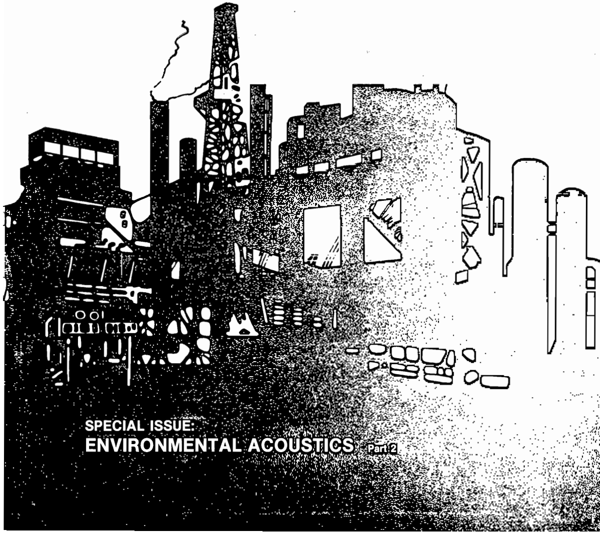
Acoustics Australia

THE BULLETIN OF THE AUSTRALIAN ACOUSTICAL SOCIETY Vol. 13 No. 1 April 1985



SPECIAL ISSUE:
ENVIRONMENTAL ACOUSTICS Part 2

ACOUSTICS AUSTRALIA —

Address all correspondence to:
The Chief Editor
C/- School of Physics
The University of New South Wales
P.O. Box 1, Kensington, N.S.W. 2033

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Cover design and layout by Lydia Lee of Leeway Graphic Design.

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EDITORIAL —

Last November the Council agreed that the time had come for our publication to have a new name and a new image. The implication in the old title that we were producing a "house" journal has been left behind and hopefully advertisers and potential subscribers will see the publication as a comprehensive review of acoustical activity both in Australia and elsewhere. Although the appearance has changed somewhat the internal structure retains its familiar form.

Our thanks go to Leeway Graphic Design for producing the new cover design and for making a number of suggestions to improve the interior layout. We would welcome your reaction to the new look. The colours used on the cover are not sacrosanct and will probably be changed from time to time.

The transition towards special issues on the major areas of acoustics has had a dramatic effect on the rate of acquisition of articles. Thanks largely to the energetic activities of Ferge Fricke the planned single issue on Environmental Acoustics has already filled two issues with one further article by Renzo Tonin still to come in the August issue. At the moment we are planning for each alternate issue to be on a special topic. Future special issues will include Computers in Acoustics, Musical Acoustics, Community Noise, Vibration, and so on into the 1990's.

One of the features of the old Bulletin over the years was the steady stream of short reports on current activities of members which have supplemented and balanced the longer articles. We are keen to continue this tradition and would invite members to send *unsolicited* (yes, we have had a few) *short reports*, consisting of 2-3 pages of double-spaced typing possibly with 1-2 photographs or illustrations, or brief *technical notes*, length about 1 page of typed material. The short reports are usually written around an individual's current work or are a summary of the activities of a group or department. Technical notes describe a single idea or procedure that the originator probably thinks is obvious but in fact is just what the world is waiting for. So, please dust the cobwebs off the old word-processor and let us share your wisdom and experience.

In this issue, apart from the special articles, we have a return of Technical Notes after a long rest. As far as possible we would like this section to consist of original notes from Australian authors but that depends on the supply. We have placed Future Events at the back of the issue to make reference easier.

Other "regular" sections, such as Standards and Publications by Australians, will appear whenever space permits.

It is with considerable pleasure that we announce that **Marion Burgess** has accepted the new position of Associate Editor. The amount of editorial work has been steadily expanding as we widen our scope and contacts. A division of editorial "duties" will ensure greater efficiency and also means that there are now two editors available to lean on correspondents and advertisers to submit their material on time. This publication has acquired a reputation for coming out on time and we hope to capitalise on this by encouraging more small advertisements for positions vacant, personal notices, etc. To this end there is a new advertising rate of $4 per cm for such notices.

Howard Pollard
Chief Editor

Developments in Marine Acoustics

AAS International Conference

The conference was held at the University of New South Wales, 4-6 December 1984. Forty-four invited and contributed papers were presented in the following fields:

Sea floor acoustic properties; Propagation in deep water; Propagation in shallow water; Noise; Scattering; and Signal processing.

Invited papers included:

E. L. Hamilton — "Acoustic and related properties of the Sea Floor".

M. A. Pedersen, D. F. Gordon and D. Edwards — "Coupling Characteristics between two underwater acoustic ducts".

R. B. Mitson — "A Brief Review of Fishers Acoustics — (I) Acoustic assessment of fish stocks — (II) Acoustic telemetry for study of fish behaviour".

Sixty-five scientists from Australia, Canada, Italy, New Zealand, South Africa and the U.S. attended the conference. Copies of the Proceedings (233 pages) are available from The Secretary, Australian Acoustical Society, c/- Science Centre, 35 Clarence Street, Sydney N.S.W. 2000.

S.A. Division

After a number of years in the S.A. Division Committee, **Bob Williamson** has stepped down as he has commenced course work in a MSc in Vibration and Noise Control, using remote superviser and video technique, from Heriot-Watt University in Edinburgh. Later this year, Bob will take study leave to go to Edinburgh where he will complete his thesis on The Influence of Lateral Reflections on the Perception of Sound in Auditoria.

The new office-bearers of the S.A. Division are:

Chairman, David Bies; Division Secretary, Adrian Jones; Divn. Treasurer/Registrar, Ken Martin; Minute Secretary, Max Lane; Acoustics Australia Rep., Peter Swift; Committee Members, Bob Boyce, John Lambert, Peter Brook; Councillors, Bob Boyce, David Bies. Sub Committees: (Activity) Peter Swift, David Bies, John Lambert, Adrian Jones. (Membership and Membership Drive) As above.

The year finished with two technical meetings. In each case the guest speaker was a past student of the Mechanical Engineering Department of the University of Adelaide.

On 15th November, 1984 **Dr. Michael Norton** spoke on his recent work in the reduction of pipe radiated noise using a newly developed dynamic damper and its potential application to the North West Shelf project. Dr. Norton's visit was sponsored by Bradford Insulation who were promoting their newly-released Acoustic Data Book.

The 13th December meeting was in the form of a seminar in conjunction with the Mechanical Engineering Department where **Dr. Chris Fuller** spoke on his work at NASA Langley Research Centre. Dr. Fuller is investigating propeller noise transmission loss of an aircraft fuselage in line with developing propeller technology. The new breed of propellers have potentially high fuel savings but are evidently very noisy. His work so far has been concerned with modelling the appropriate forcing function to apply to the fuselage.

—Peter Swift

Acoustic News from Sydney University

While some members of the department have been spending numerous days at conferences, I have spent a lot of time getting to and from one conference. The Australian Acoustical Society held its annual conference in Perth, W.A. last year. **Ted Weston and I** flew there in Ted's 21/2 seat, 100 knot, Grumman Tiger. The eight days of flying were notable for Ted's skill as a pilot and my total lack of such skills.

The trip also gave some useful anecdotal evidence of the validity of "arousal" theory. Whilst driving the aircraft, I found it all too easy to nod off to sleep during some of the longer, calmer stretches. One way I found of overcoming the drowsiness was to remove my hearing protection. Another way was to turn on the airconditioning, i.e. fly at 3000m. instead of 1000m.

The turbulence over the Nullabor was also good for removing drowsiness, anything in the stomach, us from our seats and, nearly, the Tiger from the sky. The visual stimulation of the Flinders and Mt. Lofty Ranges, the coast around the Eyre Peninsular and the cliffs around the edge of the Bight also had an effect as did the odd bollocksing from air traffic control.

We returned to massive flooding in Sydney and a flood of activity by a number of postgraduate and undergraduate students undertaking acoustics projects. **Vincentius Susilo has** finished his thesis for a M.Blg.Sc. and will be returning to his university in Indonesia shortly. His thesis was on the transmission of sound from one room to another and from one building to another through open windows. The work provides some important data for designers and some ear-unplugging ideas and information for acousticians.

Cliff Free is, I think . . ., eventually . . ., ready (well, almost ready) to submit his thesis on "Measurement of Sound Absorption Coefficients In-Situ", for his M.Blg.Sc. Other postgraduates who may yet pip Cliff at the finishing post are **Paul Uno** (Measurement of Sound Transmission Through Facades), **Urszula Mizia** (Diffusion in Rooms) and **Steve Cooper** (The Acoustics of Non-Diffuse Spaces).

In their Advanced Study Report, **Brad Sharpe** and **Debbie Drennan** have shown that of the 50 or so halls in the Willoughby Municipality almost none are suitable, acoustically, for the purposes for which they are used. The saving thing about most of them is that they are rarely used at all. **Mathew Palavidis** struggled, against many odds, (mainly the unavailability of a promised computer program) to compare the acoustic data obtained from a physical model and a computer model. In the end Mathew withdrew from his Advanced Study Report and went to work for Renzo Tonin as an acoustical consultant instead. He still hopes to complete the work at a later date.

Finally, **Andrew Madry** has joined the department. He has enrolled for a Ph.D. and has been awarded the SPCC scholarship. He joins **Roger Treagus** in the study of atmospheric sound propagation. Andrew completed his B.Sc. (Hons.) degree last year in the Physics Department at Sydney University, obtaining First Class Honours. Andrew is also an accomplished pianist.

—Fergus Fricke

(Continued on page 5)

Hearing Conservation Education in Schools

The Hearing Conservation Education in Schools Project was established by Deafness Foundation (Victoria) in early 1982. Gratefully acknowledged is the significant grant from the Lions Club International Association in support of the project. Under the Chairmanship of **Dr. Ron Barden,** the H.C.E.S. Steering Committee has met regularly to oversee and direct this most important project.

The first task was to survey existing school hearing conservation programmes in the light of the Hearing Conservation (Health) Act of 1979 regarding industry regulations. Survey results showed an urgent need for workshop safety material in technical schools and T.A.F.E. colleges, while in secondary schools a need was identified for material related to social studies, health and human relations and environmental science courses.

Consequently the Steering Committee of the H.C.E.S. Project adopted the survey's major recommendations to produce three audio visual education programmes: one directed to apprenticeship workshop safety programmes, a second directed to general secondary school programmes, and a third directed to supplying teachers and community educators with a variety of information sources.

The initial funding for the project finished in October 1983, however because of the need to carry the work through, the Foundation has continued funding it on a limited budget to complete the programmes. The material produced to date has been extremely well received by schools and has attracted widespread praise in educational circles for the quality, directness and variety of the kits.

The Health Commission of Victoria has actively supported the H.C.E.S. Project by printing a colourful wall poster "Decibel Danger", taken from the illustrations used in the H.C.E.S. kits. The poster was launched by the Hon. T. Roper, Minister of Health, during Deafness Awareness Week, and the Health Commission has sent one poster to each primary and secondary school in Victoria.

The Ethnic Affairs Commission of Victoria has also given appreciable support to the project by funding translations of the tape commentary for the apprenticeship safety programme "Loud Noise . . . the Deaf of You" in eight community languages: Greek, Italian, Turkish, Croatian, Serbian, Vietnamese, Arabic and Chinese.

Further information about the programmes and their availability may be obtained from Margaret Campbell, Deafness Foundation (Victoria), 340 Highett Road, Highett, 3190. Telephone 555-8777.

(Source: Deafness Foundation (Victoria) Annual Report 1984).

Queensland Division Update

Following is a summary of recent activities in Queensland —

- Council has resolved that a Queensland Division be formed.
- A Technical Meeting, preceded by a meeting of the Steering Committee was held at Division of Noise Abatement on November 20. **Mr. Will Tonisson,** Audiologist-in-Charge of the Brisbane Hearing Centre of N.A.L. presented a paper dealing with the anatomical process of hearing as well as contrasting normal with abnormal hearing.
- Applications for membership are still being received by the Secretary of the Steering Committee.

The application for registration of the Queensland Division is currently being processed by the New South Wales Corporate Affairs Commission. If the registration is in order, the General Secretary will proceed to arrange for the provision of the registered office of the Queensland Division with Deloitte, Haskins and Sells' Brisbane office.

—Russell Brown

Community Noise Conference, Toowoomba

Arrangements are now well in hand for the Community Noise Conference in Toowoomba, 1-3 October, 1986.

The overall theme of the conference which is being co-sponsored by the Queensland Division of Noise Abatement and the Australian Acoustical Society, is the achievement of community quietness through effective noise management. Four issues basic to this consideration are:

- planning
- education
- legislation
- administration.

Within this framework, a wide variety of issues will be considered, including environmental noise management, legislation, effects of community noise, public awareness and education programmes, assessment, enforcement, administrative policies, and noise and urban planning.

An Organising Committee has been established and the first meeting was held on Monday, 18 February, 8195. A number of "Expression of Interest Forms" have been returned, including several from overseas.

A "Call for Papers" brochure will be available by mid-year. Copies will be available from Mrs. N. Eddington, Division of Noise Abatement, 64-70 Mary Street, Brisbane, 4000. Telephone (07) 224-7698.

Victoria Division—Meeting Program

May — Visit to either Telecom, the FA18 test cell or the Arts Centre.

July — Seminar: "Industrial Noise and Hearing Conservation" with speakers from Government, ACTU, Industry and perhaps the Research Area.

September or **October** — Seminar: "On-line condition monitoring" with speakers possibly from Vipac, Robin Alfredson, Industry, etc.

November — End of year function.

Hearing Aid Conference

National Acoustic Laboratories
17-21 June, 1985

The conference will focus on determining and meeting the amplification requirements of the hearing impaired. The programme is designed for Audiologists and other professionals engaged in the provision of hearing aids and associated services. Presentations will be at an advanced level and a knowledge of current hearing aid fitting practices will be assumed.

Guest speakers will include:

Donald Dirks, Ph.D., U.C.L.A.
Harry Levitt, Ph.D., City University of New York.
Norma B. Norton, M.A., Auditory Rehabilitation Consultant.
Gerald Studebaker, Ph.D., Memphis State University.

The conference will be held at the new NAL Central Research Laboratory located at Chatswood, Sydney. The extensive acoustical and audiological test facilities within the new laboratory will be available for inspection. In addition there will be opportunities in the week preceding and the week following the conference for observational visits to NAL clinical facilities to be made. Five such clinics are located within Sydney.

The conference fee will be $150. For further details and registration form phone 02-20537.

(Continued on page 7)

International Conference on
Achieving a Better Acoustic Environment
29-30 August 1985
Hyatt Regency Hotel, SINGAPORE

Organised by National University of Singapore and Environmental Engineering Society of Singapore.

Conference Topics: Physical Acoustics, Oral Communication, Shocks, Vibrations, Solid State Acoustics, Applied Acoustics. International experts on acoustics will address participants on the main themes of the conference. Technical papers are also invited on the topics listed by 30 June, 1985.

Further details from — The Conference Secretariat, "Achieving a Better Acoustic Environment", 1 Maritime Square No. 09-22, World Trade Centre, Singapore 0409.

14th International Conference on Noise Control Engineering
18-20 September, 1985
Munich, Germany

The conference deals with the following topics —

National and international legislation and standards for noise reduction; Noise effects on man; Sound propagation in working areas; Measurement and assessment of noise; Sound intensity measurement; Structure borne noise; Noise emission data; Traffic noise; Noise prediction/prognosis and planning; Noise abatement by design and machine noise reduction.

The working language of the congress is English. There will be a special exhibition of materials and instrumentation for noise control engineering and a pre-conference-tour to the most important centres of acoustic research in the Federal Republic of Germany.

For further details contact — INTER-NOISE '85 Secretariat, c/- VDI-Kommission Larmminderung, Postfach 1139, D-4000 Dusseldorf 1, Federal Republic of Germany.

New Joint Institute of Physics/Institute of Acoustic Group

The Council of the Institute has given approval to the formation of a new group, the PHYSICAL ACOUSTICS Group, under the Chairmanship of Dr. D. P. ALMOND of the University of Bath. The object of the group is to provide a forum for Physical Acoustics which will assist in the development of the subject.

The branches of physics covered by the term physical acoustics are the fundamental aspects of acoustic wave propagation and the interactions of acoustic waves with matter. It includes: ultrasonic wave generation, propagation and scattering in solid structures; mechanical relaxation and internal friction; phonon physics; lattice dynamics and the basic physics of: ultrasonic testing and imaging; acoustic emission; photoacoustics, acoustic microscopy and of devices which employ, generate or detect acoustic waves.

Details of membership of the group may be obtained from the Registrar, The Institute of Physics, 47 Belgrave Square, London SW1X 8QX.

2nd International Congress on Acoustic Intensity
Measurement techniques and applications
Senlis, France
September 23-25, 1985

During the week following INTER-NOISE '85 (Munich, 18-20 September, 1985) the 2nd International Congress on Acoustic Intensity Measurement will be held at CETIM, Senlis, France. The congress is sponsored by the International Institute of Noise Control Engineering and by the Groupement des Acousticiens de Langue Francaise (G.A.L.F.).

Scope of the meeting — the knowledge of intensity measurement techniques and the interpretation of vector fields have progressed substantially during the least years and the method is now extensively used in industrial practice. Although special sessions are held in many conferences on acoustics more complete information on all aspects of the matter seems to be desirable. The aim of this congress is to inform both the research workers and the growing number of users on the state of the art and to offer opportunities for extended discussion between specialists.

Further particulars from:

Dr. M. BOCKHOFF
C.E.T.I.M.,
B.P. 67,
F - 60300 SENLIS, France.

International Conference on Acoustics, Speech and Signal Processing

Cosponsored by the IEE ASSP Society, The Acoustical Society of Japan and the Institute of Electronics and Communication Engineers of Japan.

Subject areas:

General Signal Processing; Spectrum Estimation and Signal Modelling; Speech Processing; Multi-Dimensional Signal Processing; Underwater Acoustics, Geophysics and Other Applications; VLSI for Signal Processing; Electro-acoustics and Psychoacoustics.

Paper summary required by 31 August, 1985.

For further information, contact
Prof. Hiroya Fujisaki
General Chairman of ICASSP 86
Department of Electronic Engineering
Faculty of Engineering
University of Tokyo
Bunkyo-ku, Tokyo, 113 JAPAN.

Report on INTER NOISE 84 Conference

The INTER NOISE '84 Conference was held in Honolulu from 3rd to 5th December, 1984. Approximately 300 papers were presented, including contributed and invited papers. A large proportion of the papers was contributed by Japanese authors. An estimated 500 acousticians attended the conference, which was held in the ballroom and adjoining rooms (named after Australian capital cities) of the Westin Ilikai Hotel. As could be expected, Americans and Japanese outnumbered their European counterparts.

The Conference was sponsored by the International Institute of Noise Control Engineering and organised by the Institute of Noise Control Engineering of the U.S.A. (INCE/USA) and INCE/JAPAN, in co-operation with the Acoustical Society of America. INTER NOISE Conferences are held in the U.S.A. in odd-numbered years. The INTER NOISE '85 Conference will be held in Munich in September, 1985. The Australian Acoustical Society is one of the twenty-three member societies of International INCE.

In his opening address, *Mr. Fritz Ingerslev*, the President of International INCE, stated that the ultimate objective of INCE's activities was to contribute to the reduction of noise pollution. He discussed the following means by which noise control could be effected: regulatory provisions, acoustic barriers, land-use planning, effective design, noise labelling.

