Acoustics Australia

Vol. 13, No. 2, August 1985. THE BULLETIN OF THE AUSTRALIAN ACOUSTICAL SOCIETY

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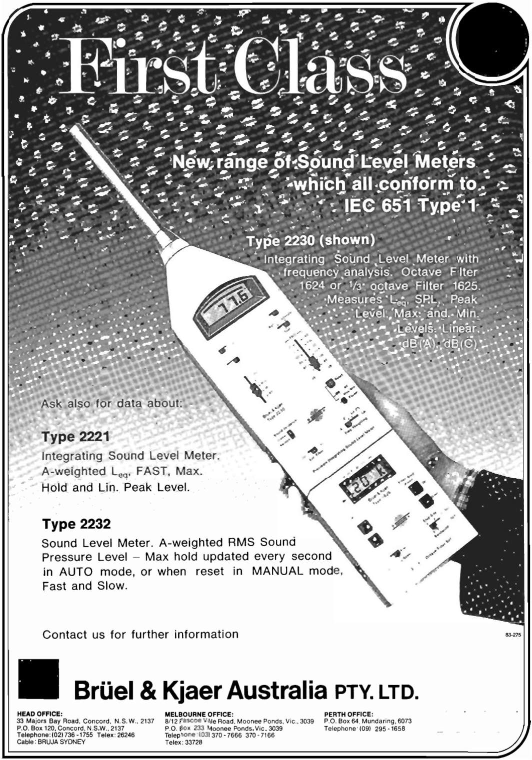
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AUSTRALIAN NEWS —

NEW SOUTH WALES

March Technical Meeting

On 20th March 1985 **Ken Willis,** Town Planner with Hornsby Shire Council, and **Steven Cooper** of James Madden, Cooper, Atkins Pty. Ltd discussed ten years experience with Hornsby Council's Code for Sound Insulation of Home Units.

The code requires that, before a building application is approved for a residential flat or home unit project, an acoustic consultant submit details of the noise controls that may be necessary, and on completion of the building a test certificate must be lodged by the consultant to show whether compliance with the performance requirements as specified has been achieved. Among the requirements to be satisfied to provide protection against external noise are that L_{10} (20 minute) and the L_T (rail traffic) shall not exceed 40dBA with the doors and windows of the flat or home unit closed. With windows and external facade doors open by a normal amount (defined as at least 5 per cent of the floor area of the room) the aforementioned values shall not exceed 50dBA. The council has the authority to nominate the units to be tested for the purpose of preparing the certificate required on completion, and may require readings to be made at locations other than those at boundary mid-points as stipulated in the code. Measurements to determine conformity with the levels laid down are specified to be made during the period 6 p.m. to 8 p.m. on Monday, Tuesday, or Wednesday evenings, although the council reserves the right to require them to be made at other times and under different conditions.

For the control of internal noise, Part 52 of Ordinance 70 is, of course, relied on, although an assurance of compliance is required from the acoustic consultant based on inspection of the project during its construction.

April Technical Meeting

The meeting room was crowded on 17th April, 1985 when **John Clear** discussed the format and areas covered in the Environmental Control Manual produced by the State Pollution Control Commission.

The control of noise from non-scheduled premises, public places, trail bikes, and from residents, has been concentrated in the hands of local councils as a result of amendments to the Noise Control Act. Further, the control of noise from vessels on navigable waters, including noise from the engines, from other machinery, and from people, has been made the responsibility of the Maritime Services Board.

In order to standarise the approach to noise problems, to show clearly the delineation of responsibilities, and to demonstrate the changes to the Noise Control Act the manual has been prepared and is expected to be available around mid-year. The loose-leaf format using a ring binder will allow for updating and for changes in future years.

May Technical Meeting

On Wednesday, 29th May, 1985 members of the N.S.W. Division were invited to a "Dissection of the EAR Laboratory at Sydney University". **Dr. Ferge Fricke** was the host and this "dissection" involved a visit to the Environmental Acoustics Research (EAR) Laboratory at the Department of Architectural Science. This laboratory has recently been constructed and includes a Reverberant Room and an Anechoic Room.

To supplement the tour of inspection, a number of the students presented short reports on their current projects.

QUEENSLAND

March Technical Meeting

On Sunday, 17th March, 1985 a group of approximately twenty-five members and interested persons was escorted on a guided technical tour of the Performing Arts Centre.

The group was shown through all areas of the Centre (except for plant rooms) by the Controller of Technical Services, **Mr. T. Everingham.** Acoustical features of the Lyric Theatre, Concert Hall and various service areas were detailed. In addition, Mr. Everingham highlighted several short-comings in the acoustical performance of some architectural designs and in the acoustic environment of some spaces.

Of particular interest to the group were the acoustic louvres in the ceiling structure of the Lyric Theatre which were oenable to change the room reverberation time by exposing various amounts of absorptive lining held against the roof. In addition, the massive acoustic doors in the Lyric Theatre which separated the rear stage from the main stage and side stage were inspected with interest. In the Concert Hall, Mr. Everingham explained the use of retractable absorptive blankets to change the room average reverberation time from 1.6s to 2.5s and the functioning of the electronic sound reinforcement system.

On the debit side, various problems were elaborated upon.

May Technical Meeting

The Acoustics of Flexible Polyurethane Foam

Mr. Ken Smith (Chief Chemist, CMA Foam Group), with assistance from **Mr. Michael Coates** (Managing Director of Industrial Noise Control), presented a discussion of the acoustical properties of flexible polyurethane foam on May 1, 1985.

Ken Smith briefly traced the history of foam from its "accidental" invention in 1849 through its early use for cushions, carpet underlays and cable wrapping. In addition he outlined the diversity of uses of modern polyurethane foam as filters, reservoirs, applicators, carriers, seals, separators, wicks, sponges, coalescents, surge mitigators as well as in noise control applications. Discussing the physical properties of polyurethane foam, Ken Smith turned his attention to the way in which foam can be cut, stapled and glued as well as contrasting its physical properties with those of fibreglass and mineral fibre. In dealing with manufacturing techniques, he discussed the way in which hole size can be regulated and how closed cell and open cell (reticulated, i.e., no windows) and unreticulated foams are formed. An appreciation of the differences between reticulated and unreticulated foams was important to the subsequent discussion of acoustical properties. As a result, Ken Smith circulated a wide variety of foam types among the audience for their perusal.

Having dispensed with the introductions, Ken Smith offered the following general guidelines regarding the sound absorption properties of foam —

Coefficient of sound absorption is:

- proportional to the thickness of foam
- in general, proportional to the number of cells per inch (porosity)
- low for closed cell foam.

Mr. Smith illustrated these guidelines with plots of absorption coefficient vs. frequency and discussed briefly the effect on the coefficient of protective facings on foam. Michael Coates took the discussion of sound absorption further by elaborating upon the relationship between flow resistivity and absorption coefficient. He, likewise, contrasted the physical properties of foam with fibreglass and mineral fibre. Finally, he dealt with some common acoustic applications of foam — silencers, architectural wall coverings and in the electronics industry.

Gauging by the questions asked by the audience the topic proved to be quite thought provoking. A vote of thanks, emphasising our appreciation of the speakers having travelled from interstate, was moved by Dr. Bob Hooker.

Queensland Division Progress

The relevant paper work associated with the formation of the Queensland Division of the Society is still with the N.S.W. Corporate Affairs Section.

In the meantime, the Organising Committee is very anxious to hear from people interested in membership of the Queensland Group. Please advise any persons you know who may be interested in their attempts to establish a Division of the Society in Queensland. The current address is:

Acoustics — Qld. Group
P.O. Box 333
Toowong, Q. 4066

AUSTRALIAN NEWS

(Continued)

VICTORIA

April Technical Meeting

Site Visit to the GMH Noise and Vibration Group

The Supervising Engineer, **Mr. Cliff Joachim,** gave an overview of the development activities of the Noise and Vibration Group at GMH Port Melbourne. In addition to achieving passenger comfort by minimizing noise and vibration, the group must also meet the requirements of A.D.R. 28A for pass-by noise and the E.P.A. stationary noise criteria.

Under the guidance of **Cliff Joachim** and **Jim Menadue** we were able to view the demonstrations that had been organized. Signature analysis and modal analysis are used to pinpoint particular noise sources and structural resonances. Sound transmission paths can be carefully investigated on a special rig where structural transmission paths can be eliminated. Elements can also be tested for airborne sound transmission and sound absorption by more traditional methods.

Our thanks to GMH and the demonstrators for a most informative evening.

May Technical Meeting

This meeting was in the form of a site visit to the Australian Government Aero Engine (F404) Test Facility in Melbourne on 30th May, 1985.

The F/A-18 Hornet fighters supplied to the Royal Australian Air Force are assembled and tested at the Commonwealth Aircraft Corporation and Government Aircraft Factories in Port Melbourne. After assembly by CAC, the F404 engine is installed in the adaptor trolley in the preparation room then the trolley is towed into the test cell for its computer controlled test program. The Primary and Secondary air intakes and Exhaust Section were open for inspection, together with the engine test area and preparation and control rooms of the facility. The Intake, Exhaust and Test Areas are lined with acoustic panels and fitted with acoustic splitters designed to alleviate noise.

Mr. Louis Challis, the Acoustic Consultant for the design and construction of the facility, was present during the visit and spoke to the members in the Administration Building prior to the inspection of the Test Facility.

WESTERN AUSTRALIA

May Technical Meeting

On 2nd May, 1985 Lynn Kirkham from the Dept. of Mechanical Engineering at the University of W.A. spoke on Acoustical Problems in the Design and Building of Pipe Organs.

Organ builders today are heirs to a vast store of empirical knowledge and techniques gained over many centuries; some of it systematised, some of it understood, some of it not, some of it probably valid, some of it probably not. The design and building of a successful organ relies heavily on that store of knowledge but also the application of modern acoustic and engineering science in some areas may help a builder design for a particular result, or anticipate and avoid (or allow room to manoeuvre around!) many problems that may occur.

Lynn Kirkham described the variables involved in the design, building and finishing of a pipe organ which include: the construction material, the absolute and relative dimensions and fine adjustment of the pipes, the layout of the sections of the organ relative to themselves and to the room, the acoustic response of the room and the listener, the dynamics of the organ air supply and regulating system, and the mechanics of the playing action. He outlined how both the empirical and theoretical knowledge can be used to produce a successful pipe organ.

Noise Abatement Regulations

The Western Australian Noise Abatement (Hearing Conservation in Workplaces) Regulations 1983 were introduced in October 1983 after extensive discussions with employer and employee groups. They are regulations made under the Noise Abatement Act 1972-1984. Amendments to the Regulations were published in the W.A. Government Gazette of 12th October, 1984.

The Regulations, with amendments, came into operation on 21st October, 1984. The twelve month period between gazettal and commencement was given to allow time for the necessary organisational measures to be taken, in particular, the training and approval of noise officers, audiometric officers and approved medical practitioners. A list of approved people, equipment and procedures will be published from time to time in the W.A. Government Gazette. The first such list which appeared in Gazette No. 77 of 26th October, 1984.

As the Regulations are of necessity written in a detailed style, summary **Guidance Notes** have been prepared to help the many people affected by the Act and Regulations to understand their obligations and rights. The Act and Regulations themselves should be referred to for details or for any legal matter. The second edition of the Guidance Notes, January 1985, includes the amendments to the Regulations and the change of the title 'Commissioner' to 'Executive Director', brought about in July 1984 when the Public Health Department was amalgamated into the Health Department of Western Australia. The list of approved people, equipment and procedures has been reproduced as Appendix VII.

Further information or advice on any aspect of the Regulations and application forms for approval as noise officers, audiometric officers and approved medical practitioners, can be obtained from the *Noise Section, Occupational Health Branch, Health Department of W.A., P.O. Box 6004, Hay Street East, Perth, W.A. 6000. Phone (09) 325 7911.*

To assist employers in meeting the obligations of employers the Occupational Health Branch has produced a ***Directory of Companies and Organizations*** interested in providing hearing conservation services. The lists for the first edition were complete as at 18 March, 1985. Inclusion in this directory does not imply any recommendation by the Occupational Health Branch of the services advertised. Persons and organizations are included solely on the basis of their applying for listing in the directory.

Those interested in being included in subsequent directories should obtain an application form by writing to the *Director of the Occupational Health Branch* at the above address, quoting file number 51/79/4.

Dr. Norton returns

Dr. Michael Norton has just returned to the Department of Mechanical Engineering at the University of Western Australia after a six-months study leave. Whilst on leave he (i) attended Inter Noise 84 at Honolulu, (ii) attended a specialist seminar series on Machinery Diagnostics and Condition Monitoring organised by Professor R. H. Lyon (from M.I.T.) and (iii) spent about five months at the Institute of Sound and Vibration Research, University of Southampton. Whilst at the I.S.V.R., working in collaboration with Dr. F. J. Fahy, he set up an experimental programme to study the correlation between high frequency

Continued on page 45

vibrations in fluid filled cylinders (associated with dispersive bending waves) and stress levels on the pipe wall. Statistical expressions to estimate stress and strain from mean square spatially averaged pipe wall acceleration levels were also developed. Some additional work was also done in conjunction with K. T. Brown (structural dynamics group at I.S.V.R.) to study some of the factors associated with experimental errors often encountered in the experimental determination of modal densities and internal loss factors for Statistical Energy Analysis applications.

New Exchange Arrangements

The Australian Acoustical Society endeavours to keep in touch with other acoustical societies and institutions through a regular exchange of publications. Recent additions to our list of contacts include the Catgut Acoustical Society and the firm of Kilde in Norway.

The Catgut Acoustical Society is a most active American-based society whose members are concerned with research and development relating to both new musical instruments and improvements to existing instruments. Founded by the famous violin maker and researcher, Dr. Carleen Hutchins, membership extends to many countries including Australia. The society publishes a semi-annual journal.

The firm of Kilde in Voss, Norway, specialises in consulting work relating to sound, noise and vibration control and also offers information services in these fields. They carry out literature surveys, develop prediction methods and provide translations of technical reports. Some recently issued reports are listed under new publications.

1985 Conference Australian Acoustical Society Motor Vehicle and Traffic Noise

The relaxed, quiet and refreshing air of Leura in the Blue Mountains to the west of Sydney, in one sense will be a good place to escape the subject of discussion at the Society's Annual Conference in November — traffic and vehicle noise. **The conference will be held on 25th and 26th November, 1985.**

Motor vehicles are recognised throughout the world as the most pervasive source of community noise in urbanised societies. The range of issues to be covered at the conference indicates that the solutions to the problem are complex and diverse and call on many professions, including vehicle designers, urban planners, architects, engineers and legislators.

This forum will provide an opportunity for all these groups to discuss the developments in their respective fields.

The conference will cover:

- Community reaction to traffic noise
- Vehicle design and maintenance
- Traffic management and noise control
- Urban planning
- Design and construction of buildings
- Modelling and prediction
- Road design and maintenance
- Legislation and controls
- Economics

The keynote address will be given by **Dr. Ariel Alexandre** of the OECD, Paris. He is a well-known researcher and author on topics of the economic and social effects of road traffic noise.

Further details can be obtained from AAS Conference Information Service on **(02) 265 8916.**

FROM THE PRESIDENT—

Due to the economic constraints imposed on all sectors of the community in the last few years, special efforts are being made in the areas of education, science and technology, to name a few, to reassess, rationalise, innovate, revitalise, streamline, amalgamate or coordinate activities to gain the maximum mileage out of the meagre funds available.

National or private committees, educational institutions, professional societies and many individuals, who are alarmed and frustrated by the lack of financial support for their activities, are hard at work to devise new approaches to deal with the various "crises".

I would like to refer to two such initiatives currently on the move, which may have implications for our Society and some of our members may not be aware of these.

The first deals with the revitalisation of the nearly defunct Experimental Building Station at North Ryde, Sydney.

Early in May, the Federal Housing and Construction Minister, Stewart West, reported that the Cabinet endorsed a plan . . . "to immediately revitalise the Federal Government's Experimental Building Station, and to streamline the nation's building research effort" . . . "the Station will be renamed the **National Building Technology Centre"** (NBTC) . . . "will be given a comprehensive charter to develop as a national centre of research excellence" . . . also that . . . "the Cabinet has agreed in principle, to move towards the establishment of a single building research organisation over the next three years, which would absorb the NBTC and the CSIRO Division of Building Research" . . . "the new-look NBTC is an important first step in our overall strategy to rationalise the nation's building research effort".

Media release, Federal Minister for Housing and Construction.

The second deals with the proposed formation of a Federation of Australian Scientific and Technological Societies.

In November last year, the heads of eight of Australia's major societies, representing over 20,000 professional scientists, met to "discuss a common approach of scientists to Australian Governments" . . . because of . . . "continuing concern over the immediate and long term effects of the neglect of sciences". (Professor Wilson).

After numerous meetings, an interim committee of the proposed Federation of Australian Scientific and Technological Societies was formed in May this year, chaired by Professor Fred Smith of Monash University. The committee's task in the next few months will be to establish the aims and objectives of the Federation with an appropriate organisational model and constitutional structure for the implementation of those aims and objectives. The Federation will have a strong voice as it will be representing the views of societies which have approximately 90,000 individual members.

The AAS at its last council meeting agreed to support actively the formation of the above body. Your journal will keep you informed on any moves by the Federation which may affect the activities of our Society.

—Tibor Vass

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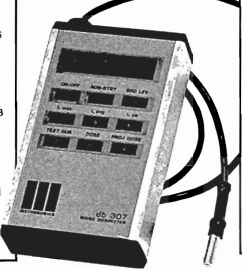

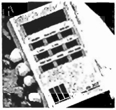
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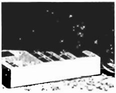
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PEOPLE —

• **Joe Hayes** had to tender his resignation from the Steering Committee of the Queensland Division as a result of a move from the "Quiet" of Mt. Tamborine in the Gold Coast Hinterland to the "Roar" of Sydney. Joe, who is putting the finishing touches to an acoustic instrument transduction system, is now working for EAR Pty. Ltd.

* * *

• **Ron Winderbank** has recently returned from an extensive business trip in China and Hong Kong.

* * *

• **Professor R. H. Lyon** is planning to come to Australia in March/April 1986 and it is proposed that a series of seminars on Machinery Diagnostics and Condition Monitoring will be held. Professor Lyon is in the process of publishing a new book on the topic. Dr. Norton can be contacted on (09) 380 3118/6 for further information.

* * *

• **Professor P. O. A. L. Davies** (Professor of Fluid Mechanics and Acoustics at I.S.V.R.), who is undoubtedly well known by many people here, will be spending a four-month sabattical at the Mechanical Engineering Department, University of Western Australia, in the middle of 1986. During that period, he plans to visit the other capital cities. Anyone interested in organising seminars/visits, etc., should either contact Professor Davies or Dr. Norton.

* * *

• **Dr. F. J. Fahy** has just published a new book which might be of interest to those people who are interested in Structure-Fluid Interactions. The book is titled "SOUND AND STRUCTURAL VIBRATION: Radiation, Transmission and Response", and is published by Academic Press Inc. (ISBN:0.12.247670.0).

* * *

• We were saddened to learn of the death of **Robert Bruce Lindsay** (1900-1985), editor-in-chief of the Journal of the Acoustical Society of America. He was Head of the Department of Physics, Brown University before his retirement after a distinguished career. He was the author of several important text books, General Editor for the Benchmark Papers in Acoustics and a former President of the Acoustical Society of America. The high standing of the Society's journal is a lasting monument to his work over many years.

* * *

• **Dr .S. A. T. Stoneman,** who is a lecturer in mechanical engineering at the University College, Swansea, U.K., is at present on leave in Australia at the CSIRO Division of Energy Technology, Highett, Victoria. Dr. Stoneman's field of research relates to the acoustic fields producing high rotor blade stresses. While in Australia he is willing to give a technical talk on his subject to any interested party.

• **Con Demos,** well known to many in the N.S.W. Division, died during May in tragic circumstances. Con joined the Experimental Building Station, now destined to become the National Building Technology Centre, back in the 1970s and later was transferred to the Acoustics Group in that organisation, with which he remained associated until his untimely death. He continued his studies during this period, gaining his Diploma of Electronic Engineering from the N.S.W. Institute of Technology.

In recent years he battled with recurring illnesses that caused him long absences from work. Con was known with affection for his friendliness and kind-heartedness, characteristics which won him many friends.

• With great sadness we report that **John Moffat** M.A.A.S. died on May 10th, many members of the Victoria Division attended the thanksgiving service held exactly twelve months after it was confirmed that John had leukemia. John will be remembered for his brightness, wide knowledge of acoustics and all things scientific and most importantly for his frankness and honesty. Our special thoughts of comfort go to Helen and her three young children.

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 —

New South Wales

Mr. B. S. Dick, Dr. N. E. Holmes, Mr. A. C. Stewart.

