The Bulletin

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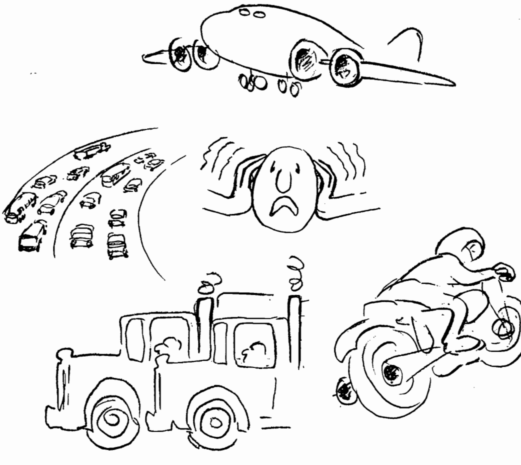

Special Issue: *ENVIRONMENTAL ACOUSTICS*

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From the President

Every year a Division of the Australian Acoustical Society undertakes the organisation of an Annual Conference and selects an appropriate theme, which is usually of interest not only to the members of the Society, but to those members of the public who are concerned with issues related to the subject matter of such a Conference.

This year, the Conference was held in Perth, on 1st and 2nd November and brought together the people, who are actively engaged or interested in the formation and or implementation of "Noise and Vibration Legislation in Australia".

The staging of a Conference always involves hard work, lots of hard work and it falls usually on the shoulders of a few people. The Perth Conference was no exception. The small Committee who undertook the responsibility of putting the Perth Conference together was aware that besides being the first time the W.A. Division was organising an Annual Conference on its own (the 1977 Conference in Perth was a joint effort with the Institute of Engineers) it was holding the Meeting in the most isolated capital of the Southern Hemisphere. The organisers can be pleased with the result. A call for papers met with an excellent response. At registration, the local members/friends gave full support (approximately half of the 100 delegates). The other 50 came from distant places including Hong Kong. Our thanks are due for all the support and congratulations must go to the W.A. Division.

The Council of the AAS meets at least twice a year to deal with the affairs of the Society. One of those meetings is held usually at Conference time and this year it was in Perth on 3rd and 4th November (Saturday and Sunday). On this occasion the Council had to deal with 3 pages of Agenda Items and 23 pages of concisely written Minutes (thanks to our hard working General Secretary) of the previous (32nd) Meeting. Topics ranged from Society's administrative matters, policy decisions, Divisional issues, Conference sponsorships to the Society's relation with such bodies as the International Institute of Noise Control Engineering.

There was also one special item on the agenda: A proposal to establish a **new Division in Queensland.** A Queensland steering committee made a very thorough and professional submission, indicating an enthusiasm and drive which are the necessary ingredients for establishing a new Division. Every Council member supported the application and, assuming that certain registration matters (it is nothing to do with a passport issue) can be resolved, we can look forward to the existence of a new vigorous Division in Queensland. Congratulations to those who worked so hard to reach this point!

One item which will affect all members, **the need for an increase in subscription fees,** was considered at the Annual General Meeting of the Society. These fees have not changed for over four years (according to my record) but all other costs have steadily risen during that period. To understand why, it may be of interest for members to know some of the expenses with which the Society is regularly faced and these include:

- Administrative costs, Divisional and Federal, e.g., mailing, secretarial, etc.
- The cost of publishing the Bulletin.
- Travel expense for one Councillor per Division to each Council Meeting, e.g., the cheapest (most practical) return air fare only.
- Support for Conferences, e.g., Developments in Marine Acoustics, Sydney, 4-6 December, 1984; 2nd Western Pacific Regional Acoustics Conference, 28-30 November, 1985, Hong Kong.

Members should look out for news in the Bulletin of the 1985 Annual Conference, and the proposed 1986 Conference in Queensland.

TIBOR VASS

Editorial

Guest Editorial

This edition of The Bulletin is one of two special issues dealing with **Environmental Acoustics.** The all-embracing term "Environmental Acoustics" is used here to cover aspects of the propagation of sound from sources such as roads, aircraft, factories, machines, mines and musicians, the transmission of sound into or out of buildings, the behaviour of sound within buildings, the reaction of people to those sounds and the control of annoyance by means of education, legislation and technology.

One of the reasons for covering such a vast subject, however thinly, is that ideas and information are changing and there is a need to update the knowledge of Acoustical Society members in this the most commonly cited field of interest. Also, as there appears to be a shift away from seeking technological solutions, to what is largely a socio-political problem, a review of the subject seems timely.

The virtual shutdown of the Experimental Building Station, the abandonment of acoustics research in the CSIRO Division of Building Research, the reduction of staff at the National Acoustical Laboratory, the absence of any viable environmental acoustics research group in an Australian university, and the lack of research expertise in the various state environmental protection authorities, has meant there have been important changes in environmental acoustics in the last decade. This situation seems at odds with the fact that the most complained of environmental factor in our urban society is noise. And in complaints we see only the top of the annoyance iceberg; the complaints received by authorities are from an educated middle-class minority, while the majority suffer in silence . . . or rather a sea of masking noise.

In the last decade too, noise control acts have been introduced. While politicians may hope that the introduction of such legislation will solve environmental noise problems, such legislation can hardly be seen as a panacea. It is understandable that politicians and research funders should be wary of technological 'fixes' which have all too rarely resulted in any improvement in the acoustical environment. What money there is nevertheless still seems to go to the technological fixers and rarely goes to those who seek to improve predictive techniques, to those trying to better assess community reactions and to those involved in education and information dissemination. If this preoccupation with technology and legislation continues we may, for example, have the chance to change the noise from helicopters, but there may not be anyone to determine whether the change is for the better or worse.

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Editorial

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Technological improvements may reduce the noise output from mines, petrochemical plants and other sources, but we will probably be no more certain of the effect of this noise on nearby residents because the predictive techniques for sound levels from such sources are somewhat dubious, to say the least. The technology for reducing motor vehicle noise may be found, or already exist, but without politicians to encourage the use of such technology and without the staff to implement changes in legislation, traffic noise will remain the major source of annoyance.

Technological improvements will be worthless too unless information is made available to those who can make use of those advances. The community at large also needs to be educated about the effects of noise so that they are aware of what sounds, under their control, are doing to them and, more importantly, to others who are subjected to those sounds.

In this issue of The Bulletin, **Rob Bullen** and **Andy Hede** present papers on the two most pervasive sources of noise in our community; aircraft noise and road traffic noise. They present ways of evaluating annoyance and look at the possibilities for reducing this annoyance in the future. **David Oldham** peers into the murky past and foggy future of sound measurement and **Paul Dubout** looks at the accuracy of acoustic measurements and, more particularly, how the accuracy sought can be achieved by the use of standards.

In the following issue there will be papers on external sound propagation, internal noise predictions, active noise control and legislation.

These papers indicate environmental noise control options for the future. There are though, less conventional options, not concerned with limiting noise levels and hours of operation which should be tried. These options include altering attitudes and behaviour. In the past neither sticks nor carrots have been used; it has been mainly verbal cajolery or abuse. A more effective stick for instance would be to introduce a tax or registration fee for motor vehicles and other sources based on noise emission. This would encourage manufacturers and consumers to produce quieter products. Alternatively, or simultaneously, people could be rewarded for having socially responsible behaviour e.g. by giving early marks, lotto tickets or other prizes to the acoustically considerate. A carrot and stick approach might be to give owners of noisy vehicles free use of public transport.

Whatever is done in future to yield an appreciable community-wide reduction in noise, will either have to be more broadly based than most existing piecemeal approaches, or else radically different to past efforts. The basis for either move is given here and elsewhere. Political motivation is the main missing factor.

FERGUS FRICKE.

Editor's Comments

We are grateful to Ferge Fricke for his enthusiasm and the effort expended in persuading so many to contribute to our special issues on environmental acoustics. The April 1985 issue will feature a second group of articles on the same general theme.

Following approval by the Council, the Bulletin will start life afresh in 1985 as ACOUSTICS AUSTRALIA. We hope this move will consolidate our position as the leading national publication in the field of acoustics. The present dual aims of presenting informed articles over the whole field of acoustics and at the same time keeping members and subscribers informed of acoustical activities in Australia and elsewhere will continue.

Howard Pollard
Chief Editor

Australian News

New South Wales

Technical Meetings:

28 June, 1984

Truls Gjestland presented a preliminary report entitled "A New Model for Assessment of Noise Annoyance". Truls, who is from the ELAB acoustical laboratory of the Norwegian Institute of Technology, was on an extremely brief visit to Australia, but despite having arrived only that morning and spent much of the day walking over Sydney's opera house, agreed to discuss his report in the evening. Certainly he and the members of the Division who attended were able to indulge in one of the best meals ever to have been served at the University of N.S.W.'s Square House. Among his numerous activities, Truls was chairman of the organising committee for the Federation of Acoustical Societies of Europe (FASE) whose Fourth Congress was held in Sandefjord in August.

Introducing the proposed new model for assessment of annoyance, Truls postulated that there is a threshold of annoyance below which an exposed person is not annoyed at all whereas, thereafter, there is increasing annoyance to a saturation level. Above the latter level, it was contended, it is not possible to be more annoyed than "very annoyed". The model is based partly on the energy concept of L_{Aeq}, takes into account the detection threshold and the saturation level, and further includes the effects of time between noticeable noise events. Hence the model becomes one of "average annoyance level" rather than "average noise level".

Also involved in the model is a masking effect which Truls described as a form of noise habituation, so that when a strong noise event contributing significantly to the noise dose is followed by a further event, the latter may be regarded as more normal and hence less annoying. This memory effect was considered likely to be a decaying exponential function with an average time constant of the order of some minutes.

The outline of the nature of the assessment was followed by an analysis of a number of studies that have been reported to determine the support they might offer the proposed annoyance model. Included were investigations on such noise events as aircraft fly-overs as reported by the Institute of Sound and Vibration Research, and of passing trucks which had been studied by others.

Finally, a laboratory experiment was described in which three groups of subjects, with ten in each group, were exposed to identical bursts of pink noise at different time intervals. The bursts changed at a steady rate of 25dB per second from 30dBA to 80dBA and back in four seconds to resemble a fast vehicle pass or a fly-over. The ambient level was maintained at a constant 40dBA. Obviously, with different intervals between bursts, the L_{Aeq} was different for each group (64, 58 and 53). However, the group with the lowest noise dose determined on this basis had the most adverse reaction to the exposure, which reaction was considered to correlate with other measurements made such as skin conductance, finger pulse rate, and heart rate.

(Copies of Truls preliminary report are available on application).

E. T. WESTON.

13 August, 1984

SONICS AND PHOTONICS: an interesting and tentertaining lecture was given by **Professor P. Greguss** from the Applied Physics Laboratories Technical University of Budapest at NML, Lindfield, N.S.W. Professor Greguss, an eminent acoustics scientist, concentrated his talk on the development of scanning sonic and optical devices derived from the cross fertilisation of ideas from both fields.

* * *

29 August, 1984

With the location of Sydney's second airport in the process of being determined, and the likely issue for public comment of an updated version of AS2021 "AIRCRAFT NOISE INTRUSION — BUILDING SITING AND CONSTRUCTION", attention has to focus on procedures adopted to monitor aircraft noise. The Department of Aviation formulates its noise exposure contours which are available for the making of decisions in regard to land usage, and to the types and construction of buildings, in part from the data it collects on the sound levels generated by aircraft operations in the vicinity of Kingsford-Smith Airport. With the prospect of a possible change to the Noise Exposure Forecast (NEF) system previously adopted by the Department, even greater importance might be considered to apply to the monitoring procedures.

A visit of inspection was arranged to enable members and friends of the Society to obtain an insight into the Department's acquisition of data on the sound levels arising from arriving and departing aircraft and their storage and analysis. Observation of the air traffic control system operating during a busy period formed part of the visit to provide an understanding of the allocation of preferred runways and preferred flight paths for noise abatement.

AAS Annual Conference

Noise and Vibration Legislation in Australia

The 1984 Annual Conference was held at the University of Western Australia on 1-2 November, 1984.

Invited and contributed papers were presented in the following fields:

- Environmental and occupational acoustic legislation
- Review and criticism of existing legislation
- Proposals for improved legislation
- Experience or problems with enforcement of or compliance with legislation

Invited papers included:

Dr. A. J. Hede — "New Directions in Environmental Noise Legislation in Australia".

C. Roberts — "The Effect of Occupational and Environmental Noise Legislation on the Mining Industry".

Dr. J. Mathews — "Protecting Workers from Noise and Vibration—A Trade Union Approach".

Copies of the Proceedings are available from AAS, c/- F. R. Jamieson, 2 Beryl Avenue, Shelley W.A. 6155 at a cost of A$35.00, including surface postage.

Of the 28 contributed papers, 9 were on Occupational Noise, 16 were on Environmental Noise and 3 covered both areas.

Of the 96 registered participants, 49 were from Western Australia, 46 from Interstate and 1 from Overseas (Hong Kong).

There were approximately equal numbers of participants from the Government sector and the other sectors of the community (see Table 1).

Table 1 Distribution of Registered Participants Australian Acoustical Society Conference 1984

SECTION	W.A.	INTERSTATE	OVERSEAS	NOT SPECIFIED	TOTAL
Government	20	27	1	N/A	48
Industry	21	12	0	N/A	33
Tertiary institutions	7	4	0	N/A	11
Unions	1	1	0	N/A	2
Not specified	N/A	N/A	N/A	2	2
TOTAL	49	44	1	2	96

K. C. Wan

1. **Welcoming address by Pamela Gunn, Chairperson, W.A. Division.**

2. **Opening address by Tibor Vass, President, Australian Acoustical Society.**

The editorial staff send greetings for Christmas and the New Year to all our readers, advertisers and sustaining members.

• Western Australia

Technical Meeting:

9 August, 1984 at Trinity College Chapel

Lynn Kirkham is a Senior Tutor with the Mechanical Engineering Department, University of W.A., where he teaches in Design Dynamics and Noise and Vibration Control. He has also had a long-standing extramural interest in organ music and the design and building of pipe organs. Whilst on leave from the university he has built a substantial pipe organ for the chapel in Trinity College, Perth, the installation of which he has just completed.

Designing and building a pipe organ is an art based on the accumulation of empirical knowledge over many centuries. Physicists and acousticians have dabbled in the area from time to time, producing information and ideas of varying degrees of usefulness to organ builders. A technical background is useful to a builder by enabling a qualitative understanding of many of the principles involved, but if an organ is to rise above being a mere pipe playing machine to become a truly musical instrument (which is by no means always the case) it is likely to do so mainly because of the artistic judgment and experience of its creator.

Lynn discussed and demonstrated the design and realisation of the organ in Trinity College Chapel, and gave an opportunity for examination of the 'works'.

* * *

• W.A. Division Office-Bearers 1984-1985

Chairperson:	PAMELA GUNN
Vice-Chairperson:	MICHAEL NORTON
Division Secretary:	LYNN KIRKHAM
Division Treasurer:	JOHN SPILLMAN
Federal Councillors:	PAMELA GUNN TIBOR VASS
Membership Grading Committee:	JOHN SPILLMAN TIBOR VASS
Registrar:	JOHN SPILLMAN
Archivist:	FRED JAMIESON
Bulletin Representative:	KAR CHAN WAN

* * *

• Conference on Community Noise

Sponsored by the Queensland Division of Noise Abatement and the Australian Acoustical Society.

Topic: Community noise and the interaction of legislation and the legal system, planning and community education.

October 1986, Toowoomba, Queensland

Details: Ms Nola Eddington, Division of Noise Abatement, 64-70 May Street, BRISBANE, Q. 4000.

○ Victoria

14th A.G.M. — Victoria

The 14th Annual General Meeting for the Victoria Division was held on the 12th September, 1984, at the Theatrette, Galleria Level of the World Trade Centre. Prior to the meeting, the members and guests had the privilege of a tour of the World Trade Centre conducted by Mr. Graham Shaw, the Principal Architect design.

The meeting was fluently conducted by the Chairman, Mr. Jim Watson. Later, Mr. Gerald Riley gave a short speech about the history of the formation of the Australian Acoustical Society, Victoria Division. He also reminded the members and the guests that this is the 20th year since the Society was founded.

Following the meeting, members and guests attended dinner at Squizzy's Bistro in the World Trade Centre for an enjoyable end to the evening.

Office Bearers 1984/1985

Chairman:
Jim Watson.

Vice-Chairman:
David Rennison.

Div. Secretary:
John Modra.

Div. Treasurer:
Geoff Barnes.

Div. Registrar/Mailing Officer:
John Upton.

Minute Secretary:
Robert Monteith.

Archivist:
Paul Dubout (not a committee member).

Committee Members:
Sin Chan, Graeme Harding, Charles Rossiter, Stephen Samuels.

Councillors:
Graeme Harding, David Rennison, Jim Watson.

Sub-Committees

Bulletin Reporting:
Sin Chan (Convenor), Charles Rossiter.

Programme:
John Upton (Convenor), Sin Chan, Charles Rossiter, David Rennison, Stephen Samuels.

Membership Grading:
Graeme Harding (Convenor), David Rennison, Charles Rossiter.

Awards and Scholarships:
Geoff Barnes (Convenor), David Rennison, Stephen Samuels, Ken Cook (Co-opted member).

Technical Meetings:

10 April, 1984

ADVANCES IN BUILDING ACOUSTICS

This meeting was to consist of presentations from three speakers on advances in building acoustics in fields of immediate interest. The first speaker, Mr. Ian Jones of Vipac and Partners, was unable to attend. His topic of "Transmission Loss of Building Facades" was not covered.

The second topic, "Atrium Spaces in building", was presented by Mr. **Jim Watson** of Watson, Moss and Grocott. Jim spoke of the acoustics of the two large open areas, the Great Space at the Collins Place Building and the Galleria at the World Trade Centre. Predictions for the spaces were that they would be noisy and reverberant, however subjectively sound levels within the spaces appeared to be lower than the measured levels would indicate. It was postulated that the reasons for this was the diffuse nature of the sound field and the occurrence of only few early reflections. The intelligibility of amplified speech in both spaces was poor due to the high reverberance. Music also had a reverberant quality and was poor at high levels. Both spaces had reverberation times of the order of 5 to 6 seconds and room volumes of 50,000 m^3. The use of directional sound sources was generally used to solved problems with amplified music and speech.

The third topic "Impace Noise Reduction in Floors" was presented by Mr. **Bill Davern** of the C.S.I.R.O. Major reductions in impact noise are achieved by the careful choice of floor underlay. The more resilient the underlay, the heavier the flooring cover and the higher the damping — the lower the impact noise transmitted. Laboratory experiments have been conducted to determine the relative effects of various parameters using a standard tapping machine as the impact noise source. Starting with a typical tongue and groove floor various treatments were compared and the relative sound levels transmitted measured.

16 August 1984

AN OVERVIEW OF ACTIVE NOISE ATTENUATION IN DUCTS

Dr. Ian Shepherd, Andrea Cabelli and Frank La Fontaine of the Division of Energy Technology, C.S.I.R.O., gave a presentation of "Active Noise Attenuation in Ducts".

Cancellation of unwanted sound by another artificially generated sound is known as active attenuation. The principle has been demonstrated in laboratory duct applications for several years. Advantages over passive methods, such as low inherent flow losses and suitability to low frequencies are well publicised, yet there are very few active systems operating in industry. This is partly due to the fact that active attenuation has some important limitations, but also because of reticence on the part of potential users and failure of potential suppliers to recognise suitable applications.

The presentation covered the basic principles of active attenuation in flow ducts, described what is achievable and considered the factors which limit application of the method. Only when these are clearly established can potential applications be realistically assessed.

9 October, 1984

SITE VISIT TO THE AERONAUTICAL RESEARCH LABORATORIES

The Activity Director, **Dr. F. P. Bullen,** gave an introductory talk outlining the work of the Aeronautical Research Laboratories. A.R.L. is the only national laboratory which contains all the aeronautical disciplines. A.R.L. must hold sufficient information to be able to solve problems that may occur in peace time, as well as in the event of conflict. Of interest to the Acoustical Socety was the work being carried out in the field of materials research, aimed at early detection methods for prevention of aircraft component failure. As we all know, air defence equipment is expensive and lifespans are generally extended to minimise replacement costs. Because of this, the work of the Materials Division is even more important.

After Dr. Bullen's introduction, the group was divided into several parties for the various presentations and demonstrations that had been organised. These included:—

- The use of acoustic emission and its relation to failures.
- Early failure prediction methods for bearings and gears using vibration analysis and signal averaging.
- Vibration and modal analysis of aeroplane structures to determine points of maximum stress and possible points of failure.
- The use of ultrasonics to assess the quality of adhesive bonds.

Our thanks go to **Sue Bowles** and the guides and demonstrators for a very interesting evening.

H. Sin Chan

• Proposal to form a Queensland Division

A meeting was held on September 4, 1984 to discuss the possible formation of a Queensland Division of the Australian Acoustical Society. Professor Anita Lawrence addressed the meeting on the technicalities involved in forming a division.

With thirty-nine attendees and twenty-five apologies — covering a wide range of interests in acoustics — it would seem that the formation of a Queensland Division is overdue.

At present, a submission to council requesting the formation of a Queensland Division is being compiled.