On each day of the Conference participants were able to choose from six parallel sessions. Papers were chanelled into the nine standard INCE categories. The most popular category (judged by the number of papers) was Analysis, which includes, inter alia, instrumentation systems, modelling, simulation, test facilities and signal processing. The large number of papers on Acoustic Intensity reflected the growing interest being shown in this subject. Of particular interest were the round-table sessions to discuss special topics which took place the day after the Conference. Topics included air-conditioning noise, noise from airports and sound intensity.

Australians contributed eight papers to the Conference. Authors included: A. Lawrence, L. & A. Challis, I. Eddington, A. Hede and R. Bullen, K. Byrne, M. Norton, I. Shepherd and W. Renew.

On the social side, the Conference Committee arranged two events to take the participants' minds away from noise. A cocktail party was held at the hotel on the first night and a coach trip was organised on the following afternoon to show the visitors the beauty of the Hawaiian countryside. During their stay, many visitors availed themselves of the opportunity to visit one or more of the other islands which make up Hawaii.

—Warren Renew.

(continued on p. 7)

Dr. Neville Fletcher has been appointed as a Commissioner to the International Commission on Acoustics. As the list printed under International News shows, Neville joins an illustrious band of acousticians who will guide the fortunes of ICA for the next few years. Apart from his official duties as Director of CSIRO Institute of Physical Sciences, Neville still finds time to direct the acoustical activities of students doing research at the University of New England. We wish him well in his association with ICA.

* * *

Cedric Roberts of Vipac, Perth, has transferred to sunny Queensland to join John Savery in the Brisbane office.

* * *

Bob Randall has returned permanently to Australia after spending several years as unofficial roving acoustical ambassador; at least he was resident in more than one country serving his masters at Bruel and Kjaer. He is now stationed at Head Office in Sydney, where he is busy setting up computer-operated large testing systems. Nice to have you back, Bob.

* * *

It is with some regret that we report that **Barry Murray** of Murray Wilkinson Acoustics is not well. Barry is currently President of the Association of Australian Acoustical Consultants, one of our sustaining members. While he is on the sick list, Barry is looking for someone who would be available part-time to hold his office together. Are there any offers? We hope that Barry will soon be fully recovered.

NEW SUSTAINING MEMBER

It is with pleasure that we announce that **Aq-Vib,** a division of Aqua-Cool Towers Pty. Ltd. of Baulkham Hills, N.S.W., has become a sustaining member of the Society.

At the same time we regret that CRA Services Ltd. of Melbourne have decided not to renew their membership.

NEW MEMBERS

- **Admissions**

We have pleasure in welcoming the following new members who have been admitted to the grade of Subscriber while awaiting grading by the Council Standing Committee on Membership — Mr. R. F. Astridge (N.S.W.), Dr. A. Cabelli (Vic.), Mr. E. E. Edwards (Q.), Mr. D. P. M. Fournier (Q.), Mr. B. Groothoff (Q.), Mr. P. D. Koorockin (Q.), Mr. G. P. Lee-Manwar (Q.), Miss F. McAlister (Q.), Mr. P. McCormack (Q.), Mr. P. A. Murphy (Vic.), Mr. M. J. O'Sullivan (Q.), Mr. A. S. Price (Q.).

- **Graded**

The following new gradings have been approved by the Council Standing Committee on Membership —

Subscriber: Mr. J. A. C. Best (Q.), Mr. E. Krievins (Q.), Mr. Tandon Naresh (India), Mr. G. H. Neumann (Q.), Mr. J. F. Savery (Q.), Mr. M. C. Stark (Q.), Ms S. Wayte (Tas.), Mr. R. G. Windebank (Q.).

Member: Mr. P. A. Murphy (Vic.).

Note: Queensland members have been attached to the N.S.W. Division until the formation of the Queensland Division has been formalised; Tasmanian members become members of the Victorian Division while, for acoustical purposes, India is part of the N.S.W. Division.

QUEENSLANDERS ON THE MOVE

December seems to be a popular month for overseas jaunts among Queenslanders . . .

Noela Eddington and **Warren Renew** are attending Inter-Noise in Hawaii.

Joe Hayes is off to San Francisco, Los Angeles, Boston and New York to interest the Americans in his company's violin electronics development.

Lex Brown it is understood, is off to Hong Kong (again) and U.K. until July 1985.

SOCIETY ARCHIVES

In response to the appeal published in the August 1984 issue, a number of members have donated personally owned back issues of the Bulletin to the Society Archives. All of the deficiencies advertised have now been satisfactorily filled. The archivist, **Paul Dubout,** wishes to use these columns to record the thanks of the Society for these kind donations.

If you have a suitable news item for inclusion in this column, please send it to **Graeme Harding, c/- 22a Liddiard Street, HAWTHORN, VIC. 3122,** or to the Chief Editor.

Graeme Harding

Australian News (Continued)

W.A. Noise Abatement Information Services

Two new information services have recently been made available to the public in Western Australia.

Advice and assistance to abate noise annoyance can be obtained from several government agencies, the choice of which depends upon the origin of the noise. To help the public solve noise problems, the **Health Department of W.A.** have installed a telephone recorded information service (telephone 325 8752). The system is designed to have information available on a continuous basis. The service provides specific information on who to contact depending on the type of the noise source and in one instance the time at which the problem arises.

Similarly, the Health Department has published a new advisory pamphlet "Sound Advice: Noise in the Community". The pamphlet is to be made available through outlets such as local government offices, public libraries, and legal aid centres, or copies can be obtained direct from the Occupational Health Branch of the Department (telephone 325 7911). A telephone call to the Occupational Health Branch can also provide a copy of a pamphlet "Industrial Deafness". The pamphlet contains a brief background on industrial deafness: "What is it? Who has it? and What can be done?" and provides brief information on new Hearing Conservation Regulations which are due to come into operation on 21st October, 1984.

The Noise Abatement (Hearing Conservation in Workplaces) Regulations 1984, amendments 1984 and Guidance Notes can be purchased for $1.10 and $1.80 respectively from the **State Government Information Centre,** 32 St. George's Terrace, Perth, W.A. 6000. Telephone: 325 0231.

International News (Continued)

Composition of ICA
for the period 1984-87

Following is a list of the current ICA commissioners:

Chairman: Prof. H. Myncke, Belgium.
Secretary: Prof. H. Kuttruff, Germany.
Members: A. Alippi, Italy; D. T. Blackstock, U.S.A.; L. Brekhovskikh, U.S.S.R.; N. H. Fletcher, Australia; S. Kameswaran, India; W. Lochstoer, Norway; P. Lord, U.K.; Z. Maekawa, Japan; J. Roux, France; A. Sliwinski, Poland.

ISVR Courses

The following courses will be conducted by the Institute of Sound and Vibration Research, University of Southampton during September 1985:

September —

9-13: Industrial audiology and hearing conservation — Advanced noise and vibration, Part I.

16-20: Technical audiology course — Advanced noise and vibration, Part II.

23-27: Applied digital signal processing.

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 of Southampton, SO9 5NH.

NEW PUBLICATIONS —

The Proceedings of the 4th Congress of the Federation of Acoustical Societies of Europe, FASE 84, is now available from: FASE 84, ELAB, N-7034 TRONDHEIM-NTH, Norway for the price of NOK 500.

The Proceedings of the DAGA '84 Congress is now available from: DPG-GmbH, Hauptstrasse 5, D-5340 Bad Honnef (FRG) at a cost of DM 88.

Reports Received

Royal Institute of Technology, Stockholm
Dept. of Speech Communication and Music Acoustics Quarterly progress and status report
STL-QPSR 1/1984
STL-QPSR 2-3/1984
(Includes Speech Production, Speech & Hearing Defects & Aids, Music Acoustics)

Institute of Sound and Vibration Research, Southampton
Technical report No. 123 — Audiometric configurations and repeatability in noise-induced hearing loss (D. W. Robinson).
Technical report No. 124 — Vibrational power transmission of an idealised gearbox (R.C.N. Leung).
Technical report No. 125 — Power flow between non-conservatively coupled oscillators (F. J. Fahy and D. Yao).

Dept. of Employment & Industrial Relations
Australian Government Publishing Service, Canberra, 1984. Fire Safety at Work.

Journals Received

Canadian Acoustics
Vol. 13, No. 1, Jan. 1985

Factory Sound Fields —Their Characteristics and Prediction

Murray Hodgson
Department of Architecture
University of Cambridge
1 Scroope Terrace
Cambridge, England CB2 1PX

ABSTRACT: The Sabine Theory, associated with the concept of a diffuse sound field, is often applied to enclosures with non-diffuse sound fields, such as factories. In this paper, with the aid of factory measurements, factories are compared to "Sabine spaces". This is done in terms of the sound propagation and the reverberation time, which are related to worker noise exposure and perceived annoyance, respectively. The main factors determining these two variables, and the implications for factory noise reduction, are discussed. Methods for predicting factory sound fields are presented and evaluated.

1. INTRODUCTION

Presented in this paper is the progress of research into the acoustic characteristics of factory sound fields and into factory-noise prediction, which was carried out at the Department of Architecture, University of Cambridge in collaboration with the Institute of Sound and Vibration Research at the University of Southampton. The research comprised theoretical and experimental studies of factory sound fields, of their prediction, and of noise-reduction measures. The experimental work involved extensive measurements in factories and in factory scale models. Further details of the research from which the discussion in this paper is derived are contained in [1,2].

The last decades have seen an increase of interest in, and need for, a better understanding of noise in factories and for accurate factory-noise prediction methods. This increase was stimulated by a greater awareness of the adverse effects of noise on man, and by increasingly stringent recommendations and regulations governing the noise exposure of factory workers. These were aimed at limiting hearing hazard resulting from workplace noise exposure. However, hearing damage is not the only worker-related aspect of factory noise; another factor, not dealt with in existing regulations, is that of comfort or annoyance in the working environment.

Noise in factories results from noisy machinery, processes and operations. Noise levels are enhanced by the confinement of the sound energy in the factory enclosure, resulting in the noise-exposure levels to which workers are subjected. In the case of impulsive noises, the enclosure also results in reverberance, caused by the finite rate of sound decay. Reverberance is believed to be related to the perceived worker annoyance with the working environment, though this has yet to be proven or quantified. It is a common experience of the acoustic consultant that factory noise-reduction measures, even when little affecting noise-exposure levels, considerably improve the working environment by reducing reverberance.

An understanding of, and an ability accurately to predict, the sound field in a factory are essential for the estimation of probable worker noise exposure and annoyance. They also allow the possibility of planning; that is, design of the factory enclosure, as well as noise source and worker-location layouts, in order to minimise noise exposure and annoyance. Further, in the case of existing factories, they permit evaluation of the efficacy and cost-effectiveness of enclosure noise-reduction measures.

Discussions with practitioners reveal that all too often, when they estimate noise levels or the efficacy of possible noise-reduction measures, the well-established Sabine theories, developed for auditoria, are applied. Unfortunately, for many factory spaces their application is invalid. It is the aim of this paper to discuss how factories differ from "Sabine spaces", and to consider the main factors influencing, and the characteristics of, factory sound fields. Methods for predicting factory sound fields, and progress on evaluation of these methods are presented.

2. SOUND FIELD MEASURES AND FREQUENCIES

The sound field in a factory may usefully be characterised by two measures, one describing the steady-state spatial, and one the temporal, behaviour of the field. These are, respectively, the sound propagation (SP) and the reverberation time (RT). The SP is the variation of the sound pressure level (L_P) with distance from an omnidirectional point source located at a position in the factory. SP is measured in octave bands or dB(A). The L_P can be normalised to the output sound power level (L_W) of the source; that is, SP is expressed as $L_P - L_W$ in dB. SP prediction is of the utmost importance, being required for the prediction of the total noise level at a receiver position in the factory; the total level is the energy sum of the level contributions from the individual sources at the position, as given by the SP and the source L_W's.

The RT is the usual room-acoustics measure, related to the rate of sound decay in the enclosure. It is normally measured in full or third-octave bands and is determined from the average of values measured at a number of source and receiver positions. The relevance of RT to factories is less obvious than is that of SP, and is a matter of some discussion among acousticians and consultants. As was mentioned above, it is likely that RT related to the annoyance caused by impulsive sounds.

It is important to consider which frequencies are of interest in factories. Noise in factories may occur at all audio frequencies.

However, the important measure for the prediction of noise-exposure levels is the A-weighted L_{eq}. Because of this weighting, low and high frequency factory noise usually, though by no means always, is of little importance. In this research frequencies corresponding to octave bands from 125 Hz to 4 kHz were investigated.

3. THE SABINE THEORY

The theory of Sabine describes the spatial and temporal behaviour of sound in enclosures which are empty, which have all three dimensions similar, and in which the surface absorption is uniformly distributed. In such enclosures the pattern of sound reflection from the enclosure surfaces is such that at any position equal amounts of sound energy propagate in all directions — the sound field is diffuse. The theory predicts a steady-state sound field composed of two contributions, as shown in Figure 1 for the cases of low and high total absorption. Within a certain distance from a sound source (the so-called "reverberation radius") a "direct field" dominates. This is unaffected by the enclosure and has a level which decreases at a rate of −6 dB per doubling of distance, due to spherical divergence. At larger distances, sound reflected from the enclosure dominates, resulting in a "reverberant field". Its level tends to decrease with volume and decreases with total absorption, but does not vary with source/receiver distance.

Regarding the temporal behaviour of the sound energy during sound decay, the level decays exponentially. The rate of decay is directly proportional to the factory volume and inversely proportional to the total sound absorption, this being composed of surface absorption, as characterised by the diffuse-field absorption coefficient, and of air absorption.

4. FACTORIES vs SABINE SPACES

Factories usually have mutually similar construction. The enclosure is erected over a floor of concrete and is supported by a portal frame system. The walls usually consist of glazing, masonry and/or cladding. The roof, often singly or multiply pitched, or sawtooth, consists of double metal, asbestos and/or plasterboard panels which are mounted on purlins attached to the portal frames. Some factories have a flat, suspended inner ceiling.

Factory spaces differ from those described by the Sabine theory with respect to their contents, shape and surface absorption. These will be discussed individually in more detail below. Because of these differences the assumptions of the Sabine theory are not met. The factory sound field may be highly non-diffuse, the SP and RT characteristics of factories may not be as described above. Predictions using the classical theories may be highly inaccurate.

5. FACTORY CONTENTS

Factories differ from Sabine spaces in that they are not empty, being "fitted" with machines, benches, barriers, mechanical services etc, both within the space and on its surfaces. These fittings scatter and absorb propagating sound. Measurements were made of the sound absorption of two industrial machines, a sheeting machine and a lathe, made of solid metal and metal-panel parts. In both cases the absorption was in the range 0.5 — 2.6 m^3 [3]. While this may be surprisingly high for metal machines, it suggests that the absorption contribution, resulting from surface absorption by the fittings in a factory, is usually a small proportion of the total absorption.

In a fitted factory — in fact, even in an unbounded region containing scatterers — sound propagates from the source to the receiver by an infinite number of paths as it "bounces" between the fittings (and the walls, if present). Sound energy radiated from the source at a certain time arrives at the receiver continuously over a long period of time; there is reverberation even if there are no bounding surfaces. Further, the sound may strike the surfaces and arrive at the receiver from any direction. The presence of fittings in a factory causes a redistribution of sound energy, relative to the case of no fittings, towards the source due to backscattering. The fittings also increase the propagation losses, in two ways. First, as discussed above, sound may be absorbed by the fittings. Secondly, and more importantly, the presence of fittings causes more sound to be scattered onto the bounding surfaces, effectively increasing their absorption. This "effective" absorption can be considerable — in fact many times greater than the fitting surface absorption. Further, the effective absorption tends to be highest at frequencies at which the empty factory surface absorption is highest. The effect of fitting scattering increases with the fitting volume density [1].

Figure 2 shows the SP, in dB(A) for the case of a flat source spectrum, measured in a typical factory when empty and fitted.

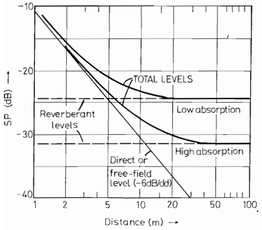

Figure 1: Direct, reverberant and total field SP predicted using the Sabine theory for a large empty enclosure with low and high absorption.

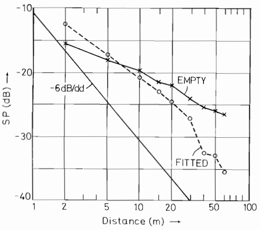

Figure 2: dB(A) SP measured in a factory when empty and fitted.

The factory had average dimensions of 54 m × 47 m × 6.3 m. Its floor and walls were made of concrete and brickwork. The roof, which was doubly pitched, consisted of suspended asbestos and plasterboard panels. When fitted, the factory contained fifty metal machines similar to those mentioned above, of which the surface absorption was measured. The SP was measured, using an omnidirectional loudspeaker array of known output power as the source, along a line down the centre of the factory. Figure 3 shows the corresponding third-octave band RT results. The introduction of the fittings decreased the RT at all frequencies, because of the increased absorption. SP levels increased slightly at short distances due to back-scattering and decreased sharply at distances greater than about 7 m due to energy redistribution and increased propagation losses.

Figure 2 also shows the general characteristics of the SP in empty and fitted factories. Both SP curves approach the free-field line at short distances. Notice, though, that levels at 2 m from the source may be several decibels above the free-field level. This implies that the influence of the factory enclosure and fittings may extend inward to operator positions. In empty factories the SP curve has an approximately constant slope; as the source/receiver distance increases, levels exceed the free-field values by increasingly large amounts. In fitted factories, on the other hand, the magnitude of the slope of the SP curve increases with distance; the SP curve diverges from the free-field line at medium distances and then curves back towards it. In very large, highly absorbent and/or densely fitted factories the SP curve may cross the free-field line. More will be said below about the shape of the RT curve.

6. FACTORY SHAPE

Factories also differ from Sabine spaces because of their shapes. They are usually large and disproportionate, with height much less than length and, often, width. Further, many factories have non-flat roofs; pitched or sawtooth roofs are common. More extremely, factories may be L- or T-shaped or have partial partitions which form coupled spaces. Here discussion is restricted to factories which are rectangular in plan shape and which have no partial partitions. Consideration of the surface-reflection pattern shows that disproportionate shape or a non-flat roof results, at all positions, in a non-uniform angular distribution of the incident sound — that is, in a non-diffuse field. In disproportionate factories no uniform reverberant field exists; in general levels decrease continuously with distance along any major dimension, as in Figure 2.

As an example of the influence of factory shape, consider long factories of the same length and cross-sectional areas, but with different cross-sectional aspect ratios. For two such cases, Figure 4 shows the SP predicted for positions down the length, using a geometric-acoustic method of images prediction method (see below and [1]). In one case the width to height ratio is 1 (duct configuration) — in the other case it is 20 (flat configuration). Clearly, levels for the flat configuration are higher at short distances and lower at large distances than for the duct configuration. More generally, for factories of the same cross-sectional aspect ratio and length, whether empty or fitted, SP levels increase at short distances and decrease at large distances as the ratio of width to height increases. Further, the total surface absorption increases with width to height ratio. For this reason, among others, the RT in fitted factories decreases with width to height ratio. However, contrary to expectation, this may not be the case for empty factories [1].