Queensland

Mr. A. W. Kapitzke, Mr. B. L. Manser, Mr. D. J. Moore.

• **Graded**

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

Affiliate:

Mr. P. McCormach, Queensland.

Member:

New South Wales

Mr. R. A. Godson, Dr. V. N. Nguyen, Mr. D. N. Nicolaisen.

Queensland

Mr. A. R. Brown, Mrs. N. J. Eddington, Mr. D. M. P. Fournier, Dr. R. J. Hooker, Mr. P. D. Koorockin, Mr. G. P. Lee-Manwar, Mr. B. L. Manser, Mr. J. F. Savery.

Western Australia

Ms. D. S. Ronowski.

Victoria

Dr. A. Cabelli.

CMA Foam Group now a Sustaining Member

CMA Foam Group, a division of Cable Makers Australia, are manufacturers in Australia of Merracel a reticulated polyurethane for acoustical purposes; their admission to the Society as a Sustaining Member is most welcome.

Jim Fowler moves to GEHA

Jim Fowler formerly of the Noise Control Branch of the EPA has joined us here at Graeme E. Harding and Associates. This should allow a bit more time for your People Columnist to write this column on time, attend to Standards matters and to carry out my Society responsibilities.

Louis Challis & CSR Acoustical Laboratories

Louis spoke briefly with your People Columnist whilst in Melbourne recently; and whilst there was not time to get all the details of how and why, I understand that agreements have been concluded whereby Louis now has in effect leased CSR's acoustical laboratories. This is important news as it means that for the first time an over-partition ceiling test laboratory is available to all manufacturers and users of ceiling tiles. Additionally of course it means that Louis can now make room-to-room partition loss sound transmission loss measurements.

B.T.R.'s Singapore Representation

Peter Howells A.A.A.S. and his wife Edna and family have gone to Singapore from B.T.R. Silentflo to work for B.T.R. Harper Projects Pte. Ltd. to relieve Morry Jefferies A.A.A.S. who with his wife Pat and family have returned to Melbourne.

Legal Issues

Whilst doing the crossword in "The Sun" recently I noticed on the same page an entry in the law list for that day in the County Court under Building cases at 9.30 a.m. B.T.R. Silentflo Pty. Ltd. versus Vipac & Partners Pty. Ltd., and at 10.30 a.m. Insulation Materials & Services Pty. Ltd. versus F. W. Nielsen Pty. Ltd. I don't think I have ever looked at the law list before, and certainly did not expect to see the names of four companies involved to various degrees in acoustics.

This Issue's Joke

Various people spoke at the meeting in the church hall; whilst the old rector was talking a man at the back of the hall called out "Could you please speak up the agnostics in here are terrible".

We have Geoff Barnes to thank for the above acoustical joke.

Readers' Response

Please send advice of new appointments, office of factory moves, new products and similar to your People Columnist, Graeme E. Harding, 22a Liddiard Street, Hawthorn, Victoria 3122 or telephone me on 819 4522.

Graeme Harding

INTERNATIONAL NEWS

12th ICA

Toronto, Canada
July 24-31, 1986

A call for papers, and Circular 2, has been issued for the 12th International Congress for Acoustics to be held in Toronto, Canada, from July 24-31, 1986 and for the three associated symposia. Papers for presentation at the Congress are invited in all fields of acoustics. Authors should send a preliminary abstract of 100 words to reach the 12th ICA Secretariat before July 31, 1985.

A call for papers has also been issued for each of the three specialised associated symposia which will focus on narrower fields of scientific interest. These symposia are:

"Underwater Acoustics" which will be held in Halifax, Nova Scotia, from July 16-18, 1986 and will focus on acoustic imaging of the sea bed, signal processing and beam forming, scattering at rough ocean boundaries, sound propagation, acoustics in the offshore industry, and inverse methods using acoustics to define the environment.

Further details:

"Units and Their Representation in Speech Recognition" which will be held in Montreal, Quebec, from July 21-22, 1986 and will focus on processes of human speech recognition, the organisation and performance of automatic speech recognition systems, and representation of these units in terms of the speech signal. The deadline for receipt of preliminary 100 word abstracts for this symposium only is September 30, 1985.

"Acoustics and Theatre Planning for the Performing Arts" will be held in Vancouver, British Columbia, from August 4-6, 1986. This symposium will bring together the acoustical design of performing arts facilities and other aspects vital to the function of an auditorium or studio space for performing arts production including room acoustics, studio and theatre planning design and theory, electroacoustics, sound effects and related topics.

Further details:

12th ICA Secretariat
P.O. Box 123, Station Q
Toronto, Canada
M4T 2L7

Underwater Acoustic Conference

The conference on Ocean Seismo Acoustics was held at the Italian resort town of Lerici from June 10 to 14. The conference was organised by the NATO sponsored SACLANT research centre in nearby La Spezzia. About 80 papers were presented during the five days of the conference to some 180 scientists from 12 different countries. The topics covered included range dependent and time independent propagation, noise, scattering, body wave, ducted wave and interface wave propagation, attenuation and sea-bed characterisation. Complete proceedings will be published by Plenum Press, N.Y.

J. I. Dunlop

WESTPAC II

Hong Kong
November 28-30, 1985

This conference has the theme of **Developments in Acoustics in the Western Pacific Region.** The conference will be held under the aegis of the International Commission on Acoustics and will be organised jointly by the Institute of Acoustics, Hong Kong Branch and the Hong Kong Polytechnic. It is co-sponsored by the Australian Acoustical Society, the Acoustical Society of Japan, the Acoustical Society of Korea and the Institute of Noise Control Engineering of Japan.

A comprehensive social program has been arranged, including a cocktail reception and a closing dinner. Sightseeing tours of Hong Kong, Macau and China will be available.

Further details:

WESTPAC II
c/- Division of Part-time and Short Course Work
Hong Kong Polytechnic
Kowloon
Hong Kong

POLMET 85

Hong Kong
December 2-5, 1985

This is the first Asia-Pacific regional conference on **Pollution in the Metropolitan and Urban Environment.** The occasion will provide a forum for discussion of policies, programs and solutions needed to deal with environmental problems created by the rapidly developing and expanding urban areas in the Asia-Pacific Region. It will provide also an opportunity for the exchange of ideas and knowledge between industrialised nations and developing countries.

Eminent speakers will present invited and contributed papers on water, waste, air and noise pollution and in a special stream invited speakers will address key issues in environmental management and planning.

Sponsors are the Hong Kong Government's Environmental Pollution Advisory Committee and the Hong Kong Institution of Engineers in association with Imperial College, London, and the United Nations Environment Program. Delegates to POLMET 85 are expected from all parts of the Asia-Pacific Region, with a strong contingent from the People's Republic of China, and also Europe, United Kingdom and the United States of America. Included will be environmental management policy-makers, academic leaders, industrialists and environmental engineers, planners and scientists.

Further details

POLMET 85 Secretariat
c/- International Conference Consultants
1st Floor
57 Wyndham Street
Central
Hong Kong
Telephone: 5-248779/5-253271
Telex: 72500 PANSY HX

XVIII International Congress on Audiology

Prague
August 24-28, 1986

This conference is organised by the Czechoslovak Oto-Laryngological Society and the topics to be discussed will include —

Education of Professional Personnel in Audiology (Moderator: Professor P. Berruecos, Mexico City, Mexico).

Neurochemistry of Hearing (Moderator: Professor J. M. Aran, Bordeaux, France).

Speech Audometry — phonological aspects and the theory of information (Moderator: Professor K. Sedlacek, Prague, Czechoslovakia).

Hearing in Old Age (Moderator: Professor G. Flottorp, Oslo, Norway).

Further details:

XVIIIth International Congress of Audiology 1986
Czechoslovak Medical Society
J. E. Purkyne
Vitezneho unora 31,
120 26 Prague 2,
Czechoslovakia

Noise and Vibration Courses

ISVR, Southampton
September 2-6, 1985

The 1985 **Advanced Noise and Vibration Course** is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. Registrants should be of degree standard or equivalent, and should have a basic knowledge of acoustics and vibration. The lecturers are from or are closely associated with, ISVR; all are specialists in the field.

The fee for the course is £420, which includes "Noise and Vibration" (edited by R. G. White and J. G. Walker) which owes its origin to this course; other relevant literature; meals and refresments at the university daily; course dinner; accommodation from Sunday to Thursday nights inclusive at a Hall of Residence within walking distance of the university. Some non-residential places are available at £370.

September 23-27, 1985

This five-day short course on **Applied Digital Signal Processing** will include demonstrations and laboratory participation. It is intended for engineers and scientists who wish to keep abreast of modern methods of signal processing with particular reference to dynamic testing. The course fee of £450 does not include lodging.

Further details:

Mrs. M. Z. Strickland
The University
Southampton SO9 5NH
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Sound Production and Hearing in Diverse Animals

Neville H. Fletcher
CSIRO Institute of Physical Sciences
Limestone Avenue
Canberra ACT

ABSTRACT: The vocal signals by which communication is achieved between members of the same species show remarkable similarity for animals as diverse as cicadas, frogs and humans. Likewise the auditory systems of these animals, although superficially very different, are all variations upon a single basic design. Some of these matters are discussed in detail and an explicit scheme for the analysis of auditory systems is given.

INTRODUCTION

Although modern acoustics is very much concerned with the behaviour of the human auditory system and with human vocal organs, it is not often that we stand back and take a much more generalised look at hearing and sound production in a large class of different animals. Certainly much of the classic work on human auditory systems relied heavily on studies of cats and guinea pigs, but in those cases similarity is quite close. What I would like to do here is to explore, much more generally, hearing and sound production in animals as diverse as humans, frogs, cicadas and crickets. I will take a physicist's approach and ignore biological niceties in order to present a coherent picture.

First let us note a few unifying principles which seem to apply to nearly all animals. The first is that sound production and hearing have developed essentially as a means of communication between members of the same species. Of course hearing also serves to give warning of the approach of predators or other dangers and vocal sounds can be used to frighten off intruders of other species, but that is not the primary evolutionary purpose of these physiological abilities.

The consequences of this communication function among members of the same species are several. In particular it leads to vocal and auditory capacities which are closely matched in frequency bandwidth and in time resolution. It also requires that each species develop a coding in the emitted sound which makes recognition of the species simple, and a further coding which conveys efficiently the desired information. There is remarkably little variation in the way in which this is done over the whole range of vocal animals.

Further, since a primary purpose of communication is social contact, all auditory systems possess some form of directional discrimination as well as an obvious intensity discrimination. At first sight the principles used appear to vary widely from one animal type to another, but we shall see that, rather surprisingly, most systems are actually variants of a particular generalised acoustical design with some features exaggerated and others suppressed.

SOUND PRODUCTION

For our present purposes, animals — and we are thinking here of land-dwelling animals — can be divided into two classes: those with lungs and those without lungs. All the larger animals, and in particular all the vertebrates, fall into the first class, while small animals such as insects may belong to the second class, which obtains its bodily oxygen needs by slightly forced diffusion along a series of tubes let into the side of the body.

An animal with lungs, though it may make sounds in a variety of ways, always produces its primary vocal sounds pneumatically by using air released from the lungs under pressure. Animals without lungs do not have this option and must produce sound by muscularly excited vibration. Let us discuss this second class first.

There are two common ways in which sound can be excited efficiently by muscular effort. Each involves a resonant structure and an exciting mechanism. In the first strategy the exciting mechanism is a sharp pic which is drawn across the ridges of a file-like structure to produce a train of regularly spaced excitation pulses. If the pic, or more usually the file, is closely coupled mechanically to a plate or membrane with a resonance frequency equal to that produced by the motion of the pic across the file, then a vibration of large amplitude will be generated and, if the vibrating structure is not too small compared with the wavelength of sound in air, efficient sound production will occur.

This mechanism, which is used by crickets and similar insects, already meets the communication needs of the animal. The song is based on a well-defined carrier frequency, that of the plate resonance, and consists of "syllables", one for each scrape of the pic across the file, as generated by a wing or leg motion. The information content of the song can be varied by changing the number of syllables in a "word" or by changing the repetition rate of syllables.

The other common mechanism, used by cicadas and similar insects, involves a ridged plate or tymbal closing the top of an air-filled cavity to produce a simple resonant structure. If the plate is distorted by muscular effort then it buckles progressively in a series of pulses related to the ridge spacing. If the pulse rate is equal to the cavity resonance frequency then sound is generated efficiently. The same coding possibilities exist. A typical example is shown in Figure 1.

For obvious reasons of efficiency both these mechanisms suggest the use of progressively higher frequencies for smaller insects, and this is what is observed in practice. For insects a few centimetres long, the song carrier frequency is typically in the range 3 to 5 kHz, and the syllable repetition rate perhaps 200 Hz. A remarkable amount of energy is often put into the production of the song — a continuously singing cicada may typically radiate 1 mW of acoustic power, which is comparable with the power of the human voice.

In insects the song serves primarily as a mating call and only the males have vocal organs. An interesting extreme case is the green Australian hedge cicada *Cystosoma Saundersii*. The male of the species has an enormous air-filled abdomen, about 4 cm long, which serves entirely as a resonator for the song, which has the unusually low frequency of 800 Hz with a 40 Hz syllable rate.

When we examine the production of sound by pneumatic power we find that just one mechanism is used. If the air passage is obstructed by a flap of cartilage, or by a pair of such flaps closing together, arranged in such a way that air pressure in the lungs will blow them open, then this simple system constitutes a pneumatic oscillator. Its operation is exactly similar to that of the lips in blowing a "raspberry", and the frequency of oscillation is just slightly above the natural resonance frequency of the vibrating flaps. The existence of a cavity on the air supply side of the system is crucial to the operation of the oscillator, as is the direction of opening of the flaps — a system with a flap blown closed like the reed of a clarinet operates in an entirely different and, for the present purpose, unsuitable way.

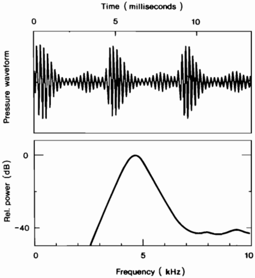

Figure 1: A typical insect song consists of a repeated series of "syllables", each associated with a wing or leg motion or with the contraction of a tymbal muscle, as shown here for the cicada. Syllables may follow each other continuously, as for the cicada, or may be grouped into "words" of three or more syllables. In more complex animals, such as frogs, the length of individual syllables in a word may vary. The acoustic spectrum is sharply peaked around the carrier frequency characteristics of the species, about 4.5 kHz for the cicada shown here.

This pneumatic oscillator is called a larynx, and systems of this type are found in humans, dogs, frogs and even (though in a modified and dual form) in birds. Although the larynx motion may be not too far from sinusoidal, the air flow through it has a strongly pulsed character and produces an excitation rich in harmonics.

It is clear that, once again, we have a vocal sound based upon a more or less regular carrier frequency, the basic oscillation frequency of the larynx. In humans this frequency itself carries valuable information — it is around 150 Hz for adult men, around 300 Hz for women, and 400 Hz or more for children.

Human speech obviously has a rich acoustic structure. Not only is the larynx sound broken up into syllables and words by changing air flow, but the distribution of energy in the upper parts of the rich pulse spectrum is varied by manipulating the frequencies of the first three resonances of the pipe-like vocal tract leading to the open mouth, by changing lip, tongue and mouth shape. The "formant" resonances are nominally around 500, 1500 and 2500 Hz, as we would expect for the impedance maxima of a cylindrical tube about 15 cm long, but can be shifted quite significantly to produce different vowels as shown in Figure 2. Human speech also involves assorted hisses and

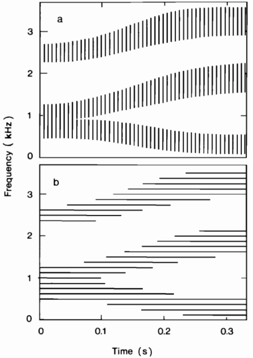

Figure 2(a): A Sonagraph-type display of the formant structure of a human speech diphthong "O-EE". The Sonagraph gives a frequency-time display with relative energy in different spectral ranges coded as blackness. Typically the Sonagraph filter has a bandwidth of 300 Hz so that individual frequency components of male speech cannot be separated, but the individual pulses from the larynx are resolved in time. The shift in frequency of the three major speech formants can be clearly seen.

Figure 2(b): If the bandwidth of the analysing filter is made much narrower, then time resolution is traded off for frequency resolution. Pulses from the larynx are no longer resolved in time but the individual harmonics of the pulse frequency are clearly visible. These vary considerably in intensity but to only a minor extent in frequency in normal speech.

clicks but the important part of the speech spectrum runs from about 300 Hz to 3 kHz. There is not a great deal of radiated energy at the larynx fundamental and in any case it is possible to deduce what its frequency is from the regular frequency spacing between successive harmonics.

Once again there is a correlation between larynx frequency and size in different animals but, since vertebrates change size significantly during their lives, this frequency is not of dominant importance for species recognition. Instead, reliance is placed upon other features of the rich vocal sound. Some more primitive animals, however, have quite sophisticated "built-in" coding. An example is the frog, some species of which have two sets of vocal flaps, in series, one with a frequency around 100 Hz and one with a much higher frequency, say 2 kHz, giving a song sound quite closely related to that of an insect.

In humans, of course, the larynx frequency can be varied by a factor of 4 or more in the artificial activity of singing, while birds do this as part of their normal vocalisation. Other pneumatically generated noises such as whistles, which are generated by the interaction between an unstable air jet and a resonant cavity, can be used as part of a song or speech but these are generally not the basic speech sounds of a species.

AUDITORY SYSTEMS

The basic requirement of an auditory system is that it be sensitive to sound pressure over the frequency range characteristic of the song or speech of the species and that its internal mechanism convert the air pressure variations associated with the sound into mechanical displacement of some internal structure to which nerve-cell transducers are attached.

Some animals, such as caterpillars, have sensory hairs which perform a similar function in relation to the acoustic velocity signals produced by the beating wings of predators, but essentially all genuine auditory systems seem to rely upon taut diaphragms as the primary transduction mechanism from acoustic pressure to mechanical vibration. The diaphragm or tympanum may be assisted, as we see later, by various resonators, couplers or phase shifting networks depending upon particular features that evolutionary processes have emphasised, while the complexity of the mechanical-to-neural transducer varies greatly with the sophistication of the vocal code of the animal concerned.

The upper part of Figure 3 shows a generalised auditory system from which we can consider all real animal auditory systems to be derived by suppressing one or more features. Interestingly all the features shown are present in the auditory systems of higher mammals, including humans, but the Eustachian tubes which connect the cavity behind the tympana to the rest of the system are so narrow relative to the size of

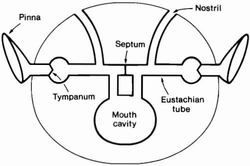

Figure 3: A generalised model auditory system from which most other systems can be derived. In mammals the Eustachian tube is so narrow that the system functions as two independent ears. In simpler animals there is generally an acoustic coupling between the two ears but some other features of the generalised system may be missing.

the tympana that effectively no sound energy travels along them and the system behaves like two isolated simple ears. In this and all other systems we assume that a neural transducer is connected to each tympanum to convert its motion to nerve impulses, but we forego any consideration of detail.

The isolated ear of the mammalian auditory system has a simple acoustic function, at least in outline, though its performance is rich in detail at higher frequencies. The pinna provides an acoustic pressure gain of 10 to 20 dB at frequencies above a few kilohertz, depending on shape and size, but the gain falls to not much above 0 dB below a few hundred hertz because of the transmission behaviour of finite flared horns. The tympanum itself is typically a tensioned conical membrane with a resonance frequency around 2 kHz, near the middle of the hearing range of interest. The Q value is typically less than unity, say about 0.5, so that its frequency response is broad. Taking account of the performance of the horn-like pinna we therefore have a system with a fairly flat frequency response from around 1 kHz to 5 kHz, with a decreasing response below 1 kHz because of the combined effects of horn cut-off and tympanum resonance, and a decreasing response above about 5 kHz because this is well above the tympanum resonance. Actually the sensitivity of the human ear is much less than would be predicted by this model below 100 Hz and above 10 Hz but this is undoubtedly due to evolutionary limitations on the neural transduction mechanism rather than to simple acoustic response.

The directional discrimination of a single mammalian ear is influenced both by the geometry of the pinna, which tends to emphasise high frequency sounds incident from along the direction of its axis, and by diffraction around the head, which produces directional maxima and minima in a more complicated way, though again favouring incidence from the ear direction. On top of this there are other complications caused by the convoluted shape of a typical mammalian pinna and, of course, the subtle psychophysical correlations between the inputs of two independent ears that are made possible by the sophistication of the mammalian brain.