Rent Your Equipment

Australian Metrosonics Pty. Ltd. now offer for rental the full range of the Metrosonics range of environmental noise instrumentation, at reasonable prices. The minimum period of rental offered is 1 calendar month and no maximum limit applies. The monthly rental is calculated at 15% per month of the ruling list price of the equipment offered. All incidental costs such as freight, insurance and taxes are to the customer's account.

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Recreational Noise and Young People's Hearing

The National Acoustic Laboratories have recently published a further report on their research into the "effects" of recreational noise on the hearing of young people (1). In this study the hearing of 141 young people, originally tested in 1972-74 at age 10-12 years, was retested after an interval of about eight years. The study showed no deterioration in hearing due to recreational noise, and indeed a slight average "improvement" was found on the second test probably due to factors connected with maturation. These results confirm those of a previous, cross-sectional study of Sydney young people published in the Medical Journal of Australia in 1982 and in more detail in various NAL reports.

(1) Norman Carter, Narelle Murray, Albert Khan and Dick Waugh. A longitudinal study of recreational noise and young people's hearing. Australian Journal of Audiology 6, 45—, 1984.

20 YEARS OF AAS

It is just twenty years since the first formative meetings which led to the formation of the Australian Acoustical Society were held. The minutes for the first meeting held in Sydney show that there were 22 people present; and the minutes of the first meeting held in Melbourne on 16th November, 1964 show that there were 44 people present. Somewhat less than half of those present at the first meeting became members of the Australian Acoustical Society and one of them Pat Murphy was admitted to the Society in the last few months. It is interesting to read the minutes of the first meetings of the steering committees in New South Wales and Victoria and to see how many of those active then are still active in the Society, and to see what a debt members of the Society have to these people who have worked very long and hard for the Society. It is also interesting to see that at one stage it was proposed to form an Acoustical Society of Australasia, in later discussions I can remember that it was agreed that the initials SAA had to be avoided to avoid confusion with the Standards Association of Australia and that the letters ASA had to be avoided to avoid confusion with the Acoustical Society of America, and hence we became the Australian Acoustical Society.

ACOUSTICS, ACCOUSTICS AND ALL THAT

We are all used to seeing *accoustics* in many places where it should not be. For example, at Telecom Research Laboratories on the door to their Anechoic and Reverberation Chambers, we see *Accoustical Laboratory.* Other spellings are seen from time to time, but those who stayed at the Princes Hotel to attend the Conference in Perth will have noticed that their room was reserved by the *Aust. Acquostical Society!*

GOOD CLEAN EARS

Bill Jones had been going deaf over many years; but had tried to ignore his growing hearing impairment. Finally he acknowledged the need to do something about it and went to see an audiologist. The audiologist commenced by examining his ears, and exclaimed "Mr. Jones, I can see cake and custard in your right ear, and jelly in your left ear; I think you are a trifle deaf".

To *Jim Menadue* must go our thanks for this acoustic joke. For those who are still groaning they can look forward to further jokes as upon hearing this one *John Upton* has promised one acoustic joke per month.

New Members

We have pleasure in welcoming the following new members of the Australian Acoustical Society, following grading by the Council Standing Committee on Membership . . .

Subscriber: Mr. J. W. Collins (Vic.), Dr. Van Ngoc Nyuyen (N.S.W.), Mr. R. J. Hooker (Q.), Ms N. J. Eddington (Q.).

Member: Mr. G. Rasile (W.A.), Mr. P. A. Cichello (Vic.), Mr. R. W. Monteith (Vic.), Mr. P. Terts (Tas.).

POTENTIAL NEW MEMBERS

We hear that *Doug Growcott* and *Tim Marks* and their respective wives have recently added a son and a daughter respectively to their families and look forward to welcoming these to the Society in about twenty years time.

Occasionally we hear of people working in the many fields of acoustics such as aircraft monitoring, audiology and the like, who are not members of the Australian Acoustical Society. Our Society needs more members and readers of this column are asked to approach all people they meet working in one of the many acoustical fields to ask if they would join the Society.

JIM MENADUE JOINS GMH

In the last People's Column we reported that *Jim Menadue* was no longer with RBK Acoustics and was looking for employment opportunities. In this column we can report that Jim has joined General Motors Holden and is now part of their acoustics or noise and vibration group.

NAL after Jack Rose

The ripples are beginning to settle after Jack Rose's retirement. **Leigh Kenna** is now in charge of Advanced Acoustic Technology; **Norm Carter** is in charge of Psychoacoustics which will include all aspects of the effects of noise on people. In Norm's domain will be **Rob Bullen** and **Soames Job** dealing with the annoying effects of noise; **Dick Waugh** dealing with hearing conservation; and Norm dealing with the effects of noise on health. Our congratulations also go to Norm for successfully completing his doctorate, which has now been conferred.

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The Effects of Aircraft Noise:

Current Knowledge and Future Research Directions

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ABSTRACT: Effective action to alleviate the disturbance caused by aircraft noise requires both a detailed understanding of the nature of the problem and a willingness to co-operate in finding solutions. This article addresses the former requirement. The current state of knowledge concerning the nature and extent of the effects of aircraft noise is reviewed, and future directions for research are proposed. As the scope for improvements in the noise emission characteristics of aircraft engines becomes narrower, the importance of such research in providing tools for planning and policy development will increase.

1. INTRODUCTION

At present in Australia over 100,000 people have their lives seriously disrupted by noise from aircraft. This figure has probably remained roughly constant for the past ten years, and there seems little chance of a dramatic improvement in the near future. The social and economic costs of such disruption include loss of time for relaxation, disturbance to sleep, inability to concentrate at work and, possibly, increased incidence of stress-related illness.

Attempts to alleviate these problems have largely been directed along three lines: improvements to the technology of aircraft engines, changes in the pattern of airport usage (or ultimately, removal of the airport itself) and land-use zoning restrictions around airports. All these strategies obviously involve costs which must be weighed against the benefits of reduced noise exposure — a difficult problem even if all the relevant costs and benefits are fully understood, and impossible if they are not. For this reason, effective action against aircraft noise has generally gone hand in hand with improved understanding of the nature of the problems created by the noise.

An example of this link can be seen from the improved methods of assessing the level of an individual noise event which were developed during the 1960s (Kryter 1970). These led to standardised and internationally accepted procedures for aircraft noise level certification, which in turn have provided the only impetus for aircraft manufacturers to produce quieter aircraft. Another example is the changes in recommended Australian land-use zoning criteria which resulted from a large study of reaction to aircraft noise in Australia (Hede and Bullen 1982).

This article reviews, from a historical perspective, the present state of knowledge concerning the effects of aircraft noise on residents. Future directions for scientific study and their possible effects on noise abatement policies and practices are considered. The focus on disturbance to residents is not intended to imply that disturbance to other people — office workers, school students etc — is negligible. It simply reflects the fact that very little is known of the kinds of problems which aircraft noise causes for such people. Studies of these problems could well be among the more important future developments in this field.

2. EARLY SURVEYS OF COMMUNITY REACTION TO AIRCRAFT NOISE

Historically, aircraft noise was the first environmental noise whose social effects were studied in detail and the body of literature concerning these effects is now quite large. Early developments centred around a few large social surveys which provided insights into the ways in which aircraft noise affects people in their everyday lives.

2.1 Borsky's Study

In the mid-1950s it became clear that due to the advent of commercial jet aircraft, levels of noise around major airports were increasing rapidly and the noise was beginning to cause serious disruption to residents. This was, of course, particularly so in the United States, where commercial air travel developed more quickly than elsewhere. The major indication of this disruption was the number of complaints received by airports, government officials and local politicians.

The first major scientific study of this problem was carried out by Borsky (1961), and this has set the pattern for most subsequent studies. Personal interviews were conducted with some 2,300 residents around three air bases in the United States. The residences were in a number of separate "neighbourhoods" and noise exposure was calculated for each neighbourhood in terms of several noise descriptors, including measures of the number of noise events per day and their average noise level.

Interviews were conducted face-to-face and the purpose of the interview was initially disguised — it was described as being concerned with neighbourhood conditions in general. This allows some questions about the effects of aircraft noise to be placed in context among questions about the closeness of schools, the safety of the area, etc, and also ensures that people do not refuse to be interviewed simply because they are not interested in aircraft noise as a problem.

Reaction to the noise was thought of in terms of "annoyance", and annoyance was assessed by the number of activities, such as conversation, watching television or sleeping, which the respondent claimed were disturbed by the noise.

Findings from the study indicated that, as expected, noise reaction tended to increase with both the level and the number of noise events. However, several other factors were also related to high noise reaction, particularly fear of aircraft crashing in the area and negative attitudes towards the air base. The latter variable was assessed by responses to questions such as "...how much concern do the air base officials have for the feelings and comfort of residents like yourself?" The picture emerged that people could show very different reactions to the same noise exposure, depending on various attitudinal factors.

Perhaps surprisingly, demographic variables such as age, sex and socio-economic status showed no relationship, or only a very weak relationship, with noise reaction.

2.2 Heathrow Airport Studies

Two surveys around London (Heathrow) Airport (McKennell 1963, MIL Research Ltd 1971) served to validate the results found by Borsky and to put them on a more quantitative basis. Methods of assessing noise exposure and noise reaction were based on those used by Borsky, and the other variables investigated were also similar.

The correlation between the noise exposure of survey respondents and their reaction to the noise was about 0.4 in both studies. This surprisingly low level of correlation has been found repeatedly in numerous social surveys since then. It indicates that only about 16% of the variation in noise reaction between individuals can be attributed to differences in their exposure. The problem of accounting for the remaining 84% of the variance has been, and still remains, one of the most important issues in this field.

In these early studies, the problem of the unexplained variance was attacked by searching for "psycho-social variables" such as fear of aircraft crashing and sensitivity to noise in general, which are correlated with noise reaction. As in Borsky's study, such variables were indeed found, and some were more highly correlated with noise reaction than was noise exposure itself. The conclusion drawn by many people — although generally not by the researchers themselves — was that noise reaction is largely "psychological", and should be amenable to manipulation by advertising and publicity designed to project a positive image of aircraft and the aviation industry.

The first of these Heathrow Airport studies included a separate sample of people who had complained about the noise. Although, as in Borsky's study and many subsequent studies, socio-economic variables were found to have only a small influence on noise reaction, they had a much stronger influence on complaint behaviour. It has also been found that complaint behaviour is not as highly correlated with noise exposure as is noise reaction. In general, the number of complaints received is a very poor guide to the extent of noise reaction in the community, complaints being determined by a large number of other factors such as socio-economic status and knowledge of the appropriate authority to receive the complaints.

2.3 TRACOR Study

A very large study (8,200 respondents) was conducted in the United States in the late 1960s (TRACOR Inc. 1971). Its major purpose was to examine in detail the "psycho-social variables" which affect noise reaction. A large number of variables was tested and non-linear regression techniques were used in an attempt to explain as much of the variation in noise reaction as possible. In this manner, 63% of the individual variation in noise reaction could be "explained". However, the meaning of many of the relationships found is far from clear. For example, reaction appeared to increase with distance from the airport (at constant noise exposure) up to a distance of five miles, and to decrease thereafter.

The complexity and obscurity of the variables necessary to predict even 63% of the variation in noise reaction has caused many people to feel that the cause of the unexplained variance should be sought elsewhere. In addition, a point which appears to have been overlooked by the early researchers is that most of their "psycho-social variables" are positively correlated with noise *exposure*, as well as with noise *reaction*. The correlation with noise exposure is difficult to explain if these variables are intended to represent attitudes or personality traits which are properties of individuals, independent of their noise exposure. For example, it is difficult to see why people who have negative attitudes towards the aviation industry would preferentially choose to live in noisy areas. On the other hand, the correlation can be readily explained if negative attitudes, fear of crashes, etc, are actually the *results* of continued noise exposure, or of noise reaction. But in this case, such variables can make no contribution towards explaining the variation in reaction between individuals, since they would actually represent a part of one's overall reaction to the noise. Such arguments have been canvassed by Alexandre (1976) and others. It now seems likely that only a few of the suggested psycho-social variables (notably sensitivity to noise in general) can be regarded as genuine pre-existing personality traits which affect noise reaction, and that in total they would not explain more than about 20% of its variance.

Before leaving the TRACOR study, another of its findings is worth noting. An estimate was made of the acoustic attenuation of each respondent's house, on the basis of such details as the number and size of windows, the type of roof, etc. (These details were recorded by the interviewers.) When the measured external noise level in the respondent's neighbourhood was corrected for the house attenuation, the correlation with noise reaction was significantly *lowered*. This implies that residents react to the *external* noise at their dwelling, and not to the noise which is heard inside their home. This intriguing finding is to some extent supported by evidence from other studies — Fields and Walker (1982) found that the construction of the respondent's dwelling showed no relationship with reaction to railway noise, and Griffiths, Langdon and Swan (1980) found that reaction to traffic noise did not alter between summer and winter, despite the fact that more people had windows open in summer.

A related finding from other studies is that noise reaction does not appear to depend on the amount of time spent at home (Hede and Bullen 1982, Fields and Walker 1982). Taken together, these two results would seem to rule out another possible cause of the unexplained variance, namely that it may be due to interpersonal differences in the amount of noise actually heard. [This explanation was proposed by Schultz (1978), among others.]

3. MORE RECENT STUDIES

3.1 The Use of Grouped Data

From the above discussion, about 60% of the total variation between individuals in their reaction to aircraft noise remains completely unexplained. In this situation, one is led to suspect that there must be gross error or inaccuracy in the measurement of either reaction or exposure. However, over the past 15 years a great deal of effort has gone into "tightening up" the measurement of both these variables. Measures of noise reaction are now available which are highly reliable (Bullen and Hede 1983) and reasonably consistent when repeated after several months (Hall and Taylor 1982). Very accurate methods of assessing the loudness of individual aircraft overflights have been known since the late 1960s (Kryter 1970) and virtually every conceivable method of combining these units into an overall measure of noise exposure has been explored, including such exotic measures as the total time a Speech Interference Level of 60 dB is exceeded (Borsky 1961) and the mean level of the five noisiest events in a day (Hede and Bullen 1982). Values of noise exposure can be calculated at individual

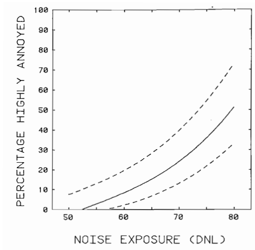

Figure 1: Dose/response relationship for aircraft noise as given by Schultz (1978). Dashed lines include 90% of the data points for the surveys considered by Schultz.

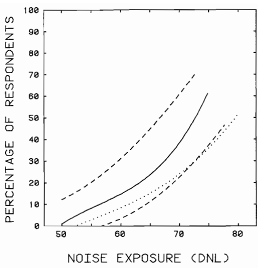

Figure 2: Dose/response curves for aircraft noise. Unbroken line: Percentage of respondents seriously affected, as defined by Hede and Bullen (1982). Dashed lines include 90% of the data points from that study. Dotted line: Schultz's curve for percentage highly annoyed.

dwellings with a standard error of only about 2 dB. Despite all this, observed correlations between exposure and reaction have remained at about 0.4.

Faced with what Langdon (1976) has called "the brute fact that physical conditions account for only a small part of total variance [in reaction]", most researchers have in the past ten years concentrated on studying properties of the *average* reaction of groups of people, rather than individual reactions. For policy development it is, after all, not necessary to predict a particular individual's noise reaction, but only the average reaction, or possibly the proportion of people who would show a high level of reaction. The unexplained variance appears to be caused by some personal property — it is not shared to any great extent by other people in the same area. This means that over a group of people, the unexplained variance is largely averaged out, and the relationship between exposure and reaction can be seen more clearly. The amount of unexplained variance in grouped data is only about 18%, compared with about 60% in individual data. Depending on the application, the averaging process can consist of simply considering the number of people "highly annoyed" and plotting the results; performing complex regression analysis on individual scores; or, more recently, using probit analysis techniques (Bullen and Hede 1984). The point in all these cases is to remove individual variation, rather than to explain it.

The two most important lines of research using these techniques have been the attempt to accurately define the dose/response relationship for aircraft noise and the search for the most appropriate descriptor of noise exposure.

3.2 The Dose/Response Relationship

Defining the curve which relates (average) aircraft noise reaction to noise exposure is the most fundamental goal of this field of research, and in most studies an attempt is made to produce such a curve. Unfortunately, the units used to measure both reaction and exposure are generally not standardised, and tend to depend on local conditions, such as the noise exposure unit which is used by the responsible body in the country concerned.

The most important work in defining a general dose/response relationship is undoubtedly that by Schultz (1978), who took eleven studies of reaction to various kinds of transportation noise, including six studies of aircraft noise, and attempted to translate their results into common units. The unit of reaction is the proportion of people who are "highly annoyed", which is roughly the proportion who would choose "highly" if asked whether they were highly, considerably, moderately, slightly or not at all annoyed. The unit of exposure is the Day/Night Noise Level (DNL) — Leq(A) for aircraft, with a 10 dB weighting for events between 10 pm and 7 am. The agreement between studies which Schultz produced is impressive. His results are shown in Figure 1.

The "Schultz curve" in Figure 1 is now the basis for much environmental planning and some legislation, particularly in the United States. It is useful as a first rough estimate of the likely effect of noise exposure from any source except impulsive noise, and is probably accurate to within about ± 10 dB. For aircraft noise, of course, this is not nearly accurate enough — differences of one or two decibels can be critical in land-use planning decisions, for example. For greater accuracy, the measurement tools employed by Schultz appear to be too crude.

Firstly, it is now almost certain that the same dose/response function cannot be applied even to all types of transportation noise (Griffiths 1983). Aircraft noise, for example, causes more reaction than either road traffic or railway noise at the same DNL, the differences being equivalent to perhaps 5 dB in exposure.

Secondly, the analysis method used by Schultz produces a "best fit" curve which tends to underestimate reaction at relatively low exposure. At about 10% highly annoyed, the curve should actually be moved about 3 dB to the left.

Thirdly, and most important in the context of aircraft noise, neither the unit of reaction nor the unit of exposure used by Schultz is optimal. Exposure units are discussed in the next section. For noise reaction, the proportion of people who are highly annoyed is a relatively unreliable measure (Bullen and Hede 1983). In addition, "highly annoyed" represents a level of reaction which most people would see as too high to form the basis of planning decisions. For example, being highly annoyed is a much higher level of reaction than believing that aircraft noise affects one's health, choosing aircraft noise as the neighbourhood feature most worth improving, or claiming that aircraft noise disturbs sleep (see Figure 2). Hede and Bullen (1982) use a somewhat lower criterion, and describe people with at least that level of reaction as "seriously affected". The difference which this makes to the dose/response curve is illustrated in Figure 2.

About half the variance in the dose/response curve, as illustrated in Figure 2, can be identified as being due to error in the measurement of either noise exposure or noise reaction. (The rest is due to real differences in reaction between people in different areas.) This gives some idea of the scope for future studies to produce a more accurate dose/response curve.

3.3 Measures of Noise Exposure

Since the earliest studies of reaction to aircraft noise, the search for the most appropriate measure of noise exposure has been seen as one of the most important aspects of the research. The reason for this is that the use of alternative measures can often make a great deal of difference to the position of noise exposure contours, and therefore to planning decisions based on those contours. However, the problem facing researchers is that values of all reasonable measures of noise exposure are in practice highly correlated, which means that they all have similar correlations with noise reaction. The unexplained variance in individual noise reaction compounds the problem. For this reason, studies comparing different exposure units require very reliable measures of both reaction and exposure, as well as sophisticated statistical analysis.

Considering the problems of addressing this question using social survey techniques, many researchers have tried to use laboratory studies to differentiate between measures of noise exposure. In a laboratory, exposure can be measured very precisely and altered at will, so that the values of different measurement units need not be highly correlated. In addition, the responses of experimental subjects are generally much less variable than the responses of residents in an interview situation. (In passing, this must be saying something about the nature of the unexplained variance in noise reaction, although no one knows quite what.) The problem with laboratory studies, of course, is to decide under what circumstances it is valid to extrapolate their results to the "real world".

Laboratory studies have been extremely successful in producing descriptors which predict reaction to a single noise event. Work throughout the 1960s resulted in the Effective Perceived Noise Level (EPNL) unit, which takes account of the differential frequency response of the human ear depending on the intensity of the noise, the presence of pure tones and the duration of the signal (Kryter 1970). Although the validity of the tone correction has recently been questioned (Scharf and Hellman 1978), EPNL is probably the most accurate method available for assessing reaction to a single non-impulsive noise event.

Unfortunately, the single-event noise descriptor is the least important component of an overall measure of aircraft noise exposure. A measure using simply the maximum level in dB(A) would not behave very differently from one using EPNL. More important is the method of combining individual noise levels into an overall index. In most units this is done by adding the noise levels on an energy basis which implies, for example, that a ten-fold increase in the number of events is equivalent in its effect to a 10 dB increase in noise level. Considerable research over the past 15 years has centred on the validity of this "trade-off". In particular, if an index is assumed to have the form (Level of events) + k . log (Number of events), the optimal value of k is sought, k = 10 giving the usual equal-energy index.

This question has been addressed in laboratory studies, notably those by Rice (1977a, 1977b). Subjects were placed in a simulated lounge-room for one hour and heard recorded aircraft overflights with varying combinations of the level and number of events. They then answered a number of questions, the most important being "How difficult would it be to get used to living with that amount of noise all the time?", scored on a 0–9 scale. Rice's results indicated that the equal-energy trade-off was roughly optimal for describing the data as a whole, but that there seemed to be an interaction between the value of k and other variables, particularly the absolute value of the number of events.