Increasing or decreasing the volume of an empty factory may change its shape, and decreases or increases the sound energy density and, therefore, SP levels. In factories with a fixed number of fittings, changing the volume also changes the fitting volume density, causing a redistribution of sound energy to larger distances. This tends to reduce SP levels at short distances and to increase SP levels at large distances. Increasing the volume increases the RT in all cases.

The influence of non-flat factory roofs is complicated. The general effect of roof contour is to cause the SP to vary with measurement direction. The variation usually is greatest at low frequencies and decreases with frequency. Figure 5 shows the dB(A) SP measured in directions along and across the roof contours in a uniformly fitted factory. The factory, which was of typical construction, has a doubly-pitched roof and average dimensions of 60 m × 50 m × 5.5 m. The result is typical; in general, large-distance SP levels are lowest in directions which cross the roof contours.

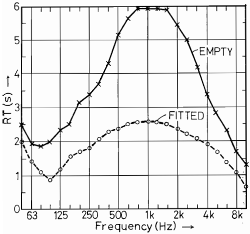

Figure 3: Measured third-octave band RT in a factory when empty and fitted.

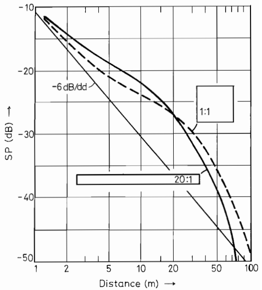

Figure 4: SP in two fitted factories of the same length and cross-sectional area as predicted using a geometric/image model. The parameter is the width:height ratio.

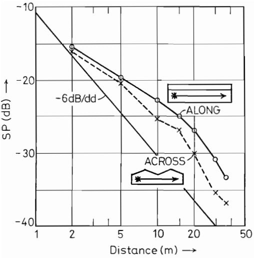

Figure 5: dB(A) SP measured in directions along and across the roof contours in a fitted factory with a doubly-pitched roof.

7. FACTORY SURFACE ABSORPTION

The third main reason why factories differ from Sabine spaces is that the surface absorption is non-uniformly distributed. The absorption of brickwork and blockwork is low at low frequencies, and increases with frequency. Panel roofs and suspended ceilings, on the other hand, may have considerable apparent absorption at low or middle frequencies, owing to their acoustically-induced vibration-response characteristics [4]. Figure 6 shows the diffuse-field absorption coefficient of a double asbestos-panel roof, estimated from measurements on a roof sample and from RT's measured in factories with this roof construction. There is evidence that the apparent absorption of lighter-weight — for example, metal panel — factory roofs occurs mainly in the more subjectively-important mid-frequency range. It can be appreciated that a non-uniform distribution of surface absorption results in a non-diffuse sound field. The influence of surface absorption depends on its distribution. Surface absorption only significantly influences short-distance SP levels when it is located on surfaces near the source. However, absorption on any surface may affect large-distance levels and the RT.

A further important point related to the influence of surface absorption must be mentioned — the absorption of most materials and surfaces varies with angle of incidence. In particular, this has been found to be the case for panel roof constructions [4]. When placed in a diffuse sound field, the effective absorption of such surfaces is the diffuse-field absorption which can be determined from Sabine's RT equation. However, if the material is located in a non-diffuse sound field, its apparent absorption in general will be different from the diffuse-field value. Measurements in full-size factories have shown that low frequency SP levels at medium and large distances often are significantly higher than would be expected from a knowledge of the diffuse-field absorption of typical factory roofs, possibly due to angle of incidence effects. In practice, it is very difficult accurately to measure the angular variation of surface absorption.

It must be emphasised that in enclosures which are disproportionate and, therefore, have a non-diffuse sound field even if the surface absorption is uniformly distributed, the Sabine RT formula cannot be used to determine an average surface absorption from the RT. However, it is still generally true that

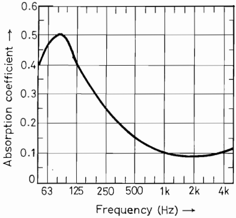

Figure 6: Estimated diffuse-field absorption coefficient of a double asbestos panel factory roof.

the RT and SP levels are high when the total absorption is low, and vice versa. This fact accounts for the variations with frequency of the RT and SP levels. Figure 3 shows the RT in a factory when empty and fitted. The shape of the curves is typical of panel-roof factories. The RT is low at low frequencies, due to ceiling absorption, and at high frequencies, due to surface and air absorption. The RT is highest at mid-frequencies. Figure 7 shows the octave-band SP results for this factory when fitted. It can be seen that short-distance levels tend to increase with frequency. This is because the strength of the dominant ceiling reflections, as well as of back-scattering from the fittings, tend to increase with frequency. Also shown in Figure 7 are the measured octave-band RT values. Notice that large-distance SP levels tend to vary with frequency as does the RT, being lowest at low and high frequencies and highest at mid frequencies.

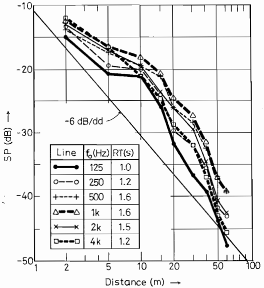

Figure 7: Octave-band SP and RT measured in a fitted factory, with frequency as the parameter.

8. CONTROL OF FACTORY NOISE

The aim of factory noise control is to improve the work environment by the reduction of noise-exposure levels and of reverberation. This may be done either at the design stage, or after the factory is built. As mentioned, the important quantity for the prediction of noise-exposure levels in a factory containing many noise sources is the sound pressure level at positions throughout the factory. The L_P at position P is the energy sum of the level contributions from each source at P, as determined from SP(P).

Clearly, the more specific objective of noise control is to minimise the RT, and the SP in the appropriate source/receiver distance range. At the design stage the factory shape and construction can be optimised. After construction, the RT can be reduced by increasing the total propagation losses. SP levels at short and large distances are reduced by increasing propagation losses and by reducing and increasing respectively, the redistribution of sound energy due to fittings. Table 1 shows some factory-acoustic parameters which can be modified in order to reduce the SP and RT in fitted factories, and the changes required.

Several further comments are necessary in relation to these results. First, the distance which delimits the short and large-distance region is typically 10 – 20 m. Also the short distance region can extend to as close as 1 – 2 m from a point source and, therefore, may include operator positions. Secondly, it is clear from Table 1 that the changes of some parameters, required to reduce the SP and the RT, are often in conflict. The same is true with respect to simultaneous reduction of short and large-distance SP levels. If, for example, it is required to reduce all variables, then the only feasible measure is to increase the surface and fitting absorptions. Measures only causing an energy redistribution are inapplicable. Thirdly, it should be noted that, in many factories, it is not possible to modify the floor, side and end wall absorption.

Because the presence of scatterers increases the effective surface absorption, a combination of scatterers and surface absorption may be especially effective for the reduction of large-distance levels and of the RT.

More generally, since the factory ceiling is often a low-frequency absorber, low-frequency scatterers, which are mid and/or high frequency absorbers, may be a particularly cost-effective treatment. A further reduction of large-distance levels may be achieved if scatterers are located in the roof void, blocking the propagation path which may short-circuit the lower fitted region. A possible application of these principles is the use of solid acoustic baffles, hanging at random locations throughout the roof void. A second possibility is the use of scatterer/absorbers of inverted pyramidial shape, suspended above individual noise sources. The scatterers should have dimensions of at least 2 m to provide adequate low-frequency scattering. Their surfaces should be covered with porous absorbent to provide mid and high frequency absorption.

TABLE 1

Changes of factory-acoustic parameters which reduce the SP and RT in empty and fitted factories

(↑ increase ↓ decrease)

Parameter	SP (short)	SP (large)	RT
Width:height ratio	↓	↑	↑
Height	↑	↓	↓
Surface absorption and distribution	↑ on surfaces nearest the source	↑	↑
Fitting density	↓	↑	↑
Fitting absorption	↑	↑	↑

One important observation, relevant to factory design, must be made about factory height. It normally is expected that decreasing the height increases noise-exposure levels; this is the case in empty factories. However, as discussed above, decreasing the height of fitted factories also causes a redistribution of sound energy, tending to decrease large-distance SP levels. In some cases this may result in decreased noise-exposure levels, contrary to expectation. An example of this is discussed in [3]. Of course, decreasing the height also reduces the RT.

Finally, a non-flat roof can be used to reduce large-distance SP levels in certain directions. Source and receiver locations should be laid out so as to maximise source/receiver distances and the beneficial effects of non-flat roofs.

9. PREDICTION OF FACTORY SOUND FIELDS

If the Sabine theory is not applicable to factories, what is there to replace it, in order that the practitioner can predict factory SP and RT? There are three choices — theoretical models, acoustic-scale modelling and empirical formulae. Each has advantaes and disadvantages which must be weighed in each individual case.

9.1 Theoretical Models

Theoretical models are based on either a wave-acoustic or a geometric-acoustic approach. According to the former approach the wave equation is solved subject to the boundary conditions imposed by the enclosure under consideration. Though a wave approach is most accurate, its practical application is limited to simply-shaped and empty enclosures. Jeske [5] presents application of wave theory to empty factory-like enclosures.

According to the geometric-acoustic approach, sound is considered to propagate as rays. Wave effects, such as diffraction and interference, are ignored. This approach is valid for sound of wavelength much less than the enclosure dimensions. Since the longest wavelength usually of interest in factories is about 2 m, and since factories seldom have dimensions less than 4 m, a geometric approach should be accurate at all but perhaps the lowest frequencies. Geometric-acoustic applications use one of two main approaches — ray tracing and the method of images. Ray tracing involves following a large number of rays, each radiated in some direction, as they propagate from the source to a receiver position. The implementation of ray-tracing methods requires complicated algorithms and lengthy computation times. Hurst and Mitchell [6] have used ray tracing to predict noise levels in factories. A method which, though in practice usually restricted in application to rectangular parallelepipeds, is more easily implemented is the method of images. According to this approach, surfaces are replaced by image rooms containing image sources from which surface reflections are considered to originate. This imaging results in an infinitely-extended image space containing an infinite number of image sources of each actual source. The image sources are assumed to be mutually incoherent. The image space also contains an infinite number of image surface planes of each real surface. At any receiver position the steady-state level due to a real source, and the sound decay, are determined from the energy sums of the contributions from all the sources in the image space. The sound decay and, therefore, the RT are determined from the temporal decay of image-source energy when the sources stop radiating; the steady state level is given by the total energy from all sources. The SP and RT depend on the spatial distribution of the image sources, and on their individual energy contributions, which themselves depend on losses suffered during propagation to the receiver. In the case of empty enclosures, propagation losses result from spherical divergence, surface and air absorption. The influence of source directivity and angularly-varying surface absorption can be incorporated into the model by weighting the energy contribution of each image source according to, respectively, the direction of the receiver from the source, and the angle at which the ray crosses the image surface planes.

The influence of fittings has been included in two ways. First, their effect on sound propagating from the image sources to a receiver has been modelled using barrier theory [7]. Secondly, a statistical approach has been taken [8,9] and incorporated into image-method models [9,10]. This was done by imaging the scatterers in the bounding surfaces, resulting in an infinite region containing scatterers superimposed upon the image sources and surfaces in the image space of the empty enclosure. The SP and RT are determined as for the empty case; however the energy contributions of the individual image sources are now substantially different.

The image method is very useful for providing a conceptual framework for considering factory acoustics. Consideration of the factory image space can lead to an appreciation of the characteristics of the factory sound field. For example, it is clear that a disproportionate enclosure with specularly-reflecting surfaces must have a non-diffuse sound field, since the image sources are not distributed uniformly throughout the image space. Further, image models have been shown to describe many observed factory-acoustic characteristics; particularly, the influences of enclosure shape, surface absorption and fittings [1,11].

Unfortunately, all theoretical prediction methods are seriously limited in practical application because of the considerable degree of uncertainty associated with their input parameters for specific factories. In particular it has yet to be determined how best to estimate the relevant absorption of a given factory roof or the total scattering cross-section density of a factory's fittings. Work is in progress, comparing theoretical prediction with full-size and scale-model factory measurements in order to evaluate the existing models and to solve the problem of parameter estimation.

9.2 Physical Scale Models

Factory SP and RT can also be predicted using acoustic scale-modelling techniques, whereby a reduced-scale model of a planned or existing factory is built and tested. Model noise-reduction measures can be introduced into the model and their performances measured. The feasibility of the scale modelling of factory sound fields has been demonstrated by successfully modelling an existing factory [2]. The factory, which produced commercial lightbulbs, had average dimensions of 120 m × 44 m × 9 m and was of typical construction. In particular, the singly-pitched roof consisted of double asbestos panels suspended on a light metal framework. The walls and floor of the model, built at 1:16 scale, were constructed of varnished timber and plastic. The roof construction was based on a distributed Helmholtz-resonator principle. The fittings were timber and cardboard blocks and tin cans of the approximate scale sizes and shapes of the main factory fittings. Figure 8 shows the RT measured in the prototype factory and its scale model. Figure 9 shows the corresponding dB(A) SP results. The model RT is within about 10% of the prototype RT at all except the lowest frequencies. The dB(A) SP is modelled to an average accuracy of about 0.5 dB. The difference between the model and prototype factory SP averaged about 1.5 dB in the individual octave bands.

Factory scale models have also been used as research tools [2], and to investigate the performance of noise-reduction treatments [12]. Clearly scale modelling requires a greater expenditure of money and time than does use of computer prediction programs. However, scale models have the advantage that they can be used in the case of non-regular configurations which are not described by existing theory. However, if scale models are to be used as design aids, which must be cost effective, then small scales, e.g. 1:50, must be chosen. Unfortunately, recent research aimed at extending factory scale modelling to 1:50 scale has shown the accuracy of the technique at small scales to be very low, for several reasons. First, scale models have an upper limit for accurate scaling, because of limitations with instrumentation and air-absorption scaling. This limit is about 2.5 kHz full scale at 1:16 scale, but only 800 Hz full scale at 1:50 scale. An 800 Hz full scale limit makes the determination of dB(A) levels impossible. Secondly, the non-omnidirectional response of even the smallest microphones at high model test frequencies has been found significantly to limit the accuracy of SP levels measured in disproportionate, non-diffuse-field models. Thirdly, the absorption coefficient of varnished timber, the most convenient material for modelling acoustically-hard factory surfaces, in some cases is too absorbent at high model frequencies. The low accuracy of 1:50 scale factory models seriously limits their usefulness.

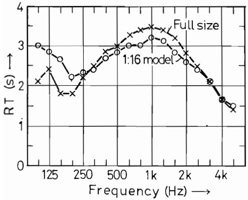

Figure 8: Measured third-octave band RT in the full-size factory and its 1:16 scale model.

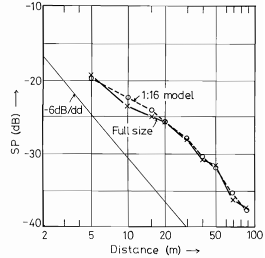

Figure 9: Measured dB(A) SP in the full-size factory and its 1:16 scale model.

9.3 Empirical Models

The limitations suffered by theoretical and physical models, because of problems with parameter estimation, suggest that empirical prediction methods, derived from measurements in factories, may be useful. Friberg [13] has developed such a method for the prediction of the RT at 1 kHz and of the slope of the dB(A) SP curve. These are determined from the diffuse-field absorption coefficient of the factory roof at 1 kHz, the factory height, and from tabulated constants describing the factory shape and fittings. Friberg's method is limited in scope and accuracy for several reasons. It provides only limited frequency information. The SP curve is assumed to be of constant slope, and only its slope, but not its absolute level, is predicted. Finally, the method does not account for the influence of non-flat roofs. Measurements of SP and RT in a large number of empty and fitted factories are in progress. These will provide data for comparison with theoretical and scale-model prediction aimed at the determination of relevant acoustic parameters. The data is also being used to develop more comprehensive empirical predictions for SP and RT [14]. The SP curve will be characterised by two straight-line segments. The predictions will provide full frequency information.

10. CONCLUSION

Two important worker-related aspects of factory noise are the noise exposure and annoyance. These are related to the factory SP, and probably RT. It is essential to understand the factors determining, and the characteristics of, SP and RT in factories. The Sabine theory is often used, for example to determine absorption coefficients from the measured RT, despite being invalid for reasons related to factory contents, shape and absorption. These reasons have been discussed with the aid of factory measurements. The implications of the discussion for the control of factory noise have been discussed; the potential use of factory shape and of scatterer/absorber combinations are of particular interest. Finally, the methods available to the practitioner for the prediction of factory SP and RT have been considered. Prediction methods based on geometric acoustics and the method of images have been found to describe many important factory-acoustic effects. However, their usefulness is at present limited by problems with the accurate estimation of the theoretical parameters in specific cases. Scale models have been investigated as alternative prediction tools. Though large-scale factory models appear to be sufficiently accurate for use as design aids, the accuracy of small-scale models has been found to be low. Empirical prediction methods, based on factory measurements have potential as prediction tools; work is in progress to develop such a method.

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EARLY WARNING FOR INDUSTRIAL DEAFNESS

Industrial deafness could be prevented if researchers at London University find a way to develop their work commercially. And the research could ensure that compensation is paid only to people who have genuinely lost their hearing. But lack of commercial interest is blocking development of the idea.

Dr David Kemp, of London University's audiology department, first showed in 1977 how the ear analyses sound by an "active feedback system" which can be shocked into generating an echo. This echo is characteristic of the individual, and identifies someone as clearly as a fingerprint does. More valuable in practice, however, is the discovery that the echo is missing in people who have lost only a little of their hearing.

If the cochlea of a healthy human ear is stimulated with a clicking sound fed in by a small earphone loudspeaker, it will echo the sound with distortion added.

This sound can be picked up and analysed by a computer to produce a printout which characterises the individual. The surprise discovery was that this echo disappears if the ear loses sensitivity by as little as 30 decibels. This is an almost indetectable hearing loss but it can signal the start of industrial deafness.

Kemp has built a laboratory system and the National Research Development Corporation (now part of the British Technology Group) holds the patents. His plan was to license any British electronics manufacturer able to make a suitcase version. Firms could then check employees' hearing when they first join and at regular intervals whilst they are on the payroll. The beauty of the system is that it provides an early warning of deafness and cannot be fooled, like current audiometric tests, by workers who only pretend they are deaf.

(*New Scientist* 8 March 1984)

Acoustic Requirements to Curb Rain Noise from Metal Deck Roofs

Renzo Tonin

Renzo Tonin & Associates Pty Ltd
160 Castlereagh Street, Sydney 2000

This technical note is the result of research undertaken by Renzo Tonin & Associates Pty. Ltd. for the N.S.W. Department of Public Works Acoustics Unit whose kind permission to publish this work is acknowledged.

Summary

A significant number of rain showers occur in a working year having rainfall intensities of up to 10mm/hr. The average duration of rain showers can be 30-60 minutes with up to half of the rainfall quantity being discharged in 6-12 minutes.

Noise levels within a typical space can be as high as 75-80 dB (A) for an untreated metal roof. A number of treatments are proposed to reduce this noise level to 50 dB (A) or less.

Strawboard roof systems appear to have a significant cost advantage over plaster board constructions for roof spans up to 10.1 metres and where structural considerations permit.

Introduction

The popularity of light-weight metal deck roofs for use in buildings where speech communication is of prime importance causes noise due to rain impact on the roof to be an important intrusive noise source.

In this report, calculation methods, criteria and construction techniques are discussed together with approximate costs to achieve acceptable noise levels.

