The Bulletin

AUSTRALIAN ACOUSTICAL SOCIETY

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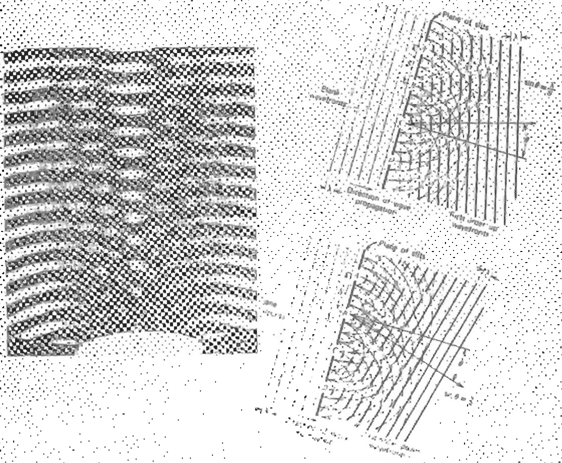

SOUND INSULATION EFFECT OF BARRIERS

PUTTING WINDOWS WHERE THEY OUGHT TO BE

HEARING CONSERVATION IN THE A.B.C.

BULLETIN OF THE AUSTRALIAN ACOUSTICAL SOCIETY

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COVER

On the left is a diffraction pattern produced by a disk-shaped barrier showing the well-known maximum along the central axis (from W. E. Kock, 'Seeing Sound', Wiley). On the right is part of the diffraction pattern for a row of slits (from A. R. Shulman, 'Optical Data Processing', Wiley).

J. Mazlin

SUSTAINING MEMBERS

The Society values greatly the support given by the Sustaining Members listed below and invites enquiries regarding Sustaining Membership from other individuals or corporations who are interested in the welfare of the Society. Any person or corporation contributing $200.00 or more annually may be elected a Sustaining Member of the Society. Enquiries regarding membership may be made to The Secretary, Australian Acoustical Society, Science House, 35-43 Clarence Street, Sydney, N.S.W. 2000.

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● NEW SOUTH WALES

Divisional Committee 1983/84

Following the Annual General Meeting of the N.S.W. Division on 17th August, 1983 and the first subsequent committee meeting, the composition of the Divisional Committee for 1983/84 is as follows:

A. R. G. Hewett, Chairman.
S. Hlistunov, Vice-Chairman.
L. C. Kenna, Secretary.
J. G. Mazlin, Treasurer/Registrar.
A. I. Zelnik, Minutes Secretary.
J. I. Dunlop, Bulletin Liaison.
Members — A. B. Lawrence, R. A. Piesse, M. Rogers, E. J. Weston.

Address for correspondence:
L. C. Kenna, 310A Bobbin Head Road, North Turramurra, N.S.W. 2074

Technical Meetings:

17th August, 1983

BLASTING CRITERIA — PANEL DISCUSSION

Carl Oesterhuis from Bruel and Kjaer described and discussed the range of recently released B & K equipment which is suited to measurement of blast.

John Mazlin of S.P.C.C. detailed the development of statutory regulations governing the control of blasting and discussed current requirements with respect to permitted times and sound levels of blasting.

Brian Scrivener of B.M.I. then described in detail the technicalities of blasting. This was supported in a most illustrative manner with a video recording of a large quarry blast, with playback and freeze facilities. The large audience of some 50 people was most appreciative of the presentation.

J. I. DUNLOP

11th October, 1893

SOUND FIELDS IN FACTORY SPACES

by **Dr. Frank Fahy**, ISVR, Southampton, England.

Following light refreshments frcm 5.30 to 6.30 an audience of thirty Society members heard an informative account of some recent work on the acoustics of factory type spaces. The work, financed by the SERC was carried out jointly by ISVR who specialised in acoustic theory and signal processing and Cambridge University whose expertise and facilities in modelling were utilised. Dr. Fahy reported the breakdown of standard Sabine and Eyring theory when applied to disproportionate volumes such as factories. Their developed models for "flat" type and "duct" type volumes agreed moderately well with factory measurements, the larger discrepancies being attributed to the unknown and difficult to measure absorption properties of factory roofs.

J. I. DUNLOP

16 November, 1983

N.S.W. Annual Dinner and Special Technical Meeting

92 members and guests arrived at Sydney Town Hall to hear the Grand Old Pipe Organ, see the restoration works and internal mechanism. Instead, owing to the operation of Murphy's Law (in the form of The Guitar Trio), they were treated to an enlightening talk by Sydney City Organist, Robert Ampt in the illustrious Council Chamber.

57 members and guests (of the 77 confirmed bookings) then went on to dinner and were treated to a sumptuous Greek repose at the Cyprus Helena Club.

J. MAZLIN

● SOUTH AUSTRALIA

Divisional Committee 1983/84

Chairman: P. Swift.
Vice-Chairman: D. Bies.
Secretary: A. Jones.
Treasurer/Registrar: K. Martin.
Minute Secretary: M. Lane.
Bulletin Liaison/Newsletter: R. Williamson.
Federal Councillors: R. Boyce, P. Swift.
Committee: M. Zockel (two other vacancies to be filled).

Sub-Committees:

Activity: D. Bies, P. Swift, R. Williamson, M. Zockel.
Membership: R. Boyce, A. Jones, P. Swift.
Membership Certificate: M. Lane, R. Williamson.

(i) H. Dean retired from the Committee after several years of invaluable service.
(ii) The membership certificate designs have been approved, printed and forwarded to Federal Council for issue.

Technical Meetings:

June 1983

John Lambert, Manager, Noise Abatement Branch of the S.A. Department of Environment and Planning, discussed aspects of the S.A. Noise Control Act and Regulations. He highlighted several deficiencies which have existed since enactment in 1976 and described the reviews currently being undertaken with a view to future changes to the legislation. In particular he addressed the problems of legislating for road traffic noise control, and the impact of excessive environmental noise on the use categories defined in the existing regulations, with special reference to the advantages and disadvantages of the E.P.A. method in Victoria.

July 1983

John Dunlavy, Managing Director of Duntech International Ltd., discussed recent research in his organisation relating to the importance of *Phase Linearity on the Perceived Quality of Loudspeaker Reproduction.* He pointed out that fewer than 1 per cent of all speaker designs, regardless of cost, are capable of reproducing a recognisable square-wave within the important regions of the audible spectrum.

Recent tests have substantiated the view that modest departures from phase linerality ($\pm$ 90° of phase error) over the audible spectrum are virtually undetectable if they occur within the amplifying portion of the audio system. However, in multiple driver systems, the human ear seems capable of detecting non-linear phase anomalies — detection often being enhanced as the listening distance from the speaker decreases to less than 4 metres.

A demonstration was given using a specially designed speaker system which could be remotely switched for either minimum phase or non-minimum phase performance while maintaining identical frequency response characteristics.

August 1983

Professor Bogner, Department of Electrical and Electronic Engineering at the University of Adelaide, presented details of his research into *Ultrasonic Remote Sensing Through Air and Fibre,* with particular application for automated wool severing and harvesting. Although based on a sonar system, specific problems are posed by multipath effects, severe clutter, frequency-dependent and fluctuating attenuation, transducer limitation of transmitted power and rapid up-dating requirements. Professor Bogner described some of his innovative methods of focussing ultrasonics in air, the characteristics and limitations of the medium as well as pulse-dispersion techniques.

October 1983

Mr. Lucien Parent, Piano Tuner and Restoration Consultant, presented an illustrated and practical demonstration of the evolution of the piano from the clavichord to the present modern grand piano.

Various aspects of piano design were discussed including the development of the iron frame, double and triple stringing, sounding board configuration, wire layout and design, key and basemer operation and fine tuning parameters. Mr. Parent claimed that he could make up to 39 adjustments on any key and string position, each of which could change the tone and response of the note. He demonstrated the importance of balancing the harmonics for each wire, particularly in the bass notes and discussed his development of a one metre piano, capable of reproducing the quality of a full sized instrument.

Proposed Meetings for 1983/1984

(1) Tour of the new S.A. Law Courts Building.
(2) Visit to the Vibration Laboratory at Mitsubishi.
(3) Visit to the S.A. Film Corporation Studios at Hendon.
(4) Digital Playback Techniques — joint meeting with the Audio-Engineering Society.
(5) Aspects of Aircraft Noise in Australia.

(Specific dates and topics will be finalised by the next issue of the Bulletin).

● Limited Edition Acoustical Products Manual

The Chadwick Group has recently published a limited edition Manual containing test data on a variety of Chadwick acoustical products available.

Test data contained in the Manual covers both Australian and overseas testing on a variety of sound absorption and high sound transmission loss ceilings and composite roof and ceiling systems.

The Chadwick Group has specialised in acoustical contracting for the past fifteen years and has developed and tested many varying systems to satisfy a variety of both acoustical and structural requirements.

Some of the major projects with which the Chadwick Group has contributed to the acoustical performance of, include:

Tullamarine International Air Terminal,
Sydney International Air Terminal,
Sydney Entertainment Centre,
Queensland Cultural Centre.

To obtain a copy of this limited edition Manual please make contact with Chadwick Industries Pty. Limited, 292 Burns Bay Road, Lane Cove, N.S.W. 2066. Phone: (02) 428 1388. Telex: 25356.

● Structural Monitoring of Off-shore Oil Platform

An Australian consulting engineer, **The Vipac Group,** claims a world first for using wave excitation to study behaviour of an off-shore oil platform.

Large mass shakers are usually used to periodically test the structural response of production jackets; however, wave excitation has the potential to provide continuous data without the use of auxiliary excitation.

Regular inspection by diving is expensive and its efficacy is hampered by marine growth. Sea conditions may be hazardous.

Vipac fitted an array of accelerometers to one leg and the deck of the North Rankine "A" structure, and designed the **Off-shore Real-time Accelerometer Condition monitor (OAC)** from scratch, to collect data.

Analysis of structural dynamic response confirmed the finite element model prediction of the design. Regular surveys will be carried out as jacket outfitting is completed, and during the life of the structure.

Structural dynamic analysis using ambient or artificial excitation may be applied to buildings, bridges, crane booms and complex mining structures.

Further information: John C. Simmons, B. Mech. E, MIE Aust., Vipac Melbourne (03) 240 8471.

● VICTORIA

AGM and address by Dr. Aram Glorig

The Victoria Division's Annual General Meeting was held on the 28th September at the RMIT. Of the five positions made vacant due to the fixed term retirements only four were immediately filled. The fifth position was however, filled at a later date in accordance with the procedures minuted at the AGM.

The office-bearers for this division are now:

Chairman, G. E. Harding.
Vice-Chairman, D. C. Rennison.
Secretary, J. H. Watson.
Treasurer, G. A. Barnes.
Registrar, J. F. Upton.
Minute Secretary, J. B. Fowler.
Federal Councillors — G. E. Harding, D. C. Rennison, J. H. Watson.
Committee Members—H. S. Chan, G. B. Cooper, J. D. Modra, S. Samuels.

Following the AGM **Dr. Aram Glorig** gave an address on his experience with America's hearing conservation programmes and the results of recent research into audiology and otology. Dr. Glorig, whose clinic in Los Angeles specialises in industrial and forensic otology, was in Australia to promote Deafness Awareness Week. Dr. Glorig commenced his address stating that there was a real need for education of the public, in all age groups, to the dangers of excessive noise. He cited an example of programmes operating in schools where workers who had worked in noisy industries gave talks on the implications of hearing impairment to school children.

It was interesting to hear Dr Glorig's view on the current criteria used to assess **industrial noise.** He felt that the equal energy concept of 3dB increase being allowed for each halving of exposure was conservative and favoured the OSHA criteria of a 5dB allowance. He did say, however, the issue was not clear cut, and that he was aware of the view that 3dB allowance should apply up to a certain level above which the 5dB allowance would apply. He stated that this scheme would make the measuring of noise dose very difficult.

Dr. Glorig moved on to the topic of **financial compensation.** Compensation for hearing loss is an expanding area of litigation in America and this in turn had brought to light many technical difficulties. One example discussed was of a worker who was employed in several noisy industries during his working lifetime. How could the responsibility for the loss be apportioned? Dr. Glorig showed that for constant exposure, most Noise Induced Permanent Threshold Shift occurs in the first decade or so. He said this and similar research, was being used to resolve issues in this type of case.

Dr. Glorig finished his talk stating that he had recently had a small magnet cemented to one of his ear drums. This, he said, would aid further audiological studies, as the ear drum could be directly excited by a small coil inserted in the ear canal. There were also, of course, possible applications for a specialist type of hearing aid. He said there were many problems still to be solved with this type of aid. One problem was that of induced hum pickup, this being clearly apparent when he recently stood too near a slide projector.

Technical Meeting:

On the 6th October a visit of inspection was made of the **Engineering Development Establishment** at Maribyrnong. E.D.E. is the primary engineering facility for the Australian Army and as such is responsible for a vast range of engineering and investigations studies concerned with the development, proving and maintaining of equipment.

The evening commenced with a briefing by **Rex Christensen,** Acting Commander, on the background of E.D.E., and this was followed by an audio visual on vehicles being tried at the Moonageeta Proving Ground. Following this, the group was divided into several parties for the various inspections and demonstrations. These included:

- engine testing and duty cycle investigations.
- inspection of the site for a very large shaker table with a capacity of 5 tonnes at 1.5g.
- climatic testing facilities.
- the use of a two channel, miniature tape recorder for the recording of dynamic stress on equipment under simulated field conditions.
- noise and vibration acquisition and analysis systems.
- the development of electrical and communications systems and testing of equipment in the electrically screened rooms.
- display of electrical generating sets.
- mobility modelling of vehicles over rough terrain using computer techniques.

The evening was well attended by members; and our thanks go to the more than a dozen personnel of E.D.E. who prepared and demonstrated the various activities.

JIM FOWLER

PUBLICATIONS EXCHANGE

For some time the Australian Acoustical Society has operated an exchange of publications scheme with a number of other societies and acoustical bodies. As of November 1983 the following organisations have agreed to such an arrangement. The chief publication is shown in brackets. These are now being received regularly and will be added to the Society's collection in the library of the National Acoustic Laboratories, Millers Point, Sydney.