Results from social surveys have given similar results. Analysis of data from different surveys has given various values of k — the first Heathrow survey gave k = 24 (though 15 was subsequently adopted), a Swiss study (Grandjean et al 1973) gives k = 7, a recent re-analysis of several studies (Fields 1984) gives a value of about 5, and an Australian study (Hede and Bullen 1982) gives a value of about 12. It appears that the equal-energy index gives a safe and reasonably accurate assessment of the overall effect of aircraft noise exposure, but that there is more to be discovered. The value of k clearly seems to alter depending on some characteristics of the noise or of the community, but exactly what these characteristics might be is elusive.

Rice (1978) has suggested that it may be the between-days variability in noise exposure which determines the operative value of k, and this suggestion is worth pursuing. However, before more progress can be made on this question a more accurate definition of the problem is necessary. In particular, it is not known at this stage precisely what constitutes a "noise event" from a psychological point of view, so it is not possible to accurately or systematically define either the mean level of all events or their number.

Apart from trade-off models of a noise exposure index, several other models have been proposed, the most important being by Rulander et al (1972). Under this model, the form of the index depends on the number of noise events per day, and in particular, depends only on the level of events when their number is greater than 50 per day. This model grew from an analysis of results from a survey in Sweden. Several attempts to test the model using results from other surveys (notably by Hede and Bullen 1982, and Fields 1984) have found it to be inferior to the equal-energy index as a predictor of reaction. In general, most alternative models appear to work well for one set of data, but none has been comprehensively replicated by other researchers.

The question of whether differential weightings should be applied to noise events occurring at different times of the day (particularly the evening and night periods) has received little attention from researchers. This is largely due to the difficulty in studying the question — the problems with doing so in a laboratory experiment will be obvious, and few airports have substantial numbers of operations at night, making social survey comparisons difficult. The most popular aircraft noise indices — the Noise Exposure Forecast (NEF) and the Day/Night Noise Level (DNL) — use weightings of 12 and 10 dB respectively for events occurring between 10 pm and 7 am. However, these figures are based largely on intuition and anecdote (Galloway 1980). The only study which has directly and comprehensively analysed this question is the recent Australian study (Hede and Bullen 1982). Here it was found that the night-time penalties used in NEF and DNL are too large, and also that an evening penalty, of about the same size as the night-time penalty, is necessary to optimally describe the data.

Results from all these lines of research have been synthesised in the Australian Noise Exposure Forecast (ANEF) exposure unit. This uses EPNL to assess the noise level of a single event, combines events using the equal-energy principle, and has a 6 dB penalty for events occurring between 7 pm and 7 am. Figure 3 shows the dose/response function derived from Hede and Bullen's study, using the proportion of people seriously affected as the measure of reaction, and ANEF as the measure of exposure.

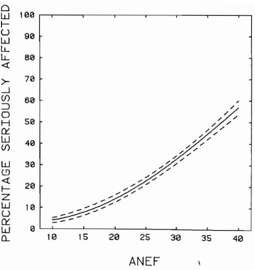

Figure 3: Dose/response curve for aircraft noise, using ANEF for exposure and percentage seriously affected for reaction. Dashed lines are 95% confidence limits for the position of the curve.

4. PHYSIOLOGICAL EFFECTS

On the periphery of main-stream research into the effects of aircraft noise has been a number of studies of possible physiological effects. These studies are rather variable in quality and no one can be judged unambiguous in its findings. Two large literature reviews (Taylor et al 1980 and Thompson 1981) have both concluded that evidence for health effects of noise in general (apart from hearing damage) is not convincing, but is suggestive.

In the case of aircraft noise, the difficulties in conducting studies of possible health effects are largely concerned with selection of an appropriate control group with which to compare the affected population. No researchers have adequately demonstrated that their control group is matched with the affected group in all relevant respects.

Effects claimed to be related to aircraft noise exposure include hypertension (Knipschild 1977), cirrhosis of the liver (Meecham and Shaw 1979), increased rates of admission to mental hospitals (Abey-Wickrama et al 1969) and increased rates of birth defects (Jones and Tauscher 1978). The importance of these effects, if they do occur, is such that producing methodologically adequate studies of the physiological effects of aircraft noise must be seen as a very high priority for future research.

5. FUTURE RESEARCH

Most of the advances in the control of aircraft noise over the past ten years have been due to improved technology in the design of aircraft engines. However, it is generally recognised that the scope for such improvements is now much less than it has been, especially in the case of large passenger aircraft. Further improvements are likely to depend more on planning decisions than on new aircraft technology and navigational aids and it is for this reason that the formulation of planning tools has been emphasised in this paper.

Priorities for future research are:

- **Studies of physiological effects** If it can be demonstrated that aircraft noise has substantial effects on the health of residents, this would have very important consequences in assessing its overall effects on the community. Many noise abatement options would then be seen to be cost-effective.
- **Further studies to define the most appropriate exposure index** Although the existing system is not dramatically flawed, improvements would be welcomed by planners and administrators who will increasingly need to make decisions on the basis of a predicted improvement of one or two decibels. Such studies will need to be large, involve many airports and use sophisticated statistical processing methods. They may also require advances in noise measurement technology which would allow the gathering of large amounts of data at many distributed sites.
- **Studies of the effects of aircraft noise on people other than residents** This will require the development of methods to assess the impact of noise on such things as the quality of work performed, or the effectiveness of teaching or hospital care. There is considerable scope for such research.
- **A new set of studies into the causes of the unexplained variance in noise reaction** It has recently been suggested (Griffiths 1983) that improved methods of psychological assessment could allow researchers to define more clearly the factors which result in individuals showing such a diversity of reactions to the same noise. Such studies would have scientific value and could conceivably result in a much better understanding of the social and psychological factors which underlie aircraft noise reaction.

All these lines of research will require a multi-disciplinary approach, involving acousticians, psychologists, epidemiologists and statisticians, among others. In the past, it has been when experts from different disciplines combine in an open and trusting way that progress in this field has been made, and the requirements of the four priority areas listed above are such that co-operation will be even more necessary in the future.

This is also true of efforts to apply this research to concrete problems of airport management. A dialogue between researchers, aircraft operators, representatives of residents and the airport authorities is essential. Solutions based on a "technological fix" which ignore the social, economic and administrative dimensions of the aircraft noise problem are not possible in the 1980s.

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NOISE: Problems and Remedies

Kenneth H. Gifford, Q.C.
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Summary of a paper presented at a seminar on COMMUNITY RESPONSE TO NOISE Organised by the Victoria Division, July 1984

A full account of this paper will be published in a subsequent issue

SYNOPSIS

1 The problem of noise is not a modern problem. It is referred to in biblical times and by the Roman classical writers.
2 The problem of noise is a growing problem in the modern community.
3 Noise today is aggressive, affecting amenity and affecting health.
4 There is a need to define the basic terms relating to noise and its controls, but there are substantial difficulties to doing so effectively.
5 Despite the expertise of acoustic consultants, there are substantial difficulties to the measurement and assessment of noise.
6 Noise today reaches nuisance proportions in a wide variety of situations affecting many aspects of modern life.
7 Noise is an increasing problem affecting amenity, health and property values.
8 Protective action to prevent noise reaching nuisance proportions is available in many situations, particularly if proper acoustic advice is obtained.
9 Noise controls in the exercise of bylaw-making powers are available but drafting and enforcement of the bylaws have their difficulties.
10 Noise zoning offers a worthwhile approach provided that it is enforced effectively.
11 Town planning powers include a power to impose noise control conditions when granting permits.
12 Enforcement orders can be given, requiring cessation of a noise nuisance. Reliance on an acoustic expert's advice may be a reasonable excuse for noncompliance, but financial difficulty is not.
13 On a prosecution for making excessive noise, neither the desirability of what has caused the noise or an intention not to make excessive noise affords a defence.
14 A long existing remedy by way of injunction granted by a superior court is available to restrain the making or continuing of a noise nuisance.

INTER-NOISE 85

Call for papers

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Factors Determining Traffic Noise Annoyance

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ABSTRACT: This paper addresses the question of the relative importance of individually noisy vehicles versus the "bulky flow" noise of traffic as determinants of community annoyance. Evidence from social surveys and laboratory studies indicates that both factors play a significant but largely independent role in causing annoyance. Noisy vehicles are shown to cause annoyance in excess of that accounted for by their contribution to the overall traffic noise level. Also, because noisy vehicles make the traffic pattern intermittent and because they often exceed the threshold level for awakening, they are primarily responsible for the sleep disturbance resulting from traffic noise. However, the background noise of the bulk flow of traffic will, on high volume roadways, cause annoyance even when none of the vehicles are individually noisy. Further, worthwhile reductions in community annoyance will depend on further quietening of all vehicles not just noisy vehicles. The finding that there are two independent determinants of traffic noise annoyance has implications for noise control.

INTRODUCTION

Road traffic noise has been identified as the noise source which currently predominates world-wide, and which will continue to be the major noise problem in the future [1]. Social surveys in several countries have indicated that more people are annoyed by traffic noise than by any other source of noise pollution [2,3]. In a U.S. survey, 40% of respondents rated traffic noise as a serious environmental problem [4]. Also, there is evidence that in Australia, approximately half the population in urban residential areas is annoyed by traffic noise [5].

Community reaction to noise is assessed using socio-acoustic studies. The socio-acoustic approach entails social surveys to determine the effects of noise on residents, in conjunction with noise measurements to determine the extent of their noise exposure. Numerous socio-acoustic investigations of community reaction to traffic noise have been carried out in a number of countries including England [6,7], Canada [8], Sweden [9], Switzerland [10] and Australia [11]. These have led to the development of several indices for measuring noise exposure, and have produced a range of estimates of the relationship between noise dose and community response.

An important issue in the area of traffic noise annoyance concerns whether community reaction is determined by individually noisy vehicles or by the overall noise of the "bulk flow" of the traffic stream. This issue has fundamental implications for noise control strategies designed to contain or reduce the extensive disturbance caused by road traffic. For example, if annoyance is caused by noisy vehicles and not by the overall bulk flow noise, then there would be no need for further reductions in the noise emission levels of new passenger cars. This is because most new cars are not, individually, either noisy or annoying. On the other hand, if noisy vehicles do not constitute a primary determinant of annoyance, then the enforcement of in-service emission standards is not an important noise control strategy.

DOSE/RESPONSE RELATIONSHIP

In socio-acoustic research, measures of community reaction are based on people's ratings of the annoyance or dissatisfaction they experience because of noise. Some investigators measure reaction in terms of mean ratings (e.g. Langdon [6]). However, it is now generally accepted that a more useful measure of community reaction is the percentage of residents reporting a high level of annoyance [12]. Noise exposure is assessed using an index that predicts community reaction. Generally, the best predictors of reaction to transportation noise are exposure indices that take account of both noise level and number of events (e.g. L_{eq}, L_{dn}). The function relating noise exposure and community reaction is termed the dose/response relationship.

The only major socio-acoustic study of traffic noise in Australia is Brown's [11] survey in Brisbane, Sydney and Melbourne (BSM). This study covered 19 sites on free-flowing roadways. Measurements were made over a 24 hr period at each site, and noise exposure was estimated in terms of a number of indices. In the social survey of 818 residents, the main measure of subjective reaction was a rating of annoyance using a scale comprising seven verbal categories. The top two categories ("a lot" and "a great deal") can be taken as indicating the respondent was "highly annoyed". The dose/response relationship for the BSM study is compared in Figure 1 with the results of the transportation noise surveys reviewed by Schultz [13].

In his synthesis of social surveys, Schultz [12] compared the dose/response functions for several sources of transportation noise, and concluded that there was such close agreement across sources that they could all be represented by a single curve. This raises the question of whether the Schultz curve rather than the BSM function should be used to describe traffic noise annoyance in Australia.

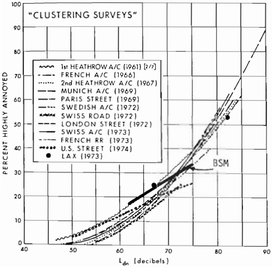

Figure 1: Dose/response functions from the BSM study and other transportation noise surveys. (Figure adapted from Schultz [13]).

However, there is some doubt about Schultz's claim that the dose/response function for traffic noise is the same as that for aircraft and railway noise. Firstly, Kryter [14] argues that traffic noise causes less annoyance than aircraft noise at the same exposure level. According to Kryter's analysis, traffic noise causes the same reaction as aircraft noise when the aircraft noise is at 10 dB lower levels. Also, there are several studies which have shown that traffic noise causes more annoyance than equivalent exposure from railway noise [15, 16]. These studies indicate that there is a difference of about 5 dB between road and rail noise for the same level of community annoyance. Further, it appears that the Schultz synthesis glosses over a considerable variation across studies in the dose/response function for traffic noise. This is illustrated in Figure 2 which shows a spread in the functions obtained in various traffic noise studies including the BSM study. Therefore, until further Australian data are available, it seems appropriate to use Brown's BSM function rather than the Schultz function to describe the dose/response relationship for traffic noise in Australia. The BSM function is given by:

$$\% \text{ Highly Annoyed} = 1.19 (L_{10}\, 18\text{hr}) - 56.8$$

An exposure level of 68 dBA (L_{10} 18 hr) is commonly regarded as the "absolute upper acceptable limit" for traffic noise [1]. It is often used as an acceptability criterion for community exposure. In Victoria, for example, this level is used as the design criterion for noise barrier construction along new freeways. Using the BSM dose/response function, it is estimated that 24% of the population will be highly annoyed by an exposure level of 68 dBA (L_{10} 18 hr). This percentage far exceeds the National Acoustic Laboratories guideline which defines "excessive" noise as that which causes a "10% highly annoyed" community response [5]. On this definition a traffic noise exposure level of 56 dBA (L_{10} 18 hr) would be considered "excessive". A level considerably below 68 dBA should be regarded as the maximum acceptable amount of traffic noise in residential areas.

As an indication of the extent of the traffic noise problem, it is worth considering that most residences along major urban roads are exposed to unacceptably high levels of noise. In Melbourne, for example, calculations of levels at more than 500 sites along primary and secondary arterial roads, indicate that 98% of premises are exposed to levels greater than 62 dBA (L_{10} 18 hr). This means that on the major roads in that city alone, more than 350,000 residents are exposed to noise in excess of this level.

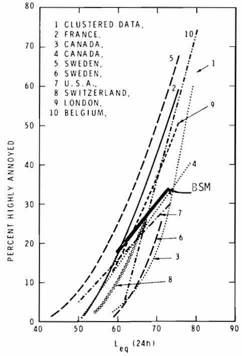

Figure 2: Comparison of the dose/response functions from various traffic noise studies including the BSM study. (Figure adapted from Ref. 17.)

EFFECTS OF TRAFFIC NOISE

As well as causing general annoyance, traffic noise adversely affects people by interfering with everyday activities, particularly:

- communication (conversation, listening to TV and radio)
- reading and studying
- sleeping and resting

The extent to which these activities are disturbed has been shown to be related to the overall amount of traffic noise [10, 13]. Also, traffic noise has been found to lead to a significant increase in behavioural responses such as closing windows, transferring activities to quieter rooms and sound-proofing the house [18].

Type of Index	Overall Noise Index (L_{eq}* or L_{10} 18 hr)		Noisy Vehicle Index (Log % HV)	
Correlation with Annoyance / Survey	Simple Correlation	Partial Correlation (Constant Log % HV)	Simple Correlation	Partial Correlation (Constant L_{10} 18 hr)
Rylander *[9]	.78	.76	.75	.72
Langdon [6]	.51	.33	.66	.56
Brown [11]	.39	.08	.59	.49

TABLE 1
Simple and partial correlations with annoyance of indices based on overall noise versus noisy vehicles

Sleep Disturbance

Sleeping is the activity most likely to be disturbed by traffic noise, in contrast to aircraft noise which is more likely to disturb communication rather than sleeping [14]. Not only does traffic noise disturb sleeping, but also it has been shown to lead to increased use of sleeping tablets [18]. Although the general noise of the bulk flow of traffic can cause sleep disturbance, this effect is even more probable when there are individually noisy vehicles in the traffic stream.

It has been found that traffic noise causes more disturbance to sleep when the traffic pattern is intermittent rather than continuous [19]. The presence of noisy vehicles will tend to make the traffic noise pattern intermittent in contrast to the continuous noise of the background bulk flow. Also, various studies have shown that individual vehicle passbys can awaken a person if the level exceeds about 35 dBA indoors. In a recent study by Vallet [20], experiments were conducted in the homes of people who had been chronically exposed to traffic noise. It was found that the average peak levels causing sleep disturbance were as follows: awakening (50.3 dBA), change in sleep state (48.5 dBA) and transient reactions (47.6 dBA). Thus, peak levels of 50 dBA were sufficient to awaken 50% of subjects. Considering that a heavy truck or an unmuffled car will produce levels well in excess of 50 dBA indoors along a roadway, it is clear that a single noisy vehicle can cause extensive sleep disturbance in areas where the bulk flow traffic noise is not at all a problem.

EXPOSURE INDICES

The main indices developed for assessing traffic noise are:

L_{eq}: Equivalent continuous sound level (over 24 Hrs)

L_{10}(18 hr): Arithmetic average of hourly L_{10}'s over 0600—2400

TNI: Traffic Noise Index = $4(L_{10} - L_{90}) + L_{90} - 30$

L_{NP}: Noise Pollution Level = $L_{eq} + k\sigma$

These indices have been found to be the best predictors of community reaction with typical correlations of about 0.3 for individual data and 0.8 for group data. There are considerable differences across studies in the predictive ability of exposure indices. For example, the correlations with individual data in Brown's survey [11] were quite low (about 0.2), whereas those in the study by Lambert [18] were comparatively high (about 0.6). Laboratory studies of traffic noise annoyance have indicated that L_{10}(18 hr) and L_{eq} are as good, if not better predictors than the more complex TNI and L_{NP} [21].

Many researchers have commented on the fact that the best exposure indices can explain only 10-20% of the variation in subjective annoyance among individuals. Psycho-social factors such as noise sensitivity and attitudes are often found to explain more of the reaction variance than does noise exposure [6]. Part of the reason for the typically low dose/response correlations for traffic noise could be the annoyance caused by individually noisy vehicles. For example, residents who are regularly disturbed by noisy cars in their quiet suburban street at night, may rate themselves as "highly annoyed" even though their overall noise exposure is quite low.

Indices such as L_{eq} and L_{10}(18 hr) can be taken as representing the overall traffic noise level comprising both bulk flow noise as well as individually noisy vehicles. Indices which represent noisy or heavy vehicles without reference to the bulk flow noise, have also been found to correlate with community reaction. One such index is the logarithm of the percentage of heavy vehicles (log %HV). In fact, there is evidence that while L_{eq} and L_{10}(18 hr) are suitable for free-flowing traffic conditions, Log %HV is a better predictor in congested traffic conditions [6]. The reason for this is presumably that free-flowing traffic is relatively constant in noise level, whereas congested traffic noise is more intermittent and has more perceptible peaks from gear changing by noisy vehicles.

PARTIAL CORRELATION ANALYSIS

The simple correlations in several studies are as high for a noisy vehicle index (Log %HV) as for overall traffic noise (L_{eq}). Indeed, in Brown's survey [11] Log %HV was found to be the best predictor of community annoyance. However, although a noisy vehicle index can be said to predict annoyance, the crucial question is whether noisy vehicles cause annoyance over and above that predicted by an index of overall noise exposure. The role of noisy vehicles can be clarified by partial correlation analysis. If one exposure index measures essentially the same underlying cause of annoyance as another, then the correlation it has with annoyance reaction will be reduced to zero when the contribution of the index is held constant or partialled out. Partial correlations were calculated for three social surveys, namely, Langdon [6], Rylander [9] and Brown [11]. The results are summarised in Table 1.

It can be seen from Table 1 that the correlation between annoyance and Log %HV was, in all cases, almost unchanged

Experiment & Design	Noise Variable	Annoyance
	Energy Average L_{eq}	% Annoyed
Experiment 1	57.5	26
Overall noise varied	62.5	47
Noisy vehicles constant	67.5	68
	No. of Noisy Vehicles	% Annoyed
Experiment 2	1	30
	3	50
Overall noise constant	4	63
Noisy vehicles varied	6	52
	12	53
	20	52
	45	45
	70	38

TABLE 2
Results of Rylander's [23] experiments on annoyance from traffic noise

when overall exposure was held constant. This indicates that the percentage of heavy vehicles has an effect on annoyance reaction that is virtually independent of overall noise level. In the case of the partial correlations involving L_{eq} and L_{10}(18hr) there was no change between the simple and partial correlations for the Rylander data and only a small decrease for the Langdon data. This suggests that overall exposure to traffic noise causes annoyance independently of the effect of heavy vehicles. However, for the Brown data the predictive ability of L_{10}(18hr) was all but eliminated when the effect of percent heavy vehicles was partialled out. The reason for the inter-study differences is not clear, but may be related to the numbers of free-flow and congested traffic sites in the various surveys. Nevertheless, the partial correlation analysis clearly demonstrates the importance of heavy or noisy vehicles in determining annoyance, and shows that they cause annoyance *in excess* of that accounted for by an index based on overall noise level.

LABORATORY STUDIES OF ANNOYANCE

Further evidence on the noisy vehicles versus bulk flow issue comes from laboratory studies in which subjects are exposed to various levels of general traffic noise with different numbers of noisy vehicles.

