Attach it to the hull of a boat, to the leg of an oil platform, or even to a seabed pipeline and it will continue happily to sense the vibration of the structure. Fit it to an industrial machine where it is constantly sprayed with coolant, or install it on a bridge in the monsoon season — it needs no umbrella.

For performance, Type 8319 is unrivalled. Its Delta Shear® piezoelectric construction — an original Bruel & Kjaer design — ensures good sensitivity, accuracy and reliability. In addition, every Type 8319 is artificially aged and individually calibrated.

The built-in line-drive preamplifier enables 8319 to be used with cable lengths up to 1 km without noise problems. You do not need an external preamplifier — just connect up to our special Line-Drive Power Supply or even better directly to a Bruel & Kjaer Signal Analyzer, and make your measurements!

New Type 4182 Probe Microphone

Bruel & Kjaer's new Type 4182 Probe Microphone is intended for measurements in situations unsuitable for conventional types of microphones, such as small cavities, awkward places and harsh environments. The Type 4182 is ideal for any measurement where it is necessary to measure very near to the sound source.

An improved method of impedance-matching has resulted in a smaller unit with a better impedance characteristic and frequency response (specified from 2 Hz to 10 kHz). Not only is the response wider, but it is also smoother, free of the "ripple" usually found in probe microphones. Its sensitivity is —50 dB relative to 1 V/Pa, with a 50 mm probe tube attached.

Among the accessories is a collection of interchangeable probe tubes (both stiff and flexible) of various lengths. Where necessary, the stiff tubes can be bent into a different shape without significant changes to the frequency response. For calibration purposes, there is also an adaptor for sensitivity calibration with a pistonphone or sound-level calibrator, and a special coupler for frequency response verification using a transmitter microphone. An adaptor for the transmitter microphone is also included.

The tip of the 100 mm stiff probe-tube can be exposed to temperatures of 700°C, which makes the Probe Microphone useful for measuring in very hot gases inside exhaust systems, such as those of an automobile. An added advantage in this case is that a very small access hole, which can be easily repaired afterwards, is sufficient. Other notable applications are sound pressure measurements inside chimney stacks, on surfaces during aerodynamic tests (again with the advantage of a very small hole), and impedance measurements in-situ with close coupled transducers such as telephone transducers and headphones.

Further information: Bruel & Kjaer, 24 Tepko Road, Terrey Hills, NSW 2084. Tel (02) 450 2066.

Pulsar
Industrial Noise Exposure Meter

At the push of a single switch the Pulsar 85E Sound Level Meters give highly accurate noise measurements throughout the range of interest in industrial legislation proposals. Exposure limits in hours per day are shown

directly on the Pulsar 85 scale. The Model 85E2 is fitted with a detachable half-inch electret microphone capsule. Both units have a retractable boom.

Pulsar's Model 85E/100A Sound Level Measurement Kit is designed for convenient, accurate and inexpensive monitoring of noise levels in industrial work areas. The Model 85E meter and Model 100A calibrator allow on-the-spot before and after calibration to ensure maximum accuracy for compliance with industrial regulations.

Further information: Pulsar Instruments, Bridlington Road, Hunmanby, North Yorkshire, YO14 OPH, UK.

industrial and medical applications both actual and potential. Roughly a third is devoted to theory and two-thirds to practical aspects. While some aspects, particularly some of the theory, are dealt with in considerable detail, it is clearly impossible, even in 580 pages, to go into much detail in many areas and it often does little more than whet the appetite. But that is a legitimate and worthwhile achievement.

With that said there are certain criticisms that need to be made. In producing this second edition, the original material has been considerably expanded but the reader is left with the impression of a fairly rough "cut and paste" rather than a re-write and that has left the text somewhat disjointed and lacking in cohesion. It has also left the indexing rather inadequate, an irritating feature in a book that one is likely to dip into for information on a particular topic. Another irritating feature for a text published in 1988 is the use of either cgs or imperial units. There are some very handy derivations of useful formulae and extensive tabulations of acoustical data but these would be much better if provided with MKS units. Most of the editing has been by way of adding more recent information but there are areas that should have been cut out or significantly amended that have slipped through.

Having acknowledged the impossibility of treating all the possible topics in ultrasonics thoroughly there are some topics that one feels should have been covered but were not. These include laser-induced ultrasound, optical interferometric detectors, acoustic microscopy, ultrasonic imaging, techniques such as synthetic aperture methods, transducer arrays and to some extent ultrasound in air. It is also difficult to be thorough in providing references but many readers of a book like this would be looking for a detailed bibliography to pursue areas of interest and unfortunately there are topics where this is far from complete.