COUPLED EARS

In all the other animals I will discuss here, the acoustic pathways between the two ears are sufficiently open that we must consider them in combination. It is interesting that this is the situation in the lower animals whose response to auditory stimuli is much simpler than in mammals. By evolutionary chance it proved more appropriate to rely upon increased acoustic sophistication at the auditory periphery rather than to undertake more complex neural processing.

The simplest auditory system is that belonging to the frog, as shown in Figure 4(a). The tympana are simple extensions of the outside skin of the head, and short wide Eustachean tubes lead directly from the ears to the mouth cavity. By chance the geometry of the auditory system of insects like the cicada, as shown in Figure 4(b), is very similar, though in this case the two tympana and the cavity are located in the abdomen and the cavity has no other function.

Acoustic analysis of this sort of system is quite straightforward, both in relation to frequency response and to directional discrimination. While diffraction around the body of the animal will certainly have some effect, this is relatively minor compared with the effect of phase differences between the sound pressure at the two tympana for various incidence directions.

Since the cavity is reasonably large, though small in dimensions relative to the sound wavelength involved, it behaves as a simple acoustic compliance, and the tympana have maximal response near their resonance frequency, which we would expect to be tuned to the carrier frequency of the song of the species, about 1.5 kHz and about 5 kHz respectively for these two cases.

It turns out from the analysis that two ears coupled by a cavity in this manner can have a cardioid response with a directional discrimination of nearly 20 dB if the Q value for the tympana is appropriately chosen. For a typical frog-like case the appropriate value is around 4, which implies that the bandwidth of the system will not be large. This is, of course, exactly what is required, given the simple amplitude-modulated nature of the frog song. An exactly similar conclusion is reached in the case of the cicada.

Since the primary purpose of the song of both male frogs and cicadas is to attract females while keeping males of the same species at a distance, this directional discrimination and frequency specificity has obvious behavioural importance. All the female has to do is to respond to the carrier frequency, check the modulation identification, and then hop in the general direction of the ear giving the stronger signal.

Birds are clearly more sophisticated animals than frogs, and most species have a complicated song which covers a reasonably wide frequency range, generally starting above about 500 Hz. It is interesting, therefore, to note the rather simple acoustics of the auditory system, a design shared with some reptiles, thus indicating their common ancestry. This is shown schematically in Figure 4(c).

At the frequencies involved in birdsong, the length of the auditory canal is not small compared with the wavelength of sound and it is therefore necessary to be rather more sophisticated about the acoustic analysis. Not only must wave propagation along the canal be considered, but also attenuation of those waves through wall effects.

Once again it turns out that the response for the ear facing the sound source is greatest near the resonance frequency, but it also tends to be large near the frequency at which the canal length is one quarter of a wavelength, so that if these two frequencies agree the effect is maximal. It also happens that, at this special frequency, the response of the ear facing away from the sound can actually be brought to zero by proper choice of the loss in the canal and the Q value of the tympana. Around this frequency the response is cardioid while for higher or lower frequencies the directional pattern is less asymmetric. Of course we would not expect a real system to behave in exactly this way, but the qualitative behaviour should be very similar to that calculated.

Finally we see in Figure 4(d) a representation of the auditory system of the cricket. As in mammals it is associated with the

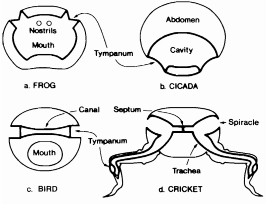

Figure 4: Specialised forms of the general model auditory system. (a) in the frog the tympana connect directly to the mouth cavity through short Eustachian tubes; (b) the cicada has a similar system but the cavity is in the abdomen; (c) the bird has a simple constricted canal connecting the two tympana; while (d) the cricket has a tubular tracheal system with tympana on the legs and open spiracles, the geometry of which varies from species to species.

respiratory system but, since the cricket is an insect, this system has a very different structure. The auditory system is located in the first pair of legs of the animal. Each leg contains a large tracheal tube connecting to a more or less open spiracle in the prothorax, and this trachea has a thin-walled tympanum (or rather a pair of tympana) in the leg wall just below the knee. The two tracheae are connected by a short tube which generally has a central septum.

Different species of cricket have different aspects of this geometry exaggerated. In some the spiracles are large and wide open and the tracheae have the form of flaring internal horns with little interconnection. In other species the tracheae are nearly cylindrical, the spiracles are small and partly covered, and the interconnecting tube is short and wide with a thin septum. Analysis of such systems with their multiple ports for sound entry and multitude of unknown parameters is a complex business. In particular the narrow tracheae have considerable wall loss and, since the sound wavelength at 5 kHz is comparable with the size of the animal, the exact placing of the legs can be important. Again however it seems clear that this system can provide substantial directionality of response.

As in man, it turns out that the neural response of many of these animals is much more restricted in frequency than we would expect from simple acoustic analysis. Such neural frequency selectivity is by no means unexpected but its mechanism is as yet obscure to those neurophysiologists studying the problem.

CONCLUSION

We have seen that systems for sound production and hearing in the animal world appear to have a common origin and a common purpose, though the ways in which they have developed show a great diversity. Understanding the acoustics of these systems is, of course, only the beginning of the study, and by far the greatest interest lies in the neurophysiological and psychophysical aspects of the problem. Nevertheless an examination of simple acoustics does give us an insight into the way in which these systems function, and acoustics provides an essential framework around which more sophisticated studies can be built.

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APPENDIX

For those interested in more detail, the analysis of frequency response and directionality for two simply coupled ears can be set out in a few lines. We choose a system like that of the bird and idealise it to a model with two identical tympana coupled by a uniform tube. The acoustic behaviour of each tympanum is expressed by its acoustic impedance Z_T — the ratio of acoustic pressure p to acoustic volume flow U at a given frequency ω. For a tympanum of mass M, area A, resonant frequency ω_0 and damping R

$$Z_T = R + j(M/A^2)(\omega - \omega_0^2/\omega). \qquad (1)$$

Description of the behaviour of the tube requires consideration of quantities p_1, U_1 and p_2, U_2 at its two ends and, if we choose the positive directions for both U_1 and U_2 to be into the tube, we can write

$$p_1 = Z_{11}U_1 + Z_{12}U_2 \qquad (2)$$

$$p_2 = Z_{21}U_1 + Z_{22}U_2. \qquad (3)$$

For a tube of cross section S and length L it can be shown that

$$Z_{11} = Z_{22} = (\varrho c/S)\coth[(\alpha + j\omega/c)L] \qquad (4)$$

$$Z_{12} = Z_{21} = (\varrho c/S)\,\mathrm{cosech}[(\alpha + j\omega/c)L] \qquad (5)$$

where ϱ is the air density and c the velocity of sound in air, and α is the attenuation coefficient, due to wall effects, for sound propagating along the tube.

Now we put the tympana across the ends of the tube, noting that this means that the acoustic flow through each tympanum is equal to that into the associated tube end. If p_L, U_L and p_R, U_R are acoustic quantities for the left and right ears respectively, then

$$p_L = (Z_{11} + Z_T)U_L + Z_{12}U_R \qquad (6)$$

$$p_R = Z_{21}U_L + (Z_{22} + Z_T)U_R. \qquad (7)$$

If sound comes from a direction at an angle θ to the left of straight ahead, then there is a phase delay at the right ear given by

$$p_R = p_L \exp[-j(\omega L/c)\sin\theta] \qquad (8)$$

and, using the symmetry relations in (4) and (5) in (6) and (7), we easily find the response of the left ear to be

$$\frac{U_L}{p_L} = \frac{(Z_T + Z_1) - Z_{12}\exp[-j(\omega L/c)\sin\theta]}{(Z_T + Z_{11})^2 - Z^2_{12}}. \qquad (9)$$

The linear motion of the left tympanum is given simply by

$$x_L = -jU_L/\omega A. \qquad (10)$$

This response is greatest at the frequency for which the denominator of (9) is smallest, which is a compromise between the resonance frequency of the tympanum ($Z_T \rightarrow R$) and the half-wave resonance of the tube ($Z_{11} \rightarrow Z_{12} \rightarrow (\varrho c/S)\,\mathrm{cosech}\,\alpha L$). Directional response is greatest for sound from the left ($\theta = 90°$) and can be made to vanish at one particular frequency for sound from the right ($\theta = -90°$) by appropriate choice of the damping coefficients R and α. In general there will be a response minimum for the left ear for sound coming from somewhere to the right of the animal ($\theta < 0$) but this will not be an exact null. Figure 5 shows calculations for a realistic case. The system therefore shows very useful frequency discrimination and directionality.

Exactly the same analysis can be used for cavity-coupled ears, such as those of cicadas and frogs, at frequencies for which the distance between the ears is only a small fraction of a wavelength. In this case

$$Z_{11} \approx Z_{12} \approx -j\varrho c^2/V\omega$$

where V is the volume of the cavity. The frequency response and directionality are similar to those of the tube coupled ears provided the cavity volume is appropriately chosen.

(Received 3 May 1985)

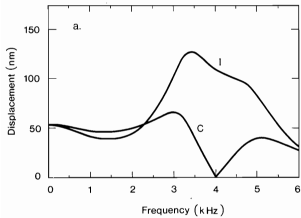

Figure 5(a): Calculated frequency response for a tube-coupled auditory system, with tube length 20 mm, tympanum resonance frequency 4 kHz and optimal damping, for ipsilateral sound I ($\theta = 90°$) and contralateral sound C ($\theta = -90°$) at 91 dB.

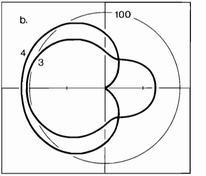

Figure 5(b): Calculated polar response of the left ear at 3 kHz and 4 kHz. The straight-ahead direction ($\theta = 0$) is upwards on the page. [From Fletcher & Thwaites 1979]

Legendary instruments together at last

Let connoisseurs and iconoclasts argue the relative virtues of instruments by Guarneri and the Amatis. Nothing will ever supplant the name Stradivari (popularly known as "Stradivarius") in the hearts and minds of the typical string fancier.

Only 800 instruments by Antonio Stradivari, the fabled 17th-century Italian craftsman, have survived, but, collectively, they have long since attained the status of legend.

Now the Tokyo String Quartet will participate in the first known performances on a matched, decorated set of Stradivari instruments, originally created to be played together but sold separately before that could happen.

These premiere performances will take place in Finland on July 28 at the Kuhmo Chamber Music Festival, on July 31 at Temple Square Church in Helsinki, and on August 1 in a gala concert at the Sibelius Academy. The Tokyo Quartet, now celebrating its 15th season, consists of the violinists Peter Oundjian and Kikuei Ikeda, the violist Kazuhide Isomura and the cellist Sadao Harada.

The two Stradivari violins, a Stradivari viola and a Stradivari cello were assembled over 20 years for a private collector by a New York-based instrument dealer, Jacques Francais.

Mr. Francais believes that the first violin—the so-called "Greffuhle" violin, built in 1709, and named for the Viscount de Greffuhle who owned it from 1882 to 1910—is "one of the greatest violins ever made."

But, Mr. Francais said recently, "equally famous and just as beautiful is the 'Ole Bull' violin", dated 1687 and named for its first known owner, the Norwegian virtuoso and composer Ole Bull. The viola, dated 1695, is particularly rare, as only 13 Stradivari violas are known to exist. A cello, dated 1688, and known as the "Marylebone", rounds out the quartet.

Mr. Francais refused to put a price on the instruments, but noted that Stradivari violins can cost $1 million. "As for a Stradivari viola, you can set your own price. They are fantastically rare."

(Tim Page in The New York Times, 26 June, 1985).

Hearing Conservation—An Industrial Perspective

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ABSTRACT: Alcoa's hearing conservation programme was initiated more than a decade ago. This paper describes the evolution of nine programme elements within the Company's mining and refining operations in Western Australia. Some of the benefits, practical difficulties and cost factors associated with a hearing conservation programme are also discussed.

1. INTRODUCTION

Alcoa's activities in Western Australia focus on the production of alumina from Darling Range bauxite. The company has minesites at Jarrahdale, Del Park, Huntly and Willowdale and refineries at Kwinana, Pinjarra and Wagerup. Approximately 16% of the world's alumina production is derived from these operations. A description of the Bayer Process, as applied in Western Australia, has been provided by Sleppy, Buckett and Sibly [1].

As with any other heavy industrial undertaking, there is a variety of physical and chemical hazards associated with the workplace environment. Industrial hygiene programmes within the Company span the recognition, evaluation and control of dusts, fibres, noise, vibration, gases, vapours, fumes, mists, thermal stress, ionising and non-ionising radiation, ergonomic hazards, potable water quality, ventilation hazards and hazardous chemicals [2]. Noise matters are therefore a small, albeit important, component of the spectrum of health-related activity that is carried out. The subject of this paper, hearing conservation, in turn represents only a portion of the areas of interest that come under the noise umbrella. Nevertheless, there have been considerable resources allocated in an attempt to ensure that risk to hearing is minimised.

2. ALCOA'S HEARING CONSERVATION PROGRAMME

The Company's hearing conservation programme is based on nine areas of activity:

- noise level measurement
- noise dose measurement
- noise warning signs
- engineering control measures
- administrative controls
- personal protective equipment
- purchasing specifications
- audiometry
- education, motivation and feedback initiatives

2.1 Noise Level Measurement

Noise level measurement was one of the first elements of the programme to get underway. A sound level meter and octave band analyser were acquired in the mid-1960s, shortly after the commencement of operation of the Company's first refinery (the Kwinana Plant). Early measurement activity was centred on noise emanating from calcination blowers, the powerhouse basement, the mechanical workshop, the rod mills and the digestion area. Since that time measurement work has been extended to all operating locations and covers a wide variety of fixed equipment, mobile equipment and portable tools.

The first annual, plant-wide, noise contour map was produced at Kwinana during 1975. The initial survey covered ground floor areas and was based on measurements taken at an 8 metre grid interval.

Noise contour maps have proven to be useful guides in studying the changing noise patterns that occur as new equipment comes on-site and older equipment is replaced or subjected to maintenance attention. They also highlight the magnitude of noise problems, assist in the development of priorities for engineering control, assist in planning for the deployment of warning signs and assist in the development of rules and procedures relating to the wearing of hearing protection.

However, for contour maps to be of any practical use, it is important that measurements are taken under comparable conditions. It is necessary to take steps to exclude noise of a temporary nature (such as that from passing traffic). It is also necessary for the officer carrying out the measurements to be cognisant of nearby vessel and unit down-time arrangements. Clearly, if a production unit is off-line for maintenance attention at the time of the survey there is potential for incorrect inferences to be drawn from the apparent improvement in the acoustic environment.

Paper presented at the Australian Acoustical Society W.A. Division Technical meeting on 28 February 1985 by Mr B.J. Chesson, B.Sc. (Hons) Physical Chemistry, Grad. Dip. Nat. Res., M.App.Sc.(Health Science). Mr Chesson is the Chief Industrial Hygienist of Alcoa Australia Limited. He is the President of the Occupational Health Society of Australia (W.A. Branch), Chairman of the Chamber of Mines of W.A. Noise Committee, a member of the W.A. Noise Abatement Advisory Committee and a member of the Occupational Health Safety and Welfare Commission of W.A.

A more sophisticated approach to contour mapping has evolved since the mid-1970s. The problem of representing noise levels in multi-level buildings, catwalks, landings, etc. has been addressed with techniques that include perspex-encased three-dimensional representations. These systems have an additional role in the educational area that is described later.

2.2 Noise Dose Assessment

Assessment of the equivalent continuous eight-hour noise dose associated with individual workers and with occupational groups commenced late in 1975. Since that time several thousand readings have been gathered and the exposure patterns for most occupational groups have been characterised. The process is an on-going one with a full cycle of measurement usually taking 18-24 months.

Results generated to date have demonstrated that maintenance groups tend to have higher exposures than production groups working in the same area — a finding that is consistent with exposure patterns associated with other types of hazard and one which reflects the nature of the tasks performed, the equipment that is used and the access that the latter group has to quiet areas, such as control rooms, for substantial periods of the day.

Noise dose results are used to rank the hearing risk associated with various occupational groups, and as a major input in the formulation of engineering noise control priorities.

A programme will not operate successfully without the commitment of the Department concerned and the full co-operation of its members. Experience has shown that this can only be achieved if there is adequate preliminary consultation with the Department and if a feedback loop (for results) is established. It was a request by a Powerhouse group in 1976 for further explanation of noise dose results that led to the development of the education programmes that are now a key element of the industrial hygiene function at each site.

2.3 Noise Warning Signs

Noise warning signs have been in use since the late 1960s. However early versions were somewhat individualistic and generally unsatisfactory by today's standards. An example of this was one which had the wording:

> "Hearing protection must be worn if in this area
> for more than two hours."

Clearly, this had a degree of ambiguity and did not adequately cover situations involving preceding or subsequent noise exposure in other parts of the Plant, or situations where the work in the area was of an intermittent nature.

The advent of the SAA Code for Industrial Accident Prevention Signs, particularly the 1979 version, greatly assisted in the process of rationalising the array of signs that were in use at the time.

Alcoa's experience with the mandatory noise warning sign outlined in AS 1319-1979 is that the message is more effectively conveyed if the symbolic representation is coupled with an appropriate supporting statement.

2.4 Engineering Control Measures

The Kwinana, Pinjarra and Wagerup facilities were commissioned in 1964, 1972 and 1984 respectively. Each plant's layout reflects the level of noise awareness and technology of its day. Some millions of dollars have been spent in the older plants on retrofit engineering controls, with action being directed at the source of the noise, along the transmission path or at the receiver. Systems that have been utilised include acoustically designed enclosures, baffles, screens, silencers, vibration isolators and sound absorbing linings.

Substitution of noisy processes and equipment with quieter ones has also been used in some instances.

There are many demands on an organisation's capital and operating funds. As a consequence, priority setting is an essential step in ensuring that resources are directed into areas that will yield the greatest benefit. Priorities and schedules for engineering noise control may be based on factors such as:

- noise level measurement results
- noise dose measurement results
- audiometer test results
- public relations considerations
- industrial relations considerations
- government relations considerations
- economic factors
- operating factors

A number of systems have been developed to assist decision-making on engineering noise control expenditure. One such is outlined in Table 1. A few of the buildings in the Kwinana Plant are listed together with the main local noise sources.

Table 1 —
ESTABLISHING NOISE CONTROL PRIORITIES
Kwiana Refinery Examples

Area	Source	Contribution to the noise problem	Engineering difficulty	Cost $
Bldg 8	Starch product pumps	2	2	30,000
Bldg 25	Rod mills	1	3	20M
	Slurry pumps	1	3	300,000
	Pan feeder motors	2	1	40,000
Bldg 35c	Descaling	2	3	unknown
Bldg 40	Product pumps	1	2	100,000
	Evactors	2	1	25,000
Bldg 46	Vacuum pumps	1	3	300,000
	Vacuum filter feed pumps	3	2	100,000
	Kelly filter feed pumps	1	2	50,000
	Hose water pumps	1	2	30,000
	Furnace blower	1	1	10,000

The Location Industrial Hygienist assessed the relative importance of the noise problems on a 1–3 scale (highest-lowest) based on his knowledge of working conditions and measurement results. Concurrently, his engineering counterpart assessed the technical difficulty in overcoming the noise problem (also on a 1–3 scale) and provided an estimate of cost.

Clearly, low cost, 1–1 matches would suggest attractive areas in which to direct funds. On the other hand, 3–3 noise sources might involve high levels of expenditure with no guarantee of successful noise reduction, and little potential impact from a hearing conservation point of view.

2.5 Administrative Controls

Administrative controls are sometimes used to reduce exposure to noise. Usually they take the form of modifications to work patterns (i.e. job rotation) or regulating the on-off time of noisy equipment or processes.

It is a common observation that when small work groups operate in a harsh environment a form of rotation usually develops. This is particularly so in situations involving work in enclosed spaces where one or more individuals might act as outside observers while the remainder of the group work inside. Also, it is sometimes possible to schedule a noisy operation for weekends or afternoon/night shift periods when the bulk of the workforce are not present.

Notwithstanding the above, there are several important practical problems that serve to limit the application of this form of control. Roberts [3] has described these as falling into the categories of labour agreements, safety considerations, job continuity and training. However, there is some prospect that some of these difficulties will be overcome within the Company with the trend towards multiskilling and the development of a more mobile workforce.

2.6 Personal Protective Equipment

Hearing protection has been available to the workforce since the commencement of operations. It is a form of control that concentrates on the receiver end of the noise path. Although not as desirable as the engineering or administrative noise control alternatives, it is useful in circumstances where the latter systems are not practicable or are likely to be long-term propositions.

The main categories in use are muffs (hat mounted and independent) and ear plugs (adaptable and reusable pre-moulded). Approximately 9% of the Company's annual personal protective equipment outlay is expended on hearing protection. Of this, about two-thirds is spent on disposable, foam earplugs. An early concern, expressed in some quarters, was that use of the plugs might lead to an increased incidence of ear infections — as a result of deployment in the caustic environment of the refineries and the dusty environment of the minesites. However, this hasn't materialised and the plugs are easily the most popular form of protection.