Acoustical Society of America
(J. Acoust. Soc. Am.).

Acoustical Society of Japan
(J. Acoust. Soc. Japan).

Canadian Acoustical Association
(Canadian Acoustics).

Acoustical Society of China
(Chinese J. of Acoustics; Acta Acustica).

Dept. of Speech Communication and Music Acoustics, Royal Institute of Technology, Stockholm
(Quarterly Progress and Status Report)

International Institute of Noise Control Engineering
(Newsletter)

Institute of Sound & Vibration Research, Southampton

Polish Acoustical Society
(Archives of Acoustics)

Back Issues of the Bulletin

A limited supply of back issues is available. The cost, including postage, is as follows:

Prior to Vol. 10, A$5.00 per issue.
Vol. 10, A$7.00 per issue.

Orders may be placed with Mrs. Toni Benton, School of Physics, University of N.S.W., KENSINGTON, N.S.W. 2033.

AUDIOLOGICAL SOCIETY OF AUSTRALIA

6th NATIONAL CONFERENCE

Call for Papers

The 6th National Conference of the Audiological Society of Australia will be held at Coolangatta, Queensland, on 18th-20th May, 1984. The deadline for receipt of offers for papers is 13th January, 1984.

For details contact: The Programme Chairman, Neil Lewis, Department of Speech and Hearing, University of Queensland, St. Lucia, Brisbane 4067.

WELCOME

To all readers of this column; welcome. In this issue we have news of moves by many members. If the column appears parochial and concerned mainly with members of the Victoria Division then readers, you have only yourselves to blame for not providing information to your People Columnist about activities of people in your State.

* * *

BERNIE COOPER LEAVES A.C.I.

Bernie Cooper M.A.A.S. has left A.C.I. Fibreglass after 13 years. Surely all members of the Victoria Division know Bernie and respect him for the mine of information concerning all aspects of fibreglass that Bernie was. Should anybody need reminding Bernie was that big fellow over 2 metres tall. Bernie has promised to provide your People Columnist with full details of what his new enterprise in the acoustics field will be for the next issue of the Bulletin.

* * *

DENIS CALE LEAVES B & O

After many many years at Bang & Olufsen, **Denis Cale** has left them due we understand to the present economic circumstances. Bang & Olufsen for those members who don't know are Danish manufacturers of high quality hifidelity sound reproducing equipment, and Denis was always able to help one select a loudspeaker or similar. Perhaps Denis too can tell us what he is doing for the next issue of the People Column.

* * *

FRANK FAHY'S VISIT

By the time you read this you will probably have heard **Frank Fahy** talk to your division. If you missed out you missed out on some very good talks. In Victoria Frank spoke to the A.A.S. at a seminar organised jointly by Monash University and the A.A.S. His talk on Sound Fields in Factories was a delight to listen to; he spoke lucidly and with the confidence of having been in factories and made measurements of the sound fields in them. It was most encouraging to find how well up with the latest work Australia is in that the overseas people don't know the answers to some of the ticklish questions much better than we do. In New South Wales I gather Frank Fahy addressed two meetings one on Sound Fields in Factories and one on Sound Intensity Measurements.

* * *

PITSTOCK PTY. LTD. MOVES

Pitstock Pty. Ltd. is a sustaining member of the A.A.S. and will be known to readers as the Australian and New Zealand licencee for Industrial Acoustics Company, Inc. of U.S.A. and also for their manufacture of Phoenix fans. They have advised us that they have recently moved to new offices at **5-15 Cottam Avenue, Bankstown, N.S.W. 2200.** Their new telephone number is (02) 708 2099. Your People Columnist thanks Mr. J. C. Fryer, Engineering Sales Manager, for providing us with this information.

* * *

DAVID EPSTEIN M.A.A.S. TO ISRAEL

From **David Epstein's** subscription notice we learn that he is at present living and working in Israel for an indefinite period. David is working at the Environmental Protection Service of the Ministry of Interior. Perhaps David when you read this you might write us a short note about acoustics in Israel.

CORRECTION

In the last People Column I reported on **Carolyn Mather's** resignation from the Society upon taking up an appointment with the Public Service Board. From Carolyn I have had a nice letter pointing out that in fact she has left the Public Service Board where she was Senior Consultant in the Management Consultancy Division and has now taken up the position of Assistant Director, Regulation and Standards in the recently restructured Victorian Ministry of Consumer Affairs. Carolyn hastens to assure the Society of her continued interest in acoustics and hopes one day to renew her active involvement in the Society.

* * *

VICTORIAN E.P.A. UNDER NEW MANAGEMENT

Now that we have the attention of all readers we can report that the **Environment Protection Authority** which was previously a department of the Ministry for Conservation is now a department of the Ministry for Planning and Environment. Rumour has it that when the restructuring of four Ministries to two Ministries was being planned and considered that it was planned to have a new Ministry of Planning and Environment. This could easily have led to the acronym MOPE; hence the choice of for instead of of.

* * *

F18 TEST CELL

A lot of work is being done in a short time by consultants and contractors associated with the F18 test cell. **Louis Challis** is the Acoustical Consultant for the project. The contractors or suppliers of noise control equipment include, so I have heard, Cord Noise Control, Gardner & Naylor, NAP Silentflo, and Sound Attenuators. These organisations we understand have received orders for tens or hundreds of thousands of dollars of absorptive panels and similar items to form part of the noise control treatment for the test cell. I also understand that for the first time the National Acoustic Laboratory and the Departments of Housing and Construction have seen fit to consider that sound isolating doors could be made in Australia with adequate performance for the test cell.

* * *

TOILET TALK LANGUAGE

From **Peter Fernside** I have learnt of work that he was involved with whilst in America concerning communication via toilets. Apparently in prisons prisoners learn to break the water seal in toilet bowls so that there is an air path between toilets. Having broken the water seal with towels or similar the prisoners can then communicate with each other by shouting down the toilets. In fact I am told one male prisoner proposed to a female prisoner on another floor; had his proposal accepted and was later married. Peter Fernside's involvement was to devise ways and means of preventing this communication between prisoners.

* * *

PETER KNOWLAND & ASSOCIATES MOVES

Peter R. Knowland & Associates Pty. Ltd., Acoustical Consultants, have moved to **Palm Court, 3,281 Pacific Highway, Crows Nest 2065.** Their telephone number remains unchanged.

* * *

BORDER ACOUSTICS MOVES

John Bowers, the Principal of Border Acoustics has advised us that his business has shifted to **13 Young Street, Mooroopna, Victoria, 3629;** with the telephone number (058) 252 071.

NEW MEMBERS

We have pleasure in welcoming the following new members of the Australian Acoustical Society:

Member: Dr. R. B. Bullen, N.S.W.; Mr. J. T. Gressieux, N.S.W.; Mr. P. J. Bunker, Vic.; Mr. P. A. Walsh, Vic.

Subscriber: Mr. P. E. Peploe, N.S.W.

Student: Mr. A. I. Zelnik, A.C.T.; Mr. G. N. Jenner, N.S.W.

* * *

APPEAL FOR NEWS

Surely there must be many companies in the Acoustical field who have new products that could have mention made of them in this column; similarly there must be many members who are moving to new jobs or positions. Please convey all of these to me so they may be mentioned in this column. News of people should be forwarded to — **Graeme E. Harding & Associates Pty. Ltd., 22a Liddiard Street, Hawthorn, Victoria 3122.**

GRAEME HARDING

Technical books at discount rates

The Australian Acoustical Society has an account with a major bookshop in the United Kingdom and offers a technical book purchase service to members of the Society on a no profit basis.

Discounts vary according to country of publication and generally are a maximum for British ranging to a minimum for American sourced publications. Books are ordered on written advice from members who should specify if the book is to be placed on back order if not immediately available. Members pay the invoiced amount (which includes postage) on delivery of the book.

Advantage: Cheap books.

Disadvantage: There is a delay of about 14 to 16 weeks on delivery of books unless airmail or accelerated surface mail is specified.

Please send orders to:

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A Simplified Probabilistic Evaluation Method For The Sound Insulation Effect Of Barriers

Mitsuo Ohta
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Maritime Safety Academy
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ABSTRACT: For a stationary random input noise of arbitrary non-Gaussian distribution attenuated by passing through a sound insulation barrier, a simplified practical method of evaluating the output level distribution at an observation point is theoretically deduced. The validity of the theoretical deduction is experimentally confirmed using observed noise attenuation data. The experimental results are in good agreement with the theoretically predicted probability curves.

1. INTRODUCTION

In the practical engineering field of noise control, a sound insulation barrier is very often constructed to produce attenuation of acoustic noise. The acoustical design and/or the evaluation problem of barriers have been already considered by many investigators [1]. Almost all of these studies, however, were confined only to the effects on deterministic signals or gross average evaluations of shielding effects.

The practical problem of the acoustical design and/or the evaluation of sound insulation barrier, needs to take the following points into consideration:

(i) In an actual living noise environment, the amplitude of the noise emitted from a sound source shows very often an irregular time pattern with pronounced maxima and minima, and the probability distribution is not a standard Gaussian distribution form. Furthermore, the energy associated with a particular frequency band fluctuates with time.

(ii) The statistics such as median and L_x sound level (like L_5, L_{10}, L_{50} and L_{90}) defined as the $(100-x)$ percentage point of sound level distribution, as well as the lower order statistics like L_{eq} (substantially the 1st order statistics of energy) are very important for the actual noise evaluation and regulation problems. Thus it is necessary to obtain an explicit expression of the output noise level distribution function.

(iii) It is important to relate the output noise evaluation indices L_x to the statistical properties (such as, the probability distribution characteristics, frequency spectrum and its temporal change, etc) of the noise fluctuation emitted from sound sources and the frequency characteristics of the sound insulation barrier.

In this paper, a simplified statistical evaluation method for predicting the noise level distribution (or noise energy distribution) is derived for the case of an arbitrary probability distribution for the random noise incident on the barrier. The emphasis in the present study is focused on how to predict the noise evaluation indices such as L_x and/or L_{eq} using information on the statistical properties of the random noise sound source and the frequency characteristics of the sound insulation barrier. Finally, the validity of the present theory is experimentally confirmed by applying it to actually observed data. The experimental results are in good agreement with the theoretically predicted probability curves.

2. THEORETICAL CONSIDERATION

2.1 Simplified Expressions of Noise Energy Distribution for Practical Use

To predict the noise evaluation index, L_x, it is first necessary to find an explicit expression for the noise level or noise energy distribution functions. Various kinds of approaches can be used to establish the form of this probability distribution. To establish a practical evaluation method, simple and known formulations for the probability expression are employed. The effect of the statistical properties of the noise energy and the frequency characteristics of the sound insulation barrier on the resultant noise level (or noise energy) distribution at an observation point will be reflected in the parameters contained in the postulated probability expressions.

The random noise energy, E, fluctuates only in the non-negative region $[0, \infty)$, and this requirement is met by the Gamma and lognormal distribution functions, so they are chosen as two simplified and basic frameworks of the probability density expression, P(E) (the mathematical backgrounds for employing the above two probability density expressions are given in Appendix [A]).

(A) Gamma distribution:

$$P(E) = \frac{1}{\Gamma(m)\ S^m} \exp(-E/S)\ E^{m-1} \quad (1)$$

with

$$m = \frac{<E>^2}{<(E-<E>)^2>}, \quad S = \frac{<(E-<E>)^2>}{<E>}. \quad (2)$$

(B) Lognormal distribution (see Appendix [B]):

$$P(E) = \frac{1}{\sqrt{2\pi}\ \sigma\ E} \exp\left\{-\frac{(\ln E - \mu)^2}{2\sigma^2}\right\} \quad (3)$$

with

$$\left.\begin{aligned} \mu &= <\ln E> = \ln <E> - \tfrac{1}{2}\sigma^2, \\ \sigma^2 &= <(\ln E - <\ln E>)^2> \\ &= \ln\left\{\frac{<(E-<E>)^2>}{<E>^2} + 1\right\}, \end{aligned}\right] \quad (4)$$

where $< * >$ denotes an averaging operation with respect to random variable $*$. It should be noted that we can increase the prediction accuracy by using higher order terms in the probability density expression [see (A-5) or (A-11) of Appendix A]. We can establish a prediction procedure on the basis of these simplified forms of equations (1) and (3) using information on moment statistics of the noise energy fluctuation, E. The general expressions for an arbitrary distribution are series expansion probability expressions taking the above Gamma and lognormal distribution functions respectively as the first terms in the expansion (see Appendix [A]).

2.2 Relationship between Frequency Characteristics of Barrier and Parameters of Energy Probability Expression

In order to determine the above parameters (m,s) or (μ,σ^2) contained in the probability density expressions, Eqs (1) and (3), it is first necessary to calculate both the mean value and variance of the noise energy, E, at an observation point. Now, let E_i (i = 1, 2, ..., N) be the input noise energy fluctuation existing in the ith frequency band for random noise emitted from the sound source, and let the transfer coefficient a_i (i = 1, 2, ..., N) denote the energy frequency characteristic of a sound insulation barrier at the centre frequency, f_{ci}, of the ith octave band (or one-third-octave band). Based on the additive property of energy quantities, the output noise energy fluctuation, E, at an observation point can be related to the energy in each frequency band by:

$$E = \sum_{i=1}^{N} a_i E_i . \quad (5)$$

Thus, the mean value and the variance of E can be easily estimated as:

$$<E> = \sum_{i=1}^{N} a_i <E_i>$$

and

$$<(E-<E>)^2> = \sum_{i=1}^{N}\sum_{j=1}^{N} a_i a_j <E_i E_j> - <E>^2 \quad (6)$$

by using the first and second order statistical moments of noise energy fluctuation, E_i (i = 1, 2, ..., N), and the frequency characteristic, a_i, of the sound insulation barrier. Thus, two parameters (m,s) (or (μ, σ^2)) in Eq. 1 (or Eq. (3)) can be directly determined by substituting Eq. (6) into Eq. (2) (or Eq. (4)).