Rylander [23] had groups of subjects rate their annoyance after being exposed to traffic noise for 45 minutes while reading. In one experiment the number of noisy vehicles was held constant (20 truck passbys at 70 dBA) while the overall traffic noise was increased from 57.5 to 67.5 dBA L_{eq}. The results as summarised in Table 2, show that annoyance increased with overall noise level even though there was no increase in the number of noisy vehicles. Thus, bulk flow traffic noise is a primary determinant of annoyance.

In a second experiment the number of noisy vehicle passbys was varied from 1 to 70 (at 70 dBA) while the background traffic noise was lowered slightly (60 to 57.8 dBA) so that the overall L_{eq} was constant at 60 dBA. It can be seen from Table 2 that even when there was no increase in overall noise, the amount of annoyance increased with the number of noisy vehicles. It is noteworthy that the maximum annoyance occurred

ROAD	FLOW (18 hour)	% NOISY VEHICLES	PREDICTED L_{10} (18 hr) dB(A)	ESTIMATED % HIGHLY ANNOYED
PRIMARY ARTERIAL	30,000	0	73.7	30.9
		5	75.2	32.7
		10	76.4	34.1
		15	77.2	35.1
		20	78.0	36.0
SECONDARY ARTERIAL	15,000	0	70.7	27.3
		5	72.2	29.1
		10	73.3	30.4
		15	74.2	31.5
		20	75.0	32.5
LOCAL CROSSING	5,000	0	65.9	21.6
		5	67.5	23.5
		10	68.6	24.8
		15	69.5	25.9
		20	70.2	26.7

TABLE 3

Effect of changes in vehicle population on three typical roadways. (Calculations based on the UK DoE method [25] assuming a speed of 60 km/h and a distance of 10 m over hard ground. Annoyance estimates are based on the BSM function).

with only four noisy vehicles and that the extent of annoyance levelled off or even decreased with further increase in number. This experiment demonstrates the importance of noisy vehicles in traffic noise annoyance, and indicates that noisy vehicles have an effect which is independent of that accounted for by overall noise level.

In a recent study by Labiale [24] subjects rated their annoyance from 30 minutes exposure to different levels of overall traffic noise (50, 55, 60 dBA L_{eq}) with either 3, 5, 15 or 30 truck passbys at 69 dBA. The levels used were specifically chosen so that for each level of overall L_{eq}, the background (i.e. bulk flow) traffic noise was virtually constant across different numbers of truck passbys. A control experiment verified that the small variation in background noise (< 2.5 dBA) was imperceptible to subjects. Analysis of variance showed that both the overall L_{eq} and the number of truck passbys were significant determinants of annoyance. This study also indicated that annoyance levels drop off after an initial increase with the number of noisy vehicles.

The important finding from these studies is that noisy vehicles cause "excess annoyance", that is, annoyance over and above that caused by their contribution to the overall noise exposure. Again it appears that even a few noisy vehicles which will produce only a small increase in overall noise level, will cause annoyance in excess of that predicted by the increase in level.

CHANGES IN VEHICLE POPULATION

Another way of approaching the noisy vehicle versus bulk flow issue is to consider how changes in the vehicle population affect traffic noise levels and the resultant annoyance. Table 3 lists the predicted exposure levels and the estimated community annoyance along three typical roadways for various vehicle populations. It can be seen that large changes are needed in the percentage of noisy vehicles (%NV) to achieve significant improvements in overall exposure and thereby to reduce community reaction. Feasible reductions of, say, 20 to 10 (%NV) on a primary arterial road and of 10 to 5 (%NV) on a secondary arterial road would result in only a few decibels reduction in exposure level, and about 2% in the percentage of the community highly annoyed. Even if it were possible to eliminate all noisy vehicles (0 %NV), the noise level experienced as a result of the bulk flow of traffic on arterial roads is still likely to exceed 68 dBA (L_{10} 18 hr).

Reductions in Emission Levels

The effect of reductions in noise emission levels for different vehicle categories has been studied using computer modelling procedures. In one such study, Nelson and Fanstone [26] examined the effects of three quietening conditions: (1) trucks quietened by 10 dBA, (2) cars quietened by 5 dBA, (3) both

	NO CHANGE		TRUCKS (- 10 dBA)		CARS (- 5 dBA)		TRUCKS (- 10 dBA) CARS (- 5 dBA)	
	L_{10}	% HA	ΔL_{10}	Δ % HA	ΔL_{10}	Δ % HA	ΔL_{10}	Δ % HA
PRIMARY ARTERIAL (2000/HR 20% HV)	80.2	38.6	- 4.2	- 5.0	- 0.5	- 0.6	- 7.8	- 9.2
SECONDARY ARTERIAL (1000/HR 10% HV)	76.3	34.1	- 1.6	- 2.0	- 3.2	- 3.9	- 6.1	- 7.4
LOCAL CROSSING (400/hr 5% HV)	72.7	29.7	- 0.7	- 0.8	- 4.5	- 5.3	- 5.4	- 6.4

TABLE 4
Effect on exposure level (dBA L_{10} 18 hr) and community reaction (% highly annoyed) of reductions in vehicle noise emissions

trucks and cars quietened by these amounts. The results for three typical road situations with estimates of the resultant changes in community reaction are summarised in Table 4. The reduction in truck emission levels will achieve significant benefits only on primary arterial roads, whereas the reduction in cars will be of most benefit on low volume roads. It is only by reducing the levels from both vehicle categories that worthwhile reductions in exposure and annoyance can be achieved in all cases. Clearly, it is important to reduce the levels of trucks and other noisy vehicles but, because cars constitute the bulk of the traffic stream, overall noise levels cannot be reduced unless car emission levels are lowered.

A recent modelling study by Stewart and Rogers [27] compared a number of scenarios for reductions in vehicle noise emissions. One scenario believed to be feasible in Australia entails phasing in reductions of 6 dBA for cars and 9 dBA for trucks over the next 15 years. This would result in the overall traffic noise levels in the year 2010 being 7 dBA lower than if no further reductions were introduced. Using the BSM function this would mean that the proportion of the community seriously affected by traffic noise would be lower by 8.4 percentage points.

This study also examined the effect of eliminating all vehicles which are individually noisy because of exhaust system tampering. Assuming such noisy vehicles constitute 10% of the population, it was found that reducing this percentage to zero lowers the overall level of traffic noise by an insignificant 0.5 dBA. Because the model conservatively assumes tampered vehicles to be only 3 dBA noisier than normal, this predicted reduction in overall noise may be an underestimate. Also, the analysis does not take account of the "excess annoyance" caused by noisy vehicles. The benefits of eliminating them are greater than suggested by their contribution to overall traffic noise levels. Nevertheless, the study does indicate that noise reductions across the whole vehicle population not just in noisy vehicles, are required to appreciably reduce traffic noise in general.

REVIEW OF EVIDENCE

It emerges, then, that it is not a question of whether noisy vehicles *or* bulk flow traffic noise is the primary cause of community annoyance. The evidence from several quite different sources establishes that *both* factors are important, and that they are virtually independent determinants of traffic noise annoyance.

Individually noisy vehicles have been shown to cause annoyance in excess of that accounted for by their contribution to the overall noise level. Also, compared with bulk flow noise, noisy vehicles are more likely to cause sleep disturbance by exceeding the threshold of awakening and by giving the traffic pattern an intermittent character.

Evidence from several sources indicates that community annoyance increases with the *bulk flow traffic noise* even if there are no vehicles which are individually noisy. Also, because the overall traffic noise level predominantly consists of background or bulk flow noise, significant reductions in traffic noise annoyance will depend on reducing the average levels of the whole vehicle population and not just of noisy vehicles.

IMPLICATIONS AND CONCLUSIONS

An implication of the finding that the noisy vehicle index (Log %HV) is independent of overall noise exposure in predicting traffic noise reaction, is that the indices most commonly used in practical noise assessment (viz. L_{eq} and L_{10} 18 hr) fail to take account of a primary determinant of community annoyance. There is a strong case to be made for using an extended index which includes a term based on the number of heavy, that is, noisy vehicles. This suggestion was made by Yeowart [28] who found that the correlation between an exposure index and community reaction could be improved by extending it to include the number of heavy vehicles between midnight and 0600 (NHV). Thus, the dose/response correlation for L_{eq} was improved when the exposure index took the form:

$$L_{eq} + .11 \times (\text{NHV})$$

Brown [11] also found that the prediction of annoyance was improved by using an exposure index comprising both an overall noise term (L_{10} 18 hr) and a noisy vehicle term (Log NHV). However, the multiple regression equation was 12 log (NHV) − L_{10} 18 hr, and the interpretation of the negative term is unclear. Thus, further research is required to resolve the question of whether an extended index should be used to assess traffic noise exposure in Australia.

The finding that noisy vehicles and bulk flow noise jointly operate as independent determinants of annoyance has implications for noise control. It demonstrates that the traffic noise problem needs to be attacked on two fronts:

- further noise emission reductions on new vehicles
- increased enforcement against individually noisy vehicles.

The traffic noise problem will continue to grow worse as the volume of traffic on the roads increases. Also it is likely that community tolerance is likely to decrease, further exacerbating the problem. It has been shown that if no further controls are introduced on new vehicle emissions, the overall level of traffic noise in Australia will steadily increase in the future [27].

This trend cannot be stopped, much less be reversed, unless there are noise emission reductions not only on noisy vehicles (trucks, buses, motorcycles), but also on cars which are not individually noisy.

Also, because of the excess annoyance caused by individually noisy vehicles and their detrimental effect on sleep, the traffic noise problem cannot be abated solely by improved emission controls on new vehicles. Enforcement of noise emission standards is essential to prevent the disturbance caused by in-service vehicles with modified or deteriorated exhaust systems.

Finally, it must be noted that even with the best possible controls on both new and in-service vehicles, there would still be an extensive traffic noise problem in Australia. An effective noise abatement strategy would require construction of noise barriers and acoustic treatment of houses along major urban roads. While such a strategy would be costly, it may soon become necessary to satisfy the community's demand for adequate protection against traffic noise disturbance.

NOTE

The views expressed in this paper are those of the author and do not necessarily represent those of the Environment Protection Authority. The author acknowledges Geza Benke's assistance with the calculations reported.

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NOISE CONTROL - A Local Government Perspective

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Summary of a paper presented at a seminar on COMMUNITY RESPONSE TO NOISE organised by the Victoria Division, July 1984.

A full account of this paper will be published in the next issue.

ABSTRACT

Noise has been a source of irritation between neighbours for as long as there have been people to make it. English law has provided remedies for settling disputes which have their origin in common law. Municipal councils in Victoria have been involved in complaint resolution since their early days because of their statutory responsibility to their local council to resolve neighbourhood complaints.

Bylaws made under the Local Government Act, the Health Act, the Environment Protection Act and Common Law provide remedies in case of noise nuisance. All operate on the basis of a courts definition of what is a 'nuisance' or 'objectionable' or 'unreasonable' except sections of the Environment Protection Act which attempts to set 'thresholds' below which a noise is not a problem.

The inspecting officer can have a large bearing on the outcome of noise complaints and at municipal level he is the most important element in noise control. Complainants do not like attending at court.

Australian Acoustical Society Annual Conference 1985

"Motor Vehicle and Road Traffic Noise"

The Australian Acoustical Society Annual Conference will be held in Leura, in the Blue Mountains, west of Sydney, from 24th to 26th November, 1985. Both invited and contributed papers will be presented. Workshops, plenary sessions and a technical visit are proposed. A call for papers will be circulated in February, 1985.

For further information please contact Anita Lawrence, Graduate School of the Built Environment, University of N.S.W., P.O. Box 1, Kensington, N.S.W. 2033 (02) 697 4850, or Leigh Kenna, National Acoustics Laboratory, 5 Hickson Road, Millers Point, N.S.W. 2000 (02) 20537.

The Conference has been timed back-to-back with WESTPAC II in Hong Kong which will be particularly beneficial for interstate delegates. The Group Development Division of World Travel Headquarters is making all domestic and international air travel arrangements, as well as arranging accommodation in Hong Kong for Australian Acoustical Society members and friends. Travel discounts will be available for a group departure from Sydney on Wednesday, 27th November, 1985.

For information regarding these arrangements please contact the Group Development Division, World Travel Headquarters, 33-35 Bligh Street, Sydney, N.S.W. 2000 (02) 237 0300 as early as possible.

● M.Sc. (Acoustics) 1985/6 Course

University of New South Wales

This course provides for graduate study and research in several important areas of acoustics, such as community noise control, noise control in industry and in buildings, auditorium design and physical acoustics. It is designed primarily for graduates in engineering, architecture, science or building who wish to specialise in acoustics and it is suitable for those who wish to find employment with noise control authorities, or in industry, to practice as consultants, to undertake research or to become part of a multi-disciplinary team in an architectural or engineering practice.

ADMISSION REQUIREMENTS

An applicant for registration for the degree course of Master of Science (Acoustics) shall have been admitted to the degree of Bachelor of Science (Architecture) or Bachelor of Science (Design Studies) at Honours level, Bachelor of Architecture, Bachelor of Building, Bachelor of Science at Honours level, or Bachelor of Engineering at the University of New South Wales, or an equivalent degree from another university or tertiary institution. In exceptional cases an applicant may be registered as a candidate for the degree if he submits evidence of such academic and professional attainment as may be approved by the Higher Degree Committee of the Faculty of Architecture.

FURTHER ENQUIRIES

Further enquiries regarding the course should be addressed to the Head, Graduate School of the Built Environment, The University of New South Wales, P.O. Box 1, Kensington, N.S.W., Australia 2033.

APPLICATIONS

Application forms for registration for the Master of Science (Acoustics) degree are available from

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Future Trends in Environmental and Building Acoustics Measurements

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ABSTRACT: Future trends in environmental and building acoustics measurements are assessed in the light of recent developments in electronics and instrumentation. It is suggested that many of today's noise units were adopted more than twenty years ago only because they could be easily measured using the technology of that time. Given the more powerful signal processing techniques available today it is possible that existing units may be re-appraised in the very near future. Given that the environmental or building acoustician is interested in measurements which correlate with human subjective response and given that human subjective response does not obey well defined laws today's technology is probably adequate for all conceivable measurements in these fields. As existing technology becomes cheaper to apply to instrumentation so instruments will be manufactured capable of performing more and more functions. Sound intensity measurements will be more widely employed in acoustics work but will not supplant sound pressure measurements. The inherent capability for self calibration possessed by microprocessor controlled instruments may make feasible the use of transducers less accurate (but less vulnerable) than condenser microphones.

1. INTRODUCTION

A comparison of two catalogues published by a major manufacturer of acoustic equipment, one produced twenty years ago and one brand new, provides a dramatic illustration of the developments in acoustic instrumentation over this period. Twenty years ago this manufacturer offered a choice of two sound level meters whilst today you can select from a list of ten.

Some of the present-day offerings do little, if anything, more than their predecessors of twenty years ago but they are appreciably lighter in weight and consume less power. The display dynamic range is usually greater than before and a DC logarithmic output is often provided suitable for driving conventional chart recorders.

The more expensive of today's sound level meters offer features which would have been undreamt of twenty years ago. Digital output, digital display, the ability to measure relatively complex noise units such as L_{eq} or SEL are now some of the options available with small hand-held instruments.

A comparison of the laboratory equipment now on offer with that available twenty years ago leads to the same conclusion. Today there is a greater choice of equipment and any particular item of equipment can do far more than its obsolete equivalent.

It is against this background that one has to try to assess future trends in environmental and building acoustic measurement. Two factors relevant to this objective can be deduced from a comparison of the old-style equipment and the new. The vast majority of instruments on sale today are either all digital (apart from the unavoidable analogue input circuitry) or hybrids. The latter usually feature analogue frequency selective networks and logarithmic convertors plus a digital display on the output side.

The second factor is the renewed interest in the direct measurement of sound intensity after decades in which noise fields have been characterised in terms of sound pressure level.

In the course of this article we will be attempting to assess how developments in these areas will affect building and environmental acoustic measurements. Firstly, however, we will briefly look at the history of the topic.

2. REVIEW

The practical measurement of sound levels (as opposed to laboratory techniques such as the Rayleigh disc or particle amplitude methods) had to await the development of suitable microphones and electronic amplification systems. At the outset it was recognised that a microphone would only respond either to the sound pressure or particle velocity and that this quantity would only be simply related to the more satisfying (to the physicist) parameter of sound intensity for the case of acoustic plane waves.

A number of different types of microphones were employed by the earliest workers in the field of noise measurement. Eventually, however, the condenser microphone became the first choice for this work. The positive attributes of this type of microphone — large dynamic range, linear frequency response and stability — outweighted its definite disadvantages such as lack of ruggedness and its unsuitability for use in humid environments.

Electronic circuits were rapidly developed which enabled the electrical signal from the microphone to be amplified, filtered into different frequency bands, "root mean squared" and used to drive a moving coil meter. Thus all the features necessary for a simple sound level measuring system were available at a very early stage in the development of practical acoustics.

In parallel with the development of sound measuring systems a number of investigators undertook work to assess the manner in which people respond to sound. The entire history of environmental acoustic measurement consists, in fact, of a series of attempts to devise objective units which correlate with the subjective response of human beings.

The first subjective attribute of a sound field to be investigated was loudness. Fletcher and Munson [1] in the United States and Churcher and King [2] in the United Kingdom demonstrated the complexity of the relationship between the human perception of loudness and the objective parameters of frequency and sound pressure level for pure tones. From this work a unit of loudness level, the phon, and a unit of loudness, the sone, were developed.

The objective of this work was meant to be the eventual development of a loudness or "phon" meter. The nature of human response, however, was so complex that this idea was rapidly abandoned in favour of simple weighting networks. Originally three weighting networks were proposed (the "A", "B" and "C" weighting networks). The intention was that the "A" network be employed for low noise levels, the "B" network be employed for medium noise levels and the "C" network be employed for high noise levels.

In practice this proved too complicated and the acoustics world very rapidly adopted the "A" weighting network for use for all noise levels.

The "A", "B" and "C" networks were based upon equal loudness contours obtained from a series of experiments in which people were asked to compare the subjective loudness of two pure tones. A similar set of experiments were conducted by Kryter to establish a set of equal noisiness contours [3]. In these experiments the subjects had to make an assessment of the relative annoyance of two sounds. The net result was a further weighting network, the "D" weighting, which is employed for aircraft noise measurement.

It should be stressed that the resulting noise units, the dB(A) and PNdB, have gained general acceptance not because they give the best possible correlation with subjective assessments of sound fields but because it was relatively easy to manufacture instruments to measure them. Zwicker [4] and Stevens [5] both developed techniques many years ago for calculating the subjective loudness of a broadband noise from its third octave or octave band spectrum. (Details of these methods are given in ISO R532.) While techniques such as these should, in theory, produce numbers which correlate better with subjective judgements they have not been taken up as at that time it proved impossible to manufacture instruments which would directly measure "Stevens Phons" or "Zwicker Phons".

Hewlett Packard did, in the late sixties, produce a "loudness analyser" which automatically produced Zwicker type plots from which the loudness of a noise could be estimated by the operator but it was hardly portable and never caught on.

Over the years further attempts have been made to devise noise units which correlate well with subjective response for noise from many different sources or which correlate well with the subjective benefit resulting from acoustic treatment. Thus the L_{10} level and the equivalent continuous noise level, L_{eq} (both weighted), have been used to measure traffic noise. Noise rating curves are used to define the degree of intrusion due to background noise in theatres and concert halls. The concept of Sound Transmission Class (STC) has been evolved as a means of specifying the sound insulation of a partition.

Some of these units, most notably the equivalent continuous noise level, are relatively easy to measure and hence have been incorporated into the specification of some sound level meters. Others, such as the Sound Transmission Class or Noise Rating, which require a certain amount of processing of octave or third octave data cannot be so easily automated. A considerable amount of effort has in fact gone into trying to produce alternatives which could be handled by simple instruments. Many people have tried to develop a technique by which the sound insulation of a partition could be specified in terms of the difference in "A" weighted sound pressure level between the source side and receiving side. Webster's proposed SI weighting for the assessment of speech interference is essentially a simplification of the Noise Rating procedure [6].

The processing of octave band or third octave band data to obtain such parameters as NR values or STC values has been considerably eased in recent years by the widespread move to the use of digital techniques by instrument manufacturers. A significant development has been the adoption of the IEEE 488/IEC 625-1 interface bus. This has considerably reduced the difficulty involved in interfacing acoustic instrumentation with micro-computers. Measured data can now be read in from the instrument by the computer, corrected if necessary, processed in accordance with the relevant procedure and an answer delivered in seconds.

The potential advantages of bus systems are even greater. It is possible for a whole range of equipment to be controlled by the micro-computer. Many standard acoustic measurement procedures e.g. sound insulation tests, can be fully automated using this system. This enables fairly difficult procedures to be handled by low level staff who have to do little more than load the computer with the appropriate software.

Despite the tremendous advances made in instrumentation in recent years, however, environmental and building acoustics measurements do not differ so very much from those being made ten or even twenty years ago. Sound pressure level is still the parameter measured. The dB(A) and the PNdB are still the broad band noise units. Where dB(A) or PNdB values are not deemed adequate octave or third octave analysis followed by some form of processing of the data is still necessary.