Rainfall Data

Reference 1 summarises rainfall intensity data for Sydney for the years 1922 to 1971. The information is presented in terms of the percentage of time that a given rainfall intensity is exceeded.

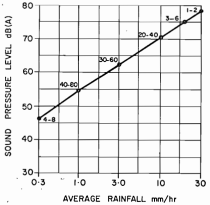

Figure 1. Rain noise on untreated roof in building space of size 10 m x 14 m x 5 m. Number above points are yearly shower occurrences during normal working times. Sydney data only.

Dubout (ref. 2) presents results of a research project which essentially concludes that the dependence of noise on rainfall intensity is:

PWL per roof sq. metre = $17.3 \log_{10}(R) + 46$ dB . . . (1)
where PWL is power level re 10^{-12} watts, and, R is rainfall intensity level in units of mm/hr.

The roofing material used in the experiment was 0.8 mm. thick galvanised steel — trough decking with a slope of about one in 35.

Given a building space of size 10 x 14 x 5 metres high which incorporates a metal deck roof and has a typical reverberation time of one second in each octave band, sound pressure levels are calculated using Equation (1). Results are shown in Figure 1.

Before an assessment of the extent of noise intrusion can be made, information is required on the frequency and duration of rain showers. Information from the Bureau of Meteorology suggests that a "typical" rain shower has the following properties:

- Average duration 30 minutes.
- Within a 6-12 minute period, approximately 35-50 per cent of rain falls. The rainfall intensity for this period is approximately twice the average rainfall intensity. From Equation (1) the sound power level for this period is 5dB more than that calculated for the average rainfall intensity over that period.
- During this period of high rainfall intensity, Dubout (ref. 2) reports that quite rapid fluctuations in noise level sometimes occur, with several audible maxima per minute, for example, in gusty conditions. No data is available on the noise level of these peaks but we assume they could be 5 dB (A) more than the average noise level.

Given the average yearly rainfall intensity data (ref. 1) and an average shower duration of 30-60 minutes then the number of showers of given intensity can be calculated. The numbers above the dots in Fig. 1 are the results of this calculation. These numbers represent the number of showers of given rainfall intensity that occur on average during a working year (a working year is 45 weeks, 5 days per week and 9 hours per day).

It is clear from Fig. 1 that a significant number of showers occur during the year with intensity 10 mm/hr and less. Hence we recommend that an average rainfall intensity of 10mm/hr be used as a design value.

Noise Criterion

The ambient noise level within a building space is usually specified in terms of an NR value. The sound level in dB (A) units is usually 5 dB more than the NR value for air-conditioning noise and continuous traffic noise. An extraneous intrusive noise source can be 5-10 dB (A) more than the ambient level before it becomes obtrusive, depending upon the use of the room.

(continued on p. 34)

Active Noise Control In Ducts

I.C. Shepherd, R.F. La Fontaine and A. Cabelli
CSIRO Division of Energy Technology
Highett, Victoria 3190

ABSTRACT: The advantages of active noise control in ducts are well publicised and several laboratory systems are now yielding impressive results. Yet there are relatively few active attenuators employed in industry. This is partly due to some important limitations of active systems but also because potential suppliers and users have not recognised suitable applications. Several systems are described and the most influential performance factors are discussed, so that potential applications can be assessed to determine the performance which can be achieved and the hardware required.

1. INTRODUCTION

Cancellation of unwanted noise by an artificially generated sound of opposite signature was conceptualised in 1939 by Lueg [1] and again by Olsen [2] in 1953; it is not therefore a new concept. Only recently however, has the range and quality of electronic components improved to the extent that practical realisation of active attenuation has become possible.

There is now a plethora of possible arrangements which have been proposed mainly for applications in flow ducts. Each has strengths and weaknesses but all show the potential for good performance at low frequency while offering practically no resistance to flow. It is these characteristics which make active duct attenuators so attractive for low frequency applications, in contrast with conventional attenuators which often provide less than adequate performance with an extremely high flow resistance.

Nevertheless, nearly all the systems operating today are laboratory models and few industrial applications have appeared [3], [4]. The reason for this is not entirely clear, although there are probably several factors, some associated with technical limitations of the method. Most active systems should be less expensive than their conventional counterpart, and because of the low flow losses result in a saving in fan power. Conceptualised as many discrete components, the systems may appear complicated, but modern components are very compact and objections concerning reliability can be eliminated by using quality components and careful design.

It remains necessary for system developers to sell the concept to potential manufacturers and users, stressing performance, value for money and reliability. This paper presents a broad description of current developments and describes the factors likely to be influential in practical applications, thus enabling the reader to make realistic assessments of potential applications.

LIST OF SYMBOLS

c	Speed of sound
$E(j\omega)$	Electrical voltage (frequency domain)
f	Frequency
$H(j\omega)$	Complex frequency response of filter
j	$\sqrt{-1}$
k	Wave number ω/c
l	Length
L	Limiting attenuation ratio
$P(j\omega)$	Fluctuating pressure signal (frequency domain)
$R(j\omega)$	Complex frequency response of loudspeaker
s	Spacing between speakers and microphones
$S(j\omega)$	Power spectral density
t	Time
γ	Loudspeaker to microphone coupling factor (via the duct)
γ_M	Microphone coupler directionality factor
γ_L	Loudspeaker coupler directionality factor
ω	Radian frequency $2\pi f$
τ	Signal delay time

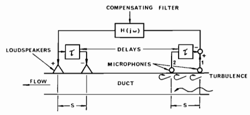

Figure 1: Swinbanks attenuator

2. STATE OF THE ART

At present, there are several flow duct attenuator systems being promoted by various groups. They are described broadly in the review paper by Warnaka [5] but the most promising are described below.

The classic paper by Swinbanks [6] described what is probably the most popular arrangement. It comprises a gang of sensing microphones, usually two, a compensating filter and a gang of loudspeakers as shown in Figure 1. Both microphones and speakers are arranged with interconnecting delays and difference junctions so that they couple with acoustic waves propagating in one direction only. This avoids an unacceptable feedback loop from the speakers to the microphones. Such arrangements have a non-uniform response which can be expressed in the frequency domain by

$$E_1(j\omega) = P_1(j\omega)[1 - \exp(-j2\omega\tau)] \quad (1)$$

where $E_1(j\omega)$ is the output of the difference junction,
$P_1(j\omega)$ is the acoustic pressure in the positive going wave,
τ is the signal delay time ℓ/c
ω is the radian frequency, and
$j = \sqrt{-1}$

This response must be compensated by the filter if wide band operation is required.

Jessel [7] proposed a different unidirectional arrangement of loudspeakers which he coupled to a single microphone. His system, illustrated in Figure 2, comprises three drivers interconnected by phase shifting and compensating elements. It can be shown that the frequency response of such an ideal system is flat provided the dipole input is filtered by a $1/(4 \sin k\ell)$ function, which is similar to that needed in the Swinbanks arrangement. The three drivers in the configuration proposed by Jessel pose practical difficulties in achieving a smooth matching of components. Furthermore, this configuration is not readily amenable to simple design changes such as altering the driver spacing.

A useful feature of both the Swinbanks and Jessel systems is that the offending sound is absorbed by the drivers and is not reflected, as in other systems. This can have important consequences depending on the application as shown by La Fontaine and Shepherd [10]. Reflected sound can be re-reflected by upstream bends, fans or discontinuities to combine with the original noise and present a more intense incident sound field.

The Chelsea Dipole [9], shown in Figure 3, reflects sound back towards the source. Acoustic coupling between the loudspeakers and microphone is minimised by a dipole arrangement of the speakers, with the microphone mounted centrally between them. The function $1/(2 \sin k\ell)$ is required to compensate for the non-uniform dipole response.

Decoupling the microphone and driver can also be accomplished electronically as in the monopole arrangement [9] shown in Figure 4. A delayed version of the loudspeaker signal is added to the microphone output, thus cancelling the sound fed back via the duct. In effect, the electronic and acoustic feedback paths constitute recursive filters with inverse responses. Like the Chelsea Dipole, the compensated monopole does not absorb the offending sound, but reflects it.

The Essex system [3], illustrated in Figure 5, is an apparently simple arrangement which attenuates periodic signals by gradually building up, over a number of cycles, a cancelling waveform which is designed to minimise the residual sound downstream. The cancelling signal is synthesised in stepwise fashion on a Charge Coupled Device (CCD) and then fed to the secondary speaker. An algorithm which continuously updates the step values to minimise the residual noise also serves as an adaptive controller. The literature available suggests that it employs a single loudspeaker and is therefore a reflecting system.

Clearly, there are many arrangements possible and the most suitable depends on the application. When assessing any given situation, the system designer needs to consider several factors which could limit performance. These factors will be discussed with respect to the most flexible arrangement, namely that of Swinbanks [6], but all the previously mentioned systems are also subject to their influence.

3. DESIGN FACTORS

Consider the Swinbanks system shown in Figure 1. It comprises a two-microphone and a two-loudspeaker unidirectional coupler which are connected by a compensating filter and amplifier. The filter compensates for the amplitude and phase irregularities which are inherent in the couplers as well as non-uniformities in the loudspeaker response. For practical purposes, the individual microphones can be considered ideal.

In the frequency domain the relationship between the microphone coupler voltage $E_1(j\omega)$ and the incident sound pressure $P_1(j\omega)$ is

$$E_1(j\omega)/P_1(j\omega) = 1 - \exp(-j2\omega\tau) \quad (2)$$

and the secondary sound is given by

$$P_2(j\omega)/E_2(j\omega) = [1 - \exp(-j2\omega\tau)]R(j\omega) \quad (3)$$

where $E_2(j\omega)$ is the output voltage of the compensating filter, $P_2(j\omega)$ is the secondary sound and $R(j\omega)$ is the complex frequency response of the individual loudspeakers.

Such a system was developed at the CSIRO Division of Energy Technology [8] and gave the attenuation shown in Figure 6 for white noise band limited between 30 and 650 Hz. An overall attenuation of 18 dB was achieved in an ideal situation which cannot be expected in practice. Factors which cause deterioration of the performance are now considered.

3.1 Noise Character and Frequency Range

Some classes of attenuators are ineffective when dealing with certain types of noise. For example, the Essex periodic system is specifically developed for periodic sound and would be useless in a random noise situation. Many other systems however, sense and condition the incoming sound so that they can operate on periodic, random or transient sounds. These systems are normally limited in frequency range only.

In flow duct applications, sound can propagate as a plane wave at any frequency or above certain cut-on frequencies, as higher order modes which, in contrast to plane waves, have non-uniform pressure distributions over the duct cross section. The cut-on frequencies are inversely proportional to the duct cross sectional dimension, and the phase speeds of higher order modes exceed the speed of sound and are also a function of frequency. For frequencies lower than the cut-on frequency of the first cross mode, sound propagates as a plane wave and the phase velocity is equal to the speed of sound.

Since the rate at which information propagates in higher order modes is different for each mode and is also a function of frequency, an attenuator capable of operating on higher order modes would need to be far more complicated than one designed for plane waves. In essence, each mode would require an independent attenuator incorporating multiple microphone and speaker arrays. Swinbanks [6] made suggestions along these lines, but it seems far more practical to focus attention on plane wave attenuators, where necessary dividing the duct into several passages, each small enough to avoid the propagation of higher order modes.

The operating bandwidth is obviously an important feature of an attenuator. A single tone or narrow band is relatively easy to attenuate, whereas it is difficult to maintain good attenuation over several octaves. While the CSIRO laboratory system achieved an attentuation of 15 to 20 dB over 4.5 octaves (from 30 Hz to 650 Hz), the requirement for such a wide bandwidth would be rare.

3.2 Reproduction Accuracy

The overall accuracy of reproduction has a strong influence on the system performance [8]. Figure 7 shows graphically, the maximum allowable error in amplitude and phase responses for any given attenuation. For example, amplitude must be uniform within ± 1 dB and phase within $\pm 5°$ if an attenuation of 20 dB is sought. This can easily be achieved over a narrow band or for a single tone, but a readily available loudspeaker will not meet such a stringent requirement over a wide band, say 2 octaves. The CSIRO sys'em achieved this accuracy for 30 Hz to 650 Hz by employing a system of motional feedback whereby the motional back-emf of the voice coil provided the feedback signal.

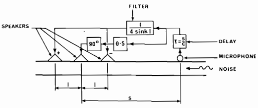

Figure 2: Jessels attenuator

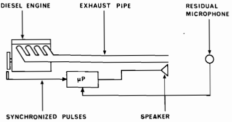

Figure 5: The Essex periodic system

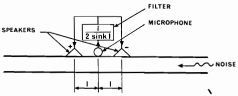

Figure 3: The Chelsea Dipole

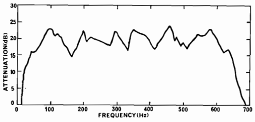

Figure 6: Attenuation vs frequency for CSIRO attenuator

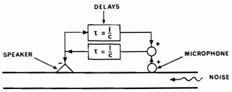

Figure 4: Monopole system with compensation

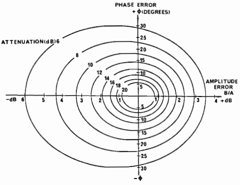

Figure 7: Influence of phase and amplitude errors on attenuation

3.3 Coupling Between Loudspeakers and Microphones

In a real system, there will be some coupling between speakers and microphones via the duct. La Fontaine and Shepherd [8] show that the maximum attentuation of a random source (which can be achieved with an otherwise perfect attenuator) is given by $L \cong \gamma$, where L is the limiting attenuation and γ is the loudspeaker-microphone coupling factor via the duct.

The coupling factor is the product of the unidirectionalities of the microphone and loudspeaker couplers γ_M and γ_L. One can employ a single microphone $\gamma_M = 1$ with a nominally unidirectional loudspeaker arrangement ($\gamma = \gamma_L$), a single loudspeaker ($\gamma_L = 1$) with a nominally unidirectional arrangement of microphones ($\gamma = \gamma_m$) or unidirectional arrangements for both loudspeakers and microphones ($\gamma = \gamma_m\gamma_L$). Since microphones are generally more accurate transducers than loudspeakers, γ_m can be made sufficiently small with relative ease. However there is another reason for employing a unidirectional arrangement of loudspeakers; that is to avoid reflection of sound back towards the source.

3.4 Absorption or Reflection of Acoustic Energy

Attenuators which do not employ a unidirectional loudspeaker arrangement, for example the Chelsea Dipole or any single speaker arrangement, reflect the acoustic waves back towards the source, whereas those with unidirectional arrangements absorb the acoustic energy. This is often an important consideration, as revealed in reference [10].

Where the offending noise is reflected back towards the source and there is a reflecting discontinuity upstream, like a bend or fan, the noise level upstream of the attenuator is increased. The level downstream will also be greater (by the same amount) than it would be with an absorbing system of the same attenuation (ratio of upstream to downstream noise level). This effect can easily render a 10 dB attenuation ineffective. Figure 8 shows the theoretical insertion loss (change produced by insertion of the system) as a function of upstream and downstream amplitude reflection ratios, for a reflecting attenuator with a nominal attenuation of 16 dB. Clearly, the insertion loss can be several dB less than the attenuation rating if upstream reflections are high. Reflections from discontinuities downstream of the attenuator are only important when coupled with a high upstream reflection and a poor attenuation rating.

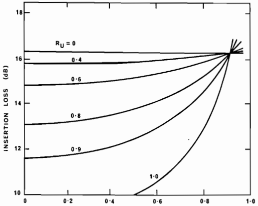

Figure 8: Insertion loss vs downstream reflection (R_D) for an attenuator employing an omnidirectional loudspeaker and unidirectional microphone with various values of upstream reflection (R_U). $\gamma_L = 1$, $\gamma_M = 0.1$, attenuation = 16.4 dB.

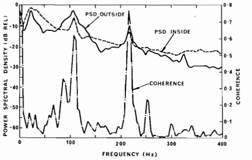

Figure 9: Pressure spectra and coherence in a fan exhaust diffuser

3.5 Flow Turbulence

To a single microphone, pressure fluctuations due to sound and those associated with flow turbulence are indistinguishable. Therefore turbulent pressure fluctuations, which do not normally correlate with the acoustic signal, cause the secondary source to inject sound which has no acoustic counterpart to cancel, producing an increase in noise. The effect of turbulent pressure fluctuations is discussed in reference [11], where it is shown that turbulence causes residual noise in an otherwise perfect attenuator.

For the system in Figure 1, it can be shown [11] that the residual noise spectrum is given by

$$S_R(j\omega) = S_P(j\omega)/[2\sin^2(\omega\ell)] \qquad (4)$$

where $S_R(j\omega)$ is the residual spectrum and
$S_P(j\omega)$ is the spectrum of the turbulent pressure fluctuation at the microphone.

Therefore, the level of residual noise is at best 3 dB less than the turbulent pressure fluctuations at the microphones. For this reason there are certainly some industrial problems which cannot be solved by active attenuation.

Figure 9 shows spectra of signals from a microphone placed inside the diffuser of an exhaust fan and from another microphone placed outside the diffuser near the exit. The microphone inside the diffuser responds to acoustic and turbulent pressure fluctuations whereas the other microphone responds to acoustic radiation from the exhaust only.

Since the acoustic content at the two positions is assumed to be related in a linear system sense, the coherence function provides a measure of the in-duct spectral density which can be attributed to acoustics. It is therefore a measure of the scope for active attenuation in accordance with equation 4. Since coherence is low everywhere except at two tonal peaks, there are only two frequencies where active attenuation can achieve much effect. For example, at 100 Hz the coherence is about 0.62. Thus 62% of the total mean square fluctuations can be attributed to sound which can presumably be attenuated to the threshold defined by equation 4. This amounts to a threshold attenuation of 5 dB at that frequency.

The microphones can be screened from turbulent fluctuations with microphone shields such as those of reference [12] which provide 10 dB to 25 dB turbulence rejection at 100 to 1000 Hz respectively. There are also multiple microphone arrangements which help, but at great expense and still only about 10 dB improvement can be realistically expected.

3.6 Adaptive Control and Optimisation

Most laboratory systems have no need for adaptive controllers but nearly all industrial applications would. Variable flow rates, fluid temperatures and fluid contents make adaptive control essential for at least two variables, say the overall gain and the time delay. In addition, drifts in the characteristics of electronic components would need to be compensated.

Utilising a microprocessor in each case, there are three broad approaches to maintaining optimum performance of an attenuator. One method adjusts a minimal number of settings on a system which is capable of uncontrolled operation for short periods, this is essentially a fine tuning function. Another approach continuously adapts the frequency response of the compensating filter, which would be either fully digital or a programmable convolver, to achieve near optimum performance [13]. A third approach [3], used in periodic noise attenuators, involves synthesising one period of the signal in the time domain by a series of steps. The individual step heights are adapted via an algorithm to minimise the residual noise. The first option is relatively simple and could be developed without difficulty. The second method is being investigated jointly by the CSIRO and the University of Adelaide Electrical Engineering Department, for possible future use in more complex arrangements.

4. CONCLUSIONS

The basic concept of active attenuation has been introduced and some of the systems currently promoted have been described.

The most important factors involved in practical implementation of attenuators have been discussed. Performance can be limited by reproduction accuracy, loudspeaker-microphone coupling via the duct, and local turbulence. Acoustic reflections from the duct elements adjacent to the attenuator also have a significant influence on reflecting attenuators.

Material is presented which enables potential applications of active attenuators to be assessed and a suitable design arrangement to be selected.