2.3 Estimation of Frequency Characteristics of Sound Insulation Barrier

Now, let us consider the sound insulation barrier shown in Figure 1. The Fresnel number, N_i, at a centre frequency, f_{ci}, of the ith octave band (or one-third-octave band) can be determined as [1]:

$$\left.\begin{aligned} N_i &= 2\ \delta\ f_{ci}/c, \\ \delta &= d_1 + d_2 - d, \end{aligned}\right] \quad (7)$$

where c is the speed of sound. As is well-known, the sound attenuation, ΔL_i, due to the construction of barrier, is predicted by use of the so-called Maekawa's acoustical evaluation chart for a barrier based on a value of N_i (e.g. see Ref. [2]). Thus, the energy frequency characteristics, a_i, of sound insulation barrier can be easily estimated as follows:

$$a_i = 1/10^{\Delta L_i/10} \quad (i = 1, 2, ..., N) \quad (8)$$

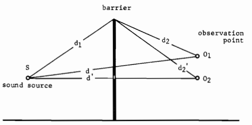

Figure 1: Arrangement of sound source, barrier and observation points.

In this case, E_i ($i = 1, 2, \ldots, N$) shown in Eq. (5) is the noise energy fluctuation existing in the ith frequency band-width at an observation point O_1, or O_2, before the sound insulation barrier is constructed. Of course, it is possible to estimate experimentally this frequency characteristic, a_i, from the actually observed data. The main purpose of the present study, however, is to predict theoretically the noise probability distribution after construction of the sound insulation barrier. The experimentally measured frequency characteristics will therefore not be used in the calculations.

TABLE 1

Energy frequency characteristics a_i of barrier

1/1 octave band centre frequency (Hz)	h = 0.8 (m)	h = 1.3 (m)
250	0.07771	0.19498
500	0.04023	0.05370
1000	0.01943	0.04897
2000	0.00996	0.02754
4000	0.00479	0.01479

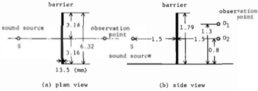

Figure 2: Layout of sound source, barrier and observation points.

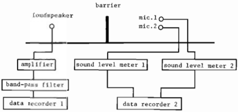

Figure 3: Block diagram of experimental arrangement.

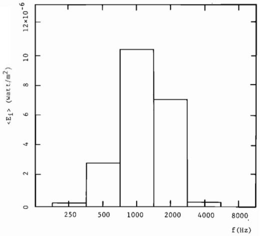

Figure 4: The averaged distribution of frequency spectrum for energy fluctuation of road traffic noise.

3. EXPERIMENTAL CONSIDERATION

The experiment was done at night (20.00 pm — 03.00 am) in a playground of our university to avoid the effect of surrounding background noise. Figure 2 shows the layout of the sound source, the barrier and two observation points. The barrier is made of a plywood panel (height: 1.79 (m), width: 6.32 (m) and thickness: 13.5 (mm)). The block diagram of the experimental arrangement is shown in Figure 3.

Using a band-pass filter and amplifier, a road traffic noise wave (road traffic noise is used as one typical example of actual random noise fluctuation of arbitrary distribution type) recorded in advance on data recorder 1 was supplied to the loudspeaker. The received acoustic waves by microphones 1 and 2 are both recorded using data recorder 2. The averaged distribution of noise energy, $<E_i>$ ($i = 1, 2, \ldots, 5$), existing in the ith frequency band of noise fluctuation radiated from the loudspeaker is shown in Figure 4. To simplify the experimental procedures, only octave-band analysis was used (accordingly, the value of N in Eq. (5) is equal to 5).

The frequency characteristic, a_i, of the barrier estimated by using Maekawa's evaluation chart [2] is shown in Table 1.

Figure 5 shows a comparison between the theoretically predicted curves using Eqs (1) and (3) and the experimentally sampled values for the cumulative distribution of noise energy fluctuation, in the case when the height of the observation point is 0.8 (m) (after constructing the barrier). The same experimental results are shown in Figure 6 in the form of a noise level distribution together with the data observed before constructing the sound insulation barrier. In another case, the height of the observation point was 1.3 (m), and a comparison between theory and experiment for the noise energy distribution is shown in Figure 7. The same results for noise level distribution are shown in Figure 8, together with the data on the input. From these figures, it must be noticed that the prediction error of the present method for noise evaluation indices, L_5, L_{10} and L_{50} usually used in the noise evaluation and/or the regulation problem is about $\pm$ 1 dB.

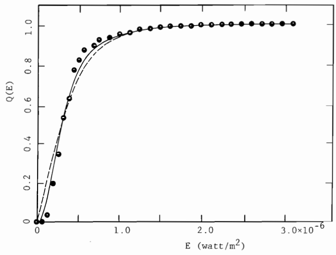

Figure 5: Comparison between theoretically predicted curves and experimentally sampled points for cumulative noise energy distribution (height of observation point: 0.8 (m)). Experimentally sampled points are marked • and theoretically predicted curves by use of Eqs (1) and (3) are shown by the dashed and full lines respectively.

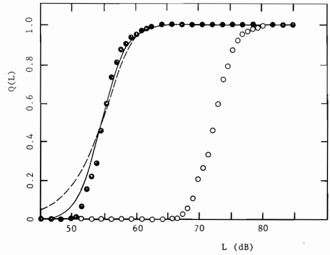

Figure 6: Comparison between theoretically predicted curves and experimentally sampled points for cumulative noise level distribution (height of observation point: 0.8 (m)). Experimentally sampled points are marked • and theoretically predicted curves by use of Eqs (1) and (3) are shown by the dashed and full lines respectively. Experimentally sampled points observed before constructing barrier are marked o.

4. CONCLUSION

A simplified prediction method for predicting the probability distribution for either noise energy or noise level after constructing a sound insulation barrier has been theoretically proposed, for a stationary random noise of an arbitrary distribution being attenuated by passing through the sound insulation barrier. The effect of the statistical properties of input noise emitted from the sound source and the frequency characteristics of the sound insulation barrier on the transmitted noise level or noise energy probability distribution is reflected in each parameter of the probability density expression. The validity of our theoretical evaluation method has been experimentally confirmed by applying it to actual noise data. The experimental results are in good agreement with theoretical curves.

Research on the probabilistic evaluation of sound insulation barriers is still in an early stage of study. The paper has focused only on some fundamental aspects. There still remain many problems when considering actual cases, and this will be a future study.

ACKNOWLEDGEMENTS

The authors would like to express their grateful thanks to Dr K. Hatakeyama and Mr U. Yoh for their helpful assistance. The authors additionally acknowledge many constructive discussions in the annual meeting of the Acoustical Society of Japan and the First Acoustics Conference of West Pacific Region.

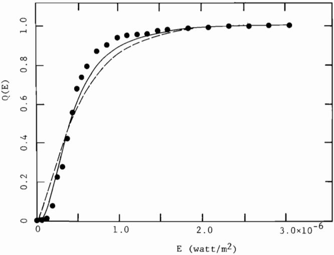

Figure 7: Comparison between theoretically predicted curves and experimentally sampled points for cumulative noise energy distribution (height of observation point: 1.3 (m)). Experimentally sampled points are marked • and theoretically predicted curves by use of Eqs (1) and (3) are shown by the dashed and full lines respectively.

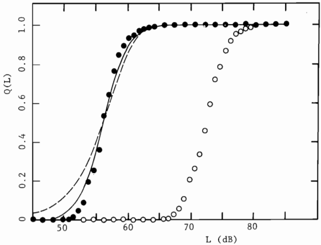

Figure 8: Comparison between theoretically predicted curves and experimentally sampled points for cumulative noise level distribution (height of observation point: 1.3 (m)). Experimentally sampled points are marked • and theoretically predicted curves by use of Eqs (1) and (3) are shown by the dashed and full lines respectively. Experimentally sampled points observed before constructing barrier are marked o.

APPENDICES

[A] Theoretical Background to Employment of Gamma and Lognormal Probability Distribution Functions

Paying special attention to the requirement that noise energy fluctuates always in a non-negative region $[0,\infty)$, the probability density function of noise energy can be reasonably expressed in the general form of a statistical Laguerre expansion series [3,4]:

$$P(E) = \frac{1}{\Gamma(m)\, S^m} \exp(-E/S) \cdot E^{m-1} \{1 + \sum_{n=3}^{\infty} A_n L_n^{(m-1)}(E/S)\} \qquad \text{(A-1)}$$

with

$$m = \frac{<E>^2}{<(E-<E>)^2>} \quad , \qquad S = \frac{<E>}{m}$$

and

$$A_n \triangleq \frac{\Gamma(m)n!}{\Gamma(m+n)} <L_n^{(m-1)}(E/S)> \quad , \qquad \text{(A-2)}$$

where $L_n^{(m-1)}(.)$ denotes the associated Laguerre's polynomial. By using the following relationship derived from the definition of the associated Laguerre's polynomial [3,4]:

$$P_\Gamma(Y,m)\ L_n^{(m-1)}(Y) = \frac{\Gamma(m+n)}{\Gamma(m)n!} P_\Gamma^{(n)}(Y,m+n) \qquad \text{(A-3)}$$

with

$$P_\Gamma(Y,m) \triangleq \frac{1}{\Gamma(m)} \exp(-Y)\ Y^{m-1}$$

(standard Gamma distribution function) (A-4)

Eq. (A-1) can be rewritten as

$$P(E) = P_\Gamma(E;m,S) + \sum_{n=3}^{\infty} B_n \left(\frac{d}{dE}\right)^n P_\Gamma(E;m+n,S) \qquad \text{(A-5)}$$

with

$$P_\Gamma(E;m,S) \triangleq \frac{1}{\Gamma(m)\ S^m} \exp(-E/S)\ E^{m-1}$$

(Gamma distribution function) (A-6)

and

$$B_n \triangleq S^n <L_n^{(m-1)}(E/S)> \qquad \text{(A-7)}$$

From Eq. (A-5), we can find that the probability density expression for a non-negative random variable of arbitrary distribution type can be always expressed in a universal form in which the well-known Gamma distribution function is the first expansion term and its successive derivatives are involved in the second and higher expansion terms. The various statistical properties of random variables are reflected in the values of each expansion coefficient.

Since the random variable E fluctuates in a non-negative region $[0,\infty)$, another random variable, Y, obtained by the non-linear logarithmic transformation ($y = \ln E$), fluctuates in both positive and negative regions $(-\infty,\infty)$. The probability density function of random variable fluctuating in positive and negative regions $(-\infty,\infty)$ can be generally expressed in a form of a statistical Hermite expansion series [3,4]. Thus, by the use of a measure-preserving transformation, the probability density function of noise energy fluctuations, E, could also be expressed as follows:

$$P(E) = \frac{1}{\sqrt{2\pi}\ \sigma\ E} \exp\left\{-\frac{(\ln E-\mu)^2}{2\sigma^2}\right\} \cdot \left\{1 + \sum_{n=3}^{\infty} C_n H_n\left(\frac{\ln E-\mu}{\sigma}\right)\right\} \qquad \text{(A-8)}$$

with

$$\mu = <\ln E> \ , \qquad \sigma^2 = <(\ln E-\mu)^2> \ , \qquad C_n = \frac{1}{n!} <H_n\left(\frac{\ln E-\mu}{\sigma}\right)> \ . \qquad \text{(A-9)}$$

By using the relation between the Gaussian distribution function and the Hermite polynomial [3,4]:

$$\frac{1}{\sqrt{2\pi}\ \sigma} \exp\left\{-\frac{(Y-\mu)^2}{2\sigma^2}\right\} H_n\left(\frac{Y-\mu}{\sigma}\right) = (-1)^n \sigma^n \frac{d^n}{dY^n} \frac{1}{\sqrt{2\pi}\ \sigma} \exp\left\{-\frac{(Y-\mu)^2}{2\sigma^2}\right\} \qquad \text{(A-10)}$$

Eq. (A-8) can be rewritten as follows:

$$P(E) = P_\ell(E;\mu,\sigma^2) + \sum_{n=3}^{\infty} D_n \left(\frac{d}{dE} E\right)^n P_\ell(E;\mu,\sigma^2) \quad \text{(A-11)}$$

with

$$P_\ell(E;\mu,\sigma^2) \triangleq \frac{1}{\sqrt{2\pi}\,\sigma\, E} \exp\left\{-\frac{(\ln E - \mu)^2}{2\sigma^2}\right\}$$

(lognormal distribution function) (A-12)

and

$$D_n \triangleq (-1)^n \sigma^n C_n \quad . \quad \text{(A-13)}$$

From the above theoretical results, we can find that the general probability expressions, Eqs (A-5) and (A-11), could be universally applicable for various kinds of random processes which fluctuate in the non-negative region $[0,\infty)$. In section 2, therefore, we have chosen the first expansion terms, the Gamma and the lognormal distribution functions, of the above general expressions as the first approximation of the probability functions for random phenomena, since the emphasis is on establishing a simplified method of probability evaluation for practical use.

[B] Derivation of Eq. (4)

Using Eq. (3) and the following relation:

$$\langle E^n \rangle = \langle (\exp(\ln E))^n \rangle = \langle \exp(n \ln E) \rangle \quad \text{(B-1)}$$

we can easily obtain the nth order moment with respect to E, as follows:

$$\langle E^n \rangle = \int_{-\infty}^{\infty} \exp(nx) \frac{1}{\sqrt{2\pi}\,\sigma} \cdot \exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\} dx = \exp\{\mu n + \tfrac{1}{2}\sigma^2 n^2\} \quad (n = 1, 2, \ldots) \quad \text{(B-2)}$$

Easily, the following relationships are obtained:

$$\left.\begin{aligned} \mu + \tfrac{1}{2}\sigma^2 &= \ln \langle E \rangle \quad (\text{for } n = 1), \\ 2\mu + 2\sigma^2 &= \ln \langle E^2 \rangle \quad (\text{for } n = 2). \end{aligned}\right] \quad \text{(B-3)}$$

Thus, solving the above equations for μ and σ^2 yields Eq. (4).