The main changes are in the quality of the instruments. They now have a much better performance specification and they are much lighter. The latter is a welcome trend after decades in which acousticians have been readily identifiable by their long arms and short tempers.

3. FUTURE DEVELOPMENTS

The most significant factor affecting future trends in environmental acoustics measurements is the use of digital technology.

Digital signal processing techniques which might find application in acoustic measuring systems are already established. In environmental acoustics one is interested in the audio frequency range from 20–20,000 Hz and the first requirement is an analogue to digital converter capable of sampling at about 40 kHz and having a resolution of at least 12 bits [7]. A few years ago such a device would have been extremely expensive but today they are common and relatively cheap. Analogue to digital converters having a faster sampling rate may become more readily available but, given the building and environmental acousticians' pre-occupation with relating measurements to human response, are not really necessary for future developments in this area.

Similarly signal processing equipment capable of handling frequencies across the audio range has been available for many years. One might expect the drastic cost reductions which have been a characteristic of the electronics revolution to continue over the years but probably not the development of radically new techniques as there is no need for them.

Since all measurements in this field should, ideally, relate to human perception and since this can never be precisely quantified it is unnecessary to strive to measure to an excessive degree of accuracy. The future will probably see the application of today's technology in a number of different ways.

Amongst the possible consequences resulting from the digital revolution are the end of the reign of the condenser microphone, the widespread use of sound intensity measurements, the development of new improved noise units and a move away from dedicated instruments towards simple to operate multi-function instruments.

3.1 Transducers

The disadvantages of the condenser microphone are well-known to all acousticians. They include high cost, lack of robustness, the necessity for a polarisation voltage and their unsuitability for use in hostile environments. The electret microphone has been suggested as a possible alternative but it is not without its own problems. Doubts have been expressed regarding its long-term stability. High levels of humidity, whilst not causing the same problems as with the condenser microphone, do affect electrets and this effect is frequency-dependent.

A frequency-dependent drift in sensitivity does not present an insurmountable obstacle to the use of electret microphones for general acoustic measurement. All that is required is a means of monitoring this drift in sensitivity and the application of a correction to any measured values.

If the advantages of electret microphones make them an attractive proposition then it is not too fanciful to think in terms of a future generation of instruments with an inbuilt calibration system. In effect a microprocessor would be programmed to perform a calibration check on a microphone (or number of microphones) prior to measurements being made and to store correction terms which could be added to those measurements.

There are precedents for this approach. Some modern digital voltmeters are "self calibrated" in this way and Hewlett Packard, some years ago, produced a range of condenser microphones which incorporated their own in-built electrostatic actuator.

3.2 Sound Intensity Measurements

One of the most exciting trends in the field of acoustic measurements in the last few years has been the move towards sound intensity measurements. So important is this field today that one recent edition of Noise Control Engineering Journal was given completely over to it [8].

The conventional condenser microphone responds to sound pressure. A sound intensity transducer ideally needs to respond to both the sound pressure and particle velocity at a point. This can be seen from an examination of the basic equation:

$$\bar{I} = (1/T) \int_0^T p\bar{u}\, dt$$

where p is the sound pressure,
u is the particle velocity,
I is the time average sound intensity, and
T is a sufficiently long averaging time.

In the case of a pure tone it is sufficient to average over one cycle. For a stochastic random signal it would theoretically be necessary for T to approach infinity. In practice some more reasonable value is employed which depends upon the judgement of the operator.

Although many attempts have been made in the past (and are still being made today) to devise an intensity measuring transducer system which can determine sound pressure and particle velocity directly the most successful approach to date has been to employ the two pressure microphone technique.

In this technique use is made of the following relationship:

$$u = (-1/\varrho_0) \int (\partial p/\partial x)\, dt$$

where ϱ_0 is the density of air.

In the two microphone technique the pressure gradient, $(\partial p/\partial x)$, is approximated as the differences in pressure recorded by the two microphones divided by their separation distance (see Figure 1).

This finite difference approximation introduces unavoidable errors in sound intensity measurements. The magnitude of the error depends upon the microphone separation, the frequency of sound, the radiating characteristics of the source, etc, and a considerable amount of work has been done to try to quantify this uncertainty [9]. In order to minimise the uncertainty, commercially available sound intensity measuring systems

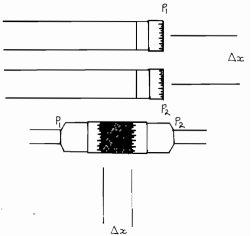

Figure 1: Finite difference approximation

$$\frac{\partial p}{\partial x} = \frac{p_1 - p_2}{\Delta x}$$

specify a number of different microphone spacings for measurements over different frequency ranges.

Sound intensity measurement is still an area of research and although one of the recent papers which was instrumental in sparking off a revival of interest in this field described an analogue system [10] the subject has only now taken off because of the digital revolution in instrumentation. Two methods are generally employed; the first utilises commercially available dual channel digital Fast Fourier Transform processors which can be programmed. Fahy and Chung [11] [12] have shown how sound intensity can be calculated from the cross spectral density of the two microphone signals. The second method involves the use of a dedicated system containing all amplifiers and processors and employing direct digital filters instead of the FFT method.

Before sound intensity measurements can take their place alongside sound pressure measurements it will be necessary for appropriate standards to be agreed. Sound intensity measurements will always be more complicated than sound pressure measurements. Since, for many applications, sound pressure measurements are adequate, it is unlikely that sound intensity measurements will ever completely supersede sound pressure measurements.

Sound intensity measurements will be employed when they offer definite advantages over sound pressure measurements. In the field of building and environmental acoustics these relate to the instruments' obvious suitability for the measurement of sound power. The sound power of a source is given by:

$$W = \int_S I_n\, dS$$

where the integral is over a closed surface, S, enclosing the source and I_n is the component of the intensity vector normal to the surface. It should be noted that this expression gives the net power radiated through the surface so that the volume enclosed by the surface should contain no sound absorbers.

Sound intensity measuring systems can also be used to measure the sound power radiated by each element of a complex partition [13] or complex machine [14]. In principle sound intensity measuring systems could also be employed to determine the relative contribution of different flanking paths in building to the total noise level in a room. They have successfully been employed to map the power flow in sound fields and to locate noise sources.

A number of developments are to be expected in this area as the technique gains more widespread acceptance. Firstly the hardware will be housed in more compact units. The B&K type 3360 system, for example, was obviously derived from their type 2131 Digital Frequency Analyser and as a result is not as compact as it might be. Now that this unit has proved itself one can surely expect an improved re-packaged version in the near future.

One might also now expect some attention to be given to a re-design of the probe system. Currently available sound intensity probes make use of conventional condenser microphones complete with pre-amplifiers (see Figure 2). As a result they are somewhat clumsy and whilst this is acceptable for use in a research laboratory it reduces the attractiveness of the method for more mundane uses. A move towards the use of electret microphones might also result in the design of more satisfactory probes.

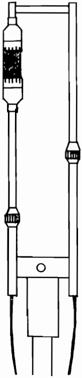

Figure 2: Intensity probe

3.3 Measurement of Complex Noise Units

All but the most simple sound pressure measuring devices now incorporate digital circuitry. Rapid developments in the world of digital electronics mean that there are now available low cost integrated circuits capable of performing many acoustic functions (e.g. digital filters). The incorporation of such circuits (and others yet to be developed) could enable even small portable instruments to perform functions undreamt of even a few years ago.

Mention has already been made of the work of Zwicker and Stevens on developing methods for calculating the loudness of broadband noise. This work has had little impact on the field of environmental noise measurement because the procedures are too complex for general field use. The "A" weighted decibel has become the accepted noise unit merely because devices capable of measuring the "A" weighted sound pressure level could be easily manufactured.

Given the advanced capabilities of modern digital integrated circuits it would now be possible to produce a meter which could read the loudness of a sound in either Zwicker phons or Stevens phons. One possible development in environmental acoustic measurements may therefore be a re-appraisal of the ubiquitous "A" weighted decibel. It may well be that the advantage to be gained from the development of a new unit are so slight that they do not justify its superseding the "A" weighted decibel. Nevertheless it is more than likely that the work of Zwicker and Stevens will be re-examined and perhaps taken further (at least for a while).

If an instrument capable of measuring units as complex as Zwicker phons can be manufactured it would be a relatively simple matter to produce a sound level meter to measure NR or NC values directly.

Programmable sound level meters will no doubt also be produced by all manufacturers permitting such things as the statistical analysis of time varying noise levels.

3.4 Undedicated Instruments

A consequence of the electronics revolution is that today's laboratory instruments can today perform many more functions than their predecessors of only a few years ago. The latest generation of twin channel FFT analysers, for example, can do so many things that there is a real danger of operator confusion. Another trend has been to incorporate all the units necessary for conducting related routine tests into one "box". For example there are now a number of building acoustics analysing systems available.

Most new instruments are essentially dedicated digital computers plus certain items of input/output hardware (e.g. analogue to digital converters, digital to analogue converters, voltage controlled oscillators, etc). Much of the hardware will be common to a number of different instruments each intended for very different applications. The differences will normally be in the built-in software and the arrangement, labelling and function of the front panel controls. With some of the presently available multi-purpose units the front panel controls can have a number of different functions and this is where operator confusion can arise. As instruments become more versatile with manufacturers offering even more functions for less cost so instruments may become more difficult to use.

An alternative approach which might find favour would be to separate the hardware from the software completely. The customer would buy a "box" containing the essential hardware and could then select from a range of available software in the form of plug-in ROM packs, bubble memories, etc, which would convert the "box" into a third octave analyser, sound intensity measuring system, twin channel analyser or whatever is desired. Problems associated with multi-function knobs and switches could be avoided by the adoption of "touch screen" technology.

4. CONCLUSIONS

Present-day environmental and building acoustic measurement techniques have evolved as a result of a compromise between the desire to obtain the best objective units possible and the limitations of instrument technology. Many of these limitations can now be overcome and future developments may see the development of new units which will replace those in current use. Acoustic intensity measurements will take their place alongside (but will not necessarily supplement) sound pressure level measurements. The ability to compensate automatically for the effects of transducers less linear than today's conventional condenser microphones may result in the general use of a different type of microphone.

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Loudspeakers, Vol. 2

New Hearing Conservation Regulations in W.A.

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The Noise Abatement (Hearing Conservation in Workplaces) Regulations 1983 came into force in Western Australia on 21 October 1984. The Regulations are the most comprehensive yet promulgated in Australia, and where a noise hazard exists they specify various requirements which must be met by the employer. The primary thrust of the Regulations is the elimination of noise hazards by engineering methods wherever and whenever this is practicable. The key requirements of the Regulations are as follows:

- arrange for noise surveys to identify areas where noise hazards exist.
- take all practicable steps to eliminate or reduce noise hazards.
- provide all workers exposed to noise hazards with suitable hearing protection and education, and ensure they participate in a programme of audiometry as specified in the Regulations.

The Regulations require that wherever there is a noise hazard the employer must appoint a Hearing Conservation Co-ordinator. The employer will also need the services of a noise officer, an audiometric officer and an approved medical practitioner, all of whom must have been approved by the Commissioner of Public Health. For instance, when a significant hearing loss has been found by the audiometric officer, the case is to be referred to the approved medical practitioner. He in turn expresses a medical opinion on whether the hearing loss resulted from occupational noise, and conveys this opinion to the worker concerned, the employer and the audiometric officer. The occupier is then under an obligation to take all practicable steps to eliminate the circumstances which gave rise to the hearing loss, and to again measure the individual's hearing within 12 months of the last test.

From the example above, it is evident that the Regulations contain many detailed provisions which are intended to ensure that hearing conservation occurs in all workplaces through, in the first instance, a process of self-regulation. Nevertheless if breaches do occur, substantial penalties exist under the Noise Abatement Act 1972-1984. By giving primacy to the elimination of noise hazards, it is intended that engineering noise control will become the predominant pathway to the protection of hearing at work. A list of approved measuring equipment and calibration laboratories has been issued by the Health Department.

Standards for Accuracy of Measurement in Environmental Acoustics

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ABSTRACT: Measurements of quantities characterising, or influencing, the outdoor or indoor acoustical environment generally achieve rather low accuracy, by comparison with measurements in other physical disciplines. This is evidenced by the large variation between the results of independent measuring organisations, when the opportunity arises to compare their measurements on essentially the same measurement subject. Standard specifications for measurement methods can limit the inter-organisation variation; this can be characterised by the standard deviation of reproduction, s_R.

This paper reviews three types of error, which the authors of standards should attempt to control: bias error, peculiar to each measuring organisation; random error, due mainly to temporal and spatial variability of the environmental sound field itself; and methodological error of the chosen method — a form of bias error imposed on every user organisation, probably not increasing s_R, but possibly making all the answers wrong.

Three main goals for a measurement standard are recommended: all users should get the same answer, within acceptable tolerances; this answer should be close to the "true" value; and the cost of the method should be moderate. Several existing Australian Standards for measurement methods in environmental acoustics are compared, with respect to how effectively they have tackled the first of these tasks. Only a few contain a statement of the value of s_R believed to apply.

Keywords: Standards, Acoustic, Environment, Measuring, Accuracy, Precision.

1. INTRODUCTION

Once there was a kind King who decided to improve his capital city in various ways. One proposal involved a three-fold increase in the road traffic passing by the domed palace of the Grand Wizard himself. The Wizard asked the King to promise that by cunning (but costly) design of the new road-works, the resulting noise intensity at his palace would not exceed the existing value. This was measured by the Wizard's noise-doctors to be 1 nhp/ell². The kind King agreed to include a no-increase clause in the works order, provided it be referenced to *his* noise-doctors' measurement of the existing intensity, namely 4 nhp/ell².

This unacceptable discrepancy was jointly investigated by the two groups of noise-doctors, but could not be resolved. Each party maintained that the other was (inexplicably) wrong. Finally they agreed to measure again simultaneously, with their instruments literally side by side. This time the results were Wizard 1, and King 0.6 nhp/ell². A datum figure of 0.8 was finally agreed to. For a long time thereafter the King was rather wary of noise-doctors, and privately resolved not to allow second opinions to be sought from them on any of his projects again!

The reader is probably confident that since the advent of the Standards Association of Australia, National Association of Testing Authorities, and silicon chips, large discrepancies in measurements in environmental acoustics like the ones in the above fairy tale are a thing of the past. Not so; similar events have actually occurred in recent years, involving leading firms of "noise-doctors" in Australia. Gross inaccuracies of measurement, with no discovered cause, will no doubt continue to occur every now and again, with no regard for the high repute of their victims or the cost of the consequences.

The aim of this paper is to consider what is being done, by way of measurement standards, to influence the accuracy achieved in environmental acoustics measurements. As a preliminary, some types of inaccuracy will be reviewed.

2. ACCURACY, PRECISION, AND "BONA FIDELITY"

In ordinary English usage the words "accuracy" and "precision" are practically synonymous. For the present purposes "accuracy" retains its usual meaning, "closeness to the truth", but "precision" will be given a narrower meaning, as explained in Section 2.2

An accurate measurement is one that deviates by only a small error from the "true" value. Three types of error, hence inaccuracy, can be recognised.

2.1 Systematic, or Bias Error

A particular measuring system consists of the operator, the instruments, the interpretation of a prescribed procedure, the measuring environment, the data processing program, etc. One or more of these elements may have certain peculiarities such that, no matter how often a measurement be repeated, the average of the results will tend to be biased to one side or the other of the "true" value. If one or more of the elements of the measuring system be replaced by nominally similar elements, the mean measured value may be observed to shift significantly. If so, it may be concluded that the two sub-systems concerned have bias errors which differ by the observed shift. The *existence* of bias error(s) *may* thus be detected by comparison of results from partially or totally different systems. The *actual size* and *sign* of bias errors can only be so determined if one of the two systems inter-compared is arbitrarily deemed to have zero (or other known) bias error; this is the well-known process of *calibration*. In complex acoustical measuring systems, the *causes* of observed bias errors are often quite tedious to discover and they are sometimes intermittent. For example, the system engaged by the King in the fairy tale seems likely to have been afflicted by such an unstable "gremlin".

For all but the simplest of the many types of measurement made in environmental acoustics, there is no reference system that is widely recognised as outstandingly accurate and against which all other systems could be calibrated. Instead, the only acceptable definition of "true value", for some measurements, is the mean of the values obtained when a large number of independent measuring systems, conforming to the same nominal description, are used to measure a quantity under identical conditions. For laboratory measurements of some of the properties of materials and machines that influence the acoustical environment, the necessary "Round Robin" inter-comparison surveys have already been conducted in some nations. However, intercomparisons of different measuring systems being applied to the measurement of environmental descriptors in the field (e.g. Noise Rating, Noise Dose, etc) have rarely been reported.

2.2 Random Error

When a measurement is repeated m times using an unchanged measuring system, although any bias error remains undetected, the spread of the individual results around their mean value is readily apparent to the operator. The standard deviation observed is a measure of the uncertainty of being able to repeat any one such measurement.

Often a measurement result is already, by requirement, the mean of k sub-measurements made to a specified procedure. The standard deviation of the k-averaged result is $k^{-1/2}$ times that of the k individual sub-measurements, provided the latter were obtained statistically independently. This will be discussed further in section 3.2.

The term "precision" is here taken to mean: "smallness of uncertainty that the result quoted for a k-averaged measurement is close to the grand mean that would be obtained if the whole k-averaged measurement were repeated many times, using the same system".

In this way, operators can increase the precision of measurements coming from measuring systems, of which they themselves are part, by simply increasing k, though in practice the square-root law imposes diminishing returns for effort expended, and there may be limitations in finding enough statistically different ways of doing the repetitions.

In environmental acoustics the largest manifestations of random variation between successive sub-measurements tend to arise from the random nature of the generation of the sound field rather than from any random variations of sensitivity or internal noise of the measuring system itself. As regards field measurements, for example, the noise from a passing stream of different vehicles, or from a number of miscellaneous machines on a factory floor, is inherently variable in level and spectrum over both space and time. Similarly, in those laboratory measurements of environment-modifying properties of materials where *random* noise is actually specified as the test sound, the need for an appropriate duration of time-averaging (analogous to increasing k), to achieve a desired degree of precision, is obvious.

To achieve an accurate measurement, it is necessary to reduce both the bias error of the whole system (by suitably precise calibration) and the random error (by suitable expenditure of averaging effort during the measurement concerned, to increase its precision). A measurement can be precise but still inaccurate, as the King discovered.

2.3 Inherent Methodological Errors

The purpose of all objective measurements of given acoustical environments (or modifiers thereof) is ultimately to enable prediction of the perception of, or reaction to, the environment concerned by a suitable representative of the human population, e.g. the mean, modal, or x-percentile person. Inaccuracy of the measurement process itself is not the only possible cause of discrepancy between the predicted and the observed reaction of said "person".

The quantity measured may itself not be a "bona fide" one. For example, due to theoretical difficulties being glossed over by approximations in a standard indirect method of measurement, the quantity is really something else, masquerading under the respectable, simple title ascribed to it. Laboratory measurements of two important environment modifiers, viz. the random-incidence sound-energy absorption coefficient, α_s, and the sound transmission loss, STL, of building materials, provide specific examples of such infidelity.

This is a type of systematic error that will tend to be similar for all measuring systems conforming to the relevant standard method, and can therefore only be detected by comparison with another fundamentally different method. This remark applies also to the errors referred to in the next paragraph. However, for the α_s measurement referred to, it has been shown that unless all test rooms are identical, there will be inter-room variation in the magnitude of this infidelity, which appears as differences of individual system bias error, as already discussed in Section 2.1.

Erroneous theories, or unjustified approximations, may also be present in the mathematical formulae by which one or more quantities are manipulated, after measurement, in order to arrive at a final predictor claimed by the author of the formula to be better than any other previously devised for correlation with subjective human responses.

The human population — the measuring system against whose subjective judgements and ratings all the objectively derived predictors have ultimately to be calibrated — is itself notoriously imprecise. Hence the accuracy of an objective predictor tends to be judged by the parameters of the linear regression between it and the actual population response (determined by social survey in the field, or psycho-acoustical laboratory experiment), over a range of magnitudes of the environmental characteristic concerned.

The offset coefficient, the slope coefficient, and the correlation coefficient (or related standard error of regression) may all be taken into account in making such judgements. Indeed, new calculation formulae for new predictors have usually been adjusted before the author goes into print (by attention to one or more of the foregoing regression coefficients) to minimise discrepancy between predicted and observed response; i.e. the methodology is pre-calibrated against human response, in at least one sample situation.

Methodological errors of the two types mentioned above, i.e. those inherent in either the definition of the measured objective quantity itself or in the processes of (hopefully) moulding it into a better predictor after measurement, are without doubt of great importance. Much of the substance of published research in environmental acoustics in the last half-century has been concerned with their reduction.

This paper, though concerned mainly with the performance of the objective measurement process itself, was bound to include some mention of methodological errors as well as random errors, and bias errors peculiar to individual systems. It may have been perceived already that the three types are not always clearly distinguishable.

3. MEASUREMENT STANDARDS

In the last forty years, by-laws and regulations influencing the amenity of the indoor and outdoor acoustical environment, couched in objective quantitative terms, have become established in many nations. Obviously, as a pre-requisite for such quantitative legislation, some agreed standards are needed for the measurement of the quantities involved.

