# THE BULLETIN

# OF THE

# AUSTRALIAN ACOUSTICAL SOCIETY

Volume 6, Numbers 1 & 2, March/June 1978

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# THE BULLETIN

## OF THE
## AUSTRALIAN ACOUSTICAL SOCIETY

# FROM THE PRESIDENT

FROM THE PRESIDENT

I expect that all members are aware by now that the 10th International Congress on Acoustics has been awarded to Australia and that it will be held in Sydney in July, 1980 with satellite conferences in Perth and Adelaide. However some of you may not have paused to consider the importance of this forthcoming event to the Society and the boost that it is expected to give acoustics in this part of the world.

As the congresses are conducted under the auspices of the International Commission on Acoustics the attention of many of the world's most eminent acoustic research scientists will be focussed on this country. However this should not deter anyone who has something to say from presenting a paper or participating in the other events that the congress has to offer. Whilst some scientific papers will be on a high plane it is the policy of the I.C.A. to ensure that the majority will be of general interest and be presented in simple terms. In short there will be something for every one of the thousand or more delegates expected to attend.

It will be apparent that the 10th I.C.A. provides us with a wonderful opportunity to strengthen the Society and to establish a reputation among the acoustic institutions around the world. Already our organising committees are putting a great deal of time and effort into the preparations. Whilst the members of those committees are so deeply involved every other member can play his or her part by stimulating interest generally and by looking for new members.

The future of the Society rests with you.

Gerald Riley
PRESIDENT

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*– The Bulletin is published quarterly by the Australian Acoustical Society, Science House, 157 Gloucester Street, Sydney, NSW, 2000*

# SUSTAINING MEMBERS
## OF THE AUSTRALIAN ACOUSTICAL SOCIETY

The Society values greatly the support given by the Sustaining Members listed below and invites enquiries regarding Sustaining Membership from other individuals or corporations who are interested in the welfare of the Society. Any person or corporation contributing $160.00 or more annually may be elected a Sustaining Member of the Society. Enquiries regarding membership may be made to The Secretary, Australian Acoustical Society, Science House, 35-43 Clarence Street, Sydney. NSW, 2000.

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# GUEST EDITORIAL

## HEARING CONSERVATION IN INDUSTRY

Heavy industry employers in Australia should have progressed past basic safety programmes to overall employee health care programmes and a vital inclusion in these must be the protection of their employees' hearing. There are very few heavy industries which do not produce noise levels which cause hearing impairment and thus it should be understood that those which do not conduct hearing conservation programmes are not fulfilling their proper obligations as responsible employers. Such employers should also be aware that they will very shortly be forced by legislation, right throughout Australia, to implement such measures.

It is not sufficient for senior company management to respond to an obligation imposed upon them purely by legislation or by escalating compensation costs in the implementation of a hearing conservation programme. There must be a realisation that the protection of employees' hearing is vitally necessary from moral, practical, productivity, financial and legal bases. Further, this realisation will only come to fruition through an absolute management commitment at the highest possible levels. This being the case then the natural progression is to utilize all of their resources in the implementation of such a programme, using already available expertise or when necessary, being prepared to employ or retain people with the necessary knowledge from outside their particular industry or firm.

It is widely accepted that any effective hearing conservation programme has two main thrusts. The most important of these is a planned engineering campaign to reduce or control existing noise sources and to ensure that future installations meet stringent emission criterion. In this regard progressive companies are issuing printed noise control specifications with all equipment and plant tenders. Manufacturers and suppliers throughout our country are experiencing real difficulties in meeting such specifications; however, continued pressure by the end-users should ensure a gradual change in design attitude by many machinery manufacturers. In the engineering arena the most troublesome facet is the modification of existing machinery. The steel industry in particular is still operating some units which commenced in the 1920's and 30's and attempts to control noise sources in these units have proved almost impossible.

There appears to be concern amongst many heavy industry companies that to embark on a noise control programme will lead them along a path of no return with attendant costs which will be out of all proportion to their normal overheads. Such attitudes are archaic and seem to indicate a lack of genuine intent on the part of employers to accept their real responsibilities in the fields of safety, health and welfare.