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(Received 5 July 1983)

DATA FROM THE EDGE OF THE SOLAR SYSTEM

The Voyager 2 spacecraft launched by NASA in 1977 will encounter the planet Uranus in late January 1986. The data from this furthest ever exploration of the solar system will be relayed back from the spacecraft via Australia, the U.S. and Spain.

Special arrangements have been completed to link the CSIRO radio telescope at Parkes with the antennas at Tidbinbilla Tracking Station. This will allow for the fastest transmission of data from the spacecraft and hence enable more complete pictures of Uranus to be built up.

The establishment of a microwave link between Parkes and Tidbinbilla will allow the two facilities to be arranged together in real time and this will create a "first" in space exploration as well as an extension of Australia's long term scientific capacities. It will complement developments for the Australia Telescope.

The Australian tracking stations were the first to receive television pictures from the moon from Apollo 11, and provided support for the Viking landing on Mars, for the shuttle and for Voyager's previous encounter with Jupiter and Saturn.

(Laboratory News, May 1983)

"Timbre Vibrato"

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Measurements of the constituent steady-state harmonics of sounds from various musical instruments show that in general, the amplitudes are spread over a significant range.

This preliminary study has been restricted to the notes A (440 Hz; 880 Hz; 1320 Hz; . . .) from a violin (muted and unmuted), a clarinet and a flute, and also the note A (220 Hz; 440 Hz; 660 Hz; . . .) from a bassoon, french horn and human voice (baritone).

To measure the spreads in amplitude of the harmonics, twelve measurements are taken at different parts of the steady state, for the principal harmonics in each sound. Tables 1 and 2 show the analysis of selected notes from each instrument. Spreads of 5 dB or less are shown in italics.

In order to check that the observed spreads are not produced by deficiencies in the spectrum analyser (Hewlett Packard 3582 A) measurements were also made on an artificial three-component sound produced by sine-wave generators at frequencies of 440 Hz; 880 Hz and 1320 Hz. The measured spreads in amplitudes for these components were 0.3 dB; 0.4 dB and 0.5 dB respectively.

These values are small compared with the spreads of the order of 10 dB per harmonic in the case of sounds from the musical instruments.

The manner in which these spreads vary over the harmonic range for the different instruments may contribute towards an understanding of musical timbre, and is the subject of current investigations.

It would appear that the spread is produced by perturbations at the source where each sound is excited. For example, in the case of the violin, the slipstick motion of the vibrating string and the slight variations of force and position of the bow with respect to the string all contribute to the spreads in amplitudes.

In designing electronic musical instruments, it would appear that if the spreads in amplitude (as observed in actual instruments) could be incorporated into the electronic instruments, then an additional degree of similarity may be achieved.

TABLE 1

Spread in Amplitudes (dB) For the First Eleven Harmonics in the Note A (440 Hz; 880 Hz; 1320 Hz; . . .) For Two Separate Soundings From Each Instrument (Violin Clarinet and Flute)

Instrument	Harmonic Number	1	2	3	4	5	6	7	8	9	10	11	Mean Spread (dB)
Violin													
	First Sound	*5*	11	*5*	10	7	7	10	6	7	8	21	8.5
	Second Sound	*3*	12	*2*	7	*3*	*5*	8	17	7	8	13	7.5
Muted Violin													
	First Sound	*4*	6	7	*5*	20	6	9	14	22	15	*3*	10.0
	Second Sound	*3*	8	*5*	8	18	*5*	8	13	6	15	*5*	8.0
Clarinet													
	First Sound	*3*	*4*	*5*	11	15	23	24	15	12	10	7	10.5
	Second Sound	*3*	*3*	*4*	8	*3*	12	17	13	22	12	7	9.0
Flute													
	First Sound	*1*	*2*	*5*	*5*	6	7	10	13	6	12	*5*	6.0
	Second Sound	*1*	*5*	*5*	8	*5*	*5*	16	13	11	7	8	7.0

TABLE 2

Spread in Amplitudes (dB) For Several Harmonics in the Note A (220 Hz; 440 Hz; 660 Hz; . . .) For Two Separate Soundings From each Instrument (Bassoon; French Horn and Vocal (Baritone))

Instrument	Harmonic Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean Spread (dB)
Bassoon																				
	First Sound	*2*	*2*	10	*3*	7	14	12	7	7	17	7	—	—	—	—	—	—	—	8.0
	Second Sound	*2*	*2*	*3*	*2*	*3*	6	*5*	11	12	8	9	—	—	—	—	—	—	—	5.5
French Horn																				
	First Sound	*1*	9	*3*	*4*	9	15	8	12	9	*5*	—	—	—	—	—	—	—	—	7.0
	Second Sound	*3*	*4*	*5*	10	7	9	12	15	8	*4*	—	—	—	—	—	—	—	—	7.5
Vocalist (Baritone)																				
	First Sound	9	6	8	20	13	11	11	9	8	14	11	9	9	14	9	13	7	6	10.0
	Second Sound	7	9	9	16	13	9	9	11	7	8	12	7	*5*	10	7	16	7	8	9.0

(Continued on Page 113)

Putting Windows Where They Ought To Be

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ABSTRACT: Windows are usually the acoustic weak link, in buildings, between the internal and external environments. Open windows present a special problem; they are necessary for ventilation but they are transparent to sound. By more judicious placement of window openings it appears possible to decrease the noise levels in buildings in many cases, even though the transmission coefficient of the window is approximately unity. Reasons and model results are presented to indicate why this is so. The implications for the measurement of facade attenuations and the reduction of traffic noise are also explained.

1. INTRODUCTION

There is a growing interest in the control of noise from transportation using buildings rather than expensive roadside barriers and reduced vehicle emissions. This trend, at least in part, has come about because of:

- A realisation that there are unlikely to be significant technological improvements to reduce vehicle emissions and even if there were it would be many years before older vehicles could be phased out of service and drivers educated not to produce unnecessary noise.
- An urban consolidation trend in many cities. In larger cities governments, commercial enterprises and individuals have realised that there is the space and the need for more dwellings in the inner city areas and along major transportation routes. The land most suitable for redevelopment is often that once used for commercial purposes (now superseded by shopping malls) and disused or underutilised railway property. These sites require special consideration for noise if successful domestic redevelopment is to take place.
- Large differences in individual reactions to noise. It may well be more economical to improve the acoustical performance of buildings subjected to the highest noise levels and the homes of those most sensitive to noise than to reduce the noise by other means.

The main noise path into buildings has long been recognised as windows (whether open or closed) though there appears to be very little evidence in the acoustics literature to support this view. The contention that windows are the weak link seems to be based on the assumptions that:

- The facade is subject to a uniform sound level.
- The facade, apart from the windows, has a uniformly high transmission loss.

These assumptions are unlikely to be true, for instance, Lawrence [1] found that, in a building specially designed to study traffic noise transmission through different facades, a uniform brick and plasterboard on stud wall with no windows or other openings gave an average transmission loss of 26 dB.

The expected value for the average transmission loss of such a construction would be approximately 50 dB. Lawrence also found that there was poor agreement between transmission loss values measured using traffic noise and a loudspeaker radiating white noise as the source.

Poor detailing and workmanship may be the cause of such low transmission loss values. Epstein [2] found that shrinkage cracks, joins, doors and window frames were the main transmission paths within buildings. These, together with the roofs (see Cook [3]), chimneys and vents are all likely to be significant sound paths into buildings. However, assuming open windows are the main sound paths into a building what methods can be used to minimise this transmission and how effective are they?

One solution that has been used is to face the building away from the major noise source; presenting blank walls, service areas, corridors, stairs and storage rooms to the noise source. The Bykker Wall housing development in Newcastle, U.K., is probably the most famous example of this type of development but there are a number of other similar schemes. Even single storey detached dwellings can give sound level reductions of the order of 20 dB(A) [4]. Another method of the self-protecting of buildings has been shown by Oldham [5]. The use of courtyards and balconies can give 10 to 15 dB(A) sound level reductions.

Courtyard houses and developments such as the Bykker Wall may not always be suitable or fashionable. Economics and buildings regulations will often mean that openable windows must face the noise source. In this paper the factors which govern the transmission of sound through open windows in conventional buildings are explored with the aid of a scale model. The performance of window itself was not looked at (as in [6], [7] and [8]) but rather the effect of its position relative to the ground and the source and the effect of the ground itself.

2. SOUND TRANSMISSION THROUGH OPENINGS

Besides the studies mentioned above ([6], [7], [8]) there have been a number of others of a more fundamental nature, e.g. [9], [10] and [11]. These show that for large openings and high frequencies the transmission coefficient is approximately unity. But these results were obtained in a reverberant field and, apart from Guy [7], did not involve surfaces of finite impedance nearby. Guy's work was carried out on sealed windows. The present work is a modified version of Guy's work, using open windows and a non-diffuse incident sound field.

Guy [7] showed that absorbent treatment near and around a closed window could have a significant effect on the transmission of sound through it (see Figure 1).

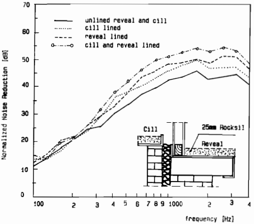

Figure 1: The effect of lining the cill and reveal with 25 mm Rocksil [7]. The insert is a cross-section of the wall and window used between the two reverberant rooms in which the sound levels were measured.

The intensity of the sound transmitted through an opening does, of course, depend on the incident intensity. The incident intensity will in turn depend on the geometry of the window, source and ground, the impedance of the ground and the frequency of the sound. For sound propagation over acoustically "soft" ground sound levels will be less close to the ground (see Figure 2 from [12]).

This suggests that ventilation openings should be placed close to the ground in order that the incident intensity is a minimum. The data presented in Figure 2 is, however, of sound pressure levels, not sound intensity. At least part of variation in sound level near the ground may be due to the change in the relationship between sound pressure and intensity. Normally it is assumed that the relationship is:

$$I = P^2/\varrho c \qquad (1)$$

Near a reflecting surface the relationship will be more like:

$$I = P^2/2\varrho c \qquad (2)$$

and in a reverberant field it will be:

$$I = P^2/4\varrho c \qquad (3)$$

The errors involved here are small but not negligible. Also, Figure 3 (from [12]) indicates that the change in relationship between I and P is unlikely to be important but it should be remembered that Figure 3 presents data for a broadband source and the information is not available for microphone heights of less than one metre.

As it was not possible to measure sound intensities it was decided to use a model room to determine the importance of factors affecting the transmission of sound through openings into buildings. By measuring sound levels within the model room the problem of the relationship between I and P is avoided.

It is likely that the sound level inside the model will be governed by the sound level at the "window". This in turn will be governed by interference between the direct and ground reflected sound, and hence the frequency of the source, the position of the source and window, and the impedance of the ground. It may seem then that no useful recommendations on window heights and ground treatment etc could possibly be made.

This may not be the case because there are limits on the geometry and most of the energy in the spectrum is around 250 to 500 Hz (2.5 and 5 kHz in the model). Also, where the source is close to a reactive surface it will appear as a dipole source to observers who are also close to ground. Thus, the sound level should reduce at a uniform rate of 12 dB/dd from the source at the ground but exhibit an interference pattern around a 6 dB/dd attenuation rate for observers away from the ground.

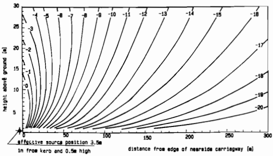

Figure 2: Propagation over grassland, correction in dB(A) as a function of distance from nearside carriageway and height above ground. [12]

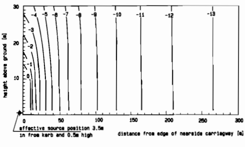

Figure 3: Propagation over hard ground, correction in dB(A) as a function of distance from nearside carriageway and height above ground. [12]

3. EXPERIMENTS

The experimental arrangement used is shown diagrammatically in Figure 4. The model was approximately 1/10th scale. The model building was made of plywood 12 mm thick.

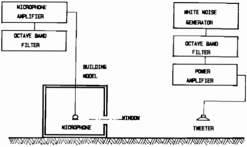

Figure 4: Diagram of experimental arrangement.

Three ground surfaces were used:

1 *hard*: wood, modelling asphalt or concrete
2 *soft*: carpet, modelling a grassed or cultivated ground ($z/\varrho c$ = 0.45 + i1.3 at 4 kHz)
3 *combination*: "soft" near the model building (representing cultivated ground) and "hard" near the source (representing a paved surface).

The maximum distance between the source and the model building was 1200 mm representing a full-scale distance of 12 m. The setback of most suburban houses is within this distance and thus the model can be used to indicate whether small gardens and strategically placed windows and building projections can be used to advantage.

The model room was a bare wooden box 550 mm wide, 400 mm high and 600 mm deep. The "window" was 50 mm high and the full width of the room. The aim of this work was to determine trends rather than predict actual levels in buildings. Hence the "model" bears little relationship to a real building. The model building is however representative of the height of a one or two storey building. In a full scale building the "window" would represent a double hung window fully open. The width of the window is obviously unrealistic but is a simple geometry representative of a room with several windows facing the street.

Sound levels inside the model were measured at four positions and averaged. With the four microphone positions chosen the average sound level in each octave band was the same as that obtained using nearly 60 different microphone positions. The standard deviations of the sound levels, measured in each octave band, using four microphone positions were less than 2.5 dB. The four octave bands used were centred on 1, 2, 4 and 8 kHz. At each of these frequencies the sound transmission through the walls of the model were not significant.

A 50 mm diameter tweeter fed with continuous octave band filtered white noise was used as the source. The microphones used were B&K ¼" mics, Type 4135, and the signals were analysed using a B&K Measurement Amplifier, Type 2606 and the Octave Band Filter, Type 1615.

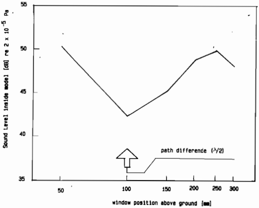

Figure 5: Internal sound level for 2000 Hz octave band and hard surface in model. Sound source 300 mm above the ground and 800 mm from building.