Even in the absence of national or state environmental laws, the marketing of goods and services has flourished for the purpose of modifying the acoustical environment. This has exerted the same pressures for standardisation of "weights and measures" as in other areas of commerce. Acoustical measurement standards, both national and international, have been created during this same period, usually lagging only a few years behind demand.

3.1 Goals for Measurement Standards

Some of the requirements that the authors of measurement standards should ideally take into consideration are discussed below.

3.1.1 Concurrence. The most fundamental and obvious requirement of a standardised measurement method is that all users (or at least, all those within a common sphere of interest) should get the *same* result, within reasonable tolerances, if they all measure the same test object or site. Two aspects of this simple statement may require further comment.

First, most national standards authorities prefer to adopt an internationally agreed form of measurement standard if available, rather than a locally drafted one, even when the sphere of common interest cannot immediately be seen to embrace the whole world for that particular acoustical measurement. Of course, when a nation is already involved in international trade in certain commodities, it is clearly preferable to adopt international standards for any required measurements of their acoustical properties; indeed, signatories of the General Agreement on Trade and Tariffs are enjoined so to do!

Second, the questions of what tolerances are reasonable, and how to achieve them, have always been the responsibility of standards committees to answer. However, until recent years the tolerances considered reasonable, if determined at all by such committees, have not been revealed explicitly in the standard as published.

Ideally, one might envisage a standards committee first writing a draft measurement standard, then testing it in a statistically controlled Round Robin survey among several measuring organisations in such a way that the overall inter-organisation variation could be resolved into its random and systematic components. For the latter component, it might even be possible by more elaborate design of the survey to identify separately the contributions to the variation due to particular elements of the systems, e.g. differences of instruments or differences of interpretation of wording of clauses in the standard.

With this information, it could be possible to judge which requirement clauses of the draft standard might most rewardingly be tightened in order to increase the reproducibility (i.e. reduce the standard deviation) between measuring organisations. Such improvement might be deemed necessary to attain some arbitrary goal for the maximum size of the standard deviation, of which more will be said in 3.1.3.

3.1.2 Costs. The effect on costs of the measurement due to changes in the tightness of the standard specifications can be judged at least approximately. One of the constraints on the authors is that the cost of the proposed standard method should be moderate, otherwise the standard will not be serving its purpose of facilitating and fostering the adoption of objective acoustical measures for law or commerce.

Tightening the specifications that tend to reduce systematic differences (and methodological errors) tends to increase capital costs for organisations setting up to do the measurements. Tightening the specifications that increase the precision achieved by each organisation tends to increase the costs of performing each measurement, due to increased person-hours, computer running-time, etc.

In private enterprise countries the performance of acoustical measurements for a fee is a well-established profession, on a nominally competitive basis. It is desirable for measurements standards to state explicitly *either* the minimum amount of averaging effort considered necessary (to achieve an unstated but implicitly defined goal of precision), *or* the minimum goal of precision itself, leaving each organisation to achieve this by its own preferred allocation of effort, provided only that each demonstrates such achievement.

Thus, when comparing quotations from competing measuring organisations for a measurement to the same standard, prospective clients can be assured of a reasonably consistent minimum quality of service being offered. It is even feasible for the same standard measurement method to include provision for its own application at more than one standardised level of precision, appropriate to different end uses of the results. To the author's knowledge, no such measurement method standard has ever been published, but the concept is not inconsistent with the established practice of providing several standardised grades of accuracy for measuring *instruments* such as sound-level meters, bandpass filters, or tape recorders.

3.1.3 Criteria for Maximum Acceptable Variability — Subjective Accuracy v. Objective Accuracy? While the matter of costs imposes a lower limit on how small a standard deviation between organisations a standards committee may achieve, there remains the question of what is a reasonable *upper* limit for the tolerances for concurrence.

In some cases, psycho-acoustic data may be available on the just-noticeable-differences (JNDs) for human subjects making magnitude judgements on the same (or a relatable) acoustical quantity. Such JNDs could provide the basis for criteria for maximum acceptable standard deviation for objective measurements, perhaps by attempting to match the two roughly.

In other cases, a measured quantity may, without further processing, be intended to serve as a predictor, or correlate, of human rating of the environment and, as already mentioned in 2.3, its performance in this regard might be judged by the linear regression with the human rating scale. The important objective measures L_{eq} (equivalent continuous sound level) and L_{10} (sound level exceeded for 10% of the observing time) are possible examples. A criterion for the acceptable between-organisation standard deviation of the objective measurement would be that it was negligible compared with its standard error of regression with subjective ratings.

As a matter of fact, the authors of measurement standards have never been known to reveal what criteria they had in mind for the maximum acceptable standard deviation between measuring organisations. In only a handful of recent cases have they even revealed what standard deviation they expect to occur.

3.1.4 Correctness. As well as ensuring that all users of a measurement standard will get the *same* answer (within reasonable tolerances), it is desirable to ensure that their mean is also the *"right"* answer. This sounds like a simple concept, but as pointed out in Section 2.3, it is not always a straightforward matter to obtain an independent estimate, of higher reliability, for the "right" or "true" value.

The mean result from a proposed standard method should be compared with results from other methods, if available, to detect the existence of infidelity and other methodological errors. If the other method(s) are demonstrably of great enough accuracy (though perhaps much higher cost) it may be possible to determine the size of the combined methodological errors of the proposed cheaper method and, by including a systematic correction in the proposed data-processing, reduce this to an insignificant level compared to the inter-organisational standard deviation.

For certain quantities in other more fundamental branches of metrology, the law of the land states arbitrarily that the "right answers" are those measured by the methods and the measuring systems, chosen and maintained for the time being for the purpose by the legally appointed national measurement standards organisation. For such quantities, the foregoing task is simple to organise. In acoustics however, in Australia, the only example is the maintenance by the National Measurement Laboratory of a set of standard microphones of accurately determined sensitivity in volt/Pascal, and a measuring system for redetermining their values. While these standard microphones may not explicitly have the unique legal standing implied above, they are accorded equivalent recognition throughout the land.

3.2 Methods of Expression of Uncertainty

Mention has been made of the use of the statistic *standard deviation* s, observed in a given sample of measurements, to quantify the uncertainty of the measurements. When applied to repetition of the same measurement m times by the same organisation, each time using its own peculiar version of the standard system specified, it might be designated the standard deviation of repetition and denoted s_r. When applied to n repetitions of the same measurement, each time by a different organisation using a potentially slightly different version of the standard system, it might be designated the standard deviation of reproduction, and denoted s_R.

Rather than conveying information on uncertainty of measurement by means of s_r or s_R alone, it is better to state also the size of the sample from which the value of s was determined, so the reader can get some idea of the likely reliability of the estimate of s. Two methods of expressing uncertainty, which are derived from both s and m (or n) with such a purpose in mind, will also be found in use in standards documents:

- The International Standard ISO 5725 is specifically intended to provide statistical guidance for authors of measurement standards, concerning accuracy and precision. In it the term Repeatability r is used for a quantity derived from s_r and m. It is defined as the difference between (just) two successive measurements by the same organisation, of the same object, which with 95% probability, would not be exceeded. It is evaluated as $r = 2^{1/2} t s_r$, where t is the factor derived from Student's t distribution, as appropriate to the 95% level of probability and the number of repetitions m from which s_r was estimated. Since the factor t is close to 2 for values of m above 6 or so, r is simply defined as $r \cong 2^{3/2} s_r$ in some other ISO documents.

An analogous quantity termed Reproducibility R is defined as $R = 2^{1/2} t s_R$, in connection with reproduction of the same measurement among n different organisations.

These two terms have not gained acceptance with acoustical standards committees in Australia, perhaps because they conflict with ordinary English usage, where a measurement said to be of "high repeatability" or "high reproducibility" would be expected to be associated with a small standard deviation, not a large one.

- In some Australian and U.S. standards the concept of 95% confidence interval is used in connection with repetition by one organisation and is defined as the interval, above and below the observed mean measurement, within which 95% of a very large number of repetitions would be expected to fall. It is defined as $t s_r$, where t has a similar meaning to above, appropriate to the interval both sides of the mean, 95% probability, and the number of repetitions m from which s_r was estimated.

Where the final measurement result is itself, by requirement, a mean of k sub-measurements, each deliberately associated with different values of the random variables known to be of most importance, then the value of s_r for a hypothetical large number of repetitions of the whole measurement can be reasonably well predicted from the standard deviation s_k of the k sub-measurements. For example, measuring sound power of a source in a reverberant room, a standard might require averaging over k sub-measurements involving statistically different, operator-selected, source positions, microphone positions, diffuser positions and, inescapably, different time-segments of output from the source. The value for s_r can be approximately predicted as $s_k k^{-1/2}$ without actually having to do a set of m repetitions of the whole k-averaged measurement.

For this last statement to be true requires a particular prescription for carrying out the m repetitions: for each of them, all those random variables not tightly specified in the standard but left to the operator to choose more or less randomly, should be selected anew, by that process. For random *time* variables, this tends to happen automatically, because the repetitions are made separately in time; but for random *spatial* variables as in the above example, the selection of fresh, independent values must be consciously made by the operator, when the determination of s_r is being made directly by actual repetition of the normal k-averaged measurement m times.

The foregoing rule for what constitutes a "repetition" conflicts with the notions of many operators, who feel intuitively that they should be allowed to demonstrate their skill at literally repeating in minute detail every action performed by them and their equipment, thereby also achieving a satisfyingly small value for s_r; generally, smaller than $s_k k^{-1/2}$, for instance. Some operators, in laboratory measurements specifying the use of random noise as the test signal, have been known to use the same short tape-recorded sample of random noise for each of their k sub-measurements, as well as detailed spatial identity between each of m repetitions. They have been very satisfied with the reduced value of s_k, and the tiny value of s_r thus obtained, but quite oblivious to the danger of temporal and spatial bias error invited by such partiality to *one* particular set selected from the possible range of random variables.

In some environmental measurements, microphone position is the only spatial variable over which the operators could have any control; but this is eliminated, in the standard concerned, by very tight specification on microphone positions. In some such cases, spatial averaging is not involved; for example, in measurement of the noise level at the position of a machine-operator's head. In other cases, while spatial averaging is an essential aspect of the method, the array of microphone positions for this purpose is very systematically specified; for example, in measurements of sound power of machines by measurements of sound pressure at points close to the machines. In both these examples, repetitions of measurements m times to directly determine s_r would *not* involve new spatial dispositions each time.

3.3 Comparison of Some Actual Measurement Standards

A selection of measurement standards for quantities in environmental acoustics, published or drafted by the Standards Association of Australia is arranged in Table 1. The purpose is to illustrate the variety of approaches to the subject of accuracy that have been adopted by the committees involved. Many of the standards and drafts included have very similar ISO

TABLE 1

Comparision of accuracy policies adopted in some Australian measurement standards, and some of their international counterparts

1	2	3	4	5	6	7
SAA or ISO No.	Year	Quantity Measured	Expected s_R stated?	Meas'mt environ. tightly specified?	Minimum averaging effort specified?	Maximum s_r specified?
AS 1055	1982(1)	Noise in residential areas	NO	(2)	NO	NO
AS 2702	1984	Road traffic noise	NO	(2)	YES (3)	NO
AS 2240	1979	Noise of individual motor vehicles	NO	YES	YES	NO
AS 2377	1980	Noise of railbound vehicles	NO	YES	NO	NO
AS 2012	1977	Noise of tractors, etc.	NO	YES	YES	YES
AS 2221/1	1979	Noise of compressors	NO	YES	YES	NO
AS 2221/2	1979	Noise of pneumatic tools	NO	YES	YES	NO
AS 1081	1975	Noise of rotating elec. machines	NO	NO (2?)	YES	NO
AS 1217/1-2	1983(1)	Sound power level of sources	YES	YES (4)	YES	NO (6)
ISO 3740, 1	1975	' ' ' ' '	YES	YES (5)	YES	NO (6)
AS 1191	1982(1)	STL of partitions, in laboratory	NO	YES	YES	YES (3)
ISO 140/1-3	1978	' ' ' ' '	YES (7)	YES	NO	YES
AS 2499	1981	'STL' of ceilings, in laboratory	NO	YES	NO	YES
AS 2253	1979	Sound insulation between spaces, field	NO	YES (8)	YES	YES
ISO 140/4	1978	' ' ' ' '	NO	(2)	YES (2)	NO
AS 1277	1983	Performance of ducted silencers	NO	YES	YES	YES
AS 2460	1981	Reverberation time of spaces, field	NO	(2)	YES	NO
AS 1045	1971	Absorption coeff. α_s, in laboratory	NO	YES	YES	NO
ISO 354	1983(1)	' ' ' ' '	YES	YES	YES	YES
AS 1935	1976	Absorption coeff. in laboratory tube	NO	YES	YES(9)	NO

NOTES:

(1) Refers to a Draft Revision publicly reviewed in this year.

(2) Not applicable.

(3) Recommended, not mandatory.

(4) Minimum room volumes recommended; absorption conditions mandatory; room qualification procedure mandatory.

(5) Minimum room volumes mandatory; absorption conditions recommended, but if not met, room qualifications procedure becomes mandatory.

(6) Except in special case of measurements on Reference Sound Sources.

(7) In a 1980 draft for revision, the statement actually appeared as a mandatory requirement!

(8) Yes, in the sense that different measurement procedures are recommended for different defined measurement situations.

(9) Only with respect to physical sampling of test material.

counterparts; where one of the Australian documents differs significantly from its ISO equivalent on matters of accuracy, the characteristics of the ISO document are tabulated beneath it for comparison.

The comparison is confined to four broad features of the standards. Column 4 reveals that only a handful of standards so far have included a statement of the variation that the authors think is likely to occur, between measuring organisations using the standard concerned.

In column 5 is a rather subjective judgement, by the present author, as to whether the standard does a good job in specifying the spatial and reflective properties of the surroundings, the meteorological conditions, etc, in an effort to reduce differences of results (where applicable). All score reasonably well on this count.

As regards the specifications for action referred to in columns 6 and 7; as mentioned in section 3.1.2, one or the other of these can be sufficient, alone, to ensure that individual organisations achieve some desired (minimum) level of precision. The first is the "recipe" type specification, the second the "performance" type specification. Normally the authors of standards, regulations, contracts, etc, are warned not to use both types, mandatorily, bearing on the one quantity in the same document. But the sin of having "YES" in both these columns is far less than that of having "NO" in both.

For the headings of columns 4 and 7, the terms s_R and s_r were used for brevity; a YES in these columns may in fact allude to the use of one of the alternatives: R, r or 95% C.I.

The Table does not include any standard acoustical measurement methods specified by Australian authorities other than the Standards Association of Australia (SAA), though a small number of these do exist. Nor is mention made of SAA *product* standards which perform a fundamental role in promoting accuracy and reproducibility in acoustical measurements. There are four, providing standard specifications for sound level meters, personal noise dose meters, some band-pass filters for frequency analysis, and tape recorders for use in sound measurements. In general, these specify point-by-point tolerances concerning departures of indicated sound pressure level from the true values, as functions of frequency, and directional and temporal characteristics of the sound. The methods for determining these errors, i.e. calibrating the instruments, are also generally feasible.

However, in using the instruments to measure arbitrary sounds of complex characteristics, it is not always possible to apply corrections for the known (permissible) errors of the instruments. Similarly, it would be difficult to predict the component of s_R likely to be due purely to legitimate differences between instruments, in a complex task such as determining L_{eq} during 1 hour at a site exposed to traffic noise: which is where the King and the Wizard had their fairy tale dispute.

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Entertainment Noise Control and Development of a Draft State Environment Protection Policy

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Summary of a paper presented at a seminar on
COMMUNITY RESPONSE TO NOISE
Organised by the Victoria Division, July 1984

INTRODUCTION

The intrusion of music noise from entertainment venues into residential premises has become a widespread and significant form of environmental noise pollution. Entertainment noise typically consists of amplified recorded or live music with prominent low frequency components and is generally heard at night when residents wish to relax or sleep. The background sound level usually decreases in the night and early morning and this further emphasises the intrinsic noise level of the music.

Residents around some entertainment venues licensed to serve alcohol also suffer considerable disturbance from patrons leaving late at night and from minor acts of vandalism and bad language. A history of such events can influence a person's general attitude to a venue and this in turn will influence subjective noise annoyance.

Notwithstanding the negative effects on nearby residents, public entertainment venues do provide an important and legitimate form of public recreation and employment.

In the preparation of the draft Policy the Environment Protection Authority of Victoria has sought a balance between the rights of residents to live in the vicinity of an entertainment venue with a minimum of disturbance and the rights of the patrons of such establishments to enjoy the music of their choice.

ENABLING LEGISLATION

Under Section 47 of the Environment Protection Act the EPA may serve a noise control notice on the occupier of premises emitting excessive noise.

The Policy, once declared by Governor-in-Council, will form the technical basis for imposing noise limits, via the noise control notice system, or non-domestic premises emitting music.

Section 55 of the Act gives powers of entry to such premises in order to determine or prescribe the noise limits for the notice.

SUMMARY OF THE DRAFT POLICY

The policy applies to all non-domestic premises which emit music noise including hotels, outdoor concert venues, recording studios, health clubs, and some retail shops and churches.

Entertainment venues are divided into two broad categories — Type 1 which emits music at least once a week on a regular basis, and Type 2 which emits music less than once a week.

CONTROLS FOR TYPE 1 VENUES

Two noise level requirements are proposed: one for day/evening hours, and another for normal sleeping or night/morning hours.

The permissible noise level for music emissions for the day/evening hours is an L_{eq} 5 dBA above an L_{90} of the background noise, measured in a habitable room of the affected residence. At this level the music could be heard, but would not unduly interfere with typical household activities.

During normal sleeping hours, generally 10.00 p.m. to 9.00 a.m., the sound level requirement is more stringent and music emissions should not be audible in any bedroom of an affected residence. The time this more stringent requirement applies will vary depending upon the day of the week and the number of operations.

CONTROLS FOR TYPE 2 VENUES

Because noise emissions are less frequent, the problems caused by Type 2 venues are less severe.

An L_{eq} of 90 dBA inside the venue is proposed as the permissible noise level, but the EPA may vary this requirement depending on individual venue circumstances. At worst the music noise levels should not interfere with speech and an L_{eq} of 65 dBA outdoors at a residence is not to be exceeded.

The hours of operation are also restricted according to start-up time, location of the venue, and the number of days of operation. The permissible daily hours of operation for a three-day outdoor music festival will be less than those allowed for a one-day indoor concert.

The suggested operating hours for an indoor venue emitting music on just one day is between 10.00 a.m. and 11.00 p.m. or 6.00 p.m. and midnight. For a similar outdoor venue the hours are between noon and 10.00 p.m. or 6.00 p.m. and 11.00 p.m. In each case the permitted finishing time is brought forward by one hour if the venue emits music noise on more than one occasion in a week.

MEASUREMENT POSITIONS

To facilitate checking compliance with the above criteria alternative measurement points may be specified and derived conditions of compliance can be applied.

CONDITIONS OF OPERATION

In addition to prescribing permissible noise levels for entertainment venues the Policy provides for the specification of operation conditions such as the installation of monitoring equipment and other devices to limit levels of output of music and public address announcements.

RESEARCH AND INVESTIGATIONS

The draft Policy was formulated on the basis of experience gained in numerous routine investigations of complaints and some systematic studies.

These have included a series of intensive case studies of residents' reaction to noise from 27 Type 1 premises and two extensive studies of local community reaction to consecutive outdoor concerts held at a Type 2 premises. Subjective reaction scores were compared with measured or estimated sound levels of music and background.

Ongoing studies that should assist in the refinement of the Policy criteria before its declaration are a social survey of a broader cross-section of Type 1 and 2 situations and a special experiment to examine sleep prevention by intrusive music.

An Industrialist's View on Community Noise Legislation

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Summary of a paper presented at a seminar on COMMUNITY RESPONSE TO NOISE Organised by the Victoria Division, July 1984

The E.P.A. must be commended for producing a noise control policy which appears to be more scientific than some of the earlier E.P.A. drafts and other standards. The E.P.A. appear to have overcome the problems associated with subjective and other imprecise methods of evaluating and assessing permissible noise levels. The sliding-scale rather than step-wise gradation of permissible noise levels and adjustments for tonal and impulse characteristics rather than arbitrary ones is more acceptable.

Unfortunately the complexity and cost of instrumentation is such that the majority of industrialists are not in a position to do their own evaluation or monitoring. One way of overcoming this would be to include an alternative approximate method using simple instruments already owned by a large number of industrialists, to arrive at a "ball-park" figure.

The *two-circle area method* of determining Permissible Noise Levels tends to discriminate against industries occupying large areas of land; this would include the case where industries are encouraged to group together in areas set aside for industries. Everything else being equal, the area concept would specify the same permissible noise level for noise sensitive areas at distances of greater than 200 metres from the boundaries of noise producers. These levels are easier to meet by a small noise producer (say a point source) as noise would attenuate by about 6 dB for doubling of distance, whereas noise from a large complex may attenuate at a rate of 3 dB or less for doubling of distance.

There is some justification to claim that *historical development* and the present *sociological balance* of the whole area should be considered when investigating noise complaints. Some people live close to large industrial complexes because development was allowed to proceed around the mill and people chose to build and live close to the mill. People, for various reasons and advantages to them, choose to live in such areas, and within certain limits, tend to habituate to and accept levels of noise which are normal in their particular area.