(Received 28 September 1984)

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STRADIVARIUS RECAPTURED

Despite efforts by the Japanese to reproduce the perfect sound of a Stradivarius violin with computers, the original has remained unique and impossible to copy — until now.

Dr Joseph Nagyvary, a biochemist at Texas A&M University, has come closer to the original Stradivarius sound than anyone in 200 years. He attributes his success to looking for chemical answers when, as he notes, "everyone else did acoustic analysis".

Although there are still 700 Stradivarius violins remaining in the world, their value, which can reach $1.6 million depending on condition, prohibits such experimentation. Dr Nagyvary had the co-operation of the Library of Congress curator, Rene Morel, who helped to make available five original samples which were being repaired.

Limited as they were, the samples were the key to the research, allowing Dr Nagyvary to studying the cellular structure and chemical composition of the violins.

He concluded that there were three types of noise filters in the original wood cells — fuzzy surfaces, an abundance of cracks and holes and a significant amount of debris.

They absorbed the high frequency noise and gave the violins a pure sound. Dr Nagyvary also found strains of numerous chemical elements like gold, silver and vanadium which he attributes to alchemists of the time who were consulted on preserving the woods.

Another key element is the varnish, which Dr Nagyvary discovered was made of the natural polymer chitin. This gave him the breakthrough in the production of his own violins. So important is the chitin varnish that modern instruments of indifferent quality are tranformed by treatment with it.

But there is more to a Nagyvary violin than that. Working with violin makers in Italy and the US, Dr Nagyvary confines his contribution to the "final 20 per cent and this is the critical part", where he treats the wood in selected spots to enhance its sound as well as apply the varnish.

Frank Lipsius in the *Australia*, 17 March 1984

NOISY SWEETS

Few things irritate more than rustling sweetwrappers in the cinema. But which is the noisiest sweet when it comes to the crunch? We bought a selection of Cellophane-clad varieties in the foyer of a local cinema and took them to W.A. Hines, who measure machinery noise in factories and offices.

John Connell, for the Noise Abatement Society, adjudicated. The noise level inside a cinema should tick over at 40 decibels.

At 45 decibels came Opal Fruits. At 52, KitKat; 54 Cadbury's Fruit & Nut; 63, Callard & Bowser toffees; 64, butterscotch; 65, jelly babies (higher if you're rummaging for the black ones) and liquorice allsorts. And the three worst offenders? The Kia-Ora slurp (last drag of liquid), a disgusting 68; box of Terry's chocolates (almost impossible to open), 69. But the award goes to Butterkist Popcorn at an awesome 77 decibels — and it can take some people up to 30 minutes to eat a bagful.

Danny Danziger, *Sunday Times Magazine*

Acoustical Activities in the Railways Department, Victoria

H. Sin Chan
Acoustical Engineer
Vicrail, Melbourne

The two major acoustical activities of the Railways Department are to implement the requirements of the following:

(a) Health (Hearing Conservation) Regulation 1978 under the Health Act 1958.

(b) State Environment Protection Policy No. N-1 (Control of Noise from Commerical, Industrial or Trade Premises within the Melbourne & Metropolitan Area).

Hearing conservation

[To implement — Statutory Rules 1978, No. 269 Health Act 1958 — Health (Hearing Conservation) Regulations 1978.]

Regulation 201 reads:

Where an employee is engaged in any process or occupation and either—

(a) the Daily Noise Dose of that employee exceeds 1.0, or

(b) the employee is at any time exposed to a noise level exceeding 115 dB(A) slow—

then the employer shall take action to ensure that the exposure of any employee does not exceed—

(c) a Daily Noise Dose of 1.0, or

(d) at any time a noise level of 115 dB(A) slow — as the case may be.

However, the Railways Department considered that any environment or work space where the noise level exceeds 85 dB(A) for 8 hours work (daily noise dose of 0.33) and any noise level exceeding 115 dB(A) then the following measures will be taken:

(i) hearing protection signs be placed around the areas concerned,

(ii) the employees concerned be audiometrically tested and be issued with earmuffs or ear plugs,

(iii) every effort should be made to reduce the noise at the source, along the path of propagation and at the receiver.

E.P.A. Noise Control Policy N-1

Sections 16, 17(1), 18, 49 and 19 of the Environment Protection Policy Act 1970 were further introduced in the State Environment Protection Policy No. N-1 February 1981: "This Order may be cited as the State Environment Protection Policy (Control of Noise from Commercial, Industrial or Trade Premises within the Melbourne & Metropolitan Area) No. N-1 (hereafter referred to as Policy) and came into operation on Monday 4th May 1981."

Following any complaints from E.P.A. and residents regarding this aspect, the Department will investigate the Effective Noise Level (measured in accordance with the provisions of Schedule 2 in the Policy) at any point in a Noise Sensitive Area and if necessary will try to control the noise level so that it does not exceed the Permissible Noise Level (calculated in accordance with the provisions of Schedule 1 in the policy) at the same point.

Building acoustics

The Department uses A.S. 2107-1977 (ambient sound levels for areas of occupancy within buildings) as a guide to design and to recommend the conditions affecting the acoustic environment within occupied spaces.

Low frequency noise and ground vibration

There are various cases of residents' complaints re noise and vibration due to railways operations adjacent to the residence. Investigation of these complaints is carried out in the following manner:

(i) To estimate L_{eq} at residence

Measure the peak noise level and estimate the L_{eq} in dB(A) using the formula:

$$L_{eq} = L_A + 10 \log (n\ell) - 49$$

where

ℓ = length of train in metres

n = number/hr

L_A = maximum pass-by of train in dB(A)

or

$$L_{eq}24\text{ hr} = L_A + 10 \log (N/200) - 20\text{ dB}$$

where N = number of trains per 24 hr period

(ii) To estimate low frequency noise

Assess the peak noise level and the frequency of occurrence, then determine the density of the lightweight loose fitting fixtures that may be easily excited by this low frequency acoustic excitation.

Perceptible vibration of any loose fixture will occur if it has a mass/unit area less than that calculated.

(iii) Ground vibration

Measure and calculate the resultant of the peak ground vibration level (3-axes) in mm/sec at the residence facade.

Use the vibration limits proposed by German Standard DIN 4150 and also a special report No. 11 published by Australian Road Research Board, "Ground Vibrations — Damaging Effects to Buildings" as the guidelines.

Assess whether the peak ground vibration level in mm/sec is perceptible (Human Sensitivity) or will affect the structure of any buildings.

Near-Grazing Sound Propagation Over Open, Flat Continuous Terrain

Keith Attenborough
Faculty of Technology
Open University
Milton Keynes
England

ABSTRACT: The literature on the propagation of sound over flat ground, without meteorological influences, is reviewed. Particular emphasis is given to the effects of the acoustic characteristics of outdoor ground surfaces. The information contained in the paper should be of practical value in estimating the propagation of sound, at frequencies up to 500 Hz, when the sound is at grazing incidence and the distances involved less than 300 m.

1. INTRODUCTION

Perhaps the most important statement to be made about propagation of sound near to open, flat, continuous ground in calm isothermal conditions is that it never happens. Not only is the propagation affected by the non-isothermal, non-stationary nature of the real atmosphere but ground surfaces are rarely flat and seldom continuous. Meteorological influences may be divided conveniently into (i) refraction effects due to wind or temperature gradients and (ii) turbulence related to wind-induced eddies and to thermal instabilities associated with heating of the ground. Absorption in the atmosphere also plays a part but is significant only at high frequencies and long ranges. For example, the attenuation remains less than 1 dB/km up to 3500 Hz [1].

In this review paper meteorological influences will be ignored and the discussion will concentrate on the interaction of sound with the ground and with various types of ground cover. The assumption will be made that the ground surface is continuous, flat, and is not disrupted by abrupt changes in character. Moreover, only point sources will be considered. Despite this formidable set of idealisations, the observations and conclusions presented here have some practical value. At frequencies up to 500 Hz, and for ranges up to 300 m the conclusions should be valid for a wide set of meteorological conditions [22]. The idealised propagation considered here is strongly dependent on the acoustical characteristics of outdoor ground surfaces. Consequently in this review considerable emphasis will be placed on discussion of these characteristics and their measurement.

Knowledge of these characteristics will be relevant to the near-grazing propagation whatever the meteorological conditions and frequency range of interest.

2. THEORETICAL CONSIDERATIONS

2.1 Analysis of sound field near to the ground

Throughout this review the time (t) and dependence $\exp(-i\omega t)$ is understood where $i = \sqrt{(-1)}$, ω is the angular frequency and use is made of the conventions: (i) that $\exp(ik_o x - i\omega t)$ represents a progressive wave travelling in the positive x direction and that (ii) positive values of the imaginary part of surface impedance indicate a stiffness-type reactance. The possibilities for confusion in studies of near grazing outdoor propagation that arise from the use of different conventions have been reviewed by Daigle et al [28].

A convenient way of representing the field due to a point source above an absorbing boundary, in general, is

$$\phi_{tot} = \exp(ik_o R_1)/ik_o R_1 + Q\exp(ik_o R_2)/ik_o R_2 \qquad (1)$$

where ϕ_{tot} is the velocity potential for the total field and Q is the spherical wave reflection coefficient. k_o is the propagation constant in air, R_1 is the length of the direct path and R_2 is the length of the specularly-reflected path as shown in Figure 1. The first term represents the direct wave from source to receiver.

Although exact integrals and asymptotic formulae are available for Q, when the ground may be described, acoustically, either as an externally-reacting fluid [2], or as a multiple-layered fluid [3-5], it is not necessary to explore these in detail. There is considerable experimental and theoretical evidence that over the frequency range of most interest in studies of outdoor sound propagation, say 100 to 4000 Hz, outdoor ground surfaces may be modelled adequately as locally-reacting.

If the assumption of local reaction is valid, then an accurate method of calculating the sound field near to the ground is given by equation (1) with

$$Q \cong R_p + (1-R_p)F(w) \qquad (2)$$

where R_p, the plane wave reflection coefficient for a locally-reacting surface has the form

$$R_p = (\cos\theta - \beta)/(\cos\theta + \beta) \qquad (3)$$

and

$$F(w) = 1 + i\sqrt{\pi}w\exp(-w^2)\mathrm{erfc}(-iw) \qquad (4)$$

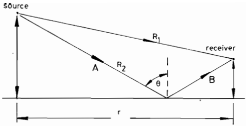

Figure 1: Geometry of specular reflection

In equation (3), $\beta = 1/Z$, where Z is the normal surface impedance of the ground normalised with respect to air, and θ is the angle of incidence defined in Figure 1. In equation (4), w, sometimes called the numerical distance, may be approximated by

$$w^2 \cong \frac{1}{2}(ikR_2)(\beta + \cos\theta)^2 \qquad (5)$$

and erfc( ) represents the complementary error function. Time dependence $\exp(-i\omega t)$ has been understood. Two useful approximations for F(w) are, for $|w| < 1$, which will be satisfied for large impedances and/or source-receiver separations which are small compared with a wavelength,

$$F(w) \cong 1 + i\sqrt{\pi}\, w \exp(-w^2) \qquad (6)$$

and, for $|w| > 1$, which requires source-receiver separations considerably greater than a wavelength and/or small impedances

$$F(w) \cong 2i\sqrt{\pi}\, w \exp(-w^2) H[-\mathrm{Im}(w)] - 1/2w^2 \qquad (7)$$

In this equation, H[x] represents the Heaviside step function, which has the value 1 for $x > 0$ and 0 for $x < 0$.

From equation (5) it is clear that the condition $-\mathrm{Im}(w) > 0$ will depend upon the relative magnitudes of the normalised resistance and normalised reactance which are the real and imaginary parts of Z respectively, and upon the angle θ.

At grazing incidence ($\theta = \pi/2$), equations (1) and (2) simplify considerably since $R_p = -1$. Hence

$$\theta_{tot} \cong 2F(w)$$

and

$$w \cong \frac{1}{2}(1 + i)(kr)^{1/2}\beta \qquad (8)$$

where r is the horizontal range.

Note that use of the plane wave reflection coefficient instead of Q would have led to the prediction of zero propagation between point source and receiver at $\theta = \pi/2$. Consequently, the contribution to the total field of the second term in the expression for Q, acts as a correction for the fact that the wave fronts are spherical rather than plane. This contribution has been called the ground wave, in analogy with the term of the same name that appears in the theory of AM radio wave propagation over the earth's surface [7].

For ranges such that $|w| > 1$, and at low frequencies (large Z), the first term in equation (7) makes a significant contribution. When multiplied out in equations(1) and (2) it gives rise to a term that has the form of a surface wave, decaying as the inverse square root horizontal range with an exponential decay with height and range superimposed. At grazing incidence, the condition for its existence simplifies to the requirement that the imaginary part of the impedance is greater than the real part. Although in different solutions to that stated here, this condition will be sufficient to create a surface wave whatever the physical and geometrical data.

This surface wave certainly has a mathematical existence; but there has not been any published data that establishes its existence as a separate physical identity in outdoor propagation. The main problem is that the resistive components of most outdoor ground surfaces give rise to appreciable exponential attenuation along the surface. This outweighs the relative strength of the surface wave component, resulting from the inverse square root dependence on range, compared with other contributions that decay at least with r^{-1}.

Using continuous sources and artificial surfaces such that the reactive part of the impedance is much greater than the resistive part at low frequencies, both Donato [12] and Thomasson [6] have shown that the surface wave term accurately represents the acoustic field near-grazing incidence and its attenuation with height above the surface. A more thorough demonstration of its physical significance will follow, however, from detection and analysis of its separate arrival in pulse propagation experiments over such surfaces.

The attenuation A, in excess of that due to spherical spreading and due to the presence of a finite-impedance boundary, known as the *excess attenuation*, may be written

$$A = -20 \log_{10} [\text{total acoustic field / direct field}]$$

At grazing incidence, this may be written

$$A = -6 - 20 \log_{10}|F|$$

It may be noted that for $|F| > 0.5$, which will occur at low frequencies for many outdoors ground surfaces, A is negative and the direct field is enhanced. In other words the shadow zone that would occur for receiver and a source of plane waves at the surface, is penetrated by the ground wave from a point source. At $|F| \geqslant 0.5$ the ground wave no longer enhances the direct field, it is effectively cut-off. A more detailed discussion of this cut-off may be found in references [7] and [13], in which will be found also plots of typical predictions of the excess attenuation spectrum both for grazing and near-grazing incidence. It should be noted that alternative expressions for the field above an impedance boundary are available that are more exact than the combined result of equations (1) to (4) [2-5, 51, 52]. However, for practical purposes, the numerical results obtained from the approximate solutions stated here are indistinguishable from those of the more exact expressions [53].

2.2 Acoustical Impedance Models For Outdoor Ground Surfaces

2.2.1 Semi-empirical formulae due to Delany and Bazley

By making measurements on many different fibrous sound absorbent materials whose porosities (Ω) were near unity and whose specific flow resistivities (σ) varied between 2000 and 80,000 MKS rayls m^{-1} Ns m^{-4}, Delany and Bazley [14] were able to accumulate a data bank indicating the dependence of both the normalised characteristic impedances (Z_c) and the normalised bulk propagation constants (k_b) of these materials on frequency. They defined power law relationships in terms of frequency as follows:

$$Z_c = 1 + 0.05(f/\sigma_e)^{-0.75} + i0.077(f/\sigma_e)^{-0.73} \qquad (9)$$

and

$$k_b = 1 + 0.086(f/\sigma_e)^{-0.70} + i0.175(f/\sigma_e)^{-0.59} \qquad (10)$$

where σ_e is the effective flow resistivity of the material in MKS units and f is frequency in Hz. These relationships are semi-empirical, in that power laws with $[f/(\Omega\sigma)]$ as parameter were expected from the theory for rigid porous media derived by Zwikker and Kosten [15]. Since $\Omega \cong 1$ for the fibrous materials under investigation, Delany and Bazley were able to replace the effective flow resistivity σ_e by the actual value σ.

Delany and Bazley [21] were first to suggest the use of equation (9) in predictions of outdoor sound propagation. This impedance versus frequency model was used in conjunction with equation (1), where Q was put equal to R_p; essentially neglecting the ground wave contribution in equation (2).

The range of validity for the formulae (9) and (10) was stated originally as $0.01 < f/\sigma_e < 1$. The effective flow resistivities of outdoor ground surfaces vary from 10,000 MKS rayls m^{-1} for loosely packed snow to over 20,000,000 MKS rayls m^{-1} for hard-packed bare ground. A typical value of flow resistivity for grass-covered ground might be 300,000 MKS rayls m^{-1}. For this value, the criterion $f/\sigma_e > 0.01$ would imply a lower limiting frequency for application of equations (9) and (10) of 2500 Hz.

Chessell [16] and others [7, 13, 20] have shown that extrapolation of the formula (9) outside its stated range of validity is justified by the excellent agreement it enables, in conjunction with equations (1)—(4), between predicted and measured propagation over grassland out to horizontal ranges of 300 m.

More recently, by using σ_e as an adjustable parameter, Embleton et al [17] have shown that it is possible to fit short-range measurements of near-grazing propagation over a variety of surfaces, from hard-packed quarry dust to snow, with reasonable accuracy.

For snow layers and forest floors which clearly have layered structures, instead of the characteristic impedance formula (effectively the surface impedance of a semi-infinite layer) (9), the surface impedance of a rigidly-backed layer has been used [18, 19]:

$$Z(o) = Z_c \coth(-ik_b d k_o) \qquad (11)$$

where Z_c and k_b are given by formulae (9) and (10) respectively, K_o is the wave number in air, and d is the thickness of the layer.

This model has been found to give improved correspondence with some measured data for grass-covered ground also [8].

The empirical formula (9) gives a fixed frequency-dependence of the impedance, and, for a typical range of effective flow resistivities, yields an imaginary part of impedance (reactance) that is greater than the real part (resistance) for some of the frequency range of interest in studies of noise propagation (100 Hz to 4000 Hz).

2.2.2 Phenomenological models for rigid-framed media

Morse and Ingard [23] have analysed sound propagation in a rigid-framed porous medium in terms of four parameters. Two of these are porosity and flow resistivity. The other two parameters are adjustable. Structure factor (k), represents the ratio of the effective density of the air in the pores, set in motion by an incident sound wave, to the equilibrium density (ϱ_p). A thermodynamic factor (g) relates to the fact that compression of the air within the pores takes place neither adiabatically nor isothermally.

According to this model, the normalised surface normal impedance is given by

$$Z_c = (g\Omega)^{1/2}[k + (i\sigma)/(\varrho_O\omega)]^{1/2}, \quad 1 < g(\omega) < 1.4 \qquad (12)$$

where ω is the angular frequency.

Several authors [24, 6, 26] have applied this model to the description of the acoustical characteristics of grass-covered surfaces. Bolton and Doak [24] have extended it, by means of a formula due to Brekhovskikh [25] for the surface impedance of a multilayer system, to grounds in which the various parameters vary with depth. The latter model was found appropriate to a gravel surface.

Donato [26] has extended the model to allow for an exponential rate of change of physical characteristics with depth. He postulates that k is a function of depth such that

$$k\Omega = (k\Omega)_o \exp(-\alpha z) \qquad (13)$$

where $(\ )_o$ represents the value of the product at the surface and z is the depth. Since it can be shown that $k \propto \Omega^{-n'-1}$, where n' is a microstructural constant [27]; equation (13) implies a porosity that *increases* with depth. This is fairly unusual in outdoor ground surfaces. The result of Donato's analysis [26] may be expressed as

$$Z_c(o) = Z_{co} J_o(2\beta/\alpha)/J_1(2\beta/\alpha) \qquad (14)$$

where Z_{co} refers to the characteristic impedance at the surface as given by equation (12), and $\beta^2 = (Z_{co})^2 k_o$.