4. INTERNAL SOUND LEVEL RESULTS

As indicated in section 2, interference patterns may occur which may obscure any underlying trends in sound levels. That interference patterns do exist can be seen from the results presented in Figure 5. The position of the maximum and minimum sound level can be predicted by the path length difference between the direct and ground reflected sound.

Considering only the case of the source 50 mm above the ground (the approximate height of motor vehicle engines and exhausts in full scale) and the source 800 mm from the window opening, there are three trends observable:

1 Sound levels are less for the "soft" ground than for the "hard" ground over the frequency range of interest and most window positions (see Figure 6).

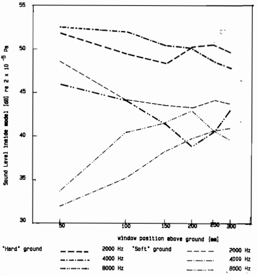

Figure 6: Internal sound levels for "hard" and "soft" ground as a function of window height and source frequency. Source was 50 mm above the surface and 800 mm from building model.

2 For the "combined" soft and hard ground low window heights give lower sound levels at 4 and 8 kHz. At 2 kHz there is a slight increase in the interior sound level for the lowest window height (see Figure 7).
3 That as the distance between the source and window increases, for a window height of 50 mm above the ground, the difference between the "hard" and "soft" ground sound levels increases (see, for example, Figure 8).

For the case where the source is 300 mm above the ground (corresponding to a high level exhaust) the trends are less clear. The different ground conditions have almost no effect on the room sound levels and interference effects dominate so that there is no preferable window height.

Finally, a reflecting projection above or below the open window does significantly affect the level of sound within the building. The protection given by balconies has been studied before e.g. [5] and qualitative evidence is available to indicate that the underside of balconies can increase the sound levels in buildings due to the extra energy reflected onto the window. However, in view of the previous work reported, it would seem unlikely that any general statement about the detrimental or beneficial effects of a projection above a window could be made.

A 150 mm horizontal projection was used at two positions above the open window to represent an eave or balcony. With this projection it would be expected that:

- for distant sources the effect of the projection would be less, and
- for lower frequencies the projection would have less effect.

Within the limits of the experiment these trends appear to exist though it is interesting to note that increases of up to 6 dB (above the case with no projection) and reductions of up to 2 dB occurred for different geometries and frequencies. A simple addition of energies would predict a maximum increase of 3 dB and no decrease in the level. The results presented in Table 1 show that for low source heights projections close to the opening have a significant detrimental effect. For other source heights and projection positions the trend is less clear though, overall, it can be stated that reflectors close to the window are detrimental.

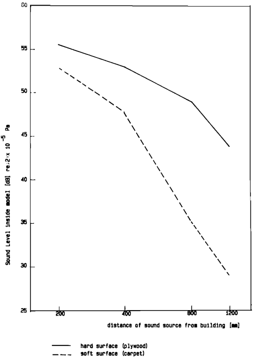

Figure 8: Sound pressure level inside model building as a function of ground surface and sound source position. Source and window 50 mm above the ground. Source frequency 8000 Hz.

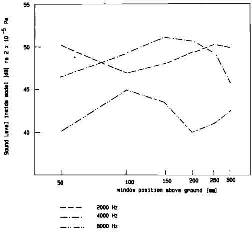

Figure 7: Internal sound levels, for a partially paved and partially cultivated ground, as a function of window height and source frequency. Source was 50 mm above the "hard" ground and 800 mm from the building model.

TABLE 1

Effect of horizontal projections on internal sound levels. 'Soft' ground case. Source distance: 800mm

Frequency	Sound Level Difference	Source Height (mm) 50	150	300
1000	Δ_1	0.5	1.0	−0.5
	Δ_2	1.5	1.0	1.5
2000	Δ_1	2.5	3.5	2.0
	Δ_2	−0.5	−1.0	0.5
4000	Δ_1	4.0	3.5	2.0
	Δ_2	2.5	1.0	0.0
8000	Δ_1	6.0	0.5	1.0
	Δ_2	3.0	−2.0	1.5

Δ_1 = Internal sound level with 150 mm projection directly above opening − Internal sound level with no projection.

Δ_2 = Internal sound level with 150 mm projection 85 mm above opening − Internal sound level with no projection.

5. CORRELATION BETWEEN INSIDE AND OUTSIDE SOUND LEVELS

It is normally recommended that noise levels be measured at least 1 metre from the facade of a building in order to determine the sound transmission through the facade. There is, however, little indication of how well such measurements correlate with interior sound levels. It seems in fact that methods of predicting interior noise levels from external sound levels and wall transmission loss values are notoriously unreliable. Part of this unreliability may be due to the external sound field measured or assumed.

From Table 2 it appears that a single sound level measurement at either the window, or 1 metre (100 mm in the model) from it, is not a good predictor of the internal sound level, even when the sound source is stationary. This statement is based on the assumption that the transmission coefficient for the window is constant over the frequency bands used. (The reverberation times in the model were 0.30, 0.25, 0.25 and 0.20 sec for the 1, 2, 4 and 8 kHz octave bands respectively, so that room absorption will account for less than 2 dB of the variation over the frequency range used. The observed variation in sound level difference is more than 6 dB.) The results presented in Table 2 were obtained using a source window distance of 800 mm.

It would seem that unless the very complex nature of the external sound field is accounted for, together with its interaction with the facade, the sound levels inside a building will be difficult to predict. In particular, it seems that a single point sound level measurement is unlikely to be capable of adequately representing the external sound field. Nor are long term average sound levels at more than one point near the facade likely to be much better as such averages will fail to take into account moving interference patterns which are likely to excite a wall or opening in a way which is not like the excitation by a diffuse sound field.

6. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The acoustic performance of buildings with openable windows seems, from the present work, to be difficult to predict. The work reported here covers only the case of openings facing the source. A further investigation involving a study of the sound levels in buildings with windows facing away from the source, is currently being undertaken. It seems that this second study will yield some more positive results.

Some conclusions can be drawn from the present study, despite the variability in results due to interference effects and despite the fact that, in practice, the noise sources will be moving and at varying distances and heights above the ground. One result is the apparent dominance of interference effects in most cases. The other conclusions are:

- lower sound levels in buildings can be achieved if cultivated or grassed areas in front of buildings are used instead of paved surfaces;
- window openings close to the ground tend to give lower interior sound levels (this conclusion is likely to be more positive for smaller window openings and windows closer to the ground);
- the nearer the noise source is to the ground the lower the interior noise levels will tend to be;
- horizontal projections from buildings tend to increase interior noise levels;
- interior noise levels cannot be accurately predicted from average external noise levels made near the facade (a better procedure may be to measure the sound intensity near the building facade).

Two of these conclusions are unfortunate as they involve conflicts with other considerations. For minimum interior sound levels, source and window heights should be minimised. The rolling noise of tyres on the road is therefore easily controlled but noise from exhausts is not so easily dealt with. In order to improve the dispersal of exhaust emissions the exhaust should be well above the ground which conflicts with the present recommendation.

Low windows may also cause ventilation and safety problems amongst other things. It seems that the solution here may be to separate the visual and ventilation functions of windows. Such a solution would also allow the maximum benefit to be obtained by any barriers, erected to reduce the noise, while maintaining an unobstructed visual field.

TABLE 2

Correlation between internal and external sound levels. 'Hard' ground case. Window and source 50mm above ground. Source 800mm from window

Frequency (Hz)	Inside sound level L_1 (dB)	Outside sound level 100mm from window L_2 (dB)	Sound level at window L_3 (dB)	L_2-L_1 (dB)	L_3-L_1 (dB)
1000	42.5	46	47.5	3.5	5.0
2000	48	53	54	5.0	6.0
4000	49	56	55	7.0	6.0
8000	43.5	53	55.5	9.5	12.0

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Hearing Conservation in the Australian Broadcasting Corporation

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ABSTRACT

The output of our national broadcasting service evolves from activities and interests in all areas of life. Thus, in the recording and broadcasting processes, some staff are necessarily subjected to the sonic environments of industry and the community.

Additionally, in recording and broadcasting within studios, both talent and production staff are exposed to high sound levels consistent with modern entertainment. Hearing conservation has therefore been introduced.

This paper is based upon an investigation into the effectiveness of this hearing conservation program [9] and includes proposed actions for a more rigorous approach that will give better administrative control and also alignment with National occupational health and safety regulations.

INTRODUCTION

The advent during the 1960's of high intensity amplified sound from pop groups, and comparable loudspeaker monitoring levels in control rooms to which talent and production staff were exposed, created the possibility of permanent hearing damage. In addition, sound leakage to adjacent areas caused annoyance and sometimes the disruption of broadcasts or of recordings.

Measurements of the sound pressure levels showed that sustained levels often exceeded limits considered safe to hearing. Thus the need for hearing conservation was recognised.

Loudspeaker monitoring levels used by sound operators in control rooms have generally tended to exceed general community listening levels for reasons such as fault detection, the need to establish the best sound quality, and internal balances of the recorded material. Musicians are subjected to the same and often higher sound pressure levels than those used in the control room situation.

Since high intensity program sounds are usually music and acceptable to musicians, production staff and the public, the fact that hearing damage could occur was not credible to all. It certainly did not give sufficient motivation to welcome change in production techniques. High sound levels in music had become a social phenomenon, personal enjoyment aside.

1. GENERAL BACKGROUND

1.1 Noise Induced Deafness

Except for an explosive type sound that can destroy hearing at once, most cases of noise-induced deafness result from exposure to continuous noise over a period of time, usually several years. Its severity is dependent upon the frequency, intensity and time relationships of the noise and individual susceptibility.

The pathological effect at least is damage and sometimes the disappearance of the fine hair cells in the inner ear [1]. This degeneration raises the hearing threshold at higher frequencies, characteristically at 4 kHz, widening to lower and higher frequencies as the loss increases with time.

It is useful to know that the ear can sustain temporary hearing losses of extent dependent upon individual susceptibility and that the audiometric curve for a wide-band exposure is similar to that for an ear with a permanent threshold shift. Repetition of a temporary hearing loss may produce permanent changes in hearing acuity, but temporary loss is not necessarily a predictor for permanent losses.

Noise-induced hearing loss is often accompanied by tinnitus, i.e. ringing or other noises in the ear that occur in the absence of external sounds. Also the phenomenon of loudness recruitment is often present. Loudness recruitment refers to an unusually rapid growth of loudness as the sound pressure level of a sound is increased.

Because of its insidious onset, noise-induced hearing loss may have reached an advanced stage before the subject becomes aware of it [2]. Then he will experience difficulty in conversing with people, particularly in a crowded room, or in discriminating female and children's voices in quiet. Help can be given to rehabilitate this kind of deafness. Recent developments in hearing aid technology have made every such person a potential candidate for rehabilitation with amplification, with greater success for listening in quiet. The danger of using a hearing aid in the noisy environment where the hearing loss was acquired is apparent, for it is there that one needs hearing protection.

A great deal of research to quantify the permanent effects upon hearing of wide-band and impulsive type sounds has provided the basis for legislations to limit noise exposure to workers in industry.

1.2 Community Noise

Upon leaving work the employee is daily subjected to community noise, from transport in air, road or rail; recreation such as noisy sports, car and motor cycle racing; noisy entertainment and home appliances such as lawn mowers.

These can contribute to his overall hearing loss and add stress factors such as annoyance and interference with speech and communication.

2. THE BROADCASTING NOISE PROBLEM

2.1 This can be divided into two categories, viz. **general industrial,** where hearing conservation can be applied using well proven methods in accordance with current legislation and Standards; and **program,** where sound levels cannot always be controlled e.g. symphony orchestras; bands; outside broadcasts for say rock concerts, noisy sports; loudspeaker and headphone monitoring.

2.2 **Extent**

The general industrial problem exists mainly for persons in workshops, air plant machinery enclosures and in administration, e.g. teleprinter/telex and office machine areas, telephone switchboards. Cleaners and drivers of heavy vehicles also share a degree of risk to hearing damage.

Program type sounds involve musicians; production personnel, i.e. program operational and technical; presentation, announcing, outside broadcast, news, current affairs, film and electronic news gathering personnel.

3. THE ABC EXPERIENCE

3.1 The high sound levels used by pop groups recording programs in TV studios caused complaints from operational staff and resulted in an instruction being issued during the early 1970s to limit sound pressure levels to:

- within studio areas — both radio and television — 100 dBC
- in control rooms — 90 dBC

and sound level meters were issued to enable levels to be checked upon request by staff members.

Although A-weighted values for maximum sound pressure levels were considered acceptable, the more conservative C-weighting was chosen to account for low frequency components that penetrate studio walls more readily.

The 90 dBC limit for control rooms is a practical one, but 100 dBC for studios is workable only for amplified music, since maximum levels for a symphony orchestra are known to exceed this, often for prolonged periods [3, 4].

3.2 A growing concern about hearing damage among orchestral players resulted in two preliminary investigations into sound pressure levels, one with the Melbourne Symphony Orchestra, the other with the Western Australian Symphony Orchestra. Both reports, prepared by Australian Government Health authorities during the late 1970's, recommended further study, since there appeared to be some risk to hearing.

3.3 **The need to review hearing conservation**

Because environmental problems with the Melbourne Symphony Orchestra rehearsal venue were believed to be causing hearing problems, and also because of the fragmented present hearing conservation program, a review was considered necessary.

Its timing is fortuitous in the present industrial situation, where special legislation appears imminent for Australian Government employment that will be more stringent than existing State Government legislations.

3.4 **Staff at risk**

ABC estimates of the number of staff at risk in the absence of hearing conservation averaged about 15% of all staff. Orchestral personnel make up an additional 8.5%. Of the 15% a much smaller percentage can be expected to sustain hearing damage at the workface which could lead to compensation claims:

(i) for program production, the risk is distributed across the total personnel, so exposure of the individual to high sound levels is reduced accordingly.
This group form the greatest proportion of the 15%.

(ii) workshop and plant maintenance personnel have a higher percentage risk among their smaller numbers but they total only about 3% of all staff.

(iii) personnel at risk in administration is also small.

The percentage of claimants for compensation for hearing loss among orchestral players has yet to be established.