Rather than be a nuisance, perhaps steady broad-band noise could be of benefit by masking the disturbing effects of fluctuating and sporadic traffic noise, which may be considerable in certain areas. If a noisy vehicle disturbs a person's rest, he eventually blames the industrial noise he hears after being awoken.

In another state, there was a move to ensure that any action taken as a result of a noise complaint depended to some extent on whether the complainant chose to reside in the area before or after the establishment of the industry.

Over twenty years ago, our company came to the conclusion that it was generally cheaper to engineer noise out at the inception of a project than to retro-fit acoustic treatment. Where a building was required for other reasons, there is at least one case where careful design ensured adequate noise reduction was achieved with no additional building cost.

However, with rising costs for industrial plant the trend now is to eliminate buildings. As a consequence, for example, outdoor boilers create problems because the manufacturers do not appear to have learnt how to eliminate noise from furnaces, fans, feed pumps, steam bleeds and steam leaks. Belt drives and gearboxes create tonal noises as they deteriorate, thus a project engineer is faced with the difficult task of predicting which items will produce noise when they deteriorate, and must take appropriate and lasting measures at the design and construction stages.

A.P.M. has paid considerable attention to intermittent noise. For example, to reduce the number of silencers on safety valves, steam systems have been altered to ensure that only a nominated small number of safety valves operate during emergencies, and these are appropriately silenced.

We have also realised that care is required in the choice of materials and in design to ensure that attenuating equipment lasts as long as associated equipment. This means that stainless steel is used extensively, acoustic material is protected against vibration and erosion, and designs often allow re-packing. For this reason, noise reduction costs in industry are high.

While everyone appears to agree with the objective of attaining higher environmental standards, these should be examined in the light of the impact of costs on the community as a whole. Presently, industry is faced with costs as a result of hearing conservation regulations (which it could be argued should receive first priority) and with costs associated with Air Policies. Especially in the present economic climate, reduction of noise to the community, although an important aim, should be put into correct perspective in relation to other priorities. Also, the standards set, as discussed previously, should be set so that the cost burden is not unrealistic when related to the real benefits. In other words, the policy should recognise and take into account cost benefits.

$1m Worth of Noise

PITSTOCK PTY. LTD., a sustaining member of the AAS, recently supplied the answer to a noise problem at the Yallourn Power Station in Victoria's Latrobe Valley. Following commissioning of stage 2 of the power station in 1982, residents of Yallourn Heights and Yallourn North drew up a petition complaining about excessive noise from the new installation. The noise source was identified as the two induced draft boiler fans. A $1 million contract has been let by the SEC to rectify the noise problems.

PITSTOCK designed and manufactured at their Bankstown Plant Power-Flow noise attenuation baffles for the four huge 32.5 square metre ducts. Made under licence to Industrial Acoustics Company Inc. in New York, these baffles are being fitted into existing ducts by the boiler contractor. The SEC hopes to reduce the overall noise level in the residential areas to 40 dBA.

PITSTOCK is actively engaged in all phases of noise pollution control, from initial evaluation of a company's requirements to design, manufacture and site assembly.

Comments on Marion Burgess' article

Dear Sir,

In an article entitled "Traffic flow and noise levels at one site" [Bulletin Aust. Acoust. Soc., 1984, 12(2), pp.51-3], Marion Burgess considered the variability associated with both measurement and prediction of traffic noise. While not disputing that such variability exists, I am compelled to comment on some of Marion's assertions which I suspect might have been intuitively rather than scientifically derived. My years of experience in this field have taught me just how complex it is and therefore I now write in order to compliment Marion's work, hopefully thereby advancing the state-of-the-art in Australia.

Having graphed her repeated observations of traffic flows and noise levels at one site, Marion concludes that the observed variability in traffic noise (which I think she loosely terms as "error") is caused by the use of short sample times. Although sample time is an important consideration in the measurement of traffic noise (UK DoE 1975), Marion's conclusion must be regarded as mere speculation in the absence of a scientifically determined causal relationship. Many other factors might also explain the reported variability which I suspect Marion may have tacitly assumed should not occur. It is indeed possible that the variability reflects real fluctuations in the traffic noise climate at the particular observation location.

Consider, for instance, estimating the effect traffic flow and composition might have on the measured noise levels. This may be achieved either by using the UK DoE prediction method or possibly by means of an unvalidated regression equation (BUR) derived previously by Marion (Burgess 1977). By applying the observed traffic characteristics tabulated below to both methods the estimated effects are obtained.

	Traffic flow (veh/h)	Proportion heavy vehicles (%)
Mean	485	29.7
Standard Deviation (s)	71.7	7.7
95% Confidence limits ($\pm 2s$)	± 143.4	± 15.4
Upper Limit ($x + 2s$)	628.4	45.1
Lower Limit ($x - 2s$)	341.6	14.3

These data may be substituted, as appropriate in two relevant equations.

$$L_{10} = 10 \log q + 33 \log (V + 40 + (500/V)) + 10 \log (1 + (5p/V)) - 27.6 \qquad (1)$$

$$L_{10} = 10.7 \log q + 0.3p + 56 \qquad (2)$$

where

L_{10} = Traffic noise level exceeded for 10% of a given one hour period

q = Traffic flow (veh/h)

V = Mean speed of traffic (km/h)

p = Proportion heavy vehicles (%)

and

Eq. (1) was obtained for UK DoE (1975)

Eq. (2) was derived (BUR) in Burgess (1977)

It is apparent in both equations that the predicted noise level increases with increasing speed and heavy vehicle proportion. For the present purpose it is the change in noise level that is of interest and this leads naturally to a "worst case" comparison. Consequently the case of the maximum flow with maximum heavy vehicle content may be compared with that of the minimum flow with minimum heavy vehicle content. Note that for the UK DoE predictions, a traffic speed of 60 km/h was used. Readers can verify for themselves that the UK DoE estimated change in noise level for the two cases varies only 0.30 dB(A) for speeds ranging from 50 to 70 km/h. Such speeds would, I believe, be typical of those at Marion's site. Reiterating, the following cases may be considered:

Case 1: 628.4 veh/h, 45.1% heavy vehicles
Case 2: 341.6 veh/h, 14.3% heavy vehicles

Change in traffic noise level from Case 1 to Case 2 predicted by Eq. (1) = 6.10 dB(A) and predicted by Eq. (2) = 12.13 dB(A).

I suggest these estimates indicate the scatter of measured traffic noise levels as shown in Marion's Figure 2 is consistent with variations in her observed traffic flow and composition, although I am certainly not offering the calculations as justification of any specific noise/flow relationship. Again I emphasise that the above estimates are based on a worse case comparison. Nevertheless variations in traffic flow and composition must remain likely explanations for the observed noise scatter. There is certainly no evidence relating this scatter to measurement sample time.

The estimates of noise level variation provided by Equations (1) and (2) differ by some 6 dB(A), and this result deserves some comment. A primary cause may well be that the unvalidated, empirically based Eq. (2) was applied outside the range of traffic flows within which it was derived. Traffic data used by Marion to produce Eq. (2) ranged from 648 to 3393 vehicles per hour. An additional difficulty, which applies to both equations, concerns the nature of the heavy vehicle population at the site which is located in an "industrial area of Sydney". Inclusion of a parameter p in Equations (1) and (2) is effectively based on an assumption of there being one uniform population of high noise output heavy vehicles. Based on Marion's comments concerning the site location and actual traffic conditions, this assumption is unlikely to be valid for the particular calculations I have conducted. It may, therefore, explain some of the 6 dB(A) difference.

A final issue I would raise concerns the absolute accuracy of traffic noise prediction values against measured values Marion presents in Figure 3 and subsequently discusses. Prediction accuracy may be defined in terms of the distribution of the differences between predicted and measured values in a given data set. If such a distribution is reasonably normal then the mean will quantify any bias in the prediction method; that is, it will quantify the tendency of the method to under-predict or over-predict. This bias may readily be removed by application of a correction factor (of equal magnitude and opposite sign to the mean of the prediction/measured difference distribution) to any subsequent predicted value. Once so corrected, the confidence limits surrounding a predicted value are related to the variance of the predicted/measured difference distribution. (For 95% confidence the limits are approximated by plus and minus two standard deviations.) In effect this parameter defines the accuracy of future predictions.

Recently I have been involved in two major studies which have investigated the accuracy under Australian conditions of traffic noise prediction methods originating in the UK and the USA [Samuels and Saunders 1982, Samuels and Fawcett 1984). These studies were based on data collected hourly over the 18-hour period 6 am to 12 midnight at some 118 sites located variously in the Brisbane, Melbourne and Perth metropolitan areas. On the basis of this experience and my comments above concerning prediction accuracy, I suspect that the regression analysis approach adopted by Marion for data collection at one site may not be an appropriate means of judging prediction of performance. While I agree with Marion's comments concerning the undesirability of underprediction, I would argue (as above) that if sufficient data are collected over a range of sites, the bias of underprediction may be successfully eliminated. It might be that a combination of site and traffic characteristics at Marion's site have influenced the form of the curves in her Figure 3. Perhaps extrapolating these results beyond the confines of that one site would be unjustified.

In closing let me reiterate that my primary purpose in writing this letter is to attempt to advance Australian knowledge and practice in the field of traffic noise. I have observed that with the improved economic outlook of late, professional and community interest in this field has been increasing. Perhaps the time is near for our Society to consider holding a workshop on the topic.

Stephen Samuels,
Senior Research Scientist,
Australian Road Research Board,
Victoria.
6 September 1984

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UK Dept of Environment (1975). Calculation of road traffic noise. HMSO. Welsh Office.

Samuels, S.E. and Saunders, R.E. (1982). The Australian performance of the UK DoE trafic noise prediction method. Proc. 11th ARRB Conf. 11(6), pp. 30-44.

Samuels, S.E. and Fawcett, G. (1984). A study of the US NCHRP traffic noise prediction method. Proc. 12th ARRB Conf. 12(6), pp. 90-98.

Reply to comments by S. Samuels

Dear Sir,

I am pleased that Stephen Samuels has been prompted by my article in the August Bulletin to present some comments on the problems associated with measuring and predicting the noise from road traffic. However I am sorry that he has misinterpreted the intent of my paper which, by presenting the results from repeated measurements at one site, was to "highlight the need for careful monitoring to ensure the values are really representative" of the noise from the road. A discussion on "the variability associated with both measurement and prediction of traffic noise" (stated by Samuels, paragraph 1) would require a major study of an extensive data bank covering a wide range of all the parameters associated with road traffic noise and such a discussion was not attempted in my article.

The confusion may have arisen from my use of the word "representative". I agree with Samuels that a short sample of traffic noise at a particular point is representative of the actual traffic at that point over that short sample time. The data presented in my article shows that, for the particular site, the measured value for L_{10} could differ by 10 dB(A) from one short sample to another. Therefore one short sample of the traffic noise is not going to provide a value for L_{10} which is "representative of the traffic noise from the road" over a time period that is any longer than the sample time. When undertaking a noise survey of an area it is sometimes tempting to divide the day into a number of time zones based on estimations of the traffic flow, such as peak flow, daytime, evening and night, and then use only short samples of the noise during those times. The range of values obtained for one site during one such time zone (daytime, non peak flow) shows that this is not a satisfactory sampling procedure.

I am surprised that Samuels considers that I have used the term "error" to refer to the observed variability in traffic noise. Apart from references to "sampling error" defined by Fisk (article reference 5) and "standard error" associated with the regression analysis the word *error* appears once in the paper and once in the abstract. In the latter case, *error* is used with reference to the application of prediction methods outside their range of validity. In the former case (Section 4.2, paragraph 1) it is not the variability which is referred to as an "error" but the assumption that a short sample is "representative of the traffic noise from the road".

My experience with measurements of road traffic noise has not led me to "speculate" or "tacitly assume" variations in observed traffic flows and noise levels should not occur. My reference to "maximum consistency" in traffic volume is a direct quote from a traffic engineering reference book (article reference 4). I agree with Samuels that the variability in noise levels is most likely to result from the variability in traffic flow and this is the reason I have presented the data for both of these parameters in the one paper. Therefore I am pleased that Samuels has calculated that the observed variations in traffic flow and composition could produce a scatter of the noise levels consistent with the observed variation. However I would like to clarify some points in this portion of Samuels' letter.

Firstly, "noise climate" is usually used to describe the variation of an unsteady sound as defined by $L_{10} - L_{90}$ and this factor was not discussed in my article. Secondly, Equations (1) and (2) do not include any terms for the distance from the road. Although the conclusions drawn by Samuels are based on the differences and will remain unaltered it should be made clear that Eq. (1) provides a predicted noise level at 10 m from the edge of the carriageway and in Eq. (2) the factor $-18.5 \log d$ (where d is the distance from the centre of the nearside carriageway) has been removed.

In his discussion on the two prediction methods Samuels suggests that Eq. (2) was applied "outside the range of traffic flow for which it was derived". In my article I have also stated that the proportion of heavy vehicles was outside the range of validity. Samuels' comment that it is unlikely that there is "one uniform population of high noise output heavy vehicles" states one of the problems faced when attempts are made to produce a practical prediction method. The inclusion of factors for subgroups of heavy vehicles based on their noise outputs may produce a more accurate prediction method. However it is in the context of planning that prediction methods are most useful and in these situations it is usually difficult to obtain detailed estimates of the traffic composition for proposed roads.

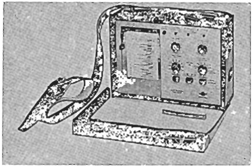
The "accuracy of future predictions" was not discussed in my article but it would appear that the application of a correction factor to remove any bias in the DOE predicted level would not involve a simple constant for this particular site. From the slope of the regression line it can be seen that as the measured L_{10} increased so did the difference between the measured and the DOE predicted values. Thus any correction factor for this site would have to depend on sound level.

I certainly agree with Samuels that the analysis of data from one site is not an appropriate method for "judging prediction performance" in general and this was not attempted in my article. My comments relate to the data obtained for the particular site except for the general warning advising caution when applying prediction methods.

As an Australian Standard on the "Measurement of road traffic noise" (AS 2702) has recently been released I agree with Samuels that the Society should consider arranging a workshop or meeting to discuss the many aspects of road traffic noise.

Marion Burgess,
School of Architecture,
University of New South Wales.
1 October 1984.

New Products



Portable Level Recorder

Level Recorder Type 2317 is a new fully-portable unit from **Bruel & Kjaer.** It is designed for field and laboratory use, for recording both AC and DC signals, vibration and noise levels, reverberation decay curves and frequency analyses. The recordings are made as a function of frequency or time on 50 mm-wide pre-printed frequency-calibrated or lined paper. New recording features incorporated into Type 2317 include six calibrated full-scale ranges, AC detection from 100μV, four well-defined AC averaging modes and AC RMS and DC signal handling up to 40V.

Type 2317 has two basic recording modes: a linear DC mode with variable zero calibration and a logarithmic AC mode with selectable 10, 25 and 50dB dynamic ranges. In the AC mode four different time-weightings can be selected: "Fast" and "Slow" in accordance with IES 651 Type 1 for sound level measurements; "Vibr." providing a 2s time constant for human vibration measurements; and "Reverb." for recording reverberation times down to 0.2s.

Eight crystal-controlled paper speeds are available and start/stop/reverse of the paper drive can be controlled remotely. The Level Recorder has facilities for filter synchronisation and external synchronisation of the paper movement. Level Recorder Type 2317 is compact, robust and ideal for use with other B & K instruments for acoustic, vibration, luminance and thermal comfort measurements.

Indoor Climate Analyzer

Bruel & Kjaer Indoor Climate Analyser Type 1213 is a handy, easy-to-operate, portable instrument for evaluating all of the basic parameters which influence the thermal environment and its effect on man. Measurements with Type 1213 are performed in accordance with ISO DIS 7726 criteria and the Analyser features a clear, easy-to-read, 20-character alphanumeric Display which also provides the user with clearly understood interactive prompts.

Using five transducers Type 1213 can measure air temperature, surface temperature, radiant temperature asymmetry, humidity and air velocity. It can be used either to obtain real-time measurements or data can be recorded and stored in its integral memory for subsequent output to a Level or X-Y recorder. Up to sixty measurements of each preselected parameter can be recorded and four different recording periods (1, 6, 24 and 120 hours) are available. Measurements are automatically spaced evenly throughout the recording period so that the Analyser can be left completely unattended.

WBGT - Heat Stress Monitor

Bruel & Kjaer WBGT - Heat Stress Monitor Type 1219 is a handy, easy-to-operate, portable instrument for measurement of the WBGT-index (Wet Bulb Globe Temperature) in accordance with ISO 7243. The WBGT-index has long been used as a guide to the level of heat stress on working man in hot environments such as steel works, bakeries, etc. Type 1219 comes equipped with a WBGT Transducer which contains sensors for measurement of Wet Bulb-, Air- and Globe Temperatures. The Monitor has a built-in non-volatile memory which stores up to 60 values of each individual parameter, plus mean, maximum, minimum values.

In addition, Type 1219 calculates the "maximum 1 hour mean WBGT" value. Recorded data is automatically measured at equal intervals throughout the selected recording period, and a choice of four (1, 2, 4 and 8 hours) recording periods is available. Type 1219 also indicates the start time at which the "maximum 1 hour mean WBGT" value occurred. Recorded data can be replayed manually on the display or output to an X-Y recorder.

Rhino-Larynx Stroboscope

Bruel & Kjaer Rhino-Larnyx Stroboscope Type 4914 provides doctors, speech therapists, music teachers and other specialists in ENT fields with a user-friendly instrument for comprehensive visual examination of the larnyx, upper respiratory tract and sinuses. The 4914 combines a stroboscope, fixed light source and frequency counter in a single unit.

The 4914 provides excellent illumination for direct observation, as well as colour video recording through flexible fibrescopes. Connection to an operation microscope is also possible. Hygiene requirements are easily met and the 4914 complies with Safety Class II of IEC 601-1 (Type BF).

Calibration Exciter for Easy Calibration of Vibration Measurement and Recording Systems

For rapid calibration and checking of vibration measurement, monitoring and recording systems, **Bruel & Kjaer** has developed a hand-held battery-powered vibration reference source, the Type 4294 Calibration Exciter.

The 4294 is intended for use with piezoelectric accelerometers and other types of vibration transducer having a mass up to 70 grammes. It permits accurate calibration and adjustment of measuring instrumentation at a reference vibration level of 10 ms^{-2} at a frequency of 159,2 Hz (1000 $rads^{-1}$). Calibration may additionally be carried out at constant velocity and displacement levels of 10 mms^{-1} and 10μm respectively.

The 4294 operates as an electromagnetic exciter driven by a stabilised oscillator. A highly accurate, constant vibration level is maintained using a built-in accelerometer to provide servo feedback. Overload is prevented by automatic power cut-off if the accelerometer mass exceeds the maximum 70 grammes.

* * *

NAP Silentflo Pty. Ltd., manufacturer of noise and vibration control systems, has recently introduced to Australia the OMEGA range of Anti-Vibration Springs.

The springs are available in a wide range of loads, from 50 kgs up to 3,000 kgs, using six basic configurations. Multiple springs are used in higher load capacities and the spring is available in strip form or as individual pieces.

Omega springs have good isolation characteristics, very high lateral stability, due to their low overall height of 40 mm, are easy to install, constructed from stainless spring steel and are coated with a dampening compound.

Their unique characteristics make them ideal for the vibration isolation of machinery and equipment, such as fans, pumps, diesel engines, heating units, etc., and the product is also used for floating floors, isolated walls and isolation of complete structures. Other versions are available for use as pipe hangers and hanging support isolators.

Full details, including literature, test reports, prices and samples, are available from NAP Silentflo Pty. Ltd, Melbourne — 21 Browns Road, Clayton 3168; or Sydney — 313 Sailors Bay Road, Northbridge 2063, or agents.

Programmable Dosimeter and Sound Level Meter

Australian Metrosonics announce the new **db-307 Metro-logger,** a hand-held computer which can serve simultaneously as a personal noise dosimeter and an integrating sound level meter, with full programmability for measuring in accordance with a variety of acoustical criteria. It quickly produces accurate answers to complex measurements and performs most acoustical measurements required in factories, communities and test laboratories.

All measured and computed data are presented on an 8-digit alphanumeric LED display. A membrane keypad permits set-up and readout, and an access code protects against tampering and reading by unauthorized persons.

Accurate test results are obtained by the microcomputer sampling the rms detector output 8 times per second. Built-in versatile software permits tests from as short as a few seconds, to many days.

The instrument is also quickly programmed by the test conductor for 3, 4, 5, or 6 dB exchange rate, optional 70, 75, 80, 85, 90 dB (A) or no threshold, and for criteria level. At power up, the display confirms the values that are currently programmed.

Watertight construction is utilized so that the db-307 may be completely immersed in water for short periods of time or confidently used in adverse environments. The db-307 is delivered complete, ready for use, with rugged quarter-inch ceramic microphone and captive 1-metre cable.

The db-307 is an outgrowth of Metrosonics' microprocessor-based Noise Profiling Dosimeters, Universal Data Loggers and L_{eq} meters. It measures dBA, L_{max}, L_{pk}, time weighted average, noise dose and test duration. The db-307 is designed for use by industrial hygienists, product test engineers, community noise abatement officers and acoustical consultants who desire a single instrument for performing all of their noise surveys. (See advertisement this issue.)

For further details contact Australian Metrosonics, 57 Lorraine Drive, Burwood East, Victoria 3151. Telephone: (03) 233 5889.