During the past five years a Western Australian Operation's Personal Protective Equipment Committee has been active in evaluating proposed items of personal protection and in establishing uniform standards and selection criteria. This has enabled medical, personnel, industrial hygiene, safety and purchasing inputs to be made prior to a new item being introduced to the sites. One important activity is the setting-up of field trials with prospective items of equipment and the collation of feedback from user groups on practical features and comfort.

The list of aspects to be considered prior to a choice being made includes level of attenuation provided, compatibility with the job, hygiene aspects, comfort, ease of fitting, communication requirements, availability of replacement parts and cost.

2.7 Purchasing Specifications

Purchasing specifications have been used for over a decade in an attempt to control the impact of new, noisy equipment on the existing acoustic environment at each site. This has tended to be one of the most difficult parts of the hearing conservation programme to implement. In the early days some vendors were inclined to ignore the specification clause or simply reply that the necessary data or technology wasn't available.

There has been considerable progress made in recent years, however, with the development of a general purchasing specification system in conjunction with other member companies of the Chamber of Mines of Western Australia [4].

The Chamber's specification has been designed for use in the acquisition of fixed equipment, mobile equipment and portable tools, and is provided with a set of guidelines that establish how it should be used. It has been developed in a climate of improving awareness of needs and increasing co-operation between purchasers and vendors. Since it embodies a standardised presentation of requirements it is seen as being advantageous to both groups.

Mobile equipment and portable tools brought onto a site by contractors may also pose a problem from a hearing conservation point of view. In recent years the Company and its contracting groups have developed written agreements that contain clauses limiting the access of noisy equipment and requiring that employees of the contractor comply with on-site safety rules (including those relating to hearing conservation).

2.8 Audiometry

Audiometric equipment was first acquired in 1970. Since that time it has been used routinely for pre-employment and periodic assessment of hearing. The present facilities are housed in the medical centres of each of the three refineries and at the Jarrahdale and Del Park minesites. They are operated by occupational health nurses under the direction of the Company's occupational physicians.

Apart from its primary use in detecting early signs of noise-induced hearing loss in individuals, audiometry plays a key role in establishing the size of the noise problem within a plant and how successful the organisation has been combatting it.

Broad trends arising from audiometric results have served to define risk areas and to assist in establishing control priorities. An aspect of audiometric testing that is sometimes not well-recognised is that it provides the audiometrist with an excellent opportunity to counsel the worker on a one-to-one basis, on measures that should be taken to protect his hearing — both at home and at work.

2.9 Education, Motivation and Feedback Initiatives

As mentioned earlier, communication programmes in relation to hearing conservation were set up in 1976. These were established with the objective of providing education, motivation and feedback to employee groups.

The educational effort was geared to convey instruction on such items as the potential health impact of workplace noise, proposed procedural changes and the fitting, maintenance and use of hearing protection. The target audience was the whole of the working community, from shopfloor to senior management.

The motivational component was designed to encourage the workforce to participate in the control aspect of hearing conservation — including areas such as the wearing of hearing protection when necessary and day-to-day attention to the maintenance of control systems.

The feedback aspect was a two-way process whereby employees were able to express their concerns and have their queries answered, while at the same time being kept informed about proposed changes to methods or equipment.

Experience has shown that attention to communication has a beneficial impact on the industrial relations climate within an organisation. Also, educational initiatives are the most effective way of dealing with non-occupational noise-induced hearing loss.

Mechanisms that have been set up to achieve the above objectives include presentations at Departmental safety meetings and communication meetings, presentation of periodic health and safety displays and provision of articles for location newsletters.

3. CONCLUSION

Alcoa's hearing conservation programme consists of nine interrelated component parts and encompasses aspects of measurement, control and education. The programme is carried out at all operating sites and covers all personnel potentially exposed to a noise hazard.

Only by implementing a comprehensive programme such as the one described can the serious social disability occasioned by noise-induced hearing loss be addressed in a satisfactory manner.

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TED WESTON — A Society Pioneer

An interview with the editors

Edward T. Weston, otherwise known as Ted, is a foundation member of the Australian Acoustical Society and one of the early workers at the Experimental Building Station, from which organisation he has now retired. He was born in Perth, W.A., attended school in Kalgoorlie and York, went to High School in Northam and then studied electrical and mechanical engineering at the University of Western Australia. After graduation, Ted worked with the Munitions Supply Laboratories in Melbourne during the war.

"I came to Sydney because there was a position advertised at the Experimental Building Station. I felt this was a heaven-sent opportunity for me because I was always interested at the university in things relating to comfort conditions and general environmental engineering. This was long before environmental engineering was available at universities."

The Weston Era at EBS

Ted's interests in acoustics were triggered by attempts to quieten his father's car while at university. At EBS his initial work was concerned with thermal problems, a low-speed wind tunnel and with daylighting. Acoustics at that stage played a small part but did give rise to an interesting court case concerning the location of a ready-mixed concrete facility.

"Having got caught up in this case I was horrified at what went on in court in deciding that this plant could be built in a residential area. The case FOR consisted in showing what a degenerate neighbourhood it was — terribly run down — terrible things went on there — therefore a ready-mixed concrete plant could only be an upgrading of the area."

Later work involved the measurement of attenuation down ducts and measurements relating to the design of studios for the introduction of television at Gore Hill. The work on ducts led to studies of fan noise, the main outcome of which in both cases was to point up a great need for further research into this aspect of acoustics. However, that had to be put on hold — where it remained thereafter except for minor forays

> *"While our main work at EBS was that of measurement of the performance of building construction in the laboratory, it was always nice to get out and solve a real problem. There was one classic case where a machine to count change had been installed in a room between the offices of two great white chiefs, the national director and the state manager. The partitions were modular, with no great sound reducing properties, but to top it off they butted at one end rather imperfectly against the glass of the windows, not even the mullions. Surprise, surprise, there was an horrific noise in both offices whenever the machine rattled into action. A specialist firm was called in whose approach to this noise problem was to pull out the partitions, fill them with mineral wool, put them back, and charge tens of thousands of dollars. Nobody noticed any difference of course, and at that stage we were called in. We could only suggest an extensive remodelling or that either the executives or the money machine be moved."*

and inclusion in programmes of future work — because of a growing number of requests for investigations into other noise problems in buildings.

Changeing construction practices brought a departure from brickwork to curtain wall construction for outside facades and to internal partitions consisting of pleasant-looking plywood but not much else. "As a result of a few rather bad failures we became involved in making some measurements to try and provide better construction methods from the point of view of cutting down sound transmission between offices and other spaces."

"In one bank building anyone in the waiting room could hear what the bank manager was telling a client two doors away. One client who was refused an overdraft stormed that the client before had received one. These problems were attributed to the behaviour of modular partitions — nobody gave much consideration to the fact that sound went through the perforated acoustic ceiling, reflected from the underside of the main slab and then came down two offices away. However, the inadequacy of many modular partitions and built-up wall constructions set a pattern for EBS work in the determination of the sound transmission properties of building construction from that time on."

By 1964 much had been done but in a rough and ready way, as there was little equipment, few staff, and inadequate financing. For instance, $5000 was initially allocated for the construction of two reverberation chambers. However, the rooms were built, although to begin with there was a dearth of suitable instrumentation which was overcome by co-operation with John Irvine, then of CSR Building Materials Laboratories, who at that stage had instruments, but no rooms in which to use them. Not too long after that the whole act was got together and it became possible to devote a staff member exclusively to the operation.

1970 saw the foundations of a capable and enthusiastic team with the transfer of John Whitlock from the thermal work and the appointment of Marion Taylor (now Burgess). With them, and with those who joined

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Estimating Noise Levels from Petrochemical Plants, Mines and Industrial Complexes

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ABSTRACT: Legislation in Australia requires that an environmental impact study be prepared for all large developments. Noise emitted by plant and activities is now considered to be an important source of pollution and so adequate techniques must be used to predict noise levels associated with developments. The three principal noise forecasting models used extensively in Europe are the OCMA, VDI and CONCAWE schemes of which the first and last relate to noise from petrochemical complexes, but which of course may be used equally well to predict noise from mines and industrial complexes generally. The algorithms used in these models rely for the greater part on interpolation of experimental data, which is a valid and useful technique, but which limits their application to sites which are more or less similar to that for which the experimental data was assimilated. In attempting to create a somewhat more general model, we have extracted as much information as possible from these schemes and, together with new algorithms, developed the Environmental Noise Model which is described in this paper. The development of improved forecasting techniques is expected to continue for some time. We make use of theoretical algorithms as much as possible but foresee that much work must still be done in the area of predicting sound propagation for complex meteorological conditions.

1. INTRODUCTION

The need for accurately forecasting the level of sound emitted by new or modified plant sites is a consequence of legislation more or less of similar form promulgated throughout the world. The government bodies incorporated to police the legislation have a responsibility to ensure that best use is being made of current technology for noise prediction. Giving the green light for commencement with a "don't-care" attitude of how specific noise targets are to be met, as long as they are met, is quite irresponsible. Similarly, the project developers must know the likely outcome of their endeavours as, in the end, we must live with each other, pollution and all.

The use of computers to perform the data analysis usually associated with forecasting appears to be now firmly entrenched with researchers and consultants alike. In all cases, the method of forecasting is of the following form:

1 Determine source power levels L_w

2 Compute total atmospheric attentuation for a given environment scenario by calculating the individual attenuation components K_i as follows:
- Geometric spreading
- Enclosures
- Barriers
- Air absorption
- Wind effects
- Temperature gradient effects
- Ground effects
- Shielding by vegetation and buildings

3 Compute the resultant sound pressure level at an environmental point

$$L_p = \sum_{\text{all sources}}^{\text{log}} [L_w - \sum^{\text{arith}} (K_i)] \quad (1)$$

The complexity of the forecasting program is invariably measured by the number of attenuation components K_i included in the calculation and by the complexity of the algorithms used to determine the components. The simplest of schemes used allows for geometric spreading only, perhaps in the form of an attenuation rate per doubling of distance (dd); a value of 4dB/dd is commonly used to take into account the effect of all attenuation components. The algorithms are predominantly of two types; one based on a theoretical approach and the other on an empirical approach. Use of theory to completely describe the real world is the ultimate objective but we must at present be content with a blend of theory and empiricism. This principle should, nevertheless, be the goal of all forecasting programs; that is, if the theory is available — use it.

The simplicity inherent in Equation 1 is that the attenuation components are functionally independent. In the real world we expect that the sound pressure level at a point in the environment is in fact more like

$$L_p = F(L_w, i_k) \quad (2)$$

in which all the individual attenuation factors i_K together with the source power levels L_w interrelate in the function F. Some of these inter-relationships have only recently been explained. For example, in the case of barrier attenuation, recent work [1] shows the effect the ground has on both sides of the barrier. Wind and temperature gradients on barrier performance have also been studied [2]. The thickness of the barrier is also a variable [3]. However, much of the work has yet to be done. We expect it will follow the course of trying to unravel the function F rather than improving on algorithms for individual attenuation components.

Perhaps the best known of the noise forecasting schemes are those of the Oil Companies Materials Association (OCMA), the Oil Companies' International Study Group for Conservation of Clean Air and Water (CONCAWE) and, the German draft standard VDI 2714 "Outdoor Sound Propagation". Presumably private companies have schemes and computer programs which are a variation of Equation 1 just as are the above-mentioned. In some cases, measurement of attenuation rates is performed and the results used to predict noise levels. This, of course, is what the forecasting schemes are trying to emulate without the need for experimental exertion.

Although there exists a plethora of schemes, there is very little reported on their accuracy. In two cases [4,5] reports of ± 2 dB accuracy are quoted but in both cases, experimental data was used to fine-tune the model. We expect that for uncomplicated environments (open plain flat terrain and mild meteorological conditions) that this result could be obtained but that schemes based on Equation 1 will always require fine-tuning in complex environments. Experience with OCMA [6] suggests ± 5 dB accuracy.

The question of accuracy is complicated by the fact that it is quite difficult to get good source power level data because of the influence of ground effects, the choice of measuring surface for the power area (spherical or box-like), near-field hydrodynamic effects (ISO 3744 allows measurements to be made as close as 0.25 m) and near-field geometric effects (for large sources the microphone measures normal as well as sideways intensity contributions rather than only the former, which overestimates L_w). It is expected [7] that errors of 2-3 dB can result from L_w determinations alone.

With logarithmic addition of sound levels, however, we are saved from embarrassingly large errors for, while a ± 3 dB error in the sound level prediction for one source may seem quite high, the error for 100 such sources randomly combined would be no more than ± 3 dB also, but the latter seems a better result.

This paper describes the Environmental Noise Model (ENM) forecasting scheme which is based on the format of Equation 1 but for which we have incorporated some inter-dependence of variables and have also included, as much as possible, algorithms based on theory rather than empirical results. In addition, the ENM concept is to perform the calculations with as little "hands-on" as possible. That is, once the environmental scenario is input, the computations are performed automatically including sectioning through contour maps and buildings and keeping track of the ground cover.

The following sections review the OCMA, CONCAWE and VDI schemes, for comparison with the ENM, followed by a description of the algorithms used for the ENM and program flowchart.

2. REVIEW OF SELECTED NOISE FORECASTING SCHEMES

2.1 OCMA

In 1972, the British member companies of the Oil Companies Materials Association (OCMA) published a revised version of the OCMA Procedural Specification NWG-1/2/3 [8]. Part 3 contains the recommendations for sound level calculations. In effect, the sound pressure level at a point in the environment is calculated from the following:

$$L_p = \underset{\text{all sources}}{\overset{\log}{\Sigma}} (L_w - K_1 - K_2) \tag{3}$$

where

L_w = source power level re 10^{12} watts

$K_1 = 10 \log (4\pi R^2) - 3\,\text{dB}$ + atmospheric attenuation

R = source to receiver distance

K_2 = ground effects + barrier shielding effects + meteorological effects

The constant K_1 is determined from Figure 1 and includes the term $10 \log (4\pi R^2)$ which accounts for spherical spreading from a point source, -3 dB which accounts for an infinitely hard ground plane coinciding with the source, and, atmospheric attenuation based in part on experiment and in part on the molecular relaxation behaviour theory of oxygen molecules in the air at a temperature of 60°F and 70% humidity. The constant K_2 is a correction for ground absorption, shielding by barriers, hills or plant buildings and meteorological effects (an average value is assumed to be valid for long data sampling periods). This data is based on noise measurements conducted in and around two petrochemical sites. K_2 is determined from Figures 2 and 3. Note that OCMA recommend that ground effects be reduced to zero if the source height is greater than 15 metres above ground. This in fact has been shown by CONCAWE experiments not to be true. In general, it is evident that the OCMA scheme is based principally on experimental data and hence limited to plant in a similar environment to that for which the data was taken. Computer programs based on the OCMA scheme are described in references [9] and [10].

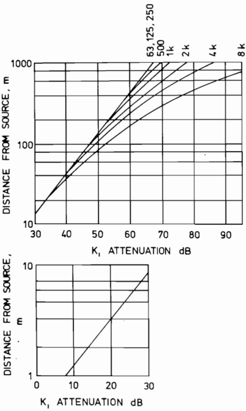

Figure 1: OCMA algorithm for determination of distance and air absorption attenuation K_1.

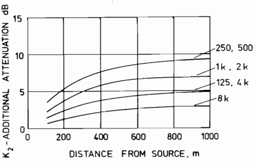

Figure 2: OCMA algorithm for ground attenuation for the case of minimal shielding.

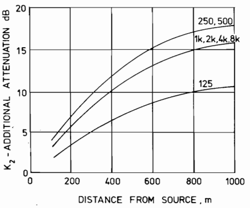

Figure 3: OCMA algorithm for ground attenuation for the case of significant shielding.

2.2 VDI-2714

In 1976 the VDI Draft Code 2714 "Outdoor Sound Propagation" was issued by the VDI committee on Noise Reduction [11]. The sound pressure level at an environmental point is calculated from the following equation:

$$L_p\,dB(A) = \sum_{\text{all sources}}^{\log} [L_w + K_1 - 10\log(4\pi R^2) + 3dB - K_2 - K_3 - K_4 - K_5 - K_6 - K_7] \quad (4)$$

The calculations are performed in units of dB(A) only, not in octaves as for the OCMA scheme, and where

L_w = source power level re 10^{-12} watts
K_1 = source directivity index
$-10\log(4\pi R^2) + 3dB$ = geometric spreading term including infinite hard plane coinciding with the source
R source to receiver distance
K_2 = atmospheric attenuation = $10\log(1 + 0.0015R)$ *dB(A)*
K_3 = attenuation due to meteorological conditions = $[(12.5/R^2) + 0.2]^{-1}$ *dB(A)*
K_4 = ground effects = $10\log[3 + (R/160)] - K_2 - K_3$ *dB(A)*
K_5 = barrier effects value 0-10 = $10\log(3 + 20d)$ *dB(A)*
d = barrier path difference
K_6 = attenuation due to woodland areas
K_7 = attenuation due to built-up areas

Meteorological effects are taken into account using charts which allow one to take into account three broad scenarios:

1 Maximum downwind sound level unlikely to be exceeded.

2 Sound level in light downwind conditions, and

3 Long-term sound level for all weather conditions.

Noise breakout from buildings is described in VDI-2571 [12] and this calculation may also be taken into account. References [13] and [14] describe applications of VDI-2714. Whilst this forecasting scheme takes more algorithms into consideration, one could argue that its accuracy is limited by its ability to account only for dB(A) levels.

2.3 CONCAWE

In 1977, CONCAWE contracted Acoustic Technology Ltd of Southampton to review the available literature to date on sound propagation in the atmosphere and to update the algorithms used in the OCMA scheme. The attenuation curves derived for OCMA were then a number of years old and were based on a limited number of noise measurements conducted around two oil refineries. The CONCAWE model enables octave band sound pressure levels to be calculated at a point in the environment for a given meteorologic scenario rather than for an average meteorological scenario as used in OCMA or a range of variations specified in VDI.

The literature survey review conducted in the CONCAWE study is quite extensive [15]. Where possible, algorithms based on theory were extracted for use in the model. In most cases, however, the theoretical approach was found to be only new and with limited experimental validation. For this reason, the authors of the CONCAWE model have apparently based many of their algorithms on experimental data but structured in such a way as to conform to the theoretical framework. This was done for the ground attenuation and all the meteorological effects.

The resultant sound pressure level in any octave is expressed as:

$$L_p = \sum_{\text{all sources}}^{\log} [L_w + D - K_1 - K_2 - K_3 - K_4 - K_5 - K_6 - K_7] \quad (5)$$

where
L_w = octave band sound power level re 10^{-12} watts
D = directivity index of source
K_1 = attenuation due to geometric spreading
K_2 = atmospheric absorption
K_3 = attenuation due to ground effects
K_4 = attenuation due to meteorological effects
K_5 = correction for source height above ground
K_6 = barrier shielding
K_7 = in-plant screening

The noise impact of industrial plant is essentially universally determined from the A-weighted sound level. Calculations of attenuation corrections in octave bands in our opinion will give better estimates of the A-weighted sound level than calculations using frequency independent parameters. The CONCAWE model considers the range of octave bands from 63 Hz to 4 KHz. The following is a brief description of the algorithms used in the CONCAWE scheme.

GEOMETRICAL SPREADING K_1

In the first instance, the source is assumed to be in free space and with the ground absent. Only point sources are considered, and the distance attenuation is

$$K_1 = 10\log(4\pi R^2) \quad (6)$$

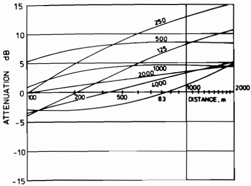

Figure 4: CONCAWE ground attenuation curves (category 4).

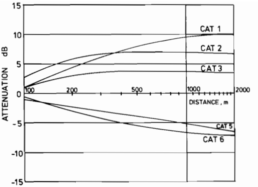

Figure 5: CONCAWE meteorological curves for 500 Hz octave.

ATMOSPHERIC ABSORPTION K_2

The method of calculation of atmospheric absorption due to Sutherland [16] was adopted by the American National Standards [17]. The CONCAWE authors acknowledge this theory to be the best available for the purposes of calculating atmospheric absorption losses of noise from industrial plant and quote it to be accurate to within $\pm 10\%$ from 0° to 40°C. The choice of the correction term K_2 is made by reference to seven tables of absorption data presented in third-octave bands. They recommend the value for the lower third-octave band be used to typify results for the octave band or in the case of pure tones, interpolation from one frequency band to the next is required.