An expression for the impedance of a layer of rigid-porous material of depth d is obtained by combining equations (11) and (12) with $k_b = Z_c$. Effectively this yields a five-parameter model [26].

Thomasson [6] expresses the relative normal admittance (inverse of Z(o) in equation (11)) in terms of four parameters as follows:

$$[Z(o)]^{-1} = a(b/c)\tanh(bcf/e) \qquad (15)$$

where, in terms of symbols already introduced,

$a = \Omega|g(\omega)|$

$b = g(\omega)/|g(\omega)|$

$c = k_b/(g\Omega k)^{1/2}$

and $e = (|g(\omega)|/\varrho_o c_o^2)^{-1/2}(2\pi d)^{-1}$

c_o being ω/k_o.

A method of obtaining an acoustical description of the ground is advocated by Thomasson [6] in which measurements of excess attenuation made in a fixed geometry (horizontal source-receiver separation = 20 m, source and receiver heights = 0.1 m) are fitted in terms of the four parameters defined above.

2.2.3 Microstructural models for ground impedance

The acoustical characteristics of fluid-saturated granular media have been of interest in diverse fields of study including underwater acoustics, seismology and chemical engineering as well as in the studies of atmospheric propagation of interest here [29]. Numerous experimental and theoretical studies of the acoustical characteristics of dry sands and soils have been concerned with the transmission of sound through such media as well as reflection from granular surfaces [30-33]. The theoretical studies have taken the classical approach pioneered by Lord Rayleigh [34] and by Zwikker and Kosten [15] based upon a conceptual model of parallel cylindrical pores running normal to the surface of a rigid porous medium. In a recent development of this approach [27] it has been found possible to describe the acoustical characteristics of granular media in terms of four parameters: porosity, flow resistivity (or air permeability), grain shape factor (n') and pore shape factor (s_f).

For low frequencies and high flow resistivities it is possible to derive simplified approximations in which the four parameters reduce to three that may be collected together in a single group called the effective flow resistivity $(\sigma_e) = s_f^2\sigma(o)/\Omega(o)$ MKS units [34].

Hence

$$Z_c = k_b/(\gamma/\Omega) = 0.218(\sigma_e/f)^{1/2}(1 + i) \qquad (16)$$

where γ is the ratio of specific heats of air.

For low frequencies and high flow resistivities it is possible to derive another approximation for the surface impedance of a rigid porous medium in which the porosity decreases exponentially with depth away from the surface [35] viz:

$$Z(o) = iZ_{co}H_o^{(2)}[2\beta/(n'\alpha)]/H_1^{(2)}[2\beta/(n'\alpha)] \quad (17)$$

where $\beta = k_{bo}(\omega/c_o)$.

Z_{co} and k_{bo} refer to the normalised characteristic impedance and complex wave number, respectively, of a semi-infinite homogeneous rigid porous medium of porosity $\Omega(o)$, as given by equation (16) and $H_n^{(2)}$ [ ] refers to a Hankel function of n-th order and of the second kind.

If the flow resistivity is sufficiently high that $[2\beta/(n'\alpha)] > 1$, then a further approximation enables a simplification of (17) which gives

$$Z(o) \cong 0.218(\sigma_c/f)^{1/2} + i[0.218(\sigma_e/f)^{1/2} + 9.74(\alpha_e/f)] \quad (18)$$

where σ_e is as defined previously and α_e, an effective rate of porosity increase with depth, $= n'\alpha/\Omega(o)\ m^{-1}$. Finally, it is possible to deduce an approximate expression for the normalised normal surface impedance of a ground that behaves acoustically as a rigidly backed porous layer [34]. This is

$$Z(o) \cong 0.00082\sigma_e d_e + i(38.99/fd_e) \quad (19)$$

In this expression d_e represents the effective depth of the layer given by Ωd m. The approximation requires not only that the flow resistivity of the porous layer be high but that its depth be small compared with the wavelength of sound within the (rigid) porous layer.

In the models of acoustical behaviour represented by equations (16), (18) and (19), σ_e, α_e and d_e may be regarded as parameters that may be adjusted to fit data for impedance versus frequency or of excess attenuation versus frequency over short ranges so that, using equations (1) to (4), the excess attenuation over longer ranges may be predicted.

3. MEASUREMENTS OF THE IMPEDANCE OF OUTDOOR GROUND SURFACES

The standard laboratory method of measuring the normal impedance of a surface by placing it at one end of a long cylindrical tube, the other end of which is closed by a loudspeaker, and by probing the interference pattern between direct and reflected sound waves above the surface, may be adapted for determining the impedance of outdoor ground surfaces [7, 18, 19, 35, 36, 37]. The modifications require the tube to be vertical and driven into the ground. The consequent disturbance of the ground is shared by an impedance meter technique [39]. An impulse technique has been developed in which, by careful choice of geometry and arrangement of the two receiving microphones, the shape of ground reflected pulsed may be compared with that of the direct pulse [43]. Consequently values of impedance versus frequency may be deduced without the necessity of corrections for atmospheric absorption or inverse square law. In the analysis, the contribution of the second term in Q (equation (2)) is ignored. This will be reasonable for the typical geometry (source receiver separation 6 m or less, source height 1.7 m and receiver height 1.26 m) and the range of frequencies (above 400 Hz) for which results have been obtained. Another pulse technique [46] requires measurements to be made in an anechoic environment. Cepstrum techniques of analysis have been suggested also [47] for the pulse received by a single microphone.

Free-field techniques, either at normal or oblique incidence [7, 38, 40, 45] rely upon choosing a geometry such that the approximation of plane wave incidence is justified. These continuous wave interference techniques, both tube and free-field are sensitive to the assumed location of the ground surface. Grazing incidence techniques, on the other hand, are relatively insensitive to this assumption. Such a technique has been described by Habault [4, 41]. Essentially this technique requires that measurements be made of sound level versus distance at each frequency of interest; the lower the frequency, the longer the range of measurement to achieve sufficient sensitivity to impedance. An alternative near-grazing incidence technique, proposed by Glaretas [42], enables deduction of impedance over the whole frequency range of interest at relatively short range and is based upon analysis of the transfer function, or, more simply, the level difference between two vertically-separated microphones, one of which is near the ground surface.

The final technique mentioned in this review was developed by Basa and Bolen [44] and uses a single microphone to measure the sound amplitude near a ground plane from a source of known free-field spectrum. By treating the impedance as an adjustable parameter in equations (1) to (4) it is possible to determine the impedance as a function of frequency. Potentially this technique suffers from the problem of non-uniqueness, since the two unknown values of real and imaginary parts of impedance cannot be determined unambiguously from a single amplitude measurement.

In terms of the smoothness of the deduced impedance versus frequency characteristics and their correspondence with theoretical predictions, measurements using the multi-microphone oblique-incidence method, the pulse method [43], and a grazing incidence method [41] are of particular significance. Examples of these are shown in the next section.

Table 1 summarises a selection of surfaces for which impedance data are available and the methods used to obtain these data.

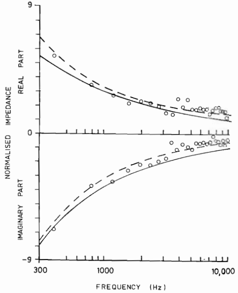

Figure 2: Impedance of a ground surface covered in hay of 40 cm height.
o measured data from reference [43] Figure 6b
——— predictions from equation (18) with σ_e = 187827 and α_e = 76
– – – – – predictions from equation (9) with σ_e = 168000

TABLE 1								
Ground Surface	Data Reference	Method of Measurement	Best Fit Model Eqns 16,18,19	Model Parameters (MKS) σ_e	α_e	d_e	Best Fit σ_e Eqn 9	Measured σ
Meadow	38, Fig.2.4b	Multi-microphone oblique-incidence	Variable porosity	120688	182	—		
Grassland	7, 13	Impedance tube Inclined track Ground wave cut-off	Variable porosity	841680	41		300,000	
	37, 42	Impedance tube Indirect, two microphone	Rigid-backed layer	575955	—	0.0083		
	35	Free-field, normal incidence						
	43, Fig.3b	Two-microphone, pulse	Homogeneous	373228	—	—	250,000	
	43, Fig.4b	Two-microphone, pulse	Homogeneous	380046	—	—	250,000	100,000
	44, Fig.1		Variable porosity	257740	103	—	150,000	300,000
	40	Indirect						
	38, Fig.2.54	Multi-microphone, oblique-incidence	Variable porosity	182418	58			
	41	Grazing-incidence	Variable porosity	59069	83			
	36, Table 3	Impedance tube	Rigid-backed	170419	—	0.038		
Stubble	6, Fig.10	Indirect, four-parameter	Variable	52605	26	—		
New sown crop	6, Fig.10	Indirect, four parameter	Variable porosity	134668	72	—		
Hay	43, Fig.6a	Two-microphone, pulse	Variable porosity	260384	33	—		
	43, Fig. 6b	Two-microphone, pulse	Variable porosity	187827	76	—		
Soil	43, Fig.7a	Two-microphone, pulse	Homogeneous	628823	—	—	450,000	
	43, Fig.7b	Two-microphone, pulse	Rigid-backed layer	320867	—	0.01	150,000	
	38, Fig.2.28	Multi-microphone, oblique-incidence	Homogeneous	1832000	—	—	832,000	
Sand	44	Indirect, one microphone	Homogeneous	94945	—	—	40,000	60,000
	35	Free-field Normal Incidence						
Forest	48	Multi-microphone, oblique-incidence	Rigid-backed layer	60,053	—	0.0325		
	43, Fig.9	Two-microphone, pulse	Variable porosity	225674	199	—	250,000	110,000
	19, pine	Impedance tube	Variable porosity	105361	81	—		
	19, deciduous	Impedance tube	Rigid-backed layer	39,382	—	0.054		
Snow (4 cm)	47 (quoted)	Impedance tube	Rigid-backed layer	22512	—	0.0325		
Snow (2 cm)	47 (quoted)	Impedance tube	Rigid-backed layer	43779	—	0.014		

4. COMPARISONS BETWEEN THEORY AND MEASUREMENT

Figures 2 to 4 show examples of the use of equations (16), (18) and (19) to fit measured data for impedance versus frequency. Other examples may be found elsewhere [34]. In each case, the fit is obtained by calculating the necessary parameters from the values of real and imaginary parts of impedance *at a single frequency*. The appropriate frequency is chosen on the basis of the least squared error over the frequency range of the data. These figures show the limitations of the proposed models above 3000 Hz. Values of the best fit parameters and appropriate models for selected data references in Table 1 are shown also in Table 1.

Several authors have fitted impedance data by using equation (9). Examples of the best fit values of effective flow resistivity, as used in equation (9), are shown in Table 1. Figures 2 and 3 show examples of corresponding fits, which may be compared with those obtained by equations (16) and (18). Where measured values of flow resistivity are available both van der Heijden [38, 48] and Bolen et al [44] have found that the measured values of flow resistivity exceed the best fit or effective values needed to fit impedance data using equation (9). This is to be expected if, as discussed in section 2.2.1, the normalising parameter in equation (9) is $(f/\Omega\sigma)$ rather than (f/σ).

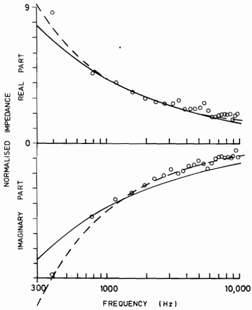

Figure 3: Impedance of a grass-covered field.
o measured data from reference [43] Figure 4b
——— predictions from equation (16) with σ_e = 380046
– – – – – predictions from equation (9) with σ_e = 264400

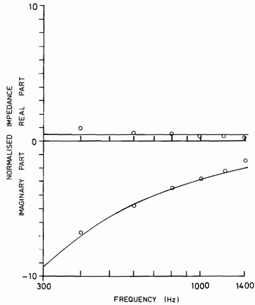

Figure 4: Impedance of a 2 cm thick snow layer.
o measured data from reference 47
——— predictions using equation (19)

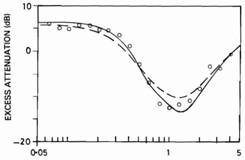

Figure 5: Excess attenuation over grass 7 cm height, source height 0.85 m, receiver height 0.1 m, horizontal separation 10 m.
o measured data from reference [8]
——— predictions using equations (1) to (4) and (18) with σ_e = 70000 and α_e = 78
– – – – – predictions using equations (1) to (4) and (9) with σ_e = 96000

A typical value of Ω for soil is 0.4. Cramond and Don's experience [43], however, is the reverse, in that their measured values of flow resistivity were considerably less than values of effective flow resistivity according to equation (9). Furthermore use of measured flow resistivity and (air) porosity in the exact rigid porous material theory [27] is not always as successful as the approximate theory (equation (16)), in which the effective flow resistivity is used as an adjustable parameter in the manner described previously.

This may be a consequence of the unreliability of the invasive methods of obtaining air permeability [43].

Typical examples of the use of equation (18) to fit propagation data is shown in Figures 5 and 6 [49, 50]. In both cases the fits obtained using equation (9) are shown for comparison.

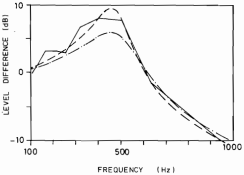

Figure 6: Level difference between two microphones at heights of 0 and 2 m above a sports field and separated horizontally by 65 m from a loudspeaker source of white noise which is 2.1 m above the ground.
——— third-octave measured data
– – – – – predictions using equations (1) to (4) and (18) with σ_e = 365000 and α_e = 180
–·–·– predictions using equations (1) to (4) and (9) with σ_e = 340000

5. CONCLUSIONS

It is possible to describe the impedance of outdoor ground surfaces by means of equations (9) and (10) which have been derived semi-empirically by equations (16), (18) or 19, which in turn have been derived as approximations of the theory for the acoustical characteristics of rigid porous materials. Consequently, by means of equations (1) to (4) it is possible to obtain predictions of the sound level at locations near to the ground that will be sufficiently accurate for practical purposes wherever meteorological influences may be ignored. For frequencies up to 500 Hz and grazing incidence the predictions will be valid for a wider range of meteorological conditions.

Equations (9) and (10) use a single ground parameter, effective flow resistivity, which may be determined from the best fit to measured data of impedance vs frequency. Equation (16) uses a single parameter which may be determined from measurement of impedance at a single (low) frequency. Equations (18) and (19) involve two ground parameters. Again these may be determined from a measurement of the complex surface impedance at a single frequency.

Values of the requisite parameters have been determined and are tabulated in this paper for a wide range of ground surfaces.

ACKNOWLEDGEMENTS

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7TH INTERNATIONAL ACOUSTIC EMISSION SYMPOSIUM ZAO-CHO, JAPAN

21st to 27th October 1984

Report by Brian Wood
CSIRO Division at Mineral Physics, Lucas Heights, NSW

The series of International Acoustic Emission Symposia have been held every second year for the past 14 years. They are an activity of the Japanese Non-Destructive Inspection Society and The Mining and Metallurgical Institute of Japan, with the support of 25 other Japanese associations.

This symposium has been growing in prestige each year. I have been able to attend the 5th, 6th and 7th symposiums and have been impressed by the organisation and standard of the papers presented.

This conference was held at Zao-Cho which is about 350 km north of Tokyo.

The conference consisted of the formal presentation of 89 reports, 3 special invited lectures, 9 poster presentations and equipment displays by about 12 agencies.

The reports were bound into a hard-covered book and were grouped in 9 categories and presented in 20 sessions. There was adequate time for informal discussion, and participants were able to meet and talk freely with many other delegates during these periods.

There has been concern for some time that the tests made on mechanical testing machines do not represent the field test situation. A laboratory test is a constant strain test, while the field test is a constant stress test. The acoustic emission from a strain controlled test provides necessary material data, but not data relating to the structural performance. With this in mind it was interesting to participate in a discussion with others when **Dr Holler** from Germany stated that ductile fracture in pressure vessels was not detectable by acoustic emission. This discussion did cause some interest, and it was shown that by undertaking adequate pre-test studies to characterise the material being tested, valid and useful tests resulted.

Dr P. Fleischmann of I.N.S.A., France was one of the keynote speakers and his address related to burst-type and continuous AE signal analysis in a broadband frequency range and its application leading to source characterisation. This address included a theoretical model and some laboratory test results on aluminium samples.

Dr T. Fowler of Monsanto Chemicals was one of the keynote speakers, and he described the techniques and standards used in his company's application of AE, and supported these statements with illustrations and results of the applied technology.

Prof. Reg Hardy from Pennsylvania State University was a keynote speaker and he spoke about AE applied to siesmic and geological structure monitoring. His address gave a valuable insight to this little used application and demonstrated the validity of the testing procedures.

Mr H. Dunegan spoke of the now accepted need which many of us are pursuing, that of linking AE and fracture mechanics especially in pipeline and pressure vessel work. He supported his address with both laboratory and field results.

Countries represented included England, France, West Germany, Italy, China, Korea, United States of America, Canada, Japan and Australia.

A number of the reports came from laboratory studies involving specific materials and the AE associated with the various deformation mechanisms operating in the usual mechanical tests. Other reports detailed work and results relating to the more theoretical aspects of source activity and AE generation. Wave propagation and some practical applications of AE were also included as a significant part of the conference.

The Australian contribution involved applications of AE in pipelines, AE equipment development, AE applied to seismic and dam monitoring, production and evaluation of standards associated with AE, as well as involvement in the International AE Advisory Committee.

This Symposium has become a valued avenue for the presentation of papers and the gathering of AE practitioners from around the world. The next symposium is planned for October 1986 at Tokyo University.

Noise Control—
A Local Government Perspective

Barry P. Stow
Chief Health Surveyor
City of Waverley
Victoria

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

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

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

LOCAL GOVERNMENT'S ROLE IN NOISE CONTROL

Municipalities in Victoria have been involved in the resolution of conflict between neighbours, and conflict between individuals and the "community" since the drafting of the first Local Government Act in Victoria. Victoria's laws were modelled on those of England and continued the practice of allowing municipalities to control "socially undesirable" situations. The following laws provide the statutory basis for Council's involvement in handling complaints, including noise complaints.

Local Government Act (By-Laws)

By-Law making powers under this act have enabled councils to make local laws controlling many types of situations, including noise emissions. Noise nuisance is not new and there are court records of noise litigation taken under by-laws going back many years. A large number of present day municipalities in Victoria have by-laws to control noise, which include controls over noises from blasting, shouting and haranguing, animals, vehicles and plant, amplified music, etc.

Health Act

The Victorian Health Act obliges Councils to attend to complaints concerning Nuisance (S.40-44).

In addition, under this Act, a person aggrieved by a Council's lack of attention to a nuisance complaint, may complain to a court who may summons an offender to attend legal proceedings and any cost incurred may be awarded against the Council.

Environment Protection Act

The Environment Protection Act "allows" Councils to deal with certain types of noise, primarily "domestic" noise. It does this by delegating to Councils, the Police, or a complainant the ability to take legal action in respect to "unreasonable" noise. Noise may be unreasonable at any time; however it is deemed to be unreasonable if it occurs outside the times prescribed by a schedule which "allows" noise from lawn-mowers, etc, during certain hours.