3.5 **The Symphony Orchestras**

(1) Two recent European studies about hearing among classical musicians [5, 6], suggest that the sound exposure sustained by the musicians in a symphony orchestra places them at risk to permanent hearing loss, besides symptoms such as hearing fatigue, ringing in the ears, headaches and tension. This is additional to stress factors such as those caused by musical demands, profession-related problems [7] and the playing environment.
A much earlier study by the British Broadcasting Corporation Research Department [3] reported peak sound pressure levels approaching 130 dB and 140 dB at less than a metre from trumpets and drums respectively.

(2) A study of the orchestras is planned so that acceptable policy and guidelines can be evolved. To be investigated are:
   (a) sound pressure levels in the playing environment
   (b) individual sound exposures using noise dosemeters
   (c) a policy for hearing measurement
   (d) methods of conservation including
      (i) administrative control, e.g. work cycle and breaks in relation to exposure
      (ii) use of hearing protection
      (iii) transparent shields behind musicians in high rise areas
   (e) the above in conjunction with ergonomic factors of the playing environment and stress factors inherent within the profession [7].

4. AUSTRALIAN LEGISLATION FOR HEARING CONSERVATION

4.1 Most State Government legislations specify the following noise exposure limits:
   (1) Daily noise dose (DND) to unprotected ears not to exceed 1.0 (L_{Aeq8} = 90 dB) (see note 1 for definitions.)
   (2) Maximum sound pressure level to unprotected ears not to exceed 115 dBA using the slow scale.

4.2 New legislation is expected for Australian Government employees which will be guided by recommendations of the National Health and Medical Research Council (NHMRC) [10].
Current recommendations of the NHMRC for noise exposure are:
   (1) DND to unprotected ears not to exceed 0.33 (L_{Aeq8} = 85 dB)
   (2) Maximum sound pressure to unprotected ears not to exceed 115 dBA using the slow scale.

5. RECOMMENDED POLICIES AND GUIDELINES

The following policies and guidelines are contained in the internal ABC report titled "Hearing Conservation, Preliminary Study" (1983) by D. H. Woolford [9]. These Recommendations will be the basis for study by the ABC.

5.1 **General**

The supervision, co-ordination, consultation, policy-making and education for all aspects of health and safety are accepted as the responsibility of top management. The modus operandi is described in the "Code of General Principles" for Australian Government employees [10].

Hearing conservation within a broadcasting organisation affects only a small minority of total staff, is one of many aspects of health and safety and is a need of only recent recognition. With a more rigorous approach it should have full status along with the other aspects of health and safety, and be administered in accordance with the above code with the assistance of NHMRC guidelines [11] read in conjunction with AS 1269-1983 [8a].

To accord with industrial trends that follow the recommendations of the NHMRC, adoption of the DND and maximum sound pressure level as stated in section 4.2 above should be most satisfactory. When the values exceed those postulated, then the exposure to employees should be reduced accordingly:

(1) by engineering control of noise
(2) administrative control of noise
(3) a combination of (1) and (2)
(4) the use of hearing protection when (1) to (3) cannot be arranged.

Application of the above is without complication in general - industrial areas.

Because the peak value of 115 dBA using the slow scale is not always met in the symphony orchestra or band, separate guidelines are therefore necessary and can be evolved from a special study, outlined above.

5.2 Recommended also:

(a) a noise rating number [8c] or noise specification to apply to all new workshop machinery, air plant, heavy vehicle cabin noise and broadcast equipment

(b) introduction of machine and area labelling where hearing could be at risk [8d].

(c) acoustic treatment of the boundaries of risk areas to reduce reverberation, e.g. workshops. Also, where possible to exclude external noise [8e].

(d) revision of ABC Engineering Division Standards and Practices ESP 24.01 of 1.2.79, "Hearing Conservation" to accord with new postulated noise exposure limits. This publication is based upon the instruction of the early 1970s, see para 3.1.

5.3 Education and Training

Education in health and safety generally, training in safety techniques, and the use of safety equipment have been continuing processes, but the area of noise-induced deafness, substantially neglected to date, requires more attention.

In formulating guidelines for education, the following aspects are recommended for inclusion, viz:

(1) the nature and causes of noise-induced hearing loss and social implications to the individual
(2) the dangers of community noise, additional to industrial exposure
(3) possible hearing loss and conservation in the areas of broadcasting where hearing protection can inhibit the work, e.g. orchestras, bands, loudspeaker and headphone monitoring
(4) the replacement of fear with knowledge. We cannot live in glass cases but with care can conserve hearing.

It is essential that education be a continuing process.

5.4 Hearing Measurement

For new staff in the ABC the present medical examination for hearing is basic, i.e. whisper and tuning fork tests. Therefore no exact record of hearing is available for use as a reference in compensation claims or for screening audiometry.

A full otological and audiological examination is recommended for new staff engaged for noisy occupations, existing staff who transfer from quiet to noisy occupations, and all who require good hearing to make and assess programs. It is necessary that records of such tests be retained by management as a reference for future tests and compensation claims.

An initial cost resulting from the introduction of a rigorous hearing conservation program is that of full hearing examinations for some existing staff already in noisy occupations. However a cost saving should be possible in this by selectively checking first those in high risk areas, followed by the selective checking of other staff from the findings.

Because of the small number of staff involved, regular screening checks may cost less using a private consultant rather than trained in-house staff, since special test environments and exacting instrument procedures are a prerequisite.

6. COSTS

6.1 Hearing conservation is obligatory, so cost benefits will arise from

(1) effectiveness of the program
(2) reduction of a stress factor with consequent better work outputs,
and
(3) control over compensation payments.

The use of expertise available within the organisation will result in cost savings. Specifically, officers of Engineering Divisions can contribute technically in noise measurement and evaluation of noise problems, vibration and noise control, administrative noise control, selection of hearing protection, education and training, all of these in conjunction with health and safety personnel. The cost of additional measuring equipment, updated hearing protection and educational material are a debit against this. Cost savings are also possible in hearing measurement outlined above.

Engineering noise control is the first remedial action for hearing conservation in most legislations. However, it is established that at present, noise control costs per worker are greater than compensation payments per worker [12]. So noise control as a total solution is not attractive to an employer. A combination of administrative noise control with hearing protection may sometimes be more acceptable, particularly when engineering noise control is not only costly but almost impossible with present technology.

CONCLUSION

A more rigorous approach is likely to be adopted in existing hearing conservation programs which will enable better hearing protection, control over compensation payments and preparation for new legislation for Australian Government employees.

The immediate study of the symphony orchestras is necessary to assess hearing conservation having regard to other stress-causing factors in the performing environment.

Note 1 Definitions [8a]

Daily noise dose (DND)

The sum of partial noise doses which are based on the various sound levels and their durations to which an employee is exposed throughout a representative working day. It is the ratio of the noise exposure experienced by a person in a working day to a reference value of noise exposure. The reference is $3.2Pa^2.h$ and corresponds to a DND of 1 [8b].

Equivalent continuous A-weighted sound pressure level (L_{Aeq8}) — The A-weighted sound pressure level which, if present for 8 hours per day, produces the same DND as that obtained from the summation of the partial noise doses over the same period.

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"Occupational Health Guide — Hearing Conservation Program." Doc. Hea — 80 — 90 **National Health and Medical Research Council.**
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(Received 4th October, 1983).

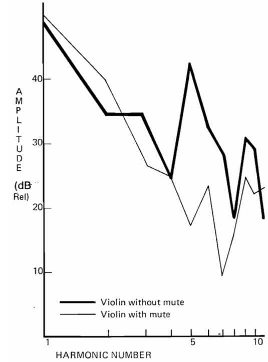
"Timbre Vibrato"

(Continued from Page 104)

While the subject of timbre is exceedingly complex, it is possible to illustrate **changes in timbre** quite simply. For example, when a violin is played with and without a mute on the bridge, it is clear to the listener that there is a marked change in timbre. This is shown in Fig. 1 for the note A (440 Hz; 880 Hz; 1320 Hz; . . .).

The major similarity in the two sounds is reflected in their common slopes for various parts of the spectrum, while the major differences lie in lower relative positions of the peaks in the higher harmonics for the muted violin.

One may regard the spreads in the amplitudes of the constituent harmonics of a musical sound as a form of vibrato — not produced by the technique of the performer, but a consequence of the nature of the musical instrument, and may be called "timbre vibrato".



Occupational Health and Safety

The Federal Government is preparing to legislate to require employers to pay greater attention to the occupational health and safety of their workforce.

Federal Cabinet has decided that an interim National Health and Safety Commission be established, its function to consult with the States, industry and employee representatives and relevant specialists on the establishment of a permanent commission and office, such to be the responsibility of the Minister for Employment and Industrial Relations.

(See reference to new legislation in paper "Hearing Conservation in the A.B.C." this issue.)

Noisy muscle molecules

Use your thumbs to gently block your ears and, with your elbows raised, make a fist. The faint rumble you hear, which should become louder as the first is tightened, is the sound of your hand muscles contracting. Although a number of theories have been offered to explain this noise, a researcher at the Mount Sinae School of Medicine in New York now believes that what you're hearing is actually the sound of molecules at work.

Physicist **Gerald Oster** has been investigating the racket muscles make and is convinced that the phenomenon is due to something known as molecular cross-bridging. Muscles are composed in part of proteins, which themselves are composed of complex molecules. It appears that in order for a muscle to contract, projections, or "teeth", on adjacent protein molecules clamp together and tighten. This emits a tiny noise which, multiplied by countless millions of molecules, becomes barely audible. "What we're hearing," Oster says, "are actual molecular events."

Oster's conclusions were drawn in part from research he conducted with **athletes,** using a newly developed transistorised stethoscope. Sensitive microphones attached to the device were placed on the subjects' forearms to detect the change in muscle sounds that results when progressively heavier weights were lifted. The procedure showed that as exertion increases, noise levels follow suit.

Our constant muscular droning is too faint for us to notice it ourselves, but under the wrong circumstances it can get us into trouble. Studies conducted by other researchers into the hunting ability of the **shark** have indicated that these creatures are acutely sensitive to low-frequency sounds. Regrettably, muscle-rumbling falls into the same frequency range — approximately 25Hz. It thus seems that in many cases a shark in search of a meal need do no more than lurk and listen and wait for prey to swim into range.

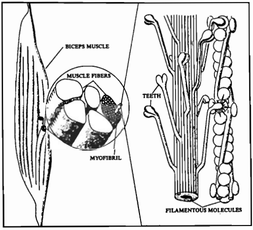
But if muscle noises can spell doom in the wild, they can save lives in other circumstances. The body's most sophisticated and essential muscle — the heart — also appears to rely on molecular cross-bridging. The new stethoscopes are commercially available and will soon be used to detect even suble changes in the heart's rumblings. And none too soon, Oster notes. "The association between low-frequency abnormalities and heart disease," he explains, "has never been adequately pursued."

(Omega Science Digest, Sept.-Oct., 1983)

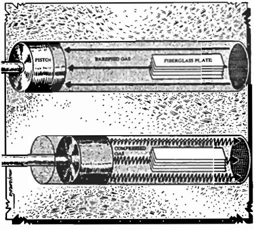
Acoustic refrigerator

The world's most unusual refrigerator is now being developed. Needing neither compressors nor motors nor complicated tubing, the experimental icebox is expected to produce its chilly temperatures using little more than sound.

Designed by a research group headed by physicist John Wheatley, the acoustic refrigerator is remarkably simple. The existing prototype is little more than a metre-long cylinder with a number of rectangular fibreglass plates stacked inside. The tube is filled with helium or other gases and is permanently closed at one end and sealed by a flexible diaphragm at the other. Attached to magnets, voice coils and wires, the diaphragm is a tiny loudspeaker, vibrating rapidly and in the process sending sound waves into the cylinder. When it does this, things start to happen.



Muscle fibres are made of threadlike myofibrils, which in turn consist of countless filamentous molecules. When a muscle contracts, adacent molecules lock together. The simultaneous linking of millions of molecules can be heard as a faint rumble.



An acoustical diaphragm—represented here as a piston — vibrates in and out at the end of a tube. On inward strokes, gas is compressed and heated; on outward strokes it expands and cools. Fibreglass plates segregate and retain both the heat and the cold.

It is one of the fundamental principles of physics that when gas is compressed it grows hotter, and when it expands it cools. In the prototype, as the diaphragm vibrates in and out, it changes the pressure of the helium in the tube, and its temperature fluctuates accordingly. "If the fibreglass plates weren't present," Wheatley says, "the diaphragm, acting like a piston, would simply cause the temperature of the gas to rise and fall steadily. The plates, however, knock this pattern out of phase."

What they do instead is transmit the heat of compression along their lengths, carrying it away from the diaphragm. One end of each plate thus grows hot while the other, stripped of its heat, becomes remarkably cold to the touch.

Although these low temperatures can be quite easily generated, they have not been harnessed and used. "This is not yet a practical device," Wheatley explains. "We still have to figure out how to dispose of the heat and use just the cold — and these are intrinsic problems, not trivial ones." Nevertheless, he adds, "I think we're working on a principle with great potential, but, to be sure, it is still just potential."

(Omega Science Digest, Sept.-Oct., 1983)

* * *

High frequency sound used to view nuclear core

Scientists have found a way of looking into the heart of a fast nuclear reactor. Until now it has been impossible to examine visually such a reactor because the core is submerged in a tank of sodium liquid metal which acts as its coolant.

In the first successful experiment of its kind, pictures have been received from inside Britain's prototype fast reactor at Dounreay in Scotland. During the experiment, scientists saw the reactor core in fine detail beneath the surface of the sodium pool.

Using a **new high-frequency sound technique** developed at the U.K. Atomic Energy Authority's Risley laboratories in Cheshire, the experts obtained clear, colour television images of the whole of the outer core.

To take the pictures, a 10m. long tube was fitted with sophisticated ultrasonic pulse-echo equipment and lowered close to the core during a routine shut-down of the reactor. High frequency pulses were then transmitted through the molten sodium.

From the echoes received from the top of the core, a computer produces a clear image of it on a colour television screen. Variations in the colour represent changes affecting the reactor core.