Data Logger with Real-Time Display

Australian Metrosonics announces its new Model dl-332 Universal Data Logger. This compact, battery-operated digital data logger replaces strip chart recorders and other data loggers for realtime display and unattended monitoring of air contaminants, toxic, or combustible gases, humidity, heat stress, and other industrial hygiene and pollution variables. It can be used with many environmental monitors that have a linear analog output.

The dl-332 is configured like a hand-held calculator and is just as easy to use. A built-in keypad enables users to program input range and full-scale reading so that data is read directly in engineering units. Users can also program an averaging period of 1-second to 4-hours for time history recording. Alarm limits and START/STOP times can also be programmed.

Fully-formated test reports can be printed on any RS-232C printer. The dl-332 can also interface with computers for real-time monitoring, data analysis and recordkeeping.

For further details contact Australian Metrosonics, 57 Lorraine Drive, Burwood East, Victoria 3151. Telephone: (03) 233 5889.

New Acoustic Literature Available

Bradford Insulation has produced a comprehensive range of acoustic literature.

The range includes a cover which details the Bradford acoustic product range, the specification of each product and their various uses.

In addition five more detailed **application brochures** have been produced covering:

- General principles of sound (noise) control
- Noise control in Factories
- Noise control in Buildings
- Sound control in Studios
- Noise control in plant rooms, includes pipework, ducting and fans.

Also available are a range of **technical data sheets** to cover the technical specifications of Bradford's products and a binder of test data which substantiates the product claims made and defines the source and method of testing.

The brochures are available from the State offices of Bradford Insulation or from their head office at 7 Percy Street, Auburn 2144, phone (02) 646 9111.

Interface for Noise and Industrial Hygiene Data Loggers

Australian Metrosonics announces availability of the Model dt-435 Data Translator that enables the company's noise and industrial hygiene data loggers to interface to an RS-232C device such as personal or mainframe computers, digital recorders and modems.

The dt-435 gives users of the Metrosonics db-301 Noise-Profiling Dosimeter, dl-331 Universal Data logger, db-653 Metroreader and Interscan 5000 series Toxic Gas Dosimeter the flexibility of writing their own programs for analysing and achieving occupational exposure data, and the opportunity to utilise computers not currently supported by the company's available software.

The dt-435 is the size of a pocket calculator and operates on an internal battery or external power. Internal switches allow selection of baud rate, parity and word size, to ensure proper communication with the receiving device.

For additional information on the dt-435 Data Translator, contact Australian Metrosonics, 57 Lorraine Drive, Burwood East, Victoria 3151. Telephone: (03) 233 5889.

Back Issues

A limited number of back issues of the Bulletin are available. The cost, including surface post, is as follows:
Prior to Vol. 10: $A3.00 per issue
Vols. 10, 11: $A5.00 per issue (or $A12.00 for 3 issues)
Copies may be ordered from: Mrs. Toni Benton, C/-School of Physics, University of New South Wales, P.O. Box 1, Kensington, N.S.W. 2033.

WESTPAC 11

Second Western Pacific Regional Acoustics Conference

Hong Kong Polytechnic

28-30 November, 1985

Following the success of the first Western Pacific Acoustics Conference which was held in Singapore in 1983 a second conference will be held in Hong Kong.

The conference will be held under the aegis of the ICA and will be organised jointly by the Institute of Acoustics, Hong Kong Branch and the Hong Kong Polytechnic. It is co-sponsored by the Australian Acoustical Society, the Acoustical Society of Japan, the Acoustical Society of Korea and the Institute of Noise Control Engineering of Japan.

For further details contact: Organising Committee Secretariat, WESTPAC II, C/- Division of Part-Time and Short Course Work, Hong Kong Polytechnic, Hung Hom, Kowloon, Hong Kong.

NATO Advanced Study Institute

A NATO Advanced Study Institute on "Ultrasonic Methods in Evaluation of Inhomogeneous Materials" will be held at the Ettore Majorana Centre for Scientific Culture in Erice, Italy, 15-25 October 1985. Approximately 15 experts from Europe and North America will present invited state of the art papers; in addition, a small number of advanced research papers by participants will be considered. Limited financial support for qualified post-doctoral fellows, post-graduates, and research works is available. As participation is by invitation only by the ASI directors, **enquiries** should be sent to A. Alippi, Istituto di Acustica - C.N.R., 1216 Via Cassia, 00189 Roma, Italy, or to W. G. Mayer, Physics Department, Georgetown University, Washington, D.C. 20057, U.S.A.

Machine Noise and Diagnostics

Professor Richard Lyon of MIT will present a special seven-day course at the Royal Olympic Hotel in Athens, Greece on 13-19 January, 1985. Professor Lyon will explore how various mechanical events such as impact, imbalance and meshing produce vibrational energy and how that energy is transmitted through and radiated by machine structures. The ways of processing output signals so that faults can be detected and recognised or operating parameters controlled will receive major attention. A liberal use of demonstrations will be made throughout the programme. For further details: Dr. Alexandra Sotiropoulou, 2 Papanikoli St., Piraeus, Greece 18537.

Japan — Australia Exchange Agreement

The Australian Academy of Science and the Japan Society for the Promotion of Science arrange exchange visits for scientists. Applications for the exchange programme in 1985-1986 are invited from senior scientists in the field of natural science (including experimental psychology) for visits of about four weeks. The Academy is responsible for air fares while the Japan Society provides maintenance allowances and pays for the cost of travel within Japan.

For further information and application forms: International Relations Section, The Australian Academy of Science, G.P.O. Box 783, CANBERRA CITY, A.C.T. 2601. Applications close 1st February, 1985.

Ray Tracing Program

Chalmers University of Technology, Sweden has produced a ray tracing procedure for use in room acoustical problems that is easy to use and whose execution time is not dependent on the number of surfaces included in the programme. The positions of surfaces, absorption and radiation characteristics can be altered as required. The programme is written in Pascal and designed to run on an IBM 3033 computer. *For further information, programme listing, etc., write to:* Per-Anders Forsberg, Chalmers University of Technology, DPT Building Acoustics, 412 96 GOTHENBERG, SWEDEN.

China — Australia Exchange Agreement

A scientific exchange agreement between the Australian Academy of Science and Academia Sinica (Beijing) has been in operation since 1977.

The Academy funds exchanges in the field of natural science. Applications from individual scientists or groups (up to a maximum of six in number) should have a specific programme or project in mind, preferably one that has been developed in consultation with the Academia Sinica Institutes that applicants wish to visit. Visits may be short term (3 to 4 weeks) exploratory or fact-finding visits or long term (up to 12 months) visits to carry out joint research work or field studies.

Application forms and a list of Academia Sinica Institutes are available from the Academy. Scientists interested in participating in the 1985-1986 programme should write to:

International Relations Section,
The Australian Academy of Science,
P.O. Box 783
Canberra City, A.C.T. 2601.

Applications must reach the Academy by 1st February, 1985.

Institute of Acoustics — Autumn Conference

The Institute of Acoustics Autumn Conference was held at a large hotel near Lake Windermere from Friday, 2nd November to Sunday, 4th November and was attended by over 140 delegates.

There were two parallel sessions with one being devoted to the 33 papers on *Speech Research.* The alternative sessions covered *Building Insulation and Privacy* (8 papers), *Ship and Diesel Noise* (10 papers), *Open Session* (6 papers) and a *Poster Session* (4 presentations). Speech research is a particularly popular field at present because of the implications for voice recognition and speech synthesis. The co-operative research by Universities and companies dealing with computers was emphasised by the attendance of many representatives from both areas. In the sessions on Noise the papers covered topics ranging from the practical problems encountered by Council officers to preliminary results from current University research projects. An open discussion on "Unresolved Problems in Building Acoustics" emphasised the practical problems related to obtaining the performance of building materials and there was a firm recommendation that the Institute should be involved with the establishment of a data base.

The **Tyndall Medal Lecture** was given by **Professor R. G. White** from ISVR at Southampton. His lecture on "Structural Dynamics and Vibration Control" provided an overview of the topic. He also gave the results of power flow measurements and discussed the development of new materials which are stiff, lightweight and heavily damped.

Although it rained heavily on Friday and Saturday to such an extent that there was local flooding, the Social Programme needed only small modifications. The Conference Dinner was an excellent meal and the after dinner speaker put everyone in a jovial mood. The rain abated on Sunday and the sunlight revealed the first snow for the season on the surrounding hills.

Overall the Conference was well organised and the relaxed atmosphere of a hotel in a delightful area of England provided an ideal background for an interesting Conference.

MARION BURGESS

Future Events

AUSTRALIA

1985

February 3-8, MELBOURNE

Australian Association of Speech and Hearing Annual Conference. The programme aims to highlight topical areas of therapeutic intervention, clinic and staff administration and professional development.

Details: ASSH Conference Secretariat, P.O. Box 29, Parkville, Vic. 3052.

October 23-25, BRISBANE

CONCRETE '85

"The Performance of Concrete and Masonry Structures".

Details: The Conference Manager, Concrete 85, The Institution of Engineers, Australia, 11 National Circuit, BARTON A.C.T. 2600.

1986

October, TOOWOOMBA

Conference on Community Noise.

Sponsored by the Queensland Division of Noise Abatement and the Australian Acoustical Society.

Topic: Community noise and the interaction of legislation and the legal system, planning and community education.

Details: Ms Nola Eddington, Division of Noise Abatement, 64-70 May Street, BRISBANE, Q. 4000.

November 24-26, LEURA, N.S.W.

AAS ANNUAL CONFERENCE

"Motor Vehicle and Road Traffic Noise".

Details: Prof. Anita Lawrence, School of the Built Environment, University of N.S.W., P.O. Box 1, KENSINGTON, N.S.W. 2033. Tel.: (02) 697 4850.

INTERNATIONAL

1985

January 13-19, ATHENS

Machinery Noise and Diagnostics.

A course presented by Professor Richard H. Lyon of MIT.

Details: Dr. Alexandra Sotiropoulou, 2 Papanikoli St., Piraeus, GREECE 18537.

April 8-12, AUSTIN, TEXAS

Meeting of the Acoustical Society of America.

Chairman: Professor David T. Blackstock, University of Texas, P.O. Box 8029, AUSTIN, TX 78712.

May 6-8, HELSINKI

Fourth International Symposium on Hand-Arm Vibration.

Details: Dr. I. Pyykko, Institute of Occupational Health, Department of Physiology, Laajaniityntie 1, SF-01620 Vantaa 62, FINLAND.

June 3-5, U.S.A.

NOISE-CON '85

INCE/USA National Conference on Noise Control Engineering.

Theme: Computers for Noise Control.

Details: Prof. R. Singh, Mech. Eng. Dept., Ohio State University, 206 West 18th St., COLUMBUS, OH. 43210.

August 4-9, MANCHESTER

International Congress on Education of the Deaf.

Details: Prof. Taylor, Dept. of Audiology and Education of the Deaf. The University of Manchester.

September 18-20, MUNCHEN, GERMANY

Enterprise 85. Organised by VDI, MUNCHEN.

Details from: Prof. E. Zwicker, Institut fur Elektroakustik der Techischen Universitat Munchen Arcisstr. 21, 8 Munchen 2.

June 3-6, ILLINOIS, U.S.A.

Eighth International Conference on Internal Friction and Ultrasonic Attenuation in Solids.

Deadline for abstracts: 15th February, 1985.

Details: Secretariat: Mary Dean, Dept. of Metallurgy and Mining Engineering, 1304 West Green St., URBANA, IL. 61801.

September GREECE

5th FASE Symposium on "Integrated Acoustical Environment Design".

Organised by the Hellenic Acoustical Society jointly with the Acoustical Society of Yugoslavia.

Details from: E. Tzekakis (5-FASE-85) 5, Agiou Seraphim Str., 546 43 Thessaloniki.

September 18-20, MUNICH

INTER-NOISE 85

14th International Conference on Noise Control Engineering.

Details: INTER-NOISE 85 Secretariat, c/- UDI-Kommission Larmminderung, Postfach 11 39, D-4000 Dusseldorf 1, Federal Republic of Germany.

October 1-4, HIGH TATRA, CZECHOSLOVAKIA

24th Acoustical Conference on "Building and Room Acoustics".

Secretariat: House of Technology, Ing. L. Goralikova, Skultetyho ul. 1, 832 27, Bratislava.

October 15-25, ITALY

Ultrasonic methods in evaluation of inhomogeneous materials. NATO Advanced Study Institute.

Ettore Majorana Centre for Scientific Culture, Erice, ITALY.

Details: A. Alippi, Istituto di Acustica - CNR, 1216 Via Cassia, 00189 Roma, ITALY.

November 4-8 NASHVILLE

Meeting of the Acoustical Society of America.

Chairman: Robert W. Benson, Bonitron Inc., 2970 Sidco Drive, NASHVILLE, TN 37204.

November 28-30, HONG KONG

WESTPAC II

Second Western Pacific Regional Acoustics Conference.

Theme: Developments in Acoustics in the Western Pacific Region.

Details: Organising Committee Secretariat, WESTPAC II, c/- Division of Part-time & Short Course Work, Hong Kong Polytechnic, Hung Hom, Kowloon, HONG KONG.

December 2-6, HONG KONG

POLMET '85, Asia & Pacific Regional Conference

"Pollution in the Urban Environment".

Details: The Secretariat, POLMET '85, 57 Wyndham St., First Floor, Central, HONG KONG.

New Publications

Internoise 83 Proceedings

Comprises preprints of 300 papers arranged as a two-volume set of 1470 pp. The papers are arranged into nine chapters as follows: Emission; Noise sources; Physical phenomena; Noise control elements; Vibration; Generation, transmission, isolation and reduction; Immission: Physical aspects of environmental noise; Immission: Effect of noise; Analysis and requirements.

Copies available from: Mrs. C. M. Mackenzie, Secretary, Institute of Acoustics, 25 Chambers Street, Edinburgh EH1 1HU, Scotland. Cost: £48.00, including packing and air parcel post.

Environmental Noise Control Manual

The N.S.W. State Pollution Control Commission has available a draft version of an Environmental Noise Control Manual at a cost of $A30.00. The manual is at present under review by local government authorities. Copies may be obtained from the **SPCC, 157 Liverpool Street, Sydney 2000.**

Attenuation of Hearing Protectors

The Fourth Edition of NAL's "Attenuation of Hearing Protectors" is now on sale in the Australian Government Publishing Service bookshops throughout Australia. It updates the information contained in the Third Edition published in 1980.

Since the Australian standard for hearing protectors (AS1270) was introduced in 1975, NAL has measured the noise reduction of more than 100 ear plugs, ear muffs and

other forms of personal hearing protector. All devices submitted for test are first subjected to a battery of accelerated aging and stress tests by the Scientific Laboratories of the New South Wales Department of Industrial Relations Division of Occupational Health. Only those that survive are sent on to NAL for acoustical evaluation.

In addition to some explanatory notes the Fourth Edition lists octave band attenuation and SLC80 values for 88 ear muffs, 29 ear plugs and 22 ear muff/safety helmet combinations. **Available from National Acoustic Laboratories, 5 Hickson Road, Millers Point, N.S.W. 2000, at a cost of $A2.10.**

Theses

Cost-Benefit Analysis of the Application of Traffic Noise Insulation Measures to Existing Houses

J. D. MODRA

Principal Noise Control Officer

Noise Control Branch

Environment Protection Authority, Melbourne

A 25,000 word project report submitted in partial fulfilment of the requirements for the Degree of Master of Engineering Science (Environmental Engineering), Faculty of Engineering, University of Melbourne.

SUMMARY

Most of the houses facing onto arterial roads in major cities are significantly impacted by road traffic noise. This problem cannot be solved in the short to medium term through vehicle noise controls. Where an immediate reduction in the noise impact of arterial roads is required the only realistic option is to retrofit noise insulation measures to the houses affected.

Six stages of noise insulation are identified. Five are for the house itself, the remaining stage being a barrier fence at the property line. Typical installation costs and noise reductions for each stage are also identified. These data are for a particular house thought to be typical of many facing arterial roads in Australia.

The property value approach is used to place a dollar value on the benefit arising from the noise reduction of each of the stages of insulation. This involves using a Noise Depreciation Index (NDI), where the NDI is the percentage change in property value per decibel change in traffic noise level. Five of the six stages are found to be justifiable on the basis of cost-benefit analysis. The sensitivity to reductions in NDI value is examined and the effect of budgetary constraints analysed.

The study is believed to be the first of its kind in Australia.

Publications by Australians

1983

Generation of Elastic Stress Waves at a T-Junction of Square Rods

(1) K. J. ATKINS
(2) K. H. YONG
(1) School of Civil Eng., Sth. Aust. Inst. of Techn., S.A. 5098.
(2) Gang-Nail Aust. Ltd., Singapore.
J. Sound Vib. **88** (4), 432-436 (1983).

Zoom Plot — A New Technique in Applied Ultrasonic Spectroscopy

D. S. BLOSER
M & A Sect., Mat. Div., AAEC.
Non-Destr Testing — Aust. **20** (6), 19-22 (1983).

Low Frequency Noise Annoyance Assessment by Low Frequency Noise Rating (LFRN) Curves

(1) N. BRONER
(2) H. G. LEVENTHAL
(1) Vipac & Partners Pty. Ltd., Sth. Yarra, Vic., 3141.
J. of Low Frequency Noise & Vibr. **2** (1), 20-28 (1983).

Assessment of Inclusion Distribution in Steels Using a Microprocessor Controlled Ultrasonic Scanning System

R. CORNISH
BHP Melb. Res. Laboratories, Melbourne.
Non-Destr. Testing — Aust. **20** (8), 23-27 (1983).

Acoustic Emission During the Plastic Deformation of Aluminium Alloys 2024 and 2124

S. McK. COUSLAND, C. M. SCALA
Aeronautical Res. Labs., Dept. Defence, P.O. Box 4331, G.P.O., Melbourne.
Materials Science and Eng. **57** (1), 23-29 (1983).

Selective Excitation of Modes of Vibration by Means of a Laser

(1) K. A. EDWARDS
(2) R. C. TOBIN, L. L. KOSS
(1) Dept. Physics, Monash University, Clayton, Vic. 3168.
(2) Dept. Mech. Eng., Monash University, Clayton, Vic. 3168.
J. Sound Vib. **90** (3), 452-455 (1983).

Ultrasonic Stress Monitoring in Underground Mining M.

T. GLADWIN
Dept. Physics, University of Queensland, St. Lucia, Qld. 4067.
Internat. J. of Rock Mec. and Mining Sciences, **19** (5), 221-228 (1983).

Determination of Two Stroke Engine Exhaust Noise by the Method of Characteristics

A. JONES, G. BROWN
Dept. of Mech. Eng. University of Adelaide, Adelaide.
J. Sound Vib. **82** (3), 305-327 (1983).

The Prediction of Sound Fields Inside Non-Diffuse Spaces: Transmission Loss Considerations

E. KRUZINS
Dept. Architectural Science, Sydney University, N.S.W. 2006.
J. Sound Vib. **91** (3), 439-445 (1983).

Modelling of Acoustic Propagation Across Warm-Core Eddies

M. W. LAWRENCE
RANRL, Edgecliff, N.S.W. 2027.
J. Acoust. Soc. Am., **73** (2), 474-485 (1983).

Pipleline Welding Codes. The Interface with Non-Destructive Testing

R. F. LUMB
Williams Bros. — CMPS Engineers, Chatswood, N.S.W.
Non-Destr. Testing — Aust. **20** (7), 11-21 (1983).

Portable Microprocessor-Controlled Instrument for Measuring the Moments of an Amplitude Histogram

I. G. REES, C. G. DON
Dept. of Appl. Physics, Chisholm Inst. of Technology, Caulfield East, Vic. 3145.
J. of Physics E. **16** (9), 832-835 (1983).

Non-Destructive Testing During the Construction and for the Preventive Maintenance of Draglines

D. G. ROLLESTONE
Aust. Iron & Steel Pty. Ltd., Port Kembla.
Non-Destr. Testing — Aust. **20** (3), 11-20 (1983).

On the Three Dimensional Analysis of Thick Laminated Plates

(1) K. K. TEH, K. C. BROWN
(2) R. JONES
(1) Dept. Mech. & Ind. Eng., Univ. of Melbourne, Vic. 3052.
(2) Aeronautical Res. Labs., Def. Sc. and Technology, P.O. Box 4331, Melbourne, Vic.
J. Sound Vib. **88** (2), 213-224 (1983).

Measurement of Nonlinear Distortion in a Band-Limited System

A. N. THIELE
Australian Broadcasting Commission, Sydney, N.S.W. 2000.
J. Audio Eng. Soc. **31** (6), 443-445 (1983).

Psychophysical Studies Evaluating the Feasibility of a Speech Processing Strategy for a Multiple-Channel Cochlear Implant

Y. C. TONG, P. J. BLAMEY, R. C. DOWDELL, G. M. CLARK
Dept. of Otolaryngology, University of Melbourne, Vic. 3052.
J. Acoust. Soc. Am. **74** (1), 73-80 (1983).

Acceleration Noise Generated by a Random Repeated Impact Process

(1) L. A. WOOD
(2) K. P. BYRNE
(1) Dept. Civil & Aeronautical Eng., Royal Melb. Inst. of Techn. Vic. 3000.
(2) The University of N.S.W., P.O. Box 1, Kensington, 2033.
J. Sound Vib. **88** (4), 489-499 (1983).