Nevertheless, for one wanting an introduction to the theory of ultrasound, or wanting to use ultrasound for some specific purpose, this is a worthwhile reference.

Ken Hews-Taylor

Cirrus
ARIA

ARIA is a new concept, an acoustic instrument capable of making almost any standard noise measurement both in real time and in a stored data mode. The system consists of:—

- A microphone and preamplifier,
- A card to fit into your personal computer,
- A suite of processing programs.

ARIA acquires noise data from the microphone and stores it on the hard disk of a portable computer. Alternatively, the data can be processed while it is being acquired to give immediate readings of any parameter of the noise. Thus, ARIA can be used both as a conventional Sound Level Meter or as a Data Lodging Meter over very long periods, for up to a year in some cases. In both stored and direct modes, it can give almost any known acoustic index and present the data in tabular or graphical form. Noise is very difficult to measure accurately as it can vary in both level and frequency so much over a very short period. Conventional Sound Level Meters are very limited in what they can measure as they are usually dedicated units which measure one aspect of the noise only, mainly due to the low performance of the computer chip used to power them. This is an inevitable consequence of the need to operate the meter with low power chips to give a reasonable battery life. With the ARIA system, the full power of 16 or 32 bit computers can be used to calculate not only simple indices, as can a conventional noise analyser, but also several indices from the same data using any one of the several programs in the ARIA suite. The data stored by the system can be reprocessed using the ARIA software to give the following information:—

- The Time History of the noise over any period.
- All the statistical indices from L0,1 to L99,9 over any time.
- The frequency spectrum in octave, one-third octave or narrow band.
- The Leq as a Time History or event coded.
- Counting of aircraft flyovers or other noise events.
- Noise above a preset threshold.

and much more.

Further information: M B & K J Davidson, 17 Roberna Street, Moorabbin, Vic 3189. Tel: (03) 555 7277.

New Publications

JOURNALS

Applied Acoustics

Vol 27, Nos 2, 3, 4 (1989); Vol 28, No 1 (1989).

Vol 27 No 4 includes "A new way of measuring the lateral energy fraction" of the early reflection pattern of a room by **M Kleiner** of Sweden.

Canadian Acoustics

Vol 17, No 3 (July 1989).

Most of this issue is devoted to details concerning the various activities of the Canadian Acoustical Association.

Chinese J Acoustics

(in English)

Vol 8, No 2 (1989).

Contents include: **Maa Dahyou,** Discrepancy in sound power determination at low frequencies; **Feng Ruo,** Ultrasonic investigation of blood; **He Zhizhou et al,** Middle ear mechanisms in protection against noise-induced cochlear damage.

J Aust Assoc Mus Instr Makers

Vol 8, No 2 (August 1989).

Shock & Vibration Digest

Vol 21, Nos 6, 7, 8, 9 (1989).

In addition to a wide range of abtracts, each issue includes a feature article. In the issues received are (in order): **J F Wilby,** Noise transmission into propeller-driven airplanes; **S S Rao,** Optimum design of structures under shock and vibration environment; **N Jones,** Recent progress in the dynamic plastic behaviour of structures, part 5; **D J Johns,** Wind-excited behaviour of structures V.

Archives of Acoustics (Poland)

(in English)

Vol 13, Nos 1-2 (1988).

Contents include: **H W Jones & H W Kwan,** Review of the transmission of sound from air to water; **R G Mayev,** Scanning acoustic microscopy of polymeric materials and biological substances; **R S Mitchell et al,** Real time signal processing techniques in a dual beam sonar system for fish stock assessment; **E Terhardt,** Intonation of tone scales: psychoacoustic considerations.

New Zealand Acoustics

Vol 2, No 1 (March 1989).

REPORTS

ISVR Technical Reports

University of Southampton

No 169, Jan 89, **J M Mason & F J Fahy,** The acoustic calibration of aircraft fuselage structures: Part 1, 34 pp.

No 174, Jan 89 (**L C Chow & R J Pinnington,** Development of damping treatment suitable for high temperature environment, 32 pp, 48 figs, 5 tables.

No 175, June 89, **R Y John,** An analysis of the time variation of the frequency response of the LMS adaptive line enhancer, 20 pp.

No 177, Mar 89, **S M Moss et al,** A study of the effect of stimulus upon the reflex response as elicited and recorded by the tympanic membrane displacement measurement device, 44 pp.

No 178, July 89, **J R Nedwell,** The pressure impulse from shallow underwater blasting, 19 pp.

No 179, July 89, **A E P Matzumoto & F J Fahy,** Nearfield acoustic holography, 107 pp.

Quarterly Progress and Status Report

Royal Institute of Technology, Stockholm

2/1989 Apr-Jun.