A fast reactor produces energy by burning the plutonium arising as a by-product of the operation of thermal reactors and also by gradually converting the non-fissile uranium, which thermal reactors cannot burn, into additional plutonium. In this way the fast reactor can extract 50 to 60 times as much energy from natural uranium as can a thermal reactor.

—From Laboratory News, Sept. 1982.

Waves Shatter Icebergs

Given their forbidding dimensions, one might think icebergs were extraordinarily sturdy. But these bobbing mountains are surprisingly brittle, often—and inexplicably — crumbling into small, floating fragments. This tendency to disintegrate has long baffled investigators. But now Vernon Squire, an oceanographer with the Scott Polar Research Institute in Cambridge, England, may have discovered its cause: seemingly harmless ocean waves.

Squire and his colleagues have recently conducted numerous experiments aboard icebergs, often landing their helicopters precariously atop the icy islands. This principal investigative tool is a "strain-meter", a sensitive instrument which, when implanted in an iceberg's surface, detects expansion and contraction caused by crashing waves. "What we discovered", Squire says, "is that waves will excite an iceberg continuously until, ultimately, it weakens and shatters. A good analogy would be a singer's voice shattering a wine glass."

Squire notes, however, that not every wave can break every berg. The strain-meter and subsequent computer stimulation of wave activity have shown that each iceberg's unique shape, volume and density will cause it to respond only to waves of a certain frequency, easily withstanding all others. As the iceberg breaks apart and its size is systematically reduced, the wave frequency to which it is vulnerable changes commensurately. The process does not stop until the berg's once-looming bulk is so diminished that only waves of unattainable frequency could damage it further.

* * *

A blind telephone operator's sight

A standard operator's console uses LEDS and the like to attract the operator's attention. Telesensory Systems of Palo Alto, California, working with Bell Laboratories, has now developed a box of tricks known as a "visually impaired operator system" (VIOS) that will pick up these visual signals and convert them into "audible and tactile" signals — a synthesised voice and a Braille display (*Bell Laboratories Record*, January 1983, p. 25). This unit is designed specifically for Bell's "traffic service position system" (TSPS) consoles that are highly automated anyway to give the operator more time to serve those customers with special needs. Moreover, their buttons are grouped logically, so that there is little difficulty in memorising their location.

The VIOS is a clever invention in many ways: for example, the modifications to the TSPS console it requires are easily achieved; the console itself is unaware of the VIOS; the units involved are compact and portable; and both sighted and visually handicapped people can use the same console. Moreover, when the system is first plugged in and "powered up", the VIOS spends the first 10 seconds going through a check routine and it continually diagnoses itself during lulls in demand. In this way it does a great deal towards making the job of the blind operator very much like that of a sighted colleague.

(Physics Bulletin, May 1983)

New Products

BRUEL & KJAER: ECONOMICAL MULTI-CHANNEL VIBRATION MONITORING

A new Multiplexer, Type 2514, has been developed to provide multi-channel facilities for Bruel & Kjaer's permanent machine-vibration monitoring systems.

Designed specifically to complement the Type 2505 Vibration Monitor, the Type 2514 offers economical coverage of up to eight monitoring points. The Multiplexer continuously steps through the chosen monitoring channels, dwelling at each channel for a selectable period of between one second and 32 hours. Each channel has individual signal conditioning and sensitivity adjustment. The output from the multiplexer is fed to the vibration monitor, where the signal level is compared with preset limits to detect changes in the running condition of the machine. Danger levels detected by the vibration monitor are indicated by an alarm and by a light flashing at the relevant channel of the Multiplexer.

The Multiplexer and Monitor use modular circuit boards for easy maintenance and specification changes, and both comply with strict MIL standards to withstand harsh industrial environments. Other features of the 2514 include: A test cycle to check for malfunctions and incorrect settings; bypassing of individual channels; manual local- and remote-channel stepping; relay for external indication of a power failure; facility for external scan control, and an optional relay box for individual remote channel warnings.

The system can be further expanded by connecting a number of Multiplexers to one vibration monitor — up to a recommended maximum of 40 channels — and also be used for other AC signals such as sound.

VIPAC: POWERFUL TWO CHANNEL FFT ANALYSER

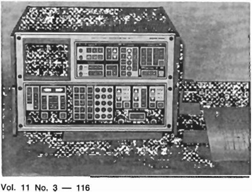
Spectral Dynamics new SD 373 two channel FFT Analyser is sold and supported in all States by **Vipac Instruments.** Menu driven with full annotation facilities this analyser is a powerful analytic tool and easy to use.

The SD 375 can be used as a signal correlator for time, amplitude and frequency up to 100 KHz.

It is also a transfer function analyser for mechanical, electrical, acoustic, hydraulic measurements. Also available through Vipac Instruments are Modal Analysis Engineering software programs which utilise the SD 375 FFT as a processor.

Options available with the instruments are a digital translator (up to x 100 zoom), 1/3 and 1/1 Octave Analysis, Digital 1/0 and a Synchronous Signal Generator for external system or network excitation.

Vipac Instruments provides full service support for the SD 375 and training and application support is readily available.



COMPUTER ASSISTED BEARING ANALYSIS

Field-proven software plus standard hardware combine in **Spectral Dynamics** bearing analysis system which is sold and supported in all states by **Vipac Instruments Pty. Ltd.**

Heart of the system is Spectral Dynamic's SD 345 Spectra Scope III Spectrum Analyzer, combined with an HP 85 Desktop Computer, a suitable tape recorder and an HP 7470A Digital Plotter.

How does this system perform an analysis?

1. A vibration signal from a transducer mounted on a bearing is recorded on analogue tape — field data captive therefor by portable equipment.
2. A spectrum of the recorded data is produced by the SD 345.
3. The frequency pattern of the spectrum is examined by the computer to determine which, if any, defect pattern indicated is present. Zoom analysis is used if close-spaced sum-and-difference frequencies need better definition.
4. If a defect is detected, a digital plot of the spectrum is automatically generated.

The software is structured to allow the parameters of any industrial bearing to be programmed on a memory tape. Each of these cassette tapes can store up to 70 bearing profiles.

The complete system hardware is portable between sites.

Software can be provided as a stand-alone package for existing customer equipment, or together with the SD 345 Spectrum Analyzer.

VIBRATION AND BALANCE SOFTWARE RANGE

Flexible noise and vibration software is available in the **ENTEK** range, sold and serviced by **Vipac Instruments Pty. Ltd.** throughout Australia.

Installation assistance, operator training and a conditional upgrading scheme is provided. HP 80 and 9800 desk top computers, most spectrum analyzers and a range of HP and other output devices are supported. New system support is constantly under development.

Programs include:

EPRAN — Transforms a single or dual-channel Spectrum Analyzer into a programmable instrument.

EMODAL — A means of using relatively inexpensive Dual Channel Spectrum Analyzers in modal analysis studies.

EMAP — Generates a three dimensional water-fall of spectrum data as a function of some third axis parameter such as speed, time, temperature.

ESIM — Used with a dual-channel Spectrum Analyzer and desk top computer to perform two-microphone sound intensity measurements.

EPLOT — General purpose two-and three-dimensional and contour plotting package.

EMESH — Powerful stand alone utility to interactively construct set of measurement locations using simple or complex shape elements, full manual additions.

EBALANCE — For multiplane balancing of rotating machinery. Exact solution when vibration readings equal number of balance planes; least-squares solution when there are more vibration readings than balance planes.

ESHAPE — Deflection shape analysis for single-channel Spectrum Analyzers. Real, imaginary or complex shape coefficients; animation (optional); graphics output; multiple shapes, locations and directions.

EMDOF — Multiple degree-of-freedom curve fit routine for stand-alone use with dual-channel Spectrum Analyzer. Curve fitting of entire frequency response measurement.

For further information on the above Vipac products contact:

Melbourne — Mr. Malcolm Mulcare — (03) 240-8471.
Sydney — Mr. Dirk Bout — (02) 736-3011.
Or Vipac offices in Brisbane (07) 371-8100 — Adelaide (08) 46-5991 — Perth (09) 361-7311.

BOOK REVIEWS

AN INTRODUCTION TO THE PSYCHOLOGY OF HEARING
2nd Edition
B. C. J. Moore
Academic Press, 1982, $A16.30 (soft covers)

When the first edition of this book was published in 1977, the world of hearing gained something it had lacked for so long; a comprehensive, readable, up-to-date introductory coverage of auditory perception. In 1982 Academic Press did the world of hearing a further considerable service by publishing **two** excellent complementary introductory volumes in the one year; the second edition of Moore's "An Introduction to the Psychology of Hearing" and J. O. Pickles' "An Introduction to the Physiology of Hearing".

The second edition of Moore's book is not just a re-run of the first edition minus typographical errors and with a few new figures. It includes an important new chapter on auditory object and pattern perception. Important because Moore has recognised that this dimension of auditory perception is as fundamental to auditory experience as the perception of pitch or loudness or location.

The first chapter is a sketch of the basic physical, anatomical, mechanical and physiological facts needed before one can start coherent discussion of psychological results. At appropriate places later in the book various areas of the sketch are filled in. For example, in Chapter 3, in the context of discussing the extraordinary human ability for distinguishing between two frequencies (1000 Hz and 1003 Hz are discriminably different) Moore introduces the controversy about mechanical and physiological sharpening mechanisms at the level of the basilar membrane. This method of organisation works well and the continual return to cochlear mechanisms in later chapters tends to give the reader an appropriate balanced view of the central role cochlear functioning has in the understanding of many aspects of auditory perception.

Chapter 2 addresses the problem of loudness and dynamic range: how a biological system can have a dynamic range of 120 dB. This is a careful, critical account, pointing to problems of interpretation of some of the results due to the methods used to gain the data. I would have preferred a greater treatment of noise here. Noise is only mentioned very briefly later in the book. There is a good account of the clinical aspects of loudness perception — how loudness recruitment and tone decay tests are used for diagnosing auditory pathology.

Chapters 3 and 4 concern pitch perception masking and frequency analysis and Moore guides the reader through these difficult areas. The coverage is too detailed and I think many students may have trouble following some of the more esoteric skirmishes between the spectral and temporal theorists. Moore introduces his own model of pitch perception and discusses it in some detail.

Binaural hearing and auditory space perception are given rather uneven treatment in chapter 5. Masking level differences and models of these phenomena are covered in detail, whereas auditory distance perception is glossed over. There is no mention of the long series of experiments by Mershon on distance perception or of the major theoretical problems in its study.

Explanations of auditory perceptual phenomena rely heavily on stimulus measurement and on understanding the basic physiological processes of hearing. In chapter 6 Moore discusses basic auditory perceptual phenomena which cannot be accounted for by the stimulus or by simple physiological processes. When we listen to two musical instruments playing together we generally do not confuse which harmonies belong to which instrument although the harmonics may be interleaved or overlapping. How can we identify one set of harmonics as one auditory "object"? Moore reviews this problem and the related problem of auditory pattern perception and shows how many of the Gestalt "laws" apply to these problems. There has been relatively little research on this area, compared to say simple pitch judgments and this chapter serves to ratify this area as one in which psychologists should be more concerned.

Chapter 7 deals with speech perception and is probably the weakest chapter of the book. There has been a revolution in this area since the first edition, but the revolution has gone unheeded. The theory that there is a special mode of speech perception has come under sustained serious attack by M. E. H. Schonten, Diehl and others but Moore makes no reference to their criticisms. There is no mention of the many studies by Efron and Deutsch on ear dominance for pitch.

The final chapter consists of notes on a random collection of auditory phenomena ranging from auditory perceptual abilities in relation to hi-fi to the psychophysics of concert hall evaluation to the results of implanting stimulating electrodes on the auditory nerve of deaf individuals to cochlear echoes. This last phenomenon is that when a click is presented to a subject, it is possible to detect, after a delay, a sound being reflected from the ear — a cochlear echo. It is now known that some types of "ringing in the ears" (tinnitus) can be objectively measured by simply placing a sensitive microphone in the ear canal. The use of these simple non-invasive methods of studying cochlear functioning will certainly increase dramatically in the next few years.

The book includes a glossary of technical terms, and a brief list of further readings at the end of each chapter. The index is inadequate. The illustrations are clear, well produced and carefully selected. The inclusion of discussions of clinically relevant material and the practical applications of the psychology of hearing interest students and add to the value of the book.

In summary, this is an excellent book for a very modest price. It provides a clear, critical and interesting coverage of the broad, complex area of auditory perception.

IAN CURTHOYS.

THE PSYCHOLOGY OF MUSIC
Edited by Diana Deutsch
Academic Press, New York, 1982

The book has 18 chapters by various authors addressing themselves to the question of how the human brain perceives and understands music. The predominant approach is that of analytical psychology. Although the book is an excellent compendium on the subject it would have been better if the subject area had been expanded to include work on the hearing mechanism by physiologists and anatomists. Rather than give a detailed chapter by chapter review, an overall assessment of the book together with some highlights of particular interest will be presented.

The natural starting point for such a book is a short discussion on psychoacoustics where the rationale behind stimulus presentation; the concept of frequency analysis by the ear including its critical bandwidth; pitch estimation (including the effect of the "missing fundamental"); loudness; timbre; and beats/roughness are introduced. There is a short section on combination tones arising from nonlinear effects on two high level sounds having a small frequency separation, and also consonance/dissonance.

A detailed discussion on timbre shows that the old idea that the ear is phase deaf does not work and the temporal evolution of sound has to be considered.

Acoustic modelling can either synthesise a sound by solving the differential equations governing the motion of the vibrating elements or perceptually by generating a sound to resemble the original without any concern for the model.

The analysis of singing is centred around the determination of the formant frequencies where there are maxima in the ability of the vocal tract to transfer sound.

An important theme that recurs in the book is the consideration of grouping mechanisms. Gestalt psychology has as basic grounds for grouping — proximity, similarity and good continuation. The fact that there are two ears means that temporal relationships are important for tones coming from different locations, and this is very important for rapid sequences.

The representation of musical pitch and its relationship to frequency has been aided by a helical plot where one complete turn of the helix represents one octave.