Naturally, the proper foundation to any engineering campaign is complete noise source monitoring and this work should only be carried out by competent persons qualified in this field using reliable, accurate equipment. Some large companies have established sound level metering as the full-time responsibility of a mechanical or services engineer. In the steel industry it has been found that plant monitoring is an on-going necessity as there are many aspects of change in steel processing which will markedly alter the generated noise levels.

Because of existing and intended legislation it is becoming increasingly important to establish actual employee exposure stated as a Daily Noise Dose or Index. This is best done by using personal dosimeters in conjunction with sound level meters. It must be appreciated that ALL monitoring which is being carried out in-plant should be fully and openly explained to the employees in the test areas as any misunderstanding or distrust on their part of the measuring can lead to industrial relations problems.

The second front to a Hearing Conservation Programme involves the aspects of employee education, audiometry, medical examination and workers' compensation. In most heavy industries it has been found that this education and protection segment of a hearing conservation programme is more easily commenced because of the engineering difficulties mentioned previously.

It should be stated from the outset that a completely honest and open approach must be taken in any hearing conservation education efforts, again because of the possibility of distrust on the part of employees if total explanations are not given. One example of this approach is by John Lysaght (Australia) Limited at its Port Kembla Plant, where hearing conservation education sessions are conducted on Monday mornings for employees who ceased work on the previous Friday. These employees have been free of exposure to industrial noise for that period and although in modern times there are obviously high social levels of noise to which they are exposed over the weekend, it nevertheless improves the chances of audiometric testing early on Monday morning being reasonably valid. During these education sessions officers of the Safety, Medical and Workers' Compensation Department explain all aspects of the hearing conservation programme to employees. Also, each participant is individually audiometrically tested and the results of their audiogramme explained to them immediately after testing. Where an employee has a loss which appears to be compensatable the Company offers to process a compensation claim for the employee if such action is desired. It is difficult to divide workers' compensation payment responsibility from a fully integrated hearing conservation programme and in fact some compensation action is inevitable when a programme is commenced. Nevertheless, companies must appreciate, together with their insurance companies, that it is economically feasible to deal with the claims now rather than at some time in the future when two points are almost inevitable. The first is the increase in workers' compensation payments for this type of disability and the second is a probable further loss on the part of the employee if hearing conservation is avoided.

The concern on the part of employers who are considering introduction of hearing conservation programmes often manifests in the problem of payment of lump sum workers' compensation claims. It must be appreciated that such claims form a continuing liability of inevitable increase and although some programmes on commencement have brought about a large number of claims, this should only prove the need of commencing a hearing conservation programme now, rather than waiting for the inevitable to occur.

E. W. TOBIN
John Lysaght (Australia) Limited.

# NEWS & NOTES

## NEW JOURNALS

That Acoustics is still thriving can be judged by the number of publications on the subject. Besides the text-books (which are appearing at the rate of about one a week) there are new journals still appearing. Two of the most recent journals to appear are 'Archives of Acoustics' and 'Acoustics Letters'.

Archives of Acoustics is the English version of the quarterly ARCHIWUM AKUSTYKI, published by the Polish Academy of Science. In presenting the first issue of Archives of Acoustics the Editor hopes that it will stimulate the co-operation of Polish and foreign acousticians. Contributions from countries other than Poland are welcome. The annual subscription rate is US$28. The editor is Dr. Stefan Czarnecki and the Editorial Office address is:

Palac Kultury i Nauki
00-901 Warszawa,
Poland

Subscriptions to:

ARS POLONA
Krakowskie Przedmiescie 7
00-068 Warszawa
Poland

Acoustics Letters is a 'continuous stream' publication, which will enable preliminary reports, new results and brief communications in all fields of acoustics to be distributed with greater speed. Each subscriber is furnished with a binder and letters are sent at frequent intervals. Contributions should be sent to Dr. J. C. Scott, Fluid Mechanics Research Institute, University of Essex, Colchester CO4 3SQ, Essex, England. The subscription rate is US$60.00 or US$15.00 (!) for an individual wishing to subscribe. Subscriptions and requests for samples should be sent to

Multi-Science Publishing Co. Ltd.
The Old Mill
Dorset Place
London E15 1DJ
England.