Includes **Gunnar Fant & Anita Kruckenberg,** Preliminaries to the study of Swedish prose reading and reading style, 80 pp.

Publications by Australians

Calculation of Elastic Constants for Crystalline Acenaphthylene, $C_{12}H_8$, using Semi-Empirical Atom-Atom Potentials

H NE, T R WELBERRY.

Res School of Chemistry, Australian National University, Canberra City, ACT 2601.

J Phys Chem Solids **49 (4),** 421-424 (1988).

Electro-Acoustic Effects in a Dilute Suspension of Spherical Particles

R W O'BRIEN.

School of Mathematics, The University of New South Wales, PO Box 1, Kensington, NSW 2033.

J Fluid Mechanics **190,** 71-86 (1988).

Feature Analysis of Musical Sounds

H F POLLARD.

School of Physics, The University of New South Wales, PO Box 1, Kensington, NSW 2033.

Acustica **65 (5),** 232-244 (1988).

Auditory Brainstem Evoked Response Variability in Clinical Paediatric Audiology. Part 2: Characteristics in Very Low Birth-weight Neonates and Infants

V SMYTH et al.

Dept of Speech and Hearing, University of Queensland, St Lucia, Qld 4067.

AJA **10 (1),** 38-42 (1988).

Children with Hearing Aids: Clinic Related Delays

L J UPFOLD.

NAL, 126 Greville Street, Chatswood, NSW 2067.

AJA **10 (1),** 1-6 (1988).

Simulation and Optimization of Multi-way Loudspeaker Systems using a Personal Computer

W WALDMAN.

W. Heidelberg, Melbourne, Vic 3018.

J Audio Eng Soc **36 (9),** 651-663 (1988).

The Size and Spectral Distribution of Conductive Hearing Loss in an Adult Population

G WALKER.

NAL, 126 Greville Street, Chatswood, NSW 2067.

AJA **10 (1),** 25-29 (1988).

On the Revised Theory of the Thermo-Elastic Effect

A K WONG, J G SPARROW, S A DUNN.

Aeronautical Res Lab, Melbourne, Vic 3001.

J Phys Chem Solids **49 (4),** 395-400 (1988).

Hearing Impairment among Orchestral Musicians

(1) D H WOOLFORD.
(2) E C CARTERETTE, D E MORGAN.

(1) Australian Broadcasting Corporation, GPO Box 9994, Sydney, NSW 2001.
(2) University of California, Los Angeles, USA.

Music Perception **5 (3),** 261-284 (1988).

Canberra Acoustics — New Joint Venture

Canberra Acoustics is a unique association of two long established professional Acoustic Consultants in the ACT region and Unisearch Limited acting through the Acoustics and Vibration Centre at the University College of the Australian Defence Force Academy. The joint venture offers the combination of experience and expertise, along with extensive measurement and research facilities, to solve acoustic and vibration problems.

Mark Eisner, the principal of Mark Eisner and Associates, has had over 20 years of consulting experience in acoustics and vibration in Australia, US and Canada. **Eric Taylor,** the principal of Eric Taylor Acoustics Pty Ltd, has had over 25 years of consulting experience in acoustics and vibration in Australia and Asia. Both of these are Member firms of the Association of Australian Acoustical Consultants. Mark and Eric are Members of the Australian Acoustical Society and actively support the recently formed ACT Group of the Society.

The **Acoustics and Vibration Centre** was established within the Department of Mechanical Engineering of the Australian Defence Force Academy in 1988. In addition to co-ordinating and developing teaching and research, the Centre has undertaken consulting projects in the areas of acoustics and vibration. The facilities of the Centre include a wide range of acoustic and vibration instrumentation and an anechoic room. Joseph Lai, Sudhir Gai, Lyle McLean and Marion Burgess undertake the acoustics and vibration work for the Centre and for any activities of Canberra Acoustics.

Further information on Canberra Acoustics can be obtained directly from the Unisearch representative at the Australian Defence Force Academy, tel (062) 68 8497 or fax (062) 47 0702.

INFORMATION PAGE

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Back issues of Acoustics Australia are available at discount rates — Leigh Wallbank, PO Box 705, SUTHERLAND 2232

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FUTURE EVENTS —

• Indicates an Australian Conference

1990

February 13-15, LEIPZIG
4th CONFERENCE ON HYDRO- AND GEOACOUSTICS
Details: Dr Wendt, Wilhelm-Pieck-Universitat Rostock, Sektion Technische Elektroink, Albert Einstein Strasse 2, Rostock, GDR-2500.

April 3-6, ALBUQUERQUE
IEEE 1990
Acoustics, Speech & Signal Processing
Details: Prof Etter, EECE Dept, University New Mexico, Albuquerque, New Mexico, USA, NMB7131.