ATTENUATION DUE TO GROUND EFFECTS K_3

The CONCAWE model uses experimental data to account for ground attenuation rather than the more complex theoretical model currently finding favour [18]. Originally, an extensive body of attenuation data taken for aircraft runups at two airfields in England [19,20] was used. However, it was found during the CONCAWE verification trials that this algorithm overestimated the ground correction term and hence the model was revised to give an improved fit to the data measured for three typical process plants in Europe [21]. The ground correction term was separated from the total measured attenuation by subtracting the geometrical and air absorption terms but only for data measured during neutral meteorological conditions (zero wind and temperature gradient). Hence the ground effects term strictly applies for ground cover similar to that of the process plants considered, namely, flat and undulating land typical of rural and residential areas. The ground effects term K_3 is derived from Figure 4. In the case of concrete covered ground or water, a value of -3 is assumed for all frequencies.

TABLE 1:
CONCAWE determination of Pasquill Stability Category from meteorological information

Wind* Speed m/s	Day Time Incoming Solar Radiation mW/cm²				1 hour before sunset or after sunrise	Night-Time Cloud Cover (octas)		
	>60	30-60	<30	O'cast		0-3	4-7	8
≤1.5	A	A–B	B	C	D	F or G**	F	D
2.0–2.5	A–B	B	C	C	D	F	E	D
3.0–4.5	B	B–C	C	C	D	E	D	D
5.0–6.0	C	C–D	D	D	D	D	D	D
>6.0	D	D	D	D	D	D	D	D

* Wind speed is measured to the nearest 0.5 m/s.
** Category G is restricted to night-time with less than 1 octa of cloud and a wind speed of less than 0.5 m/s.

ATTENUATION DUE TO METEOROLOGICAL EFFECTS K_4

This is perhaps the most difficult of all algorithms to formulate as the theory is not well understood at present. The two principal meteorological variables are wind and vertical temperature gradient (a positive gradient is called temperature inversion, zero gradient is neutral and a negative gradient is termed lapse). Intuitively, one expects that sound intensity changes are related to a variation in density of hypothetical sound rays emanating from a source. A refraction of the sound rays can result in changes to the ray density and hence to the sound intensity. It has been established [22] that the curvature of sound waves is mainly dependent on the vertical gradient of the speed of sound whether this be caused by wind gradients or temperature gradients and Piercy, Embleton and Sutherland [23] conclude from Parkin and Scholes' measurements that refraction due to vertical wind and temperature gradients produce equivalent acoustic effects which are essentially additive.

Hence CONCAWE grade meteorological effects into six categories based on a combined vertical gradient. The temperature gradient is coded in terms of a Pasquill Stability Category A-G shown in Table 1. Category A represents a strong lapse condition (large temperature decrease with height) where category G represents a temperature inversion as may be found on a calm starlit night.

The vertical temperature gradient so categorised is then combined with the magnitude of the wind vector measured at ground level (i.e. the proportion of the wind vector pointing from source to receiver) using Table 2. This results in one of the six meteorological categories for which attenuations were experimentally obtained from the three European process plants mentioned above. A typical correction is shown in Figure 5 for the 500 Hz octave band.

TABLE 2:
CONCAWE determination of meteorological category

(Decreasing Attenuation ↓)

Meteorological Category	Pasquill Stability Category A,B	C,D,E	F,G
1	$v < -3.0$	—	—
2	$-3.0 < v < -0.5$	$v < -3.0$	—
3	$-0.5 < v < +0.5$	$-3.0 < v < -0.5$	$v < -3.0$
4*	$+0.5 < v < +3.0$	$-0.5 < v < +0.5$	$-3.0 < v < +0.5$
5	$v > +3.0$	$+0.5 < v < +3.0$	$-0.5 < v < +0.5$
6	—	$v > +3.0$	$+0.5 < v < +3.0$

* Category with assumed zero meteorological influence

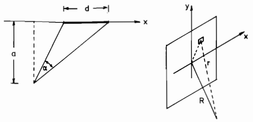

Figure 6: Geometry for determination of line and plane source algorithms.

CORRECTION FOR SOURCE HEIGHT ABOVE GROUND K_5

From the research literature, CONCAWE concluded that the ground effect decreases exponentially with an increase in grazing angle from 0° to a value of zero at angles greater than 5°. However, an experiment by CONCAWE of attenuation rates for various source and receiver heights did not appear to substantiate this algorithm. They have, nevertheless, decided to retain it.

BARRIER SHIELDING K_6

The attenuation due to barriers is calculated using the method of Maekawa but modified to account for wind and temperature gradients using the approach of De Jong *et al* [2]. This modification is basically a ray theory approach which modifies the height of the source and receiver because of ray curvature resulting from wind gradients and will be discussed in the following section. However, the technique is also applicable to temperature gradients which also cause ray curvature.

The familiar Maekawa chart which relates to barrier attenuation is represented by the following set of equations:

$$N = \pm \text{ path length difference } / (\lambda/2) \qquad (7)$$

where N is the familiar Fresnel number, and, λ is the wavelength.

Then for

$$\begin{array}{ll} -0.3 \leqslant N < -0.02 & K_6 = 5.65 + 66N + 244N^2 + 287N^3 \\ -0.02 \leqslant N < 1.0 & K_6 = 5.02 + 21.1N - 19.9N^2 + 6.69N^3 \\ 1.0 \leqslant N < 18.0 & K_6 = 10 \log N + 13 \\ N \geqslant 18.0 & K_6 = 25 \end{array} \qquad (8)$$

The algorithm ignores sound diffraction sideways around the edges of the barrier but one could of course calculate this contribution and include it as a separate source.

IN-PLANT SHIELDING K_7

CONCAWE concluded that, based on measurements conducted by others, shielding of sources by typical plant found in refineries is negligible and hence K_7 should be set to zero. Of course this may not be true close to the plant nor for large solid shielding obstacles which then may be classed as barriers.

The validation of the CONCAWE model shows prediction errors of ±2 dB typically for the three petrochemical plants studied. Of course one must take into account that the model has been tuned to the three plants and so one could expect larger errors than this when the model is applied to other situations.

3. ALGORITHMS FOR CALCULATION OF SOUND ATTENUATION

The ENM program is structured in a similar way to the CONCAWE model in that it takes the attenuation algorithms into account separately and endeavours to make use of the best available technology. This is true particularly of the ground effects algorithm for which there appears to be good collaborating experimental evidence. In addition, the ENM program is structured to allow automatic calculations at multiple points without the need for operator intervention. The following sections describe the nature of these algorithms and compare them with the CONCAWE model.

GEOMETRIC SPREADING A_1

All sources are considered firstly in the absence of the ground, that is, as if they were suspended in free space. Sources are of three types; point, line and plane. The CONCAWE model considers point sources only.

For point sources, the attenuation due to geometric spreading is that for spherical radiation,

$$A_1^{point} = 10 \log (4\pi R^2) \qquad (9)$$

For line sources, the attenuation for monopole radiation of a source of length L is [24],

$$A_1^{line} = 10 \log (4\pi a l/\alpha) \qquad (10)$$

where
- L is the source length
- a is the perpendicular separation of the receiver from the line source axis, and,
- α is the subtended angle in radians (see Figure 6)

For plane sources, the sound pressure resulting from monopole radiation of a rectangular source of area A is (see Figure 6)

$$p^2 = \iint_A (W\varrho c/A) \,.\, \{1/(4\pi r^2)\} \, dx\,dy \qquad (11)$$

where
W is the total source power and,
ϱc is the characteristic impedance of air

measured at a point which is a distance R from the source acoustic centre. The integration was performed numerically for different sized sources and for different angles subtended with the plane. Variation of pressure with angle and plane aspect ratio was shown not to vary significantly for most situations and so the results were condensed into a single non-dimensionalised curve shown in Figure 7. The attenuation for plane sources is then calculated by determining the value of C from this figure, and hence,

$$A_1^{plane} = 10 \log (4\pi R^2) + C \qquad (12)$$

DIRECTIVITY CORRECTION A_2

A frequency independent directivity correction term is included in the ENM model and is based on array co-ordinates recommended in Australian Standard AS1217 — "Methods of measurement of airborne sound emitted by machines". These co-ordinates are points on the surface of a hypothetical sphere whose centre coincides with the acoustic centre of the sound source [25]. The program interpolates values for directions of source to receiver which do not coincide with these array co-ordinates.

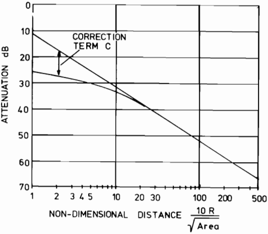

Figure 7: Correction term for sound pressure level determination of plane sources.

ENCLOSURES

The ENM program allows sources to be enclosed or unenclosed. Enclosures are defined as a collection of rectangular surfaces with an absorptive face on the side nearest the source and having a sound transmission loss. The total power level of all sources within the enclosure is first determined. The total sound pressure level inside the enclosure and close to the surfaces is

$$L_{p,inside} = L_{w,total} + 10\log\{Q/(4\pi r^2) + 4/(Abs)\} \quad (13)$$

where

$Q/(4\pi r^2)$ is the direct field term and is approximately the reciprocal of the sum of all the surface areas comprising the enclosure,

Abs is the total absorption within the enclosure and is obtained by summing the absorption of all surfaces comprising the enclosure.

Assuming that the sound within the enclosure is mostly reverberant, the sound power "emitted" through each enclosure surface to a free field outside is

$$L_{w,surface} = L_{p,inside} - 6 + 10\log A - TL \quad (14)$$

where the term $(L_{p,inside} - 6)$ is approximately the sound intensity incident in the direction of the surface and hence "emitted" through the surface [26]. Directivity of surfaces is specified in a similar manner to sources.

BARRIER ATTENUATION A_3

The Maekawa theory for predicting noise reduction from barriers is commonly used today. New developments in this field [1,27,28], however, include the influence of the ground on both sides of the barrier. At certain frequencies, the ground effect can become more important than the barrier attenuation and hence the results based on an ideal half infinite barrier can be substantially in error. Other complications arise when the barrier is not infinitely wide, as is assumed by Maekawa's theory. The usual method of calculating the noise contribution around the sides of the barriers by Maekawa's algorithm can be done [29] but the complexities involved in a program such as ENM are quite significant. One would require a very sophisticated sectioning algorithm to determine the width of barriers. In contrast, sectioning vertically is quite straightforward.

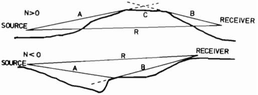

Figure 8: Geometry for calculation of the height of barriers.

Ground contours are digitised in the ENM program as a sequence of co-ordinates. The topography of the ground in a straight line between the source and receiver is determined by scanning co-ordinate pairs. A hypothetical thick barrier is then constructed according to the maximum angle subtended to the topographical feature as viewed alternatively from the source and receiver (see Figure 8). The Fresnel number N is then

$$N = \pm(A + B + C - R)/(\lambda/2) \quad (15)$$

and Equation 8 is used to compute the attenuation A_3. This, of course, is the same algorithm used by CONCAWE.

AIR ABSORPTION — A_4

The algorithm for the calculation of air absorption is based, as is the CONCAWE model, on American National Standard ANSI S1.26 [17].

The ENM program calculates the value of air absorption in third octaves and logarithmically sums the result to octaves.

WIND AND TEMPERATURE EFFECTS — A_5

The effects of refraction of sound in the atmosphere can best be thought of in terms of sound ray propagation. Curvature of sound ray paths is a result of variations in the speed of sound with height. Sound speed variations can either be caused by changes in air density due to temperature or simply by movement of the air medium itself. Intuitively, one would expect that sonic speed variations caused by a combination of these two effects would be additive. Examination of measurements conducted by Parkin and Scholes shows there is some evidence to support this theory [23] and hence we proceed upon the following lines.

The wind profile at low altitudes is determined by the ground surface roughness and may be expressed in the following simplistic form.

$$u(Z) = u_0 Z^{\xi} \quad (16)$$

where ξ is approximately 0.15, u(Z) is the wind speed at height Z and u_0 is a constant [15].

If one were to assume that meteorological data was taken at two "standard" heights namely, at 1 metre and at 10 metres then the wind gradient at 10 metres is

$$du/dZ = u\xi/10. \quad (17)$$

Strictly, the wind gradient is a vector. Hence u is the component of the wind in the direction from source to receiver and measured at a height of 10 metres above ground level. u is positive in the direction source to receiver and negative in the reverse case.

For simplicity, it is assumed that the vertical temperature profile is linear i.e. the vertical temperature gradient is a constant. The speed of sound is proportional to the temperature to the half power, or

$$c = c_0(T/273)^{1/2}. \quad (18)$$

The vertical sonic speed gradient is then

$$dc/dZ = (dT/dZ)\{10.29/(10dT/dZ + T_0 + 273)^{1/2}\} \quad (19)$$

where dT/dZ is the vertical temperature gradient, °C/metre, and T_0 is the ambient temperature at the 1 metre height.

A positive vertical temperature gradient (temperature increases with height) is termed a temperature inversion, a negative temperature gradient is a lapse condition and a zero gradient is a neutral condition.

The radius of curvature for a sound wave propagating nearly parallel to the ground is given by [2]

$$r = c_0/(\text{total vertical sonic gradient}). \quad (20)$$

We will assume the total vertical sonic gradient is the arithmetic sum of the wind and temperature induced gradients and hence,

$$r = c_0/(du/dZ + dc/dZ) \quad (21)$$

where, if r is positive then the rays are curved downwards and if r is negative, then upwards.

In the case of open terrain, we have taken the data of Parkin and Scholes [20] as summarised by Piercy [23] for observed excess attenuation of ground-borne aircraft noise measured under a variety of weather conditions and used the total vertical sonic gradient to classify the results. Table 3 shows the value of attenuation so obtained for two source-receiver distances.

TABLE 3:
Values of excess attenuation A_5 due to wind and temperature effects

Total Vertical Sonic Gradient	FREQUENCY									
	31.5	63	125	250	500	1k	2k	4k	8k	16k
110 metres										
+0.075	−2	−2	−0.5	3	−2	−5	−2	−2	−2	−2
−0.075	1	1	2.5	0	2	6	10	6	6	6
616 metres										
+0.075	−5	−5	−2	0	−9	−9	−6	−7	−7	−7
−0.075	5	5	6	4	7	7	7	6	6	6

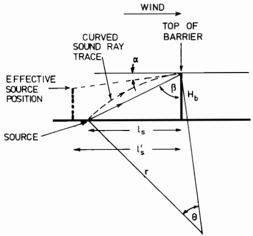

Figure 9: Geometry for calculation of effective source height assuming a positive vertical sonic gradient.

Values of A_5 are interpolated for other distances except that saturation is assumed to occur further than 616 metres and for values of total sonic gradient greater than 0.15.

Wind and temperature effects on barriers are treated in a similar manner to DeJong [2]. In essence, the height of source and receiver are modified to take into account the ray curvature. From Figure 9, and assuming a positive vertical sonic gradient,

$$h_s = H_b - |r|\,\theta \sin\alpha \quad (22)$$

$$\ell'_s = |r|\,\theta \cos\alpha \quad (23)$$

where
H_b is the barrier height above the source
$\alpha = (\pi - \theta)/2 - \beta$
$\beta = \cos^{-1}(H_b/A)$, and
$\theta = \pm\cos^{-1}\{1 - (A^2/2r^2)\}$, $r > A/2$ (saturation is assumed for high sonic gradients)
A is source-barrier top distance
Note: θ takes the same sign as $(du/dZ + dc/dZ)$.

These equations apply also to the receiver side of the barrier.

Given new locations of source and receiver, the barrier attenuation is recalculated using Equations 8.

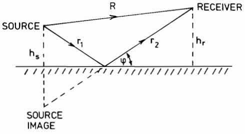

Figure 10: Geometry for ground absorption algorithm.

GROUND ATTENUATION — A6

Propagation of sound from a source placed above a semi-infinite ground plane has been extensively reviewed. Reference to Figure 10 shows that specular reflection may be considered simply by creating an image of the source in the ground. The expression for the plane wave reflection coefficient R_p may be written as

$$R_p = \{\sin\phi - (\varrho c/Z_g)\} / \{\sin\phi + (\varrho c/Z_g)\} \quad (24)$$

where
ϱc is the characteristic impedance of air, 407 MKS Rayls
Z_g is the impedance of the ground surface and is given by

$$Z_g = \varrho c[1 + 9.08(1000f/\zeta)^{-0.75}] + i\varrho c[11.9(1000f/\zeta)^{-0.73}] \quad (25)$$

where f is the frequency and ζ is ground surface flow resistivity, CGS rayls

Typical values of flow resistivity for various ground surfaces are shown in Table 4 [18].

The sound pressure measured at the receiver is

$$p/p_0 = [\exp(ikR)]/R + [R_p \exp\{ik(r_1 + r_2)\}]/(r_1 + r_2) +$$
$$[(1 - R_p(F(w) \exp\{ik(r_1 + r_2)\}]/(r_1 + r_2) \quad (26)$$

TABLE 4:
Flow resistivity of various surfaces for use in ground attenuation algorithm (after Embleton Inter-noise 80)

Description of Surface	Flow Resistivity in Rayls (CGS units)
Dry snow, new fallen 4″	15 to 30
Sugar snow	25 to 50
In forest, pine or hemlock	20 to 80
Grass: rough pasture, airport, public buildings, etc.	150 to 300
Roadside dirt, ill-defined, small rocks up to 4″	300 to 800
Sandy silt, hard packed by vehicles	800 to 2500
"Clean" limestone chips, thick layer (1/2 to 1 inch mesh)	1500 to 4000
Old dirt roadway, fine stones (1/4″ mesh) interstices filled	2000 to 4000
Earth, exposed and rain-packed	4000 to 8000
Quarry dust, fine, very hard-packed by vehicles	5000 to 20,000
Asphalt, sealed by dust and use	> 20,000

where F(w) is the boundary loss factor and is determined for small w from the series

$$F(w) = 1 + i\pi^{1/2} w \exp(-w^2) - 2iw[1 - 2w^2/3 + (2w^2)^2/(1 \times 3 \times 5) - \ldots] \qquad (27)$$

and w is the numeric distance given by

$$w = \tfrac{1}{2}(1+i)\,[k(r_1 + r_2)]^{1/2}\,(\varrho c/Z_g + \sin\phi) \qquad (28)$$

$$k = 2\pi f/c$$

The first two terms of Equation 26 represent the direct and specularly reflected waves. For hard surfaces, these two terms predominate and the result is an attenuation spectrum with regularly spaced nulls because of phase cancellation. For soft surfaces, however, the third term of Equation 26 predominates and is a result of the mis-matching of the spherical wavefronts of source and image at the ground surface. At the interface, another wave called the "ground wave" exists which makes the sound pressure level close to the ground non zero.

The ground effect attenuation is then calculated from the following

$$A_6 = 10 \log |\{\exp(ikR)\}/R|^2 - 10 \log |p/p_0|^2 \qquad (29)$$

which is the difference in magnitudes between the direct field in the absence of the ground and the total field in the presence of the ground.

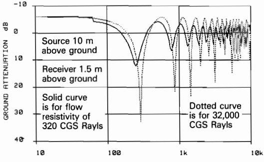

Figure 11: Typical plot of ground attenuation algorithm result.

Figure 11 shows results of calculations using Equation 26 with the ground resistivity as parameter. The ENM algorithm calculates values of A_6 at one seventh octaves and combines these to octaves.

The CONCAWE model uses experimental data in preference to this theoretical analysis but the data is limited to one ground type.

In the ENM program, a ground type code is input along with other contour information. As mentioned previously, a vertical cross-section of the ground is taken from each source to receiver point in order to calculate barrier effects. We have chosen to average the ground types in cases where there is not a single ground type. There is no physical justification for this decision, rather, we consider it a temporary measure to be replaced when more is known about the effects of changes in ground types.

Whenever a barrier is interposed between source and receiver, we calculate the reflection angle ϕ for two cases; first we consider the receiver is at the top of the barrier and calculate ϕ_s for the case source/top-of-barrier and, secondly, we consider the source is at the top of the barrier and calculate ϕ_R for the case top-of-barrier/receiver. We then assume ϕ to be an average of ϕ_s and ϕ_R. Again, this treatment is expected to be replaced when the current theoretical work on barriers in the presence of the ground is experimentally validated.

4. ENVIRONMENTAL NOISE MODEL STRUCTURE

The ENM model comprises a number of individual input, calculation and output programs. The general program structure is shown in Figure 12. All input data is stored as disk files. Source and surface data include power levels, directivity, source direction cosines (to orient the source), surface transmission loss and absorption, co-ordinate information, source type and size and other information. Meteorological data includes temperature, humidity, wind speed and direction, and vertical temperature gradient.

Ground contour maps are digitised in sections. Contours are digitised as sets of co-ordinates which make up the contour. Information such as the contour height, ground type and title are stored for each contour. The program permits sectioning from one point to another to aid in interpreting the topography and to assist with decisions about placement and height of barriers.