INCIDENCE OF NOISE COMPLAINTS

As an illustration of the numbers of noise complaints received by Councils, the following table shows the number of complaints received by the City of Waverley in the period 1980-1983 in the categories of barking dogs and general noise.

NOISE COMPLAINTS—WAVERLEY

	1980	1981	1982	1983
Barking dogs	39	106	116	158
General noise	87	116	84	124
TOTAL	136	222	200	282
	(14.6)	(21.3)	(21.5)	(21.6)

(Figure in brackets shows percentage of total complaints received of all types)
Population — 125,000. Houses — 35,000. (1983)

It will be noted from the table that the number of "noise" complaints is increasing and this seems to be the trend experienced by most Councils. In fact, the number of complaints of all types received by Waverley Council is increasing so that noise is not the exception. The "general noise" complaints in the table include complaints such as amplified music, noise machinery, air conditioners etc.

The number and the type of complaints dealt with by the Council can be compared with the numbers received by the EPA, as disclosed by its last annual report [3] — many of these are, of course, passed on to Councils. Figure 1 has been extracted from the EPA report.

The other 52 councils in the Metropolitan area of Melbourne would receive similar numbers of complaints to Waverley.

It can be seen from above that municipalities have been, and are involved in dealing with community noise problems. I expect that this will continue not only because of the continuing existence of the legislation referred to, but also because most people tend to see their Council as the first point of contact for their complaints, whatever they are about.

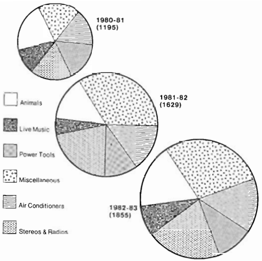

Figure 1: Number and type of complaints received by the Environment Protection Authority of Victoria, 1982-3

LEGAL PERSPECTIVES OF NOISE CONTROL

The Health Act and By-Laws legislation which Councils use in attending to noise complaints derives from English historical precedent, based on complaints between "individuals" established by Common Law and Nuisance legislation. The Environment Protection Act originates in American legislation and generally operates on a different concept, whereby policies are developed for the "protection" of a section of the environment and "emissions" prescribed at a level that the environment can cope with.

The law of nuisance is a fascinating portion of the English legal system which harks back to the days of antiquity. There are in fact three types of nuisance: Nuisance at Common Law, described as either Public or Private, and Statutory Nuisances.

These nuisances are commonly defined as:

1. **Common Law Nuisances**
   (a) **Public Nuisance**
   It must affect the public at large.
   (b) **Private Nuisance**
   An act or emission connected with the use of land which causes an interference to another person's use or enjoyment of his land. A single act can never be a private nuisance, there must be either repetition or a continuing state of affairs.
2. **Statutory Nuisance**
   An act or emission which has been designated a nuisance by some law.

COMMON LAW

Common Law is law which has not been formulated as Statutes by Parliament, but is the result of hundreds of years of judicial argument and decisions. It is embodied in "Case Law". The essential difference between Common Law and Statute Law is that Common Law results from the legal action of individuals or groups of individuals whereas Statutory Law is designated as such by Governments.

In attempting to establish a nuisance, there are two factors which are important.

1. The need for the complainant or aggrieved person to establish that his occupation of his land is affected by noise.
2. The merits of the case.

PRIVATE NUISANCE

A private nuisance is a tort, which is a civil wrong for which courts can provide a remedy, usually damages.

A private nuisance is one which interferes with a person's rightful enjoyment of land or of some rights connected with it. There must not only be an act or emission to cause a nuisance, but also damage. Damage is usually either damage to someone's property or unreasonable interference with his use or enjoyment of it. In the case of noise this could be brought about by vibration, loss of sleep, interference with communication etc. It is of interest to note that a Private Nuisance action may be brought to court only by the occupier of land or persons having a requisite interest including owner/occupiers and tenants but not relatives or visitors to the land.

The Courts have held that to establish a private nuisance exists requires proof of the following:

- There must be material interference with property or personal comfort.
- It is no defence for the defendant to show that he has taken all reasonable steps and care to prevent noise.
- The noise need not be injurious to health.
- Temporary or transient noise will not generally be accepted as a nuisance.
- The Courts do not seek to apply a fixed standard of comfort.
- It is no defence to show that the plaintiff came to the nuisance.
- The Courts will not interfere with building operations conducted in a reasonable manner.
- Contrary to the general rule in a law of tort, malice may be a significant factor.

It is important to note that any individual has a right at law to "sue" for private nuisance, irrespective of any laws relating to noise which may be on the Statute books.

PUBLIC NUISANCE

While a private nuisance is a tort, a public nuisance is both a tort and a crime, punishable by law. The essential difference between the two is the extent to which the nuisance affects people.

Lord Justice Denning, who is perhaps the greatest authority on nuisance, when questioned on how many people were needed to establish a public nuisance has said: "I decline to answer the question of how many people are necessary to make up Her Majesty's subjects generally. I prefer to look at the reason of the thing, and to say that a public nuisance is a nuisance which is so widespread in its range, or so indiscriminate in its effect, that it would not be reasonable to expect one person to take proceedings on his responsibility to put a stop to it, but that it would be taken on the response of the community at large."

On considering this definition, therefore, the following matters must be taken into account:

- The number of persons affected
- Trivial matters will not be considered
- Public nuisance may also be a private nuisance.

STATUTORY NUISANCE

A statutory nuisance has been held to be "one which, whether or not it constitutes a nuisance at common law, is made a nuisance by statute, either in express terms or by implication" — Hailsburys Laws of England (4th ed. Vol. 34 p. 102), though the Victorian Health Act lists a number of Statutory Nuisances (Sec. 43) "Noise" is not included.

However, it has been held elsewhere (Ristevski v. Leung 16/2/82 Unreported) that the legislature intended the Health Act (Sect. 40) to encompass both common law and statutory nuisances.

The Victorian Health Act is therefore a powerful means of overcoming nuisances.

SOLVING NOISE NUISANCES

The most important element in solving Noise Nuisance problems from Local Government's perspective is the council officer responsible for handling these complaints. Though all of the legislation mentioned allows councils to prosecute offenders, the number of court appearances is extremely rare. Generally, most complaints are dealt with on the spot by the inspecting officer who acts as arbiter in respect to compliance or non-compliance with the statutes. Often the mere appearance of the council officer on the scene will be sufficient encouragement for the more co-operative members of the community to "do the right thing" by their neighbours. If this doesn't work, recourse to letters requesting compliance or the service of official notices, will obtain the co-operation of another segment of offender.

In my experience, there is only a small percentage of persons found in complaint handling who will not co-operate and these require a process of education and attention which is the bane of any council officer's existence. The success of inspectorial programs can be measured by the number of satisfied complainants. While the degree of lack of success can be related to the number of court appearances required, it is a measure of our approach at Waverley, that the number of appearances in court by council officers in respect to noise nuisances is minimal and would be less than one percent of the total of all complaints handled.

Of course this is not to say that all councils adopt the same attitude towards complaint handling and often a council's policy may be not to interfere in relations between neighbours. This attitude is a product of area, for example, my experience has been that the numbers of complaints received in country areas, in all categories, is less than that received in metropolitan areas, and this reflects the difference in community attitudes.

On the other hand, the very nature of the law itself deters many people from complaining in the first place. Most people have an aversion to appearing in court, perhaps imagining that it will equate to something they have seen on television. Those persons who have experienced the Victorian court system will be reluctant to re-appear within it, as invariably the complainant places himself on "trial" along with the defendant. People feel obliged to be represented in court which involves considerable cost. Court administrations seem designed to function to suit their own needs rather than those of the public using them.

The inspectorial work of adjudicating between neighbours as a response to complaints, can be a most unpleasant task; it is thus often not a popular job. Sad to say, this often affects an officer's approach to this work and his response to the genuine complainant. This task may be particularly frustrating if a council does not have a clear policy on complaint handling, and the enforcement of its legislative responsibility. In this case the onus for solving problems is left to the officer, who may buckle at the strain because of the weight of responsibility. Conversely complainants may be quite happy to complain to the council and expect action to be taken, but when the council's actions cannot resolve the problem and recourse is required to the courts, they will refuse to take part. In my view, it is desirable that a dispute resolution procedure be established which would enable the settlement of inter-neighbour disputes without the interference of the legal profession and the need for neighbours to appear in court.

Another aspect of the resolution of Noise Nuisances which is important is the use of technical equipment to assist in evaluation of complaints. In the case of noise nuisances, council officers make use of noise measuring equipment and the comparison of relative sound pressure levels with standards as an aid to complaint resolution. This works simply and well when community standards are set out as they are in Australian Standard 1055 — Noise Emissions in Residential Areas. I have found that this document is readily understood and accepted by lay persons (i.e. complainants). On the other hand, I would say that the policies emanating from the Environment Protection Authority are overly complex and invariably force recourse to noise consultants. This may be great for consultants but it hardly encourages a person to persevere with complaints. A complainant has to be determined when it is necessary to employ a consultant and a solicitor before being able to proceed with a complaint at law.

The complexity of the EPA standards makes enforcement of the law at municipal level difficult as the sophistication of the equipment required makes it expensive to purchase and maintain, and requires a higher skill on the part of the operator. Noise complaints are only a relatively small proportion of total complaints, therefore such equipment is not likely to be fully utilised. I often wonder whether the level of sophistication is warranted for the sort of complaint situations encountered. Most complainants are reasonable, average people with a reluctance to complain, their perception of a problem and the extent of concern in a neighbourhood is often as good an indication as any as to the size of the complaint situation.

The policies adopted by the EPA also attempt to legalise levels of noise because they prescribe an artificial threshold which assumes that no person will be aggrieved by noise up to the level "allowable". This may be fine for the factory owners, and may be justifiable in economic terms, but it could — if the Health Act and common law did not exist — take away the right of an individual to the enjoyment of his land and thus create two levels of freedom, which is contrary to the very foundations of our society. Recently at Waverley we had the experience of a noise from a factory which was within EPA's permissible limits but which was the object of six complaints. The local court accepted that it was a nuisance under the health act and convicted the offender.

The traditional way of resolving noise complaints is for the complainant to commence private legal action for nuisance. As discussed earlier, these days most complainants are either not financially able or do not have the inclination to take matters into their own hands; however, those that do seem to be relatively successful. There are the reasonably recent examples in Melbourne of a squawking duck at Frankston and noise associated with the City of Doncaster Swimming Complex. Surprisingly, although few cases get to court, when they do, magistrates seem to be sympathetic towards complainants and take, in my experience, a relatively simplistic view of what is and isn't a nuisance.

CONCLUSION

Noise nuisance is likely to continue to be a source of friction within the community. The fixation of strict guidelines and detailed controls is not likely to provide a solution to differences in perception of sound levels by individuals. The time proven methods of dealing with complaints between individuals have worked in the past but this effectiveness has been hampered in recent years by a court system which has become inaccessible to large sections of the community.

(Received 23 July 1984)

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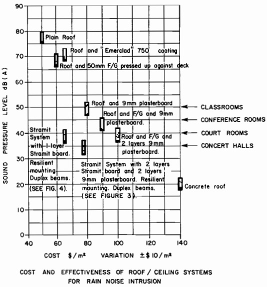


Fig. 2

Summary of performance of various roof/ceiling constructions (October 1983 costs).

Recommended maximum intrusive noise levels, are, for example:

Building Space	Max. Rain Noise Level dB (A)
Concert Halls	35
Court Rooms	40
Conference Rooms	45
School Class Rooms	50

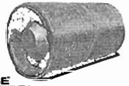
Design Recommendations

Figure 2 summarises results of calculations of noise levels for various roof and ceiling treatments. Costs per square meter of ceiling/roof system installed are also presented.

Given the rain noise criterion for the building space, an appropriate ceiling system may be chosen from Fig. 2.

References

1. Bureau of Meteorology Bulletin No. 49, 1974 (Tables 17A, 17B, etc.).
2. P. Dubout, The Sound of Rain on a Steel Roof. Journal of Sound and Vibration (1969) 10 (1), 144-150.



TECHNICAL NOTES —

Measuring Hearing Loss

Macquarie University expertise and equipment has been used to pioneer a technique to investigate hearing loss in children in Australia.

The technique, known as **transtympanic electrocochleography,** has been in use overseas for some time, but the lack of equipment and suitably qualified personnel has precluded its introduction in Australia.

The technique is used in cases where a child's hearing is impossible to assess using the more conventional methods. It is particularly useful with children who are multiple handicapped, have severe behavioural problems, are hyperactive or are frightened and thereby incapable of co-operating with medical staff.

The technique involves inserting a needle electrode, under general anaesthetic, through the eardrum and into the close proximity of the cochlea (the hearing organ of the ear).

The equipment consists of one part which records the responses (electrodes, amplifiers, filters, averager, display and permanent recording devices), and a separate part which provides the necessary sounds to evoke a response from the nerve of hearing.

The machine actually does the hearing for the child; it **records the cochlea's response to sound** and a computer analyses it without the patient having to co-operate.

The child's response to sound is thus detected and the technique provides an accurate picture of the auditory function of the cochlea and the information obtained helps to locate the actual site of the auditory dysfunction.

The equipment, also fulfills another function. It **records the auditory brain-stem evoked response,** which assesses the integrity of the nervous pathway to the brain. These two techniques are most useful in cases where it is very important to investigate a child's hearing when no other technique has been successful. They are also useful in adults where various oto-neurological conditions are indicated.

(From The Australian Physicist, Aug. 1984).

Damping down factory noise

Monash mechanical engineers have developed a way of substantially reducing noise levels in the metal fabrication industries.

Their noise reduction technique, which involves the use of specially-designed absorbing devices which convert mechanical vibrations into heat, has been developed mainly to reduce noise in tank making operations in which sledge-hammers are used to form tank components from huge metal sheets.

But it can be applied equally as well to the reduction of noise in rivetting operations associated with ship and aircraft building and to the control of shipboard noise.

Senior lecturer in mechanical engineering, **Dr. Len Koss,** who has developed the noise reduction device with the assistance of M.Eng. student **Marcus Pandy,** says noise levels in tank making operations can reach a peak of 120dbA.

By attaching the deceptively simple-looking absorbing devices to the metal which is being hammered, Koss and Pandy have been able to reduce the noise level by six to 12 decibels, depending on the number of absorption devices used.

Moreover, as well as reducing noise levels when the hammer strikes the metal, the noise absorbers eliminate the shrill, persistent ringing sound that normally follows impact of the hammer on the metal.

The absorbing devices are simple rectangular beams with an outer layer of steel on one side, strips of rubber and steel on the other side, and a very thin layer of rubber between to absorb the vibration.

They have been tested on three different types of tank cylinders. Two of the tests were carried out in the department of mechanical engineering's laboratory at Monash; the third at the Brooklyn plant of Rheem Australia Ltd.

The aim now is to optimise the design. This will involve a good deal of mathematical work to determine how much rubber is needed and how the design can be varied to achieve optimum noise damping effect.

Koss says the noise reduction technique can be applied to any structure provided it is possible to measure the structure's "average admittance" (the ratio of velocity to force) and an absorbing device can be built to match it.

"The vibrating power flows from the end cap, cylinder, or whatever, into the absorbing beam and is dissipated in the rubber," he says.

"It is the same concept as matching a loudspeaker to an amplifier. However, instead of doing it electrically we're doing it mechanically over a broad frequency range."

Koss believes the technique could be useful for noise reduction in rivetting operations and for the control of shipboard noise, particularly noise in small ships such as fishing trawlers, where the crew are located very close to the engine room. In the latter case, the absorbing beams could serve two functions — as structural components and as noise absorbers.

—(From Monash Review, March 1984)

Future of the Compact Disk

A recent seminar in the United Kingdom on digital audio featured Bjorn Bluethgen, the head of special technical assignments at Polygram in Hanover. Polygram is a manufacturer of compact disks. According to Bluethgen, the compact disk medium will be enhanced in coming years with a visual capability. A link between compact disks and television sets is in the offing, allowing a display of textual information simultaneous with musical performance. The system will also be capable of storing still pictures in full colour that change every 12 sec., as an accompaniment to the music.

(From Computer Music Journal
V.8, No. 3, 1984)

Technical Notes (Continued)

Use of Pre-1970 Accelerometers

During a series of vibration measurements involving multiple accelerometers a discrepancy was observed in the low frequency (<30Hz) measurement results between different models of B & K Accelerometers.

Further investigation revealed a non-linearity in the low frequency response of the earlier models of B & K Accelerometers (models 4329 and 4334). The degree of error was found to be dependent on both the magnitude and frequency of the driving source and appeared to excite a resonance in the 4-5 Hz region giving errors from 10-35 dB with respect to a new B & K type 4368 accelerometer.

Discussions with Mr. N. Clark of the NML revealed that earlier B & K accelerometers (pre-1970) used a different type of piezoelectric material and the errors observed would more than likely be the result of the piezoelectric material ageing.

—Steven Cooper
James Madden Cooper Atkins
Acoustical Consultants, North Sydney

Electronic aid helps deaf to 'feel' speech

Deaf people will be able to "hear" with their fingers using a new electronic aid which its creators believe is better than the bionic ear.

The concept, called a speech feeler or "tickle talker", was revealed yesterday at the Royal Victorian Eye and Ear Hospital in Melbourne.

The new aid consists of a processor attached to the hip, and wires attached to electrodes on four finger rings.

The processor translates sounds into the electrodes on the fingers, where the stimulation of the nerves at the appropriate intensity tells the deaf person what sound was made.

For instance, an "ess" sound would activate one of the electrodes on the little finger, subsequent sounds are transmitted to other fingers and words become discernible.

One of the combined Eye and Ear Hospital-Melbourne University team which has worked on the concept for the past two years, **Dr. Peter Blamey,** said a child would take at least six months to be able to absorb the "code", but lip reading would also be helpful.

The "tickle talker" is believed to be the first method in the world to allow deaf people to follow speech through skin.

The research team believes the device could be used for more people who get incomplete help with a normal hearing aid or even a bionic ear, which is used to stimulate residual hearing nerves rather than the skin.

A standard hearing aid and the advanced bionic ear introduced last year amplify sounds at different frequencies, but if the sensory cells or hearing nerves are damaged or destroyed no amount of amplification can help the patient.

The team is led by **Professor Graeme Clark,** who also pioneered the bionic ear in Australia six years ago.

He said yesterday that the new aid could supplement information received from a hearing aid, or be used for profoundly to totally deaf children too young to benefit from a bionic ear.

The aid is expected to increase the alertness of deaf people because they will be able to "hear" sounds even though they cannot see the source.

—Mark Hooper, The Australian, 22 Nov. 1984.

Helicopter Noise in London

The control of helicopter noise in London represents a success story in which the GLC, with only limited powers, has been able to prevent a potentially major problem from developing. By introducing a helicopter "type" classification system based on noise emission levels, helicopter noise exposure has been contained within acceptable levels over most of London.

The GLC's type classification procedure is not meant to duplicate helicopter noise certification which has been under consideration by the International Civil Aviation Organisation (ICAO) for more than ten years. Instead, the council's noise standard is meant to reflect "local environmental needs". It is the noise impact of the overall operation from a heliport that is important to the local community so total noise exposure becomes the important factor. Helicopter noise exposure has been expressed in terms of the Noise and Number Index (NNI), which was originally developed for fixed wing aircraft and which links together average peak noise levels and the number of aircraft movements. As noted by David Corfield in an earlier edition of this Bulletin (Vol. 1, No. 1), Noise and Number Index is not an ideal unit and has suffered considerable criticism even for its designed application to fixed wing aircraft, however, it is probably the best indicator available.