• April 19-20, PERTH
1990 AAS ANNUAL CONFERENCE
Interior Noise Climates.
Details: AAS 1990 Conference Secretary, PO Box 5077, Cloisters Square, Perth 6000. Tel: (09) 327 8818.

• May 1-3, SYDNEY
TACTILE AIDS, HEARING AIDS AND COCHLEAR IMPLANTS
Details: National Acoustics Laboratory, 126 Greville Street, Chatswood, NSW 2067.

May 21-25, PENNSYLVANIA
MEETING OF ACOUSTICAL SOCIETY OF AMERICA
Details: Murray Strasberg, ASA, 500 Sunnyside Blvd., Woodbury, New York 11797, USA.

June 6-8, BRIGHTON (UK)
16th CONGRESS OF A ICB
The Future for Noise Control — towards an interdisciplinary approach.
Details: Dr. iur. Willy Aecherli, Rechtsanwalt Hirschenplatz 7, CH-6004, Luzern, Switzerland.

June 19-23, LEUVEN
SYMPOSIUM ON PHYSICAL ACOUSTICS
Details: Prof Leroy, Katholieke Universiteit Leuven Campus Kortrijk, E-Sabbelaan, B-8500 Kortrijk, Belgium.

August 8-10, GOTHENBURG
INTERNATIONAL TIRE/ROAD NOISE CONFERENCE.
Details: Intern. Tire/Road Noise Conference, C/- Sandberg, Swedish Road and Traffic Research Institute, S-581 01 Linkoeping, Sweden.

August 13-15, GOTHENBURG
INTERNOISE 90
Dept Applied Ac, Chalmers University Technology, S-412 96 Goteborg, Sweden.

• September 18-20, MELBOURNE
VIBRATION & NOISE CONFERENCE
Details: L Koss, Dept Mech Eng, Monash University, Clayton, Melbourne, Vic, 3168.

• October 15-19, MELBOURNE
METROPOLIS '90
Details: Secretariat, 545 Royal Parade, Parkville, Vic 3052.

October 22-25, SENDAI
10th INTERNATIONAL ACOUSTIC EMISSION SYMPOSIUM
Details: Prof Niitsuna, Engineering, To hoku University, Aramaki aza Aoba, Sendai 980, Japan.

October 29-31, KUMAMOTO
INTERNATIONAL JOINT MEETING
Workshops on Acoustic Emission in Civil Engineering and Acoustic Emission and Rock Fracture Mechanics.
Details: Dr Ohtsu, Dept Civil & Env Engineering, Kumamoto University, Kurokami 2-39-1, Kumamoto 860, Japan.

• November 21-23, BALLARAT
AAS ANNUAL CONFERENCE
Details: Stephen Samuels, ARRB, PO Box 156, Nunawading, Vic 3131.

November 26-30, SAN DIEGO
MEETING OF ACOUSTICAL SOCIETY OF AMERICA
Details: Fredrick Fisher, Marine Physical Lab, P-001, Scripps Institute Oceanography, Univ California, San Diego, La Jolla, CA 92093-0701, USA.

1991

May 5-9, BALTIMORE
MEETING OF ACOUSTICAL SOCIETY OF AMERICA
Details: Murray Strasberg, ASA, 500 Sunnyside Blvd., Woodbury, New York 11797, USA.

November 4-8, HOUSTON
MEETING OF ACOUSTICAL SOCIETY OF AMERICA
Details: Murray Strasberg, ASA, 500 Sunnyside Blvd., Woodbury, New York 11797, USA.

• November, BRISBANE
WESTERN PACIFIC REGIONAL ACOUSTICS CONFERENCE IV
Details: Unisearch Ltd, PO Box 1, Kensington, NSW 2033.

• December, SYDNEY
INTER-NOISE 91
Details: Unisearch Ltd, PO Box 1, Kensington, NSW 2033.

New Address for Society

The Science Centre Foundation, which provides secretarial services and a mailing address for the Council of the Society and for the NSW Division, has moved from Clarence Street, Sydney, to the corner of Womerah Avenue and Liverpool Street, Potts Point.

The **new postal address** is
Private Bag Number 1
Darlinghurst, NSW 2010
with telephone number (02) 331 6920 and fax (02) 331 7296.

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Ties — $20. Scarves — $30.

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Parkville 3052.

1990 AUSTRALIAN ACOUSTICAL SOCIETY CONFERENCE

Date: 19-20 APRIL 1990

Venue: COTTESLOE BEACH RESORT, PERTH

Theme: INTERIOR NOISE CLIMATES

Details: AAS 1990 Conference Secretary
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Cloisters Square
PERTH 6000
Tel: John Macpherson (09) 327 8818

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