All input data stored on disk is used by the calculation program unless files have been pre-marked to preclude them being input. In this way, various scenarios may be studied by simple file markings. This is especially useful when examining noise from open cut mine sites for which the ground topography is continually changing.

Calculations may be performed at selected points in a regular grid (multiple point calculation) or at an individual point. In the case of multiple point calculation, a contour plot of the dB(A) value is available. in the case of single point calculation, detailed results are printed for each source and algorithm.

5. CONCLUSION

It appears from the theoretical and experimental work reported in the literature that much is still to be done towards understanding the intricate mechanisms which control the propagation of sound in the atmosphere. Certainly the linear models, of which the Environmental Noise Model presented here is one, which have appeared over the last decade are becoming more complex in their use of theoretical algorithms. Linear models are defined here to be those based on independent algorithms. We expect this type of model will grow further in complexity and will always be useful but we foresee the future holding more promise for models perhaps based on numerical methods such as Finite Element Analysis.

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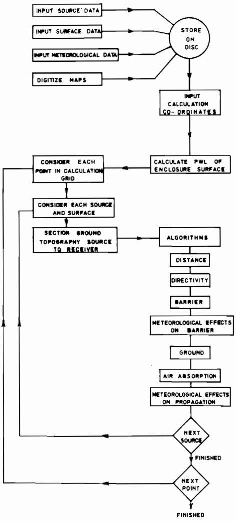

Figure 12: ENM program flowchart.

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A Statistical Estimation Method of Noise Level Probability Distribution of Arbitrary Type Based on the Observed L_{50} Data

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ABSTRACT: A new statistical method of estimating arbitrary noise level probability distribution of non-Gaussian type by using only the experimentally observed data on L_{50} is theoretically proposed. The validity and effectiveness of the proposed method is experimentally confirmed by using a digital simulation technique and applying it to the actually observed data of road traffic noise. The experimental results are in good agreement with the theory.

1. INTRODUCTION

It is common that only certain specific evaluation indices, such as L_x and L_{eq}, are measured in practice in relation to noise evaluation and/or regulation. For example, only L_{50}, prescribed as the environmental standard, is frequently measured in Japan. As is well known, however, L_{50} is not always effectual for various noise level fluctuations and so many other evaluation indices (L_{eq}, L_5, L_{10}, L_{90}, L_{95}, ...) have been proposed. From the above point of view, many trials for finding the relationship between L_{50} and another individual noise evaluation index, such as L_{eq}, have been carried out under the assumption that the value of L_{50}, calculated from the experimentally observed instantaneous noise data, is deterministic and unchangeable. But originally this experimental value of L_{50} should be regarded as stochastic and changeable, since the primary noise level fluctuation is generally a stochastic process and the noise evaluation index is calculated by using finite instantaneous noise data.

In this paper, a new statistical estimation method for various evaluation indices is derived from the same finite data length of instantaneous noise level fluctuation by using only the experimentally observed sample data on L_{50}. The theoretical result is universally applicable to arbitrary random noise of non-Gaussian distribution type. Next, the validity of the above theoretical estimation method is experimentally confirmed by using a digital simulation technique and applying it to the actual road traffic noise data.

2. THEORETICAL CONSIDERATION

2.1 Statistical Information on the n-th Order Derivative of Noise Level Probability Distribution

Let X_i be the i-th instantaneous value observed experimentally at time t_i for a random noise level fluctuation X(t) with arbitrary probability density function (abbr. pdf), f(X). Suppose that the sampled datum of L_{50} is given from $(2m+1)$ instantaneous values $X_1, X_2, \ldots, X_{2m+1}$, and that only the L_{50} data are preserved. When X_i and X_j ($i \neq j$; $j = 1, 2, \ldots, 2m+1$) are statistically independent of each other, the cumulative distribution function (abbr. cdf), G(W) of the median (= L_{50}) obtained from $X_1, X_2, \ldots, X_{2m+1}$ can be given as follows [1]:

$$G(W) = \frac{(2m+1)!}{(m!)^2} \int_{-\infty}^{W} F^m(\omega)[1-F(\omega)]^m f(\omega)\, d\omega$$

$$= K(F(\omega)) \quad (1)$$

with

$$F(W) = \int_{-\infty}^{W} f(\omega) d\omega \quad (2)$$

and

$$K(u) = \frac{(2m+1)!}{(m!)^2} \int_{0}^{u} \xi^m (1-\xi)^m d\xi . \quad (3)$$

The functional form of G(W) can be determined in advance by using the experimentally observed data $L_{50}(i)$ ($i = 1, 2, \ldots, N$) for the median level. For instance, by considering the well-known statistical property that G(W) tends to a cumulative Gaussian distribution for an arbitrary functional form of f(W) as the value of m in Equation (1) is large, we can introduce the probability expression of Gram-Charlier A type [1] (applicable universally to every continuous level type of distribution) as the functional framework of G(W), as follows:

$$G(W) = \int_{-\infty}^{W} N(\omega;\mu_\omega,\sigma_\omega^2) d\omega -$$

$$\sum_{n=3}^{\infty} A_n \sigma_\omega N(W;\mu_\omega,\sigma_\omega^2) H_{n-1}\left(\frac{W-\mu_\omega}{\sigma_\omega}\right) \quad (4)$$

with

$$N(\omega;\mu_\omega,\sigma_\omega^2) \triangleq \frac{1}{\sigma_\omega \sqrt{(2\pi)}} \exp\left\{-\frac{(\omega-\mu_\omega)^2}{2\sigma_\omega^2}\right\}, \quad (5)$$

$\mu_\omega \triangleq \langle\omega\rangle_\omega$, $\sigma_\omega^2 \triangleq \langle(\omega-\langle\omega\rangle)^2\rangle_\omega$ and

$$A_n \triangleq \frac{1}{n!} \langle H_n(\frac{\omega-\mu_\omega}{\sigma_\omega}) \rangle_\omega . \tag{6}$$

Hereupon, the relationship between the Gaussian distribution and a Hermite polynomial:

$$N(\omega;\mu,\sigma^2)\ H_n(\frac{\omega-\mu}{\sigma}) = (-1)^n\ \sigma^n\ \frac{d^n}{d\omega^n} N(\omega;\mu,\sigma^2) \tag{7}$$

has been used. And $<\bullet>_\omega$ denotes an averaging operation with respect to random variable ω.

The parameters μ_ω, σ_ω^2, A_n (n = 3, 4, ...) in Equation (6) can be estimated by using observed data $L_{50}(i)$ (i = 1, 2, ..., N) as

$$\hat{\mu}_\omega = \frac{1}{N} \sum_{i=1}^{N} L_{50}(i),$$

$$\hat{\sigma}_\omega^2 = \frac{1}{N} \sum_{i=1}^{N} L_{50}^2(i) - \hat{\mu}_\omega^2, \tag{8}$$

$$\hat{A}_n = \frac{1}{n!} \frac{1}{N} \sum_{i=1}^{N} H_n(\frac{L_{50}(i)-\hat{\mu}_\omega}{\hat{\sigma}_\omega}).$$

It is needless to say that the functional form of G(W) in Equation (1) can be determined by substituting Equation (8) into Equation (4).

The main purpose of this paper is to estimate the cdf F(X) by use of G(W) and the relationship Equation (1). As one approach, let us start our analysis from the derivatives of Equation (1). By use of Bell's polynomial [2], we can easily obtain

$$G_1 = K_1F_1,$$

$$G_2 = K_1F_2 + K_2F_1^2, \tag{9}$$

$$G_3 = K_1F_3 + K_2(3F_2F_1) + K_3F_1^3,$$

$$G_4 = K_1F_4 + K_2(4F_3F_1 + 3F_2^2) + K_3(6F_2F_1^2) + K_4F_1^4, \ldots,$$

where

$$G_\ell \triangleq \frac{d^\ell G(W)}{dW^\ell}, \quad K_\ell \triangleq \left.\frac{d^\ell K(\xi)}{d\xi^\ell}\right|_{\xi=F(W)} \quad \text{and}$$

$$F_\ell \triangleq \frac{d^\ell F(W)}{dW^\ell} \quad (\ell = 1,2,3,\ldots). \tag{10}$$

We now pay special attention to the differential coefficients at $\hat{\mu}_\omega$ since the sample mean provides stable information on the moment statistics obtained from sample data and the unbiased estimate of the median. The statistical information on the n-th order derivative (n = 1, 2, ...) of F(X) can be given successively as follows:

$$F_1 = (\hat{\mu}_\omega) = G_1(\hat{\mu}_\omega)/K_1(1/2),$$

$$F_2(\hat{\mu}_\omega) = [G_2(\hat{\mu}_\omega) - K_2(1/2)F_1^2(\hat{\mu}_\omega)]/K_1(1/2),$$

$$F_3(\hat{\mu}_\omega) = [G_3(\hat{\mu}_\omega) - K_2(1/2)(3F_2(\hat{\mu}_\omega)F_1(\hat{\mu}_\omega) - K_3(1/2)F_1^3(\hat{\mu}_\omega)]/K_1(1/2), \ldots, \tag{11}$$

where $F(\hat{\mu}_\omega) \cong 1/2$ has been used. By using Equations (4) and (7), $G_\ell(\hat{\mu}_\omega)$ (ℓ = 1, 2, ...) contained in the right side of Equation (11) can be directly calculated as

$$G_\ell(\hat{\mu}_\omega) = N(\hat{\mu}_\omega;\hat{\mu}_\omega,\hat{\sigma}_\omega^2) \sum_{n=0}^{\infty} (-1)^{\ell+1} \frac{\hat{A}_n}{\hat{\sigma}_\omega^{\ell-1}} H_{n+\ell-1}(0)$$

$$= \frac{(-1)^{\ell+1}}{\hat{\sigma}_\omega^\ell \sqrt{(2\pi)}} \sum_{n=0}^{\infty} \hat{A}_n H_{n+\ell-1}(0) \tag{12}$$

with

$$\hat{A}_0 = 1, \quad \hat{A}_1 = \hat{A}_2 = 0. \tag{13}$$

Furthermore $K_\ell(1/2)$ (ℓ = 1, 2, ...) in Equation (11) becomes as (see Equation (3))

$$K_\ell(\tfrac{1}{2}) = \frac{(2m+1)!}{(m!)^2} \left.\frac{d^{\ell-1}}{d\xi^{\ell-1}} [\xi^m(1-\xi)^m]\right|_{\xi=1/2}$$

$$= (2m+1)! \sum_{i=0}^{\ell-1} (-1)^i \ .$$

$$\frac{(\ell-1)!}{i!(\ell-1-i)!(m-\ell+1+i)!(m-i)!} (\tfrac{1}{2})^{2m-\ell+1}. \tag{14}$$

2.2 Estimation Methods of Noise Level Probability Distribution

Let us consider how to estimate the noise level probability distribution F(X) based on the statistical information given by Equation (11). We can find the following two estimation methods:

Method 1

As a direct estimation method, F(X) is approximated in the form of a Taylor expansion expression as follows:

$$F(X) = F(\hat{\mu}_\omega) + \sum_{n=1}^{\infty} \frac{1}{n!} F_n(\hat{\mu}_\omega)(X-\hat{\mu}_\omega)^n$$

$$(F(\hat{\mu}_\omega) \simeq 1/2). \tag{15}$$

At this time, F(X) can be estimated easily by substituting Equation (11) into Equation (15). It is needless to say that F(X) defined in the region [0⩽F(X)⩽1] is employed as the cdf of noise level fluctuation.

Method 2

As an indirect estimation method, the functional framework of F(X) applicable to an arbitrary probability distribution form is introduced in advance and then the unknown parameters contained in the above functional framework are estimated by use of Equation (11). Let us employ the Gram-Charlier A type probability expression as the functional framework of F(X), as follows:

$$F(X) = \int_{-\infty}^{X} N(x;\mu_x,\sigma_x^2)\,dx -$$

$$- \sum_{n=1}^{\infty} B_n \sigma_x N(X;\mu_x,\sigma_x^2) H_{n-1}\left(\frac{X-\mu_x}{\sigma_x}\right) \qquad (16)$$

$$(\mu_x, \sigma_x^2, B_1, B_2, \ldots: \text{unknown parameters}).$$

At this time, by setting $\mu_x = \hat{\mu}_\omega$ ($= \sum_{i=1}^{N} L_{50}(i)/N$; sample mean of observed median data) and by using Equation (11), we obtain the following simultaneous equations

$$\frac{1}{\sigma_x}\{H_0(0)+B_1H_1(0)+B_2H_2(0)+\ldots\} = \sqrt{(2\pi)}F_1(\hat{\mu}_\omega)$$

$$\frac{1}{\sigma_x^2}\{H_1(0)+B_1H_2(0)+B_2H_3(0)+\ldots\} = \sqrt{(2\pi)}F_2(\hat{\mu}_\omega)$$

$$\frac{1}{\sigma_x^3}\{H_2(0)+B_1H_3(0)+B_2H_4(0)+\ldots\} = \sqrt{(2\pi)}F_3(\hat{\mu}_\omega)$$

$$\ldots, \qquad (17)$$

where

$$H_\ell(0) = \begin{cases} (-1)^{\ell/2}(\ell-1)!! & (\ell: \text{even number}) \\ 0 & (\ell: \text{odd number}), \end{cases}$$

$$(2\ell-1)!! = (2\ell-1)(2\ell-3)\ldots3.1. \qquad (18)$$

The unknown parameters σ_x^2, B_1, B_2, ... can be estimated by solving Equation (17).

3. EXPERIMENTAL CONSIDERATION

3.1 Digital Simulation

In this section, the validity of theoretical estimation methods has been confirmed experimentally by use of digital simulation technique. As one of the most basic and important examples, we considered the idealised special case when the pdf of random noise level fluctuation is Gaussian type. Concretely, after generating 5100 independent Gaussian random numbers with mean 60.0 and variance 5^2, we have obtained 100 sample data on L_{50} (i.e. N = 100 (see Equation (8)) and m = 25 (see Equation (1)).

Table1:
A comparison between the experimental values and theoretically estimated values for representative noise evaluation indices in the case of using digital simulation technique

Noise evaluation indices	L_{eq}	L_5	L_{10}	L_{90}	L_{95}
Experimental values	62.9	68.3	66.5	53.7	51.9
Theoretically estimated values by using method 1	61.9	67.0	65.8	53.8	52.5
Theoretically estimated values by using method 2	62.3	67.7	66.0	53.8	52.1

Table 1 shows a comparison between the experimental values (calculated directly from 5100 Gaussian random numbers) and theoretically estimated values obtained by using methods 1 and 2 for several representative noise evaluation indices. Hereupon, the expansion expression from the first term to a term containing the coefficient $F_5(\hat{\mu}_\omega)/5!$ in Equation (15) and the cdf expression from the first term to a term containing the expansion coefficient B_6 in Equation (16) have been used. It is obvious that the results of simulation experiment are found in good agreement with the theoretical results.

3.2 Application to Road Traffic Noise Data

The samples of road traffic noise data have been observed at intervals of 5 seconds in Hiroshima City, and 14 sample data of L_{50} were obtained by setting m = 25 (cf. Equation (1)). Table 2 gives a comparison between the theoretical and experimental values for several noise evaluation indices. Hereupon, an expression of F(X) containing from the first term to a term with expansion coefficient $F_5(\hat{\mu}_\omega)/5!$ in Equation (15) and the cdf expression containing from the first term to a term with expansion coefficient B_6 in Equation (16) have been used. From this table, we can find that the estimation error of evaluation indices usually used in the noise evaluation and/or regulation problems are almost within ± 1 dB.

4. CONCLUSION

In this paper, a new statistical method of estimating the arbitrary noise level probability distribution of non-Gaussian type (from which the representative noise evaluation indices commonly used in the noise evaluation and/or regulation problems can be calculated) by using only the experimentally observed data on L_{50} has been theoretically proposed. Then, the validity and effectiveness of the proposed method has been experimentally confirmed by using a digital simulation technique and applying it to the actually observed data of road traffic noise. Experimental results obtained, not only by digital simulation but also by road traffic noise data, are in good agreement with the theory.

Such a statistical estimation method based on L_{50} data is still in an early stage of study. So, the main purpose of the present study has been focussed on its methodological viewpoint. There still remain many future problems; such as to confirm experimentally the effectiveness of the proposed method by applying it to other actual road traffic noise data; and to consider the estimation error for evaluation indices in the case when X_i and X_j [i,j = 1, 2, ..., 2m+1; see Equation (1)] are correlated with each other.

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Table 2:
A comparison between the experimental values and theoretically estimated values for representative noise evaluation indices in the case of applying the proposed method to actual road traffic noise

Noise evaluation indices	L_{eq}	L_5	L_{10}	L_{90}	L_{95}
Experimental values	75.2	79.8	78.0	69.8	68.4
Theoretically estimated values by using method 1	74.3	78.1	77.3	69.6	68.8
Theoretically estimated values by using method 2	74.5	78.5	77.3	69.4	68.3

(Continued from page 58)
them later, began an era of considerable productivity and the opportunities to extend the growing capabilities to wider horizons. Traffic and aircraft noise problems began to receive attention, often in co-operation with Anita Lawrence of the University of New South Wales. One of the interesting events early in that period was monitoring the arrival of Concorde at the end of its first and highly controversial flight to Sydney.

"We were able to get a position on the airfield itself near the intersection of the two runways. Everybody else was so convinced that, being so noisy, the Concorde would fly in over Botany Bay — so they all went out in a boat to make their measurements. Instead, the Concorde duly came in from the north, so we were in a pretty good position to get it. We wore that recording thin as far as the tape was concerned. It was played on every public relations opportunity."

As part of cost-cutting recommended by the 'Razor Gang', the Federal Government decided to terminate the EBS in 1981.

Other Activities

As a natural corollary to his acoustical activities, Ted has been involved in many standards committees over the years and has helped draft a number of standards including those dealing with transmission through walls.

Ted's involvements with the Australian Acoustical Society started when he, Peter Knowland and John Irvine started editing a Newsletter for the New South Wales Division. In 1972 this publication developed into The Bulletin. For some time The Bulletin was produced by the same editorial committee, later joined by Marion Burgess and then Richard Heggie and Ferge Fricke. Ted was also involved in some of the early conferences. Those run in conjunction with other bodies, such as the Institution of Engineers, were not always successful from an acoustical viewpoint. As Ted comments: "Acoustics tends to be a tag end to other professions. Mechanical engineers are supposed to know something about acoustics but tend to think they know a lot more than they really do and are quite happy to make solutions which are apt to be incorrect. In some government departments you can get a job as an engineer but you could not get a job as an acoustics officer or as an acoustician, if it is an engineering department. Efforts have been made for some years for membership of the Australian Acoustical Society to be a qualification which entitles you to a position in its own right. Public Service Boards and the like have not accepted that yet."

On the whole Ted thinks that the Society has fulfilled its original functions which include the organisation of conferences, symposiums and a publication. One shortcoming has probably been getting younger members involved in the running of the Society's activities. Consideration could be given to an educational programme which would appeal to senior school children and which would include lectures and demonstrations to high schools. Otherwise, Ted declined to gaze into the crystall ball and predict what the Society might be doing in, say, ten years time.

As for his own future, Ted hopes to continue his present activities of lecturing in the Acoustics of Buildings course at the University of New South Wales and some freelance consulting. We wish him every success in his retirement.

TECHNICAL NOTES

Acoustics in School Music Rooms

The Noise group of the Greater London Council Scientific Services Branch has for many years offered recommendations concerning the acoustics of school music and practice rooms. Class music lessons usually involve the whole class in some type of music making activity which they do together or independently. Musical instruments such as xylophones, metallophones, drums, electric synthesizers and keyboards are used. Following complaints about the poor standard of acoustics in some music rooms, it was decided that a number of music rooms should be visited and measurements and observations made.

Twenty-one schools were surveyed. The reverberation time (RT) and noise level inside the classrooms were measured in all the music rooms visited. Teachers were also questioned on their attitude to the acoustic environment using a short questionnaire.

Analysis

One of the first impressions received was the sheer volume of the noise. Levels in a general class music lesson were generally between 85 and 95 db (A) when instruments were being played, and a maximum level of 110 db (A) was measured during a lesson involving percussion instruments. This was also the main finding of the teachers' questionnaire. The teachers were concerned about noise levels and the sources of noise. The sounds which are wanted in the classrooms are the teacher's voice and the sound of children playing instruments; all others are unwanted. Hence, excessive reverberation noise, noise generated by feet and chairs, and noise from outside the room which was heard because of poor insulation, were all considered intrusive.

Generally dissatisfaction did not increase proportionally with reverberation time, as some teachers were unhappy with rooms that had a relatively short RT. In these cases it was found here that the rooms usually had an RT spectrum in which the values did not decrease significantly at high frequencies. However, over a certain value of RT, all teachers were annoyed.