## NOISE AND STRUCTURAL RESONANCES IN INDUSTRIAL EQUIPMENT

What began as an interest in noise problems caused by air flowing past truck radiators has developed into a basic research programme that may eventually help design engineers prevent structural failures in large power-generating plants.

When air flows past a series of tubes, like those in car or truck radiators, air flow is disrupted and a humming noise can develop. With some designs, this noise becomes annoying and can even cause discomfort.

The fluid dynamics of the problem are complicated, and at present each case must be treated on a trial and error basis. There is an acute lack of experimental information about the problem and as yet there is no universal approach to solving it. But according to Mr. Martin Welsh and Dr. Don Gibson, it should be possible to provide one.

*Acoustic resonance wind tunnel*

Their first step was to simplify the problem as far as possible. Even a single tube or bar in a duct will produce a whistling sound as air flows by. Martin Welsh has therefore designed and built a wind tunnel to study the way this single bar disrupts air flow and generates sound.

As air moves past the bar, the bar sheds vortices — small eddies of air — that in certain circumstances are reinforced in the duct to give a resonating tone. The tone is caused by reflection of sound off the duct walls and not by vibration of the bar itself. In the laboratory, noise from even a single bar can be so loud that the experimenters must wear ear muffs.

The phenomenon can also cause structural fatigue and failure, since the resonant tone is actually a fluctuating pressure that causes a fluctuating force on the bar. This in turn can cause stress and structural fatigue in the bar. Welsh and Gibson hope eventually to provide information that will help prevent both the noise and fatigue problems.

According to Welsh, many theories have been proposed about vortex shedding, but there is little detailed experimental data on the resonant phenomenon. The wind tunnel being used for the Division's study was built using very fine tolerances, so that this detail can be obtained.

Welsh can vary the position of the bar in the duct, and he can vary the angle and speed at which the air stream strikes the bar. Experimental information is collected automatically under the control of a microprocessor, or a correlation and probability analyser. All experimental readings are fed eventually into the CSIRO's SIRONET computer system for analysis.

*Reprinted from CSIRO Eng Events.*

## TEXTBOOKS: CHEAPER AT HALF THE PRICE

As a professional institution the Australian Acoustical Society recognizes it has an obligation to its members, and the community in general, to ensure that its members are professionally competent. Part of this competence comes through continuing education, and self-education, through reading, is an important aspect of this.

At present a text-book retailed in Australia is markedly more expensive than the same book bought in Europe or North America. The Australian Acoustical Society is aware that its members need to buy books and should buy books. It has therefore decided to provide a further service to its members to reduce the financial burden of self-education. The Society has arranged to supply books, to its members, at substantial discounts.

How will the scheme operate? From time to time booklists and prices will be sent to members. If a member wishes to buy one of these books he should send his request, with a cheque or postal order made payable to, "The Australian Acoustical Society", to:

Bruce Gore
Education Sub-Committee Convenor
Australian Acoustical Society
C/– Science House,
35 Clarence Street,
Sydney, N.S.W. 2000

If a member wishes to purchase a book which has not been included in the Society's booklist, he should send a request for a price to Bruce Gore, with as much of the following information as is possible:

(i) Author's name
(ii) Title of the book
(iii) International Standard Book Number (ISBN)
(iv) Publisher
(v) Date and place of publication

We commend the scheme to you and hope you will make full use of it. We also hope that members of the Acoustical Society will avail themselves of other services provided by the Society and indicate where the Society could do more for its members.

## JUMBLED HEARING CAUSES READING PROBLEMS

According to some recent educational research at Oxford, some children may be backward readers because they cannot organise properly what they hear. To read "The cat sat on the mat", you have to recognise that cat, sat and mat are the same but for the initial consonant. It is that sort of classification that readers seem to find difficult (Nature, vol 271, p 746).

L. Bradley at the Human Development Research Unit of the Park Hospital and P. E. Bryant of the Department of Experimental Psychology of Oxford University have tested 60 backward readers aged about nine and of normal intelligence, and 30 normal readers, about three years younger but having the same reading age as the backward readers (this was to compensate for differences that might be the consequence rather than the cause of backward reading).