All the signs are that noise exposure from helicopters will increase unless action is taken. Worldwide the rate of increase in the registration of helicopters is more than double that of light fixed wing aircraft. Helicopters can gain access to many sites in an urban area such as London which would be completely out of the question for even the lightest fixed wing aircraft. Unless the landing site is used for more than 28 days a year, no planning consent is required.

Progress on the introduction of helicopter noise certification is disappointing. The latest meeting of the ICAO Noise Committee will recommend to the international authority that the proposed noise limits should be relaxed by 3EPNdB because, as one member put it, of the economic situation and lack of technical advance since the last meeting in 1979. Even so, helicopter noise certification will in the long term go some way towards encouraging the manufacture of quieter helicopters which may be able to operate in cities without unreasonable damage to the environment. Local noise limits will still be required in order to deal with the environs of the heliport and, to a more limited extent, noise problems throughout the route network.

The means open to local authorities, with responsibility for environmental matters, to control helicopter noise is limited in spite of recent amendments to the CAA regulations which now give some rights to be heard for those with objections on environmental grounds to the granting of air transport licences. It is the GLC's policy to develop with the London boroughs some means of dealing with complaints about noise from helicopters (and aircraft) and for the continued control of helicopter flights in urban areas. Perhaps a special control zone could be set up in the framework of air traffic regulations to protect sensitive areas from noisy helicopters. The question of licensing operations from short-term helicopter landing sites is also being actively pursued.

—John Simson
Scientific Services Branch, Greater London Council.
(From London Environmental Bulletin, Vol. 1 No. 3)

NEW PRODUCTS —

Programmable Personal Noise Dosimeter and Integrating Sound Level Meter

Australian Metrosonics

Microcomputer technology has permitted development of a hand-held computer which can serve simultaneously as a personal noise dosimeter and an integrating sound level meter, with full programmability for measuring in accordance with a variety of acoustical criteria. It produces accurate answers to complex measurements required in factories, communities and test laboratories.

The **db-307** is an outgrowth of Metrosonics microprocessor-based Noise Profiling Dosimeters, Universal Data Loggers and L_{eq} meters. It measures dBA, L_{max}, L_{pk}, time weighted average, noise dose, projected 8-hour noise dose, and test duration. The db-307 is designed for use by industrial hygienists, product test engineers, community noise abatement officers and acoustical consultants who desire a single instrument for performing all of their noise surveys.

A membrane keypad allows touch-control of all functions with an 8-digit alphanumeric LED display to provide on-the-spot readout.

With "SND LEV" readout, the db-307 serves as a *digital sound level meter* updating its display four times per second. At the end of test, the L_{max} readout indicates highest level of any noise intrusion; the L_{pk} readout indicates the peak pressure of blasts, sonic booms, or other impact noise.

With L_{eq} readout, the db-307 serves as an L_{eq} meter for measuring *community noise.* The average sound level can be read by the operator accurately and repeatably after the level converges to a constant value. L_{max} and L_{pk} can be read during or after test.

The db-307 can be quickly programmed for any exposure criteria. It provides readings of both noise dose and L_{avg}. There is no need to resort to graphs to convert percent dose to equivalent steady dBA level. It is very simple to calibrate, by merely applying an acoustical calibrator and adjusting sensitivity to read the calibration level on the "SND LEV" display.

The db-307's greatest convenience is its ability to compute 8-hour dose after monitoring a representative sample of time-varying noise. The user does not have to separately measure elapsed time and then perform auxiliary computations to estimate 8-hour dose.

The db-307 is housed in a rugged lightweight aluminum extrusion which is brush finished and anodized to withstand field environments. The housing also protects against RF interference.

The entire db-307 is watertight and will even withstand complete immersion in water for short periods. The captive microphone extension cable is sealed against water penetration, as is the recessed sensitivity-adjust potentiometer on the top panel. The db-307 can be confidently used to gather data and display its results in mines and other adverse environments.

Further information from Australian Metrosonics, 57 Lorraine Drive, BURWOOD EAST, VIC. 3151, Telephone: (03) 233 5889.

New B & K Noise Level Analyzer

A new self-contained portable Noise Level Analyzer introduced by **Bruel & Kjaer** offers a wide range of features for accurate on-site analysis of community noise, airport and traffic noise or any other acoustical event requiring accurate measurements and extensive statistical analysis of collected data.

The Bruel & Kjaer Type 4427 Noise Level Analyzer represents an innovative design concept, complying with the relevant sections of IEC 651 and ANSI S 1,4 (1983) Sound Level Meter Specification Type 0. It permits fast, user-friendly dialogue selection of instrument settings and *provides data collection, storage, level analysis and print-out in one compact unit.* Time-saving menu-driven procedures allow easy interactive instrument set-up, reducing the need for instruction manuals. Sophisticated dataprocessing facilities incorporated in the 4427 allow comprehensive front-end processing of signal data.

The detector circuit provides F, S, I and Peak plus 3s and 5s Takt-Maximalpegel responses in parallel with True Linear 1s L_{eq} responses. A built-in IEC/IEEE or optional RS-232C communication interface port provides for remote set-up and control with the same ease as operating the frontpanel keypad.

The LMS detector dynamic range of 110 dB ensures that no information from the input signal is lost, and a wide range of levels can be measured with extreme accuracy.

A built-in graphic printer allows fully annotated permanent records to be made on metallised paper.

Powered by batteries, the Noise Level Analyzer offers this unique combination of features in a compact unit ideally suited for field operation.

Further information from Bruel & Kjaer, P.O. Box 120, CONCORD, N.S.W. 2137, Telephone: (02) 736 1755.

B & K Application Package Expands 2032/34 Analyzer Capabilities

Bruel & Kjaer introduce the BZ 7006, an Application Package for the Graphics Recorder Type 2313. The Application Package is designed to be used in a measurement system with the Dual Channel Signal Analyzer Types 2032/34 and the 2313. The numerous features of the Analyzer are expanded with the BZ 7006 to include fully annotated and documented plots of the Analyzer display including the measurement and display set-ups; envelope analysis; and 1/3 and 1/1 octave displays.

The Dual Channel Signal Analyzers Type 2032 and 2034 are designed for flexibility. They can measure and display up to 34 different functions directly, without the need for user programming, both during and after a measurement. A built-in 12" raster-scan display offers 801-line resolution — twice the resolution of a conventional 400-line analyzer — with extremely powerful and flexible cursors.

The BZ 7006 in combination with the Type 2313 Graphics Recorder provides *documentation possibilities* which include full-page completely annotated plots of the Analyzer display and superimposed displays and/or plots of two signals. Other possibilities include enhanced line width for easy identification of superimposed and normal plots, addition of personal text to dual-format and superimposed plots, two types of line interpolation for precision of presentation, and selectable bipolar or unipolar axes for sound intensity plots.

The BZ 7006 provides the ability to *format measured data* in 1/3 and 1/1 octave form, which allows simple and comprehensive comparison of spectra. Envelope Analysis, a state-of-the-art method of detecting developing faults in rotating machinery, provides the user with a clear display of the envelope of a time-domain signal as well as a spectrum of the envelope. Other applications include *fault detection* in many types of mechanical systems. The BZ 7006 also allows direct storage and retrieval of Analyzer data using the B & K Digital Cassette Recorder Type 7400.

An additional feature is the ability to make a hard-copy plot of octave data in either the user-selected format or in the ISO-recommended format.

Operation of the BZ 7006 is determined by a set of 22 user-defined parameters.

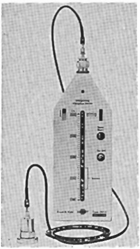
New Products (Continued)

Vibration Meter for Marine Environments

For vibration measurements on-board ship and in other applications where resistance to moisture ingression is desirable, **Bruel & Kjaer** has developed a water-protected version of the hand-held general-purpose Vibration Meter Type 2513. The new model, **Bruel & Kjaer Vibration Meter Type 2518,** is particularly suitable for predictive maintenance of pumps, engines and other on-board machinery.

The Type 2518 has been developed specifically for reliable performance under exacting conditions. With its rugged design and simple operation it is ideally suited for vibration severity measurements and condition monitoring of engines in harsh environments, performed by operators without extensive experience in measuring procedures.

The Type 2518 gives a *true RMS indication of wide-band vibration velocity from 0,01 to 100 mm/s in three measuring ranges.* Results are displayed on a clear, easy-to-read solid-state "thermometer" display. It is a light, compact, yet accurate instrument for day-to-day vibration measurements in marine environments. The Vibration Meter is equipped with **B & K Delta-Shear® Accelerometer Type 4368** which is connected to the Meter using a co-axial cable and moisture- and splash-proof adaptor supplied with the instrument.



MICRO SHORT Leq METER

M. B. & K. J. DAVIDSON PTY. LTD. together with **Cirrus Research** announce a new integrated family of noise meters — the CRL 2.22 Leq series.

Designed under a British Department of Industry MAPCON grant, the CRL 2.22 has already been chosen by the Open University for use in the acoustic part of the new "Environmental Control and Public Health" course and plays a significant role in it. Now, Cirrus Research have commissioned a new technology analogue meter only 12.5 mm (half inch) deep allowing the construction of a super slim sound level meter only 23 mm deep — the world's slimmest analogue unit. Both Leq and sound level can be measured over a 53 dB span and the maximum Leq time is over 8 hours allowing use for a full working day. The accuracy is to the full specification of BS 5969 or IEC 651 Grade 2. Sound Exposure Level is also fitted so that the noise dose of individual workers can be measured on a direct energy scale.

Although the CRL 2.22 is a normal hand-held unit the most powerful feature of the CRL 2.22 is "Short Leq". With a micro-computer plugged into the "Computer" output, to provide memory, the CRL 2.22 becomes a powerful data acquisition unit under direct keyboard control. Any Leq period from 1 second up to several hours can be used as a data base or a variable time base can be used depending on the level existing at the time. With, say, a BBC Model "B" computer the noise level can be plotted second by second over a full working day with a maximum storage of over 100,000 values.

Software for the CRL 2.22 is available on cassette or disc and is fully user friendly and guides the operator with a simple menu option.

For further details contact Mr. Kevin Davidson of M. B. & K. J. DAVIDSON PTY. LTD., P.O. Box 4, OAKLEIGH, VIC. 3166, Tel.: (03) 568 1933. Fully qualified engineers are available to discuss all applications.

Mikrofon-Aufnahmetechnik

(Use and Placement of Microphones)

by Michael Dickreiter

S. Hirzel Verlag Stuggart, 1984, 139 pp., 157 diags. & tables, DM48. ISBN 3-7776-0388-0.

The proper use and placement of microphones for activities ranging from speech to choral items and from ensembles to orchestras, is usually considered an art. This book addresses itself to this problem and introduces a lot more science into the use of microphones. The first several chapters discuss the fundamentals of sound waves and room acoustics. The discussion on room acoustics considers both direct and reflected sound, and then after discussing absorption, leads onto the concept of the reverberation time of a hall.

The next group of chapters deals with the characteristics of the various types of sound sources and discusses loudness, frequency spectrum, and radiation pattern (polar diagram). The specific sound sources discussed in detail are string instruments, woodwinds, brass instruments, percussion instruments including the piano, and speech and singing.

The next group of chapters discusses the characteristics of microphones which includes directional properties and frequency response. There is a detailed discussion on the use of microphones for stereo systems which also considers the effects of different arrival times of acoustic signals at microphones and the use of artificial heads. One chapter discusses some of the special microphones such as the Lavalier, directional tube microphone, and the flat plate microphone.

Then the framework built up in all the preceding sections is put together to show how microphones should be placed for all the different types of sound sources. Thus the book is a very useful reference for a sound engineer who wants to place microphones for the best effect. The fact that the book is written in German will make it difficult for the English-speaking reader. However, the diagrams are very good and anyone with some knowledge of acoustic engineering will gain much useful information without needing to translate large amounts of text into English.

ROBERT W. HARRIS

Proceedings of Noise-Con 83

Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie N.Y. 12603.
Price: $US42

Ed. R. Lotz

The 1983 National Conference on noise control engineering was held 21-23 March, 1983 at the Massachusetts Institute of Technology with its theme "Quieting the Noise Source". It is perhaps unfortunate that this volume of proceedings has been passed on for review so late as the Conference will have been two years previous by the time the reader has ordered his copy. Nevertheless there is a mount of information in these proceedings some of which will not date for years to come. For the postpaid price of $US42 there are some 470 pages containing 52 technical papers mostly of an applied and specialised nature. There are papers in the usual well catered fields such as orifice noise, fan noise, but also in the less referred areas e.g. printers. Some papers are very specialised and may only have relevance to one-off consulting problems e.g. predicting noise from printer linkage mechanisms. A list of the technical sessions titles with the number of papers in each is given — Valves and Orifices (5); Printers and Other Mechanisms (6); Structural Design and Other Source Quieting (8); Fans and Turbomachines (7); Air Conditioners, Fans (8); Motors and Transformers (8); Tire Road Interaction, Burners and Combustors (6); Industrial Forming Machines (4).

—John Dunlop

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Format: Author, issue, first page, title.

A. ARTICLES

B. REPORTS

C. AUTHOR INDEX

D. BOOK REVIEWS

E. LETTERS

Australian Acoustical Society Annual Conference 1985

"Motor Vehicle and Road Traffic Noise"

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

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

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

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

Back Issues

A limited number of back issues of the Bulletin are available. The cost, including surface post, is as follows:

Prior to Vol. 10: $A3.00 per issue
Vols. 10, 11: $A5.00 per issue (or $A12.00 for 3 issues)

Copies may be ordered from: Mrs. Toni Benton, C/- School of Physics, University of New South Wales, P.O. Box 1, Kensington, N.S.W. 2033.

ADVERTISER INDEX

Readers are asked to mention this publication when replying to advertisements.

FUTURE EVENTS —

1985

May 6-8, HELSINKI

Fourth International Symposium on Hand-Arm Vibration.
Details: Dr. I. Pyykko, Institute of Occupational Health, Department of Physiology, Laajaniityntie 1, SF-01620 Vantaa 62, FINLAND.

June 3-5, U.S.A.

NOISE-CON '85

INCE/USA National Conference on Noise Control Engineering.

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

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

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

Deadline for abstracts: 15th February, 1985.

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

• June 17-21, SYDNEY

HEARING AID CONFERENCE
New National Acoustic Laboratories.
Details: Phone (02) 2-0537.

(See Aust. News this issue).

August 4-9, MANCHESTER

International Congress on Education of the Deaf.

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

August 26-29, GREECE

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

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

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

August 29-30, SINGAPORE

ACHIEVING A BETTER ACOUSTIC ENVIRONMENT

Topics: Physical Acoustics, Oral Communication, Shocks, etc.
Details: Conference Secretariat, 1 Maritime Square No. 09-22, World Trade Centre, Singapore 0409.

(See Intnl News this issue).

September 18-20, MUNCHEN, GERMANY

Enterprise 85. Organised by VDI, MUNCHEN.

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

September 18-20, MUNICH

INTER-NOISE 85

14th International Conference on Noise Control Engineering.
Details: INTER-NOISE 85 Secretariat, c/- UDI-Kommission Larmminderung, Postfach 11 39, D-4000 Dusseldorf 1, Federal Republic of Germany.

September 23-25, SENLIS, FRANCE

2nd INTERNATIONAL CONGRESS ON ACOUSTIC INTENSITY.

Details: Dr. M. Brockhoff, CETIM, BP 67, F-60300 Senlis, France.
(See Intnl News this issue).

September 24-27, CRACOW, POLAND

NOISE CONTROL '85
International Conference.
Details: Noise Control '85, Institute of Mechanics and Vibroacoustics, Al. Mickiewicza 30, 30-059 Krakow, Poland.

October 1-4, HIGH TATRA, CZECHOSLOVAKIA

24th Acoustical Conference on "Building and Room Acoustics".
Secretariat: House of Technology, Ing. L. Goralikova, Skultetyho ul. 1, 832 27, Bratislava.

October 15-25, ITALY

Ultrasonic methods in evaluation of inhomogeneous materials. NATO Advanced Study Institute.
Ettore Majorana Centre for Scientific Culture, Erice, ITALY.
Details: A. Alippi, Istituto di Acustica - CNR, 1216 Via Cassia, 00189 Roma, ITALY.

(See Vol. 12 No. 3 p. 105).

• October 23-25, BRISBANE

CONCRETE '85

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

November 4-8 NASHVILLE

Meeting of the Acoustical Society of America.
Chairman: Robert W. Benson, Bonitron Inc., 2970 Sidco Drive, NASHVILLE, TN 37204.

• November 24-26, LEURA, N.S.W.

AAS ANNUAL CONFERENCE
"Motor Vehicle and Road Traffic Noise".
Details: Prof. Anita Lawrence, School of the Built Environment, University of N.S.W., P.O. Box 1, KENSINGTON, N.S.W. 2033. Tel.: (02) 697 4850.
(See Vol. 12 No. 3 p. 88).

November 28-30, HONG KONG

WESTPAC II
Second Western Pacific Regional Acoustics Conference.
Theme: Developments in Acoustics in the Western Pacific Region.
Details: Organising Committee Secretariat, WESTPAC II, c/- Division of Part-time & Short Course Work, Hong Kong Polytechnic, Hung Hom, Kowloon, HONG KONG.
(See Vol. 12 No. 3 p. 105).

December 2-6, HONG KONG

POLMET '85, Asia & Pacific Regional Conference
"Pollution in the Urban Environment".
Details: The Secretariat, POLMET '85, 57 Wyndham St., First Floor, Central, HONG KONG.

December 2-6, CHRISTCHURCH

1985 AUSTRALASIAN CONFERENCE ON COASTAL & OCEAN ENGINEERING
Details: The Conference Convenor, 1985 Coastal Conference, P.O. Box 8074, Christchurch, New Zealand.

1986

April 8-11, TOKYO

INTERNATIONAL CONFERENCE ON ACOUSTICS SPEECH & SIGNAL PROCESSING
Details: Prof. H. Fujisaki, General Chairman of ICASSP 86, Dept. Electronic Eng., University of Tokyo, Bunkyo-ku, Tokyo, 113 Japan.
(See Intnl News this issue).

May 12-16, CLEVELAND, U.S.A.

Meeting of the Acoustical Society of America.
Chairman: Arthur Benade, Case Western Reserve University, Physics Department. Cleveland, Ohio 44106.

May 1986, WIEZYCA, POLAND

3rd International Spring School on Acoustoopics and Applications.
Organised by the University of Gdansk.
Details from: Prof. A. Sliwinski, Uniwersytet Gdanski, Instytut fizyki Dosw. ul. Wita Stwosza 57, 80-952 Gdansk.

July 8-11, GYOR, HUNGARY

6th FASE-Symposium on "Subjective Evaluation of Objective Acoustical Phenomena".
Secretariat to be announced.

July 24 - Aug. 1, TORONTO

12th ICA
Details: 12th ICA Secretariat, Box 123, Station 'Q', Toronto, Canada M4T 2L7.
(See Vol. 12 No. 2 p. 61).

• October, TOOWOOMBA

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

Topic: Community noise and the interaction of legislation and the legal system, planning and community education.
Details: Ms Nola Eddington, Division of Noise Abatement, 64-70 May Street, BRISBANE, Q. 4000.
(See Aust. News this issue).

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