Teachers did not consider their pupils to add to the absorption in a reverberant space — to them an increased number of children meant an increase in noise sources, which they did not want in a reverberant room.

Conclusions

The following conclusions were reached from the work:

- The most important aspect of a good environment in music rooms is the elimination of intrusive background noise. This includes noise from feet and chairs, unwanted noise from instruments, excessive reverberation in the room and noise from outside the room.

The intrusive noise would be a drawback in any classroom, but when part of the teaching and learning process involves the pupils making sounds, probably all at the same time, nuisance caused by unwanted noise assumes a much greater magnitude.

- No school music room with a long reverberation time, i.e., 1.4 seconds or greater, was found to have satisfactory acoustics.

These rooms are always difficult for teaching and cause problems for both teachers and pupils. When designing a music room it is best to aim for a low RT.

- The absorption of children should not be included in the RT calculations for music rooms.

The optimum RT should be obtained without including children, then if a full class is present the additional absorption will compensate for the additional noise source.

- The spectrum of the RTs must be considered. If the RTs at high frequencies are longer than those at low frequencies the room is likely to sound harsh and noisy;
- Any music room with poor sound insulation will become a nuisance to the music teacher and the class, and will reduce the effectiveness of the lesson.

Also, the music class itself is likely to cause disturbance.

Recommendations

1. All music rooms should have fitted carpets to provide absorption and muffle the sound of feet and chairs. Rubber mats should be put under instruments such as metallophones and drums so that they do not clatter on tables or ring excessively.
2. The RT of music rooms should be approximately 1 second, with part of this absorption derived from carpeting. Where carpet is fitted, high frequencies should be absorbed efficiently, otherwise care must be taken to include a material which will absorb high frequencies. If a carpet is not laid the reverberation time should be made shorter than 1 second.
3. When designing, children should not be included in RT calculations.
4. Noise insulation between a music room and other rooms should be a minimum of 45 dB. Care should be taken to provide well-fitting doors and lobbies between rooms.

To sum up, the idea of a music lesson as sweet voices raised in unison is no longer valid. Now we must design for something altogether more robust.

— Sue Bird
Scientific Services Branch
Greater London Council
(in London Environmental Bulletin, Autumn 1984)

Electronics and the Body

The electronics of the human body is a rapidly advancing research frontier at which electrical engineers have a vital role to play, according to Professor J. R. James of the Royal Military College of Science, Shrivenham. Delivering his Presidential Address to the Institution of Electronic and Radio Engineers, Professor James described how micro-electronics and information technology have been driving forces in the development of a wide range of medical equipment.

Diagnostic imaging is one area in which there have been enormous advances. Just over a decade ago the concept of obtaining cross sectional images of the human body from x-ray scans was pioneered by EMI. The subsequent development of computerised tomography, with its hardware implementation of rapid computational techniques, led the way to other methods such as ultrasound imaging, which provides better discrimination between soft body tissues (although bone or air pockets are a problem) and is thus ideal for use in obstetrics. Similar processing techniques can be applied to measuring the Doppler shift due to blood flow where fine manipulation of an ultrasound transmitting head gives valuable information about blood dynamics. Digital image processing techniques and false colour displays offer valuable methods of noninvasive measurement of cardiac and vascular diseases, and it is not difficult to envisage future computer-managed diagnostic clinics for routinely checking patients.

Another major advance in the imaging field is the application of nuclear magnetic resonance to medicine. NMR probes the atomic state itself, by perturbing the magnetic spins of nuclei and measuring the time taken for recovery, and can hence detect subtle changes in body chemistry at the onset of a disease. There are no known damaging effects, although images are less well resolved than x-ray scans, and the amount of information potentially available far exceeds that available from macroscopic imaging systems. These techniques, are, however, at present expensive and exciting new possibilities which could well be cheaper are therefore being explored. These include microwave diffraction tomography, which necessitates extensive data processing of wave scattering equations and the use of a scanning microwave retina, and applied potential tomography, in which low frequencies are used to map the conductive properties of tissues to discriminate between them.

Sophisticated computational procedures resulting from defence studies are being used for the simultaneous solution of the wave and heat diffusion equations for human tissue in the heat treatment of tumours. Hyperthemia — the raising of the whole or part of the body to 42-43°C — is an effective way of killing tumour cells; used in conjunction with radiotherapy or chemotherapy, lower doses are required and the patient can tolerate longer treatment. Waveguides have been developed to deliver heat to tumours up to a few centimetres below the skin surface and lower frequencies and equipment which, for example, sandwiches the body between capacitor plates, are aimed at deep-seated tumours. Such machines rely heavily on RF engineering techniques evolved for high power radars and industrial heating. A second problem — charting the internal body temperature without excessive use of invasive probes — remains to be solved.

Continued on page 79

Advances in Digital Recording

CTS Recording Studios in Britain has installed the first sound-mixing desk in the world which can process, in a digital form, all the signals for a multi-track music recording.

Although many recording studios now use digital tape recorders, they must mix the signals from the microphones in analogue form before storing on tape. They also have to convert the digitally recorded signals back to analogue for processing, remixing and editing to produce a two-track stereo record, from a 24-track master recording.

CTS bought its digital-recording desk from the British firm Neve. The Department of Trade and Industry gave CTS an interest-free loan for one year to buy the recording desk, under the scheme intended to encourage British companies to invest in British technology.

Neve began work on the digital signal processor (DSP) in 1978, and soon joined forces with the BBC's research department. The company is now making a second desk for the BBC.

The analogue signals coming in from the microphones are sampled at a rate of 48,000 times a second, and coded in 16-bit binary words. The digital stream runs on a fibre-optic signal bus which can carry 128 separate sound signals at the same time. Signals from 48 microphones can be fed into the desk, and then mixed, split, and processed before they are fed out as separate streams to the 24 tracks of a Sony digital tape recorder.

All the mixing and processing, for instance to combine the sound of several microphones covering a single musical instrument and accentuate some of its frequences more than others, is achieved by mathematically doctoring the data stream under the control of the software in the DSP.

The sound engineer has more than 1000 conventional knobs and slider controls to work. Because it is impractical for one engineer to control so many knobs during a hectic recording session, often with an orchestra costing up to £35,000 a day, the knobs can be preset before the session and their settings logged on a conventional computer disk. When the desk is switched on, data is loaded from the disk, and the desk parameters automatically reset.

The control data for knobs and dial settings is stored in half a megabyte of memory. When this is saved on floppy disk, the engineer can keep a copy of his or her own favourite set-ups. If there is a power cut, the desk relies on 64 kilobytes of battery-powered memory to reserve vital functions.

Because signals are handled in digital code, technical tricks that are difficult or impossible on an analogue desk become easy. For instance, the sound coming from different microphones can be delayed by the number of milliseconds which exactly matches the time taken for sound to travel from an instrument or group of instruments to the microphone. In this way there is no time error when the sound reaches several microphones which are spaced at different distances.

CTS ordered DSP in March 1982, when it was still unfinished. In return for this faith, CTS was quoted a price of £310,000. At today's prices the DSP desk would cost £500,000. Problems in the software delayed commissioning until early this year. Record and film companies can use the processor for £150 per hour.

(From New Scientist 14 March, 1985).

Some new trivial units

10^{-15} bismol	= 1 femto-bismol
10^{-12} boos	= 1 picoboo
1 boo^2	= 1 boo boo
10^{-18} boys	= 1 attoboy
10^{12} bulls	= 1 terabull
10^1 cards	= 1 decacards
10^{-9} goats	= 1 nanogoat
2 gorics	= 1 paregoric
10^{-3} ink machines	= 1 millink machine
10^9 los	= 1 gigalo
10^{-1} mate	= 1 decimate
10^{-2} mental	= 1 centimental
10^{-2} pedes	= 1 centipede
10^6 phones	= 1 megaphone
10^{-6} phones	= 1 microphone
10^{12} pins	= 1 terapin

(Philip Simpson in The NBS Standard, Jan. 1970)

NEW PRODUCTS —

Stramit Handi-board

Stramit HANDI-BOARD represents the most important product development to Stramit Board since it was first produced. It was developed at Stramit's production facility in Bendigo, Victoria.

New HANDI-BOARD retains most of the time-honoured benefits of Stramit Board . . . thermal insulation, sound insulation, fire resistance and strength. But it is lighter, easier to erect, and it costs less.

Stramit HANDI-BOARD is 36mm. thick and 1220mm. wide. It is available in standard lengths of 2.4, 2.7 and 3 metres.

Further information from Stramit Ltd., 96 Franklin St., Melbourne, Vic. 3000. Tel. (03) 329 7611.

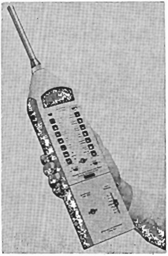
Flagship for B & K Sound Level Meter Range

Bruel and Kjaer announces a new top-of-the-line addition to its range of sound level meters, the modular Precision Sound Level Meter Type 2231. An integrating sound level meter meeting Type 1 accuracy specifications, it sets new standards for versatility and convenience. The measurement applications are numerous, ranging from industrial noise and community noise to architectural acoustics and research and development.

The outstanding feature of the 2231 is its modular construction. The Sound Level Meter derives its many measurement capabilities from *a series of interchangeable Application Modules.* Whenever a different module is loaded the instrument software is reformatted, enabling it to perform the necessary measurement functions. Three Application Modules are currently available. As standard the 2231 is supplied with Application Module BZ7100, which is an *Integrating Sound Level Meter Module.* Application Module BZ7101 is a *Statistical Analysis* module allowing measurement of L_N, Cumulative Distribution, and Probability Distrbiution. Application Module BZ7102 is a *"Taktmaximal"* module allowing measurements according to the German "TA-Larm".

A selectable polarization voltage allows the use of almost any microphone in the B & K range, and further increases the measurement possibilities. The standard microphone allows measurements in the range from 24 dB to 130 dB in seven overlapping 60 dB ranges. Results are displayed on an advanced Liquid Crystal Display which includes a quasi-analogue scale and allows alphanumerics to be displayed clearly. The soft-touch controls give full tactile feedback, but ensure almost silent operation.

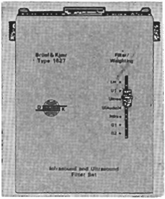
Octave band and 1/1-1/3 octave band analysis are possible with Filter Sets Type 1624 and 1625 respectively. A new Filter Set Type 1627 takes advantage of the extended frequency response of the 2231, and allows measurements in the infrasound and ultrasound ranges. AC and DC Output sockets allow chart or tape recording of the sound signal.



Infrasound and Ultrasound Filter Set

The new Infrasound and Ultrasound Filter Set Type 1627 from Bruel and Kjaer is intended primarily for use with the new Modular Precision Sound Level Meter Type 2231. Its six filter networks include G1 and G2 which allow infrasound measurements in accordance with ISO/DIS 7196. Measurements of audible sound in the presence of ultrasonic noise are possible with filter network U (Audio) which complies with IEC TC 29-169/WG.16. The other filter networks are: U1, a proposed weighting which approximates the sensory perception of ultrasound; Ultra, a 12,5 kHz high pass filter; Infra, a 20 Hz low pass filter. The Filter Set also has a Linear setting. Included with the Filter Set is a special microphone adaptor which extends the useful low frequency range of the standard ½-inch microphone to below 1 Hz.

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



AN INTRODUCTION TO THE PHYSIOLOGY OF HEARING

by James O. Pickles

Academic Press Australia, 1982, A$20.35, ISBN 0 12 554752 8

In the Preface to his book, Pickles recognises that there have been rapid advances in the study of auditory physiology in the last fifteen years and, furthermore, that there is a need to introduce these advances to an audience outside the circle of specialists in the subject. Pickles' aim, therefore, has been to compile a new text on auditory physiology, principally for students of varying background and their specialist or non-specialist teachers. As one with an interest in this area, I applaud Pickles' intention. I am also firmly of the view that Pickles' accomplishment in this book deserves high praise.

The book is logically organised and begins with a basic revision of the physics of sound. There follows a discussion of the outer and middle ears, the cochlea, the auditory nerve and the mechanisms of transduction and excitation in the cochlea. The second half of the text is concerned, in a less detailed fashion, with the ascending auditory pathways, functional properties of neurons in the brainstem auditory nuclei and auditory cortex, the centrifugal auditory systems and a brief discussion of the physiological bases for psychophysical observations and sensorineural hearing loss. Each chapter of the book begins with an overview of the area to be discussed and is completed by a summary and reference to other publications for further reading. Such an approach is always helpful, particulary for students.

The book has several major strengths. Of particular appeal is the author's literary style. Rarely does one find a text of this nature which is so easy to read. The appeal of style is also reinforced by the frequent referencing of original papers. Pickle's ability to extract the essence of the data and arguments in these papers and to present them to the intended readership in a concise and logical framework is evident throughout the text. The presentation of data, theories and disagreements is consistently balanced and the reader is left in no doubt where controversy exists in the literature. Furthermore, the limitations of our knowledge and interpretations of some data are also made explicit.

Of particular value are Pickles' descriptions of the evidence concerning the amplitude of movements in the cochlea at threshold and the so-called "second filter". The historical perspective and the development of ideas concerning the nature of the travelling wave of the basilar membrane also makes very interesting reading. Part of this interest is generated from the unthreatening description of the techniques, and their possible limitations, which have been employed in these difficult investigations. It is perhaps unfortunate that this section of the book was completed just as the more recent reports showing that tuning of the basilar membrane can be comparable to that observed in the neuronal elements were appearing in the press.

The wide and considered selection of diagrams from source publications is particularly pleasing. The other diagrams in the book, which are either original or adaptations from those of others, are both uncomplicated and explicit. In general, the use of diagrams throughout the text is excellent, though the section on the gross functional anatomy of the cochlea is a little disappointing.

My only other criticism of this book arises in the Preface. Here, Pickles advises readers with various interests in auditory physiology, which chapters may be of most relevance and which chapters could be left alone. I would contend that all serious students, teachers and practitioners in auditory physiology should read this excellent publication **in toto**. In doing so all will benefit by gaining a fuller understanding of the broad subject which is auditory physiology.

Alan Pettigrew,
Senior Lecturer in Physiology, The University of Sydney.

SEISMIC MOUNTINGS FOR VIBRATION ISOLATION

by Joseph A. Macinante

Wiley, New York, 1984. 279 pp., ill. Price: A$49.95.

One of the greatest problems an engineer should (but doesn't) consider is the use of appropriate theory or models for a particular design. Every theory is a simplification of reality, but how simple should it be? All too often the choice is between a rule of thumb (or back of envelope calculation) and a sophisticated computer program. The result is that there are design failures or unnecessarily high design or consultancy fees (or both).

This situation is very common in the field of vibration isolation. Noise and vibration from plant rooms in buildings should not be a problem but it is because of the use of inappropriate theory. No doubt this situation would change if such failures were catastrophic. They aren't, and so building occupiers generally put up with the problem, swear, move, swear under their breath, or, as sometimes happens, move the plant room or offending piece of equipment.

Will Joe Macinante's book change this? Certainly, if designers and consultants read and understand "Seismic Mountings for Vibration Isolation"; they should at least realise the limitations of thumb rules and be aware of more appropriate alternatives. Better building environments must surely follow.

The book is a basic text but, as it does not go into derivations, it is basic to practitioners rather than students. The book is promoted as being for engineers and architects. It would be an unusual architect who would read it even though chapter 3 on "Basic Principles of Vibration Isolation" provides guidelines which architects would find very useful. The book is for practising engineers.

Chapter 1 is an introductory one. Chapter 2 is on terminology and theory, dealing with different types of vibration and its measurement. Basic principles of controlling vibration in buildings is covered in chapter 3. Vibration criteria and seismic mountings are dealt with in chapters 4 and 5 respectively.

It is chapters 6, 7, 8 and 9 on Design Model for a Seismic Mounting, Free or Natural Vibrations, Mounting for Machinery on Suspended Floors and Mounting for Sensitive Equipment, where Macinante makes his main contribution, and it is these chapters which should be of greatest interest to engineers and noise and vibration consultants. The design model used in this work is the damped two-mass one. To go with this model there is comprehensive design data and worked examples. This mode is, I suggest, far more appropriate for buildings than either thumb rules or aerospace modal analysis programs.

Don't forget Crede, Timoshenko and Bishop, but put Macinante's book on top. Macinante has distilled the essence of those texts and presented it with his own work in a highly readable and accessible form. He deserves to be congratulated, read and followed.

Fergus Fricke
Dept. Architectural Science, University of Sydney.

THE ACOUSTIC SENSE OF ANIMALS

by William C. Stebbins

Harvard University Press, Cambridge, Mass., 1983. 168 pages. Australian price $36.50.

Review copy from Book & Film Services, P.O. Box 226, Artarmon, N.S.W. 2064.

Readers of this journal will not need to be reminded of the importance of human hearing, but it is not often that we have an opportunity of standing back to survey in broad perspective the nature and significance of the auditory sense across the whole animal kingdom. Professor Stebbins' elegantly written book provides just such an opportunity and I recommend it warmly to biologists, psychophysicists and engineers alike.

Between a short introduction on sound and hearing and an epilogue which emphasises the unsolved nature of many current problems in the field, there are six chapters dealing in turn with insects, fishes, amphibians, reptiles and birds, terrestrial mammals, aerial and aquatic mammals, and primates. Nearly equal space is given to each chapter, and homo sapiens appears only as one of the more interesting primates.

For each set of animals Stebbins describes the basic auditory physiology, gives information on the frequency variation of the threshold of hearing and on the animals' ability to discriminate differences in direction, frequency and loudness, and then relates these findings to individual behaviour and group communication. He also describes in some detail the way in which these auditory characteristics are measured in each case — often a matter of great experimental subtlety. Those of us brought up in the physical sciences cannot but admire the dedication needed to measure the auditory threshold curve of a Caiman crocodile!

The book is written rather in the style and at the level of "Scientific American" and is not burdened with excessive detail. Anatomical terms, I am delighted to say, are explained concisely as they occur so that no prior knowledge of biological terminology is required. The same is true of the small amount of physics. The diagrams, which are well chosen, all come from the published literature and are appropriately referenced, but this is the limit of literature citation. This makes the book a relaxed and pleasant experience, though it might prove a little frustrating to a serious student. There is, however, a list of suggested further readings — about half a dozen for each chapter — and since these are mostly to more detailed books and reviews they should provide the necessary links to published work.

Finally let me say that this book is not just a catalogue of experimental results. It is a nicely balanced view of a wide and important field, integrated into a broad evolutionary framework. It should be required reading for all those who study animal physiology or behaviour and is certainly highly recommended for all those interested in a wider view of acoustics. I read it from cover to cover in three evenings and enjoyed it — I am sure you will too.

Neville Fletcher

STANDARDS

Activities of SAA Acoustics Committee for year 1984/85

Committee AK-, Acoustics Standards Committee and Committee AK/-/1, Executive

Dr. R. G. Burden retired from committee activities after holding the position of Chairman of the Acoustics Standards Committee since 1968 and Professor A. Lawrence was appointed by the Association as the new Chairman early in 1985. A review of the structure of the several acoustics committees is to be undertaken during the remainder of 1985.

Committee AK/1 — Terms, Units and Symbols

The revision of AS 1633-1974, Glossary of Acoustics Terms has been completed and the new standard will be published during June 1985. The next project for this committee will be on the subject of basic quantities.

Committee AK/2 — Instrumentation and Techniques for Measurement

During this year Committee AK/2 published the seven part revision of **AS 1217-1972.** Methods of measurement of airborne sound emitted by machines. The new standard, published in seven parts now aligns with ISO publications on the same subject.

Published:

AS 2659 Guide to the use of sound measuring equipment.
Part 2—Portable equipment for integration of sound signals.

AS 2680 Acoustics — Performance requirements for tape recording equipment for use in acoustical measurement systems.

Under consideration:

Revision of AS MP44 Guide to the use of sound measuring equipment. Part 1 — Portable sound level meters. (The revised standard will be published as AS 2659 Part 1).

Revision of AS 1081 Method of measurement of airborne noise emitted by rotating electrical machinery. Documents rotating electrical machinery.

Documents AK/2/8O13, Guide for the use of sound measuring equipment, Part 3. Equipment for frequency and time analysis of sound signals. (This new standard will be published as AS 2659 Part 3).

Committee AK/3 — Hearing Conservation

Work has just commenced aimed at the revision of AS 1270-1983, Hearing protection devices and AS 1269-1983, Hearing Conservation.

Committee AK/4—Architectural Acoustics

Published:

AS 1277 Acoustics — Measurements procedures for ducted silencers.
The publication of this standard is preceeding any work still considered by ISO.

It is envisaged that the following standards will be forwarded for publication during the month of June 1985:

Revision of AS 1191-1976 Method for laboratory measurement of airborne sound transmission loss of building partitions.