The book is comprehensive and also considers other aspects such as timing by musicians, rhythm and tempo, the acoustic environment and absolute pitch. Anyone who is interested in recent research on how we perceive music will find this book a useful addition to their library.

ROBERT W. HARRIS

INTERNATIONAL NEWS

ISVR SHORT COURSES 1984

The Institute of Sound and Vibration Research, Southampton is one of the foremost centres for the study of sound and vibration phenomena. As well as research and consultation, a variety of courses is presented regularly. Following is a list of short courses available during 1984.

March 26-30 — Instrumentation and Measurement Techniques for Vibration Control.
26-30 — Engine Noise and Vibration.

April 2-6 — Clinical Audiology.
2-6 — Environmental Health Officers Course.

April 9-13 — 2nd International Conference on Recent Advances in Structural Dynamics.
— Instrumentation and Measurement Techniques for Noise Control.

June 5-7 — Vehicle Noise and Vibration (to be held in London).

September 10-14 — Industrial Audiology and Hearing Conservation.
17-21 — Technical Audiology 'A'.
17-21 — 13th Advanced Noise and Vibration Course.

For further information about the ISVR Continuing Education programme and other specialist courses, contact:
Dr. J. G. Walker, ISVR Short Course Organiser
or Mrs. M. Z. Strickland, ISVR Conference Secretary
Institute of Sound and Vibration Research,
The University,
Southampton S09 5NH.
Tel. 0703-559122, exts. 2310/532. Telex: 47661.

INTER-NOISE 84

The Institute of Noise Control Engineering (INCE/USA) has issued the Announcement and Call for Papers for INTER-NOISE 84. INTER-NOISE 84, the 1984 International Conference of Noise Control Engineering, will be the thirteenth in a series of International Conferences on Noise Control Engineering which began in 1972 in Washington, DC. INTER-NOISE 84 will be held at the Hotel Ilikai in Honolulu, Hawaii on December 3rd-5th. Deadline for receipt of abstracts is 15th March, 1984.

Copies of the Announcement and Call for Papers are available from the INTER-NOISE 84 Conference Secretariat, P.O. Box 3469, Arlington Beach, Poughkeepsie, NY 12603, U.S.A.

11 ICA

The opening session of the Paris 11 ICA under the presidency of Professor Rene Lehmann was held in the grand amphitheatre of the Sorbonne on 19th July. The programme from then until the conclusion on 27th July comprised 19 invited papers, more than 700 contributed papers under ten classifications, 22 structured sessions, poster sessions, 24 round tables, a technical exhibition, 9 technical visits, excursions for accompanying persons and concerts. There were more than 1200 participants, including 15 from Australia. For the contributed papers there were 18 author/part-authors from Australia.

Both the general and specific organisation of all aspects of the Congress were judged to be excellent. The approximate ratio of contributed papers in English, French and German was 25:10:2. The published proceedings of 11 ICA differed from the past practice of having one summary page for each paper. Instead, each paper was given in full, that is of four pages. As participants of past ICAs will recall, this overcame the sometimes — unsuccessful search for copies of papers. On the other hand the participants placed a great strain on the efficiency of the French postal system when going through the exercise of mailing back the 7 kg of proceedings within the standard 5 kg limit cardboard box!

KEN COOK

NEW PUBLICATIONS

From the Polish Acoustical Society

Archives of Acoustics (Contents in English)
Vol. 7, No. 3-4, 1982

CONTENTS

Archives of Acoustics
Vol. 8, No. 1, 1983

CONTENTS

From the Royal Institute of Technology, Stockholm
Quarterly Progress and Status Report 1/1983
Dept. of Speech Communication & Music Acoustics

CONTENTS

Speech Research
Summaries of current research
Jan.-Dec., 1982

From Bruel & Kjaer
Technical Review
System Analysis and Time Delay Spectrometry
H. Biering and O. Z. Pedersen
Part 1 in No. 1 — 1983
Part 2 in No. 2 — 1983

From I. INCE
Newsletter 30, June 1983
Includes list of acoustical journals and acoustical societies.
Newsletter 31, September 1983
Includes table of contents for Proceedings Inter-noise 83.

From CSIRO Institute of Energy & Earth Resources
Minerals and Energy Bulletin
No. 9, July 1983; No. 10, October 1983.

From CSIRO
Industrial Research News
159, July 1983; 160, September 1983.

Laboratory News
July 1983; September 1983.

NOISE-CON 83

The Proceedings of the Conference "Quieting the Noise Source" has been published and is available for US$42.00 surface mail (Add US$12.50 for air mail) from Noise Control Foundation, P.O. Box 3469, Arlington Branch, POUGHKEEPSIE, NY 12603, USA.

PAPERS ON GUITAR ACOUSTICS

Ten papers on guitar acoustics given at sessions D and M at the 103rd ASA meeting in Chicago, 27th April, 1982, plus one paper given at the International Conference on Musical Acoustics in DeKalb, 24th April, 1982, have been assembled by Professor Thomas Rossing, Northern Illinois University, and published as a special issue of the *Journal of Guitar Acoustics.* Copies may be ordered from The Editor, Journal of Guitar Acoustics, 11,000 Seymour Road, Grass Lake, MI49240. Price is $U.S.10.00 plus $1.00 for mailing ($3.00 overseas).

Theses

THE TURBULENT JET IN ORGAN FLUE PIPES
with an addendum on The Acoustics of the Clavichord

Suszanne Thwaites
Ph.D. Thesis, University of New England

SUMMARY

The planar air jet produced by the slit in organ flue pipes was investigated experimentally and found to spread out and decay in velocity in a manner characteristic of fully turbulent plane jets. The complex propagation constant of acoustically generated waves on this jet was measured for the range of frequencies and blowing conditions typical of real organ flue pipes. The disturbance phase velocity and the disturbance growth were both found to be surprisingly well described by the theoretically predicted forms for plane laminar non-spreading jets, provided allowance was made in these theories for the turbulence and the spreading. This involved using the concept of an eddy viscosity and also allowing the jet parameters as a function of the disturbance from the slit.

The acoustic admittance of the jet in a real organ pipe was measured as a function of the frequency, the blowing conditions and the jet deflection at the edge. The admittance magnitude and phase were used, in conjunction with the results for the jet behaviour, to isolate and identify the various drive mechanisms occurring in the jet-pipe interaction. The two established drive mechansims were found to be operating but their relative magnitudes were found to be different from theoretical predictions. An experiment was performed using a jet with a pulsating velocity to attempt to discover the relative importance of the two drives. This produced a modification to the drive equation yielding quite good agreement with the organ pipe results. A deviation from expected behaviour, as yet to be explained, was found in the jet admittance magnitude and phase for very low frequencies and high blowing pressures.

Various acoustical features of the fretted clavichord were investigated both theoretically and experimentally. The excitation mechanism, in which a metal blade strikes the string and holds it deflected, yielded an excitation force spectrum with a smooth slope of 6 dB/oct. Energy loss through the paired strings occurred primarily through the bridge to the soundboard, interaction between the strings giving a two stage decay. The measured soundboard response from 50 to 1000 Hz was well accounted for theoretically by a series of couplings between its normal modes and those of the enclosed air cavity, considerably modifying the system response. The sound pressure level and the sound decay time to inaudibility across the compass of the instrument were consistent with the string and soundboard behaviour.

AN EVALUATION OF AN ACOUSTIC EMISSION TRANSDUCER CALIBRATION TECHNIQUE

Brian Wood
M.Sc. (Acous.) Thesis, University of New South Wales

SUMMARY

Acoustic emission is the term given to a stress wave generated in a material from a source which is activated by a stress concentrated in the source area. Analysis of the acoustic emission pulse received by an array of transducers can locate the source of the emission, and an analysis of an individual pulse can give some information on the characteristics of the source. The physical properties of the material being monitored will affect parameters such as the duration, peak amplitude and the rise time of the detected pulse. For any meaningful interpretation of the pulse parameters to be made, the total transfer characteristics of the system, including propagation path, transducer and electronics, must be determined.

A number of transducer and system calibration techniques have been examined and reported upon, and special attention has been given to a simple but effective artificial source which employs the breaking of a pencil lead using a common pencil fitted with a small Teflon guide ring. This technique has been evaluated on a number of materials, and geometrical configurations, using various couplants between the transducer and material surface and a selection of transducers.

The variation in the peak amplitude and rise time of the detected pulse was measured for various source to transducer separation and found to depend on both the physical properties of the material being tested and the source-transducer separation. The sample geometry affected the detected pulse to a varying extent due to the complex effect of the sample dimensions on the particular wave propagation modes. The presence of a couplant between the transducer and the material surface being monitored improved the signal transfer for material surface to transducer with little variation between the couplants tested.

A selection of transducers designed for various uses were compared using a standard experimental arrangement and their responses showed a considerable variation.

The results obtained showed that the simple pencil lead breaking source is suitable as a standard source for both laboratory and field surveys, and also allowed a simple evaluation of the total system response in a wide variety of conditions. The existence of different modes of surface wave propagation has been identified as a possible cause of error in standard defect location and analysis techniques.

ABSTRACTS

Acoustic emission measurements of a shape-memory alloy

Rong S. Geng, Bryan Britton and Raymond W. B. Stephens
Physics Department, Chelsea College, University of London, Pulton Place, London, SW6 5 PR, United Kingdom

J. Acoust. Soc. Am. **73**, 1217 (1983)

ABSTRACT
A description is given of a systematic study of the acoustic emission (AE) characteristics of a specific shape-memory alloy, a copper-based Betalloy. Using a narrow-band AE measuring system, a considerable change in AE signals was observed in the different phase states of the Betalloy, the changes being particularly significant in the slope changes of the amplitude-distribution curves. By careful correlation of AE signals with the stress-induced martensitic transformation, it was found, in repetition cycles, that a reversible AE energy release accompanied the austenite-martensite transition process, which is in direct conflict with the "Kaiser effect". This observation implies that caution is necessary in applying the AE technique for evaluating failure in shape-memory alloys. The values derived from the AE data for the stress required to induce martensitic transformation and for the temperature at which the transformation is initiated are in good agreement with those obtained from stress-strain measurements.

Acoustic and perceptual indicators of emotional stress

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ABSTRACT
Tape recordings of telephone conversations of Consolidated Edison's system operator (SO) and his immediate superior (CSO), beginning an hour before the 1977 New York blackout, were analyzed for indications of psychological stress. (SO was responsible for monitoring and switching power loads within the Con Ed network.) Utterances from the two individuals were analyzed to yield several pitch and amplitude statistics. To assess the perceptual correlates of stress, four groups of listeners used a seven-point scale to rate the stress of SO and CSO from either randomized vocal utterances or transcripts of the randomized utterances. Results indicated that whereas CSO's vocal pitch increased significantly with increased situational stress, SO's pitch decreased. Listener ratings of stress from the voice were positively related to average pitch. It appears that listeners' stereotype of psychological stress includes elevated pitch and amplitude levels, as well as their increased variability.

Spectral analysis of impulse noise for hearing conservation purposes

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ABSTRACT
Damage-risk criteria for impulse noise does not presently take the spectrum of the impulse into account; however, it is known that the human auditory system is spectrally tuned. The present paper advocates the extension to impulse noise of the noise dose concept which is widely used for continuous noise. This approach is based upon **sound exposure** instead of sound pressure. An A-weighting filter or an octave band analysis can then be used to take the spectral content of the impulses into account. The equipment needed for applying these procedures for impulse noise is an integrating sound level meter or a digital Fourier processor. Generalized spectral methods have been evaluated by means of an impulse simulation applied to a mathematical model of the human hearing mechanism. The results of this simulation agree with the most recent experiments on impulse noise and fully support the proposed rating methods. This conclusion must be emphasized as it leads the derivation of a uniform procedure for predicting loudness and damage risk for hearing which is applicable for continuous noise as well as for impulse noise.

An analysis of community complaints to noise

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ABSTRACT
Noise complaints received Army-wide for a one-year period were analyzed (a) to determine the relationship between the nature of the complaint and the type of noise and (b) to determine the relationship between complaints and the day-night level (DNL). For blast noise, 77% of complaints mentioned vibration or physical damage or both, thus confirming the validity of the C-weighted DNL as a better measure of blast noise than the A-weighted DNL. The relationship between DNL and complaints, however, was a very weak one. Instead, the data confirmed an independent finding of a recent study of Air Force noise complaints — that complaints are generated by unusual rather than typical noise levels. Since a valid measure of community response to noise should be functionally relatable to the noise dose, complaints do not appear to be a good measure of the community response. To deal with the wide variability in the emotional tone of the complaints a psychological model was developed and tested. The implications of this model for how an airport or Army base should deal with complaints are discussed.

CONCLUSIONS

The analysis of these data confirms the wisdom of policy which differentiates between annoyance and complaints and assesses the environment based on annoyance rather than complaints. As this paper shows, adverse noise environments may exist without complaints and conversely, acceptable noise environments may exist with complaints. While community response in terms of high annoyance correlates with DNL, complaints correlate only with arousal.

The analysis also highlights the importance of responding to complainants the first time they complain. The data show that first-time complainants are generally courteous and reasonable. Complainants only become unreasonable after having been ignored. In practice, it is far less trouble for an administrator to deal with complainants at their first complaint than deal with community action at a later point.

Inter-laboratory variability of sound absorption measurement

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ABSTRACT
Sound absorption measurements have been made at a number of acoustical laboratories in Canada and the United States using the same specimen and the same measurement equipment and procedure. The results provide insight into the effect of reverberation room and diffuser geometry on measured absorption coefficients.

CONCLUSIONS

From the data collected from these round robin measurements it can be concluded that:

(1) the reproducibility of sound absorption measurements that use a standard procedure is no better than that obtained when each laboratory uses its own measurement procedure for the A mounting;

(2) the larger variability observed during the ASTM round robin when the E-400 mounting was used is probably due to details in the construction of the mounting frame and to the use of only one specimen position.

There is also evidence that reverberation rooms with a large rotating vane located in the centre show smaller standard deviations for the measured absorption coefficient, particularly at low frequency.