The children were asked to select the odd one out of four words such as weed, peel, need, deed. On a number of such tasks, about 92 per cent of the nine-year-old backward readers made at least one mistake, and 85 per cent made more. Of the six-year-old normal readers, about 54 per cent made one mistake and only 27 per cent made more.

Just to check that, despite their precautions, the experimenters hadn't unconsciously provided cues in the emphasis with which they read the words out to children, they ran another test in which the children were given a word and asked to produce one which rhymed. Again, more of the backward readers (39 per cent) failed on one or more trial than the normal readers (7 per cent), despite the difference in age.

Bradley and Bryant seem to have stumbled on a small but fundamental defect in some children whose consequences for the child's educational development could extend far beyond these early stages.

## PITCH MEMORY SEEMS SINISTER

Left handed people are supposed to have more reading difficulties and poorer visual and spatial ability than right handers. But new evidence suggests that when it comes to remembering musical notes they are better than right handers (Science, vol 199, p 559).

Diana Deutsch of the University of California at San Diego was collecting subjects who had very good pitch memory for an experiment. She noticed that there were too many left handers among her subjects so she measured the pitch memory and handedness of 129 unselected undergraduates.

Deutsch measured pitch memory by presenting a pure test tone followed by six other tones and then a second test tone. The subject has to say whether the two test tones are the same or different: 24 tests were given to each participant. She measured handedness with a standard test that reveals which hand a person prefers and how strongly.

As a group the left handers made significantly fewer errors than the right handers but there was also more spread in the number of errors made by the left handers. Deutsch thought that the spread might occur because strong left handers differ from moderate left handers. When she divided the left and right handers into strong and moderate subgroups she found that it was the moderate left handers who made the fewest errors — the other three did not differ from each other.

Why are moderately left handed people better? Deutsch believes it is because their brains are less rigidly divided into dominant and nondominant hemispheres. Pitch memory would then be stored on both sides of the brain and there would be less chance of making an error. It is too early to say why moderate right handers don't have the same advantage but it is clear that handedness researchers should not treat people with weak hand preferences as a single "ambidextrous" group.

*From New Scientist 23rd February, 1978.*

## UNIVERSITY OF ADELAIDE

**Activities of the Department of Mechanical Engineering**

The Department of Labour and Industry of South Australia has awarded a grant for industrial noise control research to the Department of Mechanical Engineering of the University of Adelaide. It is expected that the grant will be used along lines which will help South Australian industry to meet existing and anticipated noise regulations both for the purpose of hearing conservation and for community acceptance. The programme has been in operation for approximately 15 months. Some of the work carried out in the Department of Mechanical Engineering with the sponsorship of this grant is here briefly summarised.

With the active co-operation of Hills Industries the use of shear in the design of a thirty six hole punch has been investigated by Mr. Ewin Semple and Mr. Colin Hansen. They found it was possible to reduce noise levels at the operator's position by 10 dBA by grinding the punch so that the individual punches penetrate the metal sequentially, and the differential height between the lowest and highest punch was equal to the thickness of the metal punched. Grinding the punch to the requirement for noise reduction is easily accomplished with very little extra time required. Extension of the basic idea to other punches is now being investigated.

Noise control for circular saws has been the subject of continuous investigation by Dr. Manfred Zockel and Mr. Stewert Page. They have shown that aerodynamic noise associated with air flow over the teeth, and surface noise associated with resonant vibration of the blade are two important sources controlling noise from circular saws. The aerodynamic noise is found to increase approximately 15 dBA with each doubling of the blade tip speed, and to be predictable for all types of blades within plus or minus 2 dBA. The prediction depends solely upon the tip speed and the extent to which the teeth extend laterally past the surface of the blade. For high speed saws the aerodynamic noise controls, but for tip speeds less than about 60 m/sec the blade surface noise becomes important. In this latter case noise reductions of the order of 10 to 15 dBA have been achieved using blade vibration damping. Various damping techniques have been investigated and these have been rank ordered in terms of ease of application, cost, and effectiveness for various noise control applications. This work is continuing.

A systematic programme has been undertaken to measure and catalogue information about flow resistance for