Document AK/4/85-12, Methods for assessing and predicting speech privacy and speech intelligibility.

Work is proceeding on the revision of AS 2021-1977 Code of practice for building siting and construction against aircraft noise intrusion. The draft and the required period of public comment has been completed and it will be postal ballotted during the month of June.

In hand:

Revision of AS 2107-1977 Code of practice for ambient sound levels for areas of occupancy with buildings.

Revision of AS 1045-1971 Method of
Revision of AS 1045-1971 Method of measurement of absorption coefficients in a reverberation room.

Committee AK/5 — Community Noise

Published:

AS 2702 Acoustics — Methods for the measurement of road traffic noise.

Revision of **AS 1055-1978** Code of practice for noise assessment in residential areas.

The revised version was published in three separate parts and it now aligns with the practice outlined in the equivalent ISO documents.

New work considered by Committee AK/5 is in the area of building siting with respect to traffic noise.

Committee AK/7 — Noise in Ships

This committee has recently been reactivated and its first tasks are the revision of the following standards:

AS 2254-1979 Recommended noise ratings for various areas of occupancy in vessels.

AS 1948-1976 Method for measurement of airborne noise on board vessels.

AS 1949-1976 Method for measurement of airborne noise emitted by vessels on waterways and in ports and harbours.

Committee AK/8 — Noise from Agricultural and Eearthmoving Machinery

This committee has met recently and is now considering the revision of AS 2012-1977, Method for measurement of airborne sound from agricultural tractors and earthmoving machinery.

Work is also proceeding on the preparation of a new standard dealing with noise produced by edge-trimmers and brush-cutters.

Committee AK/11 — Audiology

This committee, previously a sub-committee of AK/2, is actively working on the following projects:

Revision of AS 1088-1971 Methods of measurement of the electro-acoustic characteristics of air conduction hearing aids.

This standard will be replaced by IEC 118 and its various parts.

Revision of AS 1591 Instrumentation for audiometry. Part 5-1974 Wide band artificial ear.

Revision of AS Z43 Instrumentation for audiometry. Part 2-1970 Reference zero for the calibration of pure tone audiometers. (The revised standard will be published as AS 1591, Part 2).

Committee AK/12 — Measurement of Noise from Household and Small Appliances

This is a recently formed committee and at its first meeting it was decided that the first task will be that of preparing a general document dealing with noise from household and small appliances based on an existing IEC document.

M. Maffucci
SAA

International

ISO 7029 "Acoustics — Threshold of Hearing by Air Conduction as a Function of Age and Sex for Otologically Normal Persons".

Numerous data on the elevation of hearing threshold levels increasing with age exist in various publications, but there are certain numerical differences between them which may be attributed to the use of different criteria of selection for test populations, different audiometric techniques, etc. However, a thorough examination of the data has enabled a representative set of values to be established. This International Standard is based on these values which refer to screened populations of otologically normal persons.

PUBLICATIONS BY AUSTRALIANS —

We are grateful to Richard Rosenberger, University of N.S.W., for this updating of the listing of publications by Australian authors. Any other information on publications for this section should be sent to the Associate Editor.

Sound Attenuation in Forests

F. FRICKE

Dept. Architectural Science, Univ. of Sydney, N.S.W. 2006

J. Sound Vib. **92** (1), 149-158 (1984).

Vibration of a Light Loaded Tapered Circular Beam

H. P. W. GOTTLIEB

School of Science, Grifith Univ., Nathan, Queensland 4111

J. Acoust. Soc. Am. **75** (1), 264-265 (1984).

Application of Two-Variable Taylor Series to the Ray Theory of Propagation in an Unbound Medium

M. HALL

Defence Sc. and Techn. Org. (RANL), P.O. Box 706, Darlinghurst, N.S.W. 2010

J. Acoust. Soc. Am. **75** (5), 1433-1442 (1984).

Using Eigenvalue Analysis to Identify Interference in Ambient Sea Noise Vertical Directionality Measurments

D. J. KEWLEY

Dept. Def., Weapon Syst. Res. Lab., Def. Res. Centre, Salisbury, S.A. 5108

J. Acoust. Soc. Am. **75** (3), 826-833 (1984).

Acoustic Impedances Obtained Using a Spark and Steady Tube—A Comparison

J. MATHEW, R. J. ALFREDSON

Dept. of Mech. Eng., Monash University, Clayton, Vic. 3168

Noise Contr. Eng. J. Jan/Feb., 12-18 (1984).

Thermally Induced Vibrations of Viscoelastic Shallow Sells

J. MAZDUMAR, D. HILL

Dept. Appl. Mathematics, University of Adelaide, Adelaide

J. Sound Vib. **93** (2), 189-200 (1984).

Acoustic Emission: The Versatile NDT Tool

D. McCONVILLE

Acoustic Emission Div., Metlab Mapel, Australia

Non-Dest. Testing — Aust. **20** (11/12), 23-25 (1983).

Mechanism of the Generation of External Acoustic Radiation from Pipes due to Internal Flow Disturbances

M. P. NORTON, M. K. BULL

Dept. Mech. Eng., University of Western Australia, Nedlands, W.A. 6009

J. Sound Vib. **94** (1), 105-146 (1984).

Digital Reconstruction and Display of Compound Scan Ultrasound Images

D. E. ROBINSON

Commonwealth Dept. of Health, Ultrasonics Institute, 5 Hickson Rd., Sydney

IEEE Trans. Sonics Ultrasonics **31** (4), 396-406 (1984).

Point-Source Representation for Laser-Generated Ultrasound

L. R. F. ROSE

Aeronaut. Res. Labs., Melbourne, Vic. 3207

J. Acoust. Soc. Am. **75** (3), 723-733 (1984).

On the Energy Radiated by Rayleigh Waves

L. R. F. ROSE

Aeronautical Res. Labs., Melbourne, Vic. 3207

Wave Motion **6** (4), 359-361 (1984).

NEW PUBLICATIONS —

INTER-NOISE 84 Proceedings

"International Co-operation for Noise Control", was the theme of INTER-NOISE 84, held in Honolulu, Hawaii on 3-5 December, 1984. The 1426-page conference proceedings, comprising 299 papers have been published in two volumes. The conference was organised in co-operation with the Institute of Noise Control Engineering in Japan and the proceedings are therefore a complete and up-to-date summary of the state of noise control engineering in Japan.

Further details, including contents list and order form:

Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie N.Y. 12603 U.S.A.

Archives of Acoustics

For some time now we have been receiving regularly Archives of Acoustics published by the Polish Acoustical Society fully in English. In a recent letter, the Editor-in-Chief, Professor Malecki, pointed out that he was most willing to publish papers by members of the Australian Acoustical Society or to receive reviews of Australian publications in acoustics. Whenever space permits we list the contents of issues received in the New Publications section.

The following publications are held temporarily in the Acoustics Laboratory, School of Physics, University of N.S.W. They may be inspected or photocopies ordered by contacting Toni Benton on (02) 697 4542.

Reports Received

KILDE reports

The consulting firm Kilde, Postboks 229, N-5701, Voss, Norway have sent the following reports in English:

Measurement of road traffic noise (report 47), 25 pp.

Noise from construction sites (report 49), 21 pp.

Noise from railway traffic (report 67), 24 pp.

Noise from shooting ranges (report 73), 19 pp.

Aircraft noise in the Nordic countries (report 123), 36 pp.

Background material for the Nordic rail traffic noise prediction method (report 130), 19 pp.

The reports have been prepared for bodies such as the Nordic Council of Ministers' Noise Group and OECD Environmental Directorate.

Royal Institute of Technology, Stockholm

Quarterly report STL-QPSR 4/1984

Includes reports on musical acoustics; speech and hearing defects and aids; summary of reports (abstracts from STL-QPSR for 1984).

Quarterly report STL-QPSR Jan.-Mar. 1985.

Includes reports on Speech production, analysis and recognition, Speech & Hearing defects and aids.

Institute of Sound and Vibration Research, Southampton

D. W. Robinson et al: Auditory impairment and the onset of disability and handicap in noise-induced hearing loss. Technical report 126, Nov. 1984.

S. J. Elliott and **P. A. Nelson:** Models for describing active noise control in ducts. Technical report 127, April 1984.

Journals Received

Applied Acoustics, Vol. 18 No. 4, 1985

Contents: **T. E. Vigran** (Norway), Measuring the acoustic properties of ducts —**J. M. H. Peters** (U.K.), Some discriminatory remarks on Webster's horn equations — **A. M. Bruneau** et al (France), An apparatus for fast control of acoustic properties of materials — **A. Elmallawany** (Egypt), Calculation of sound insulation of ribbed panels using statistical energy analysis — **F. Fricke** (Australia), The future of architectural acoustics research and testing in Australia — **W. A. Utley** and **L. A. Miller** (U.K.), Occupational noise exposure on construction sites.

Acta Acustica, Vol. 10 No. 1, 1985
Acta Acustica, Vol. 10 No. 2, March 1985.

J. Catgut Acoustical Society, No. 43, May 1985

Contents include: **G. Caldersmith** (Australia), The violin quality debate: subjective and objective parameters — **M. E. McIntyre** and **J. Woodhouse** (U.K.), On measuring wood properties, part 2 — **J. Meyer** (Germany), The musician's subjective impression of sound on the concert platform.

Canadian Acoustics, Vol. 13 No. 2, April 1985.

Contents: G. R. Ebbeson & N. R. Chapman, Sound propagation over an isolated seamount off the Canadian west coast — **M. J. R. Lamonthe & J. S. Bradley,** Acoustical characteristics of guns as impulse sources — **R. W. Guy & A. de Mey,** Measurement of sound transmission loss by sound intensity — **H. W. Kwan & H. W. Jones,** Acoustical exploration technique for detecting oil trapped under sea ice.

Australian J. Audiology, Vol. 7 No. 1, May 1985.

TECHNICAL NOTES —

(Continued)

Implant technology is a third area of great potential. Modelling neurons as electrical networks has met with some success but tapping into the nervous system to control body function is at present at a very early stage of development. Some equipment has, however, been developed, such as a control unit for cryoanalgesia. The patient applies low level electrical signals to the skin to locate nerves generating pain. Unwanted nerve signals can then be blocked off by applying jamming electrical impulses or cryogenic probes, replacing pain killing drugs. It is also possible to implant sensory probes or capsules containing signal processing electronics so that a patient can control body function by radio link. A particularly interesting development concerns trials where blind patients control an electronic implant attached to their visual cortex.

In concluding his Presidential Address Professor James deplored the number of young engineers who turn to careers in computing rather than in analogue hardware design.There is a rapidly decreasing number of people who can turn a concept into a design that can be mass produced with a good degree of reliability; this is perhaps a fault of the engineering profession, which perceives good career progress as moving away from "hands on" experience to management roles. What a contrast, commented Professor James, with the medical profession, in which it is the surgeons who daily work with their hands who receive greatest respect and reward.

— *Sally Croft*
(in Physics Bulletin, Jan. 1985)

Underwater Concerts

As the clock struck midnight in Valencia, California, some 160 sophisticated concertgoers floated like jellyfish in the College of the Canyons swimming pool.

It looked quite pointless from poolside, because the music they heard was underwater, absorbed as much through the listeners' heads as through their ears.

This was the final concert of the evening at the eighth annual Contemporary Music Festival of the California Institute of the Arts. The festival features composers who are experimenting with new musical ideas.

But none is striking out in a direction as different as Michel Redolfi, composer and conductor of "Sonic Waters".

One hears differently in the water. The eardrums play a minimal role. Instead, according to Mr. Redolfi, the sound is picked up largely through the bones of the head. This means that regardless of where the swimmer is or what direction he is facing, the music seems to come from the nape of the neck, where bones are thin.

The sounds of flutes, harps, synthesizers and trumpets are crisp and pure underwater. And these are the sounds of "Sonic Waters".

On the other hand, bass frequencies are difficult to use in water. They require more voltage than Redolfi feels entirely safe using in the water. It's a problem he is trying to solve.

Percussion doesn't transmit well in the water, either. It's dull and flat, as if heard from behind a wall. But Redolfi claims that sharp rhythms are annoying when one is floating in the water. Rhythm is related in gravity, and in the water gravity isn't strongly felt. So his music uses rhythm in surges like the surf.

With all the possibilities electronics offers for new kinds of musical performance, he says, "I think it's a waste of time to concentrate entirely on the concert hall."

Once a part of France's new-music composing establishment, which clusters around various academic institutes, Redolfi has spent the past three years at the Center for Musical Experiment at the University of California at San Diego. Here he has written music to be heard through water, researched underwater acoustics, and developed aquatic sound equipment.

He has put on some 40 concerts so far. He has toured the country playing swimming pools, and two concerts have been in the ocean. Last September he held a concert in an underwater park in a cove in La Jolla, CA. Listeners swam and dove while Redolfi's music was broadcast from a 10-foot wide float he calls a jellyfish, bobbing in the centre of the cove.

(Extracted from J.Acoust.Soc.Am. Aug. 1983, original article in Christian Science Monitor)

LETTERS —

The "Grandfather" Clause

At two Annual General Meetings of the Australian Acoustical Society motions to remove Clause 16 (d) from the Memorandum and Articles of Association have been defeated. As 16 (d) is the so-called "grandfather" clause which allows anyone with verified practical or theoretical experience in acoustics to become a Member of the Acoustical Society, removal of that Clause would effectively change the Society from a learned one to a Professional Institution. In my opinion (see The Bulletin, **10**, pp. 114-116, 1982) this change would be an unfortunate one.

I would like to point out to members of the Society that since the Annual General Meeting at Cowes in 1981 the Council of the Society has been resisting attempts to bring in new members using Clause 16 (d). As this is discriminating (it could lead to legal action against the Society), and also contrary to the wishes of the majority of members at two Annual General Meetings, I would like to make members aware of the situation and request that the Council of the Society apply Clause 16 (d) or change it in a way that is acceptable to a majority of members of the Society.

Fergus Fricke

Senior Lecturer
Department of Architectural Science
University of Sydney
10 April 1985

THESES —

The use of vibration measurements to monitor the condition of the die in the die box in the steel wire drawing process

Sergije Hlistunov
M.Sc. (Acoust.) Project Report, University of New South Wales

Summary

The use of vibration monitoring to assess the mechanical integrity of components in a manufacturing facility where motion occurs is reviewed. The operation of a steel wiredrawing process is described with particular emphasis on wear mechanisms and how vibration monitoring can be used in this situation.

An accelerometer was used to monitor the vibration of the die assembly in a steel wiredrawing unit by tape recording at selected times the output of the transducer and subsequently the acquired data was analysed in the frequency domain by computing the power spectral density. The power spectral densities and quantities derived from them such as the mean, median and variances, were examined for correlations with the various physical parameters associated with the wiredrawing process such as tensile strength, die wear (the parameter of real interest), wire speed, wire diameter, etc. The results showed general trends, however, since the wire speed was observed to be a dominating factor, it was difficult to assess die wear using the observed data, although a new die did tend to give a broader spectrum at lower frequencies than a worn die. A very exhaustive investigation using 100 per cent monitoring of vibration and other parameters would be required to determine definitely if die wear can be assessed by vibration monitoring.

1st S.A. Congress

Pretoria, South Africa
October 2-4, 1985

To celebrate its **tenth anniversary**, The South African Acoustics Institute (SAAI) is organizing the **First South African Congress on Acoustics.**

For the past ten years the annual SAAI conference has been restricted to a particular topic. Now the SAAI, in association with a number of organizations representing a broad spectrum of interest in acoustics, is offering all interested parties the opportunity to discuss their particular fields.

In addition to Contributed and Invited Papers, Technical Visits, an Exhibition and Social Functions will be organised. The Registration Fee will be approximately R250.

Further details:

Symposium Secretariat S.379
CSIR, PO Box 395, Pretoria
RSA 0001
Telephone (012) 86-9211
x 3576/2077

ADVERTISER INDEX

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

INFORMATION for CONTRIBUTORS

Articles for publication in The Bulletin may be of two types:

(a) Short articles which will appear as a Report or Technical Note;

(b) Long articles which may take the form of a discussion, review, tutorial or technical paper. A referee's report will be sought for the latter.

Forthcoming closing dates for the receipt of these articles are as follows:

Vol. 13, No. 3 — Long articles: September 13 — Short articles: October 25.

Vol. 14, No. 1 — Long articles: January 10 — Short articles: February 21.

Contributions should be sent directly to the Chief Editor. **Manuscripts should be typed with double spacing and should have ample side margins.**

Articles should include a title, author's name, address and organisation (if applicable), and, in the case of long articles, be accompanied by an abstract of approximately 200 words.

The **body of the text** should be divided into numbered sections and preferably contain frequent subheadings, which greatly assist the reader in following the development of the paper. Any standard system of referencing is acceptable.

To assist the printer, footnotes should be avoided. Instead, place additional material in brackets or include in reference section. Equations, tables and figures should be numbered sequentially. A list of captions for figures should be supplied on a separate sheet. **It is recommended that captions give a complete explanation for each figure,** thus obviating the need to refer to the text for identifying details.

Drawings and **photographs** may be prepared to any convenient size and will normally be reduced to single column width. **Authors are requested to plan the proportions of diagrams so that they will fit preferably into a single column width.** Drawings should be supplied with complete lettering. Captions will be added by the printer. Please allow for the proportional reduction in size and thickness of the lettering. In general, typed lettering is unsatisfactory.

Reprints of papers may be ordered prior to publication by request to the Chief Editor.

FUTURE EVENTS —

● Indicates an Australian Conference

1985

September 12-13, LONDON

3rd INTERNATIONAL MEETING ON LOW FREQUENCY NOISE & VIBRATION
Details: Conference Secretariat LF85, 107 High Street, Brentwood, Essex, U.K.

September 18-20, MUNICH

INTER-NOISE 85
14th International Conference on Noise Control Engineering.
Details: INTER-NOISE 85 Secretariat, c/- VDI-Kommission Larmminderung, Postfach 1139, D-4000 Dusseldorf 1, Federal Republic of Germany.

September 23-26, SENLIS, FRANCE

2nd INTERNATIONAL CONGRESS ON ACOUSTIC INTENSITY.
Details: Dr. M. Brockhoff, CETIM, BP 67, F-60300 Senlis, France.
(See Vol. 13 No. 1 p. 6).

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 22-24, PENNSYLVANIA

4th Conference on AE/MS in Geological Structures and Materials.
Details: Prof. H. R. Hardy Jnr., College of Earth & Mineral Sciences, Dept. of Engineering, Pennsylvania State University, 104 Mineral Sciences Building, University Park, PENNSYLVANIA 16802.

● 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.

October 28-November 1, NEVADA

2nd International Conference on Acoustic Emission
Details: Alan T. Green, Conference Chairman, C/- AE Technology Corp., 1812J Tribute Road, Sacramento CA 95815, U.S.A.

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 Aust. News this issue).

November 23-30, 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.
(See Intnl News this issue).

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

March 24-26, LONDON

INTERNATIONAL CONFERENCE ON SPEECH INPUT/OUTPUT
Techniques and Applications
Details: Conference Services, IEE, Savoy Place, London WC2R OBL, U.K.

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 Vol. 13 No. 1 p. 6).

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 Acoustooptics 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 15-21, BRAZIL

4th BRAZILIAN ACOUSTICAL SYMPOSIUM
Details: Brazilian Acoustical Assoc.- ABRAC, Avenida Ataulfo de Paiva, 1079-Grupo 405, Leblon-CEP 22.440, RIO DE JANEIRO.

July 24 - Aug. 1, TORONTO

12th ICA
Details: 12th ICA Secretariat, Box 123, Station 'Q', Toronto, Canada M4T 2L7.
(See Intnl News this issue).

August 24-28, PRAGUE

18th INTERNATIONAL CONGRESS OF AUDIOLOGY
Details: Czechoslovak Medical Society J. E. Purkyne, "18th International Congress of Audiology", tr. Vitezneho unora 31, 120 26 Praha 2, CZECHOSLOVAKIA.
(See Internl News this issue).

September, HUNGARY

6th FASE SYMPOSIUM
"Subjective evaluation of objective acoustical phenomena"
Details: Prof. T. Tarnoczy, Acoustics Laboratories, P.O. Box 132, 1502 BUDAPEST.

● 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.

October 21-24, TOKYO

8th International Acoustic Emission Symposium Call for papers; deadline March 1986.
Details: Prof. Dr. K. Yamaguchi, Institute of Industrial Science, University of Tokyo, 22.1 Roppongi-7, Minato-ku, TOKYO 106, JAPAN.
(See Vol. 13 No. 1 p. 5).

December 8-12, CALIFORNIA

MEETING OF THE ACOUSTICAL SOCIETY OF AMERICA
Chairman: Alan H. Marsh, DyTec Engineering Inc., 5092 Tasman Drive, Huntington Beach, CA 92649, U.S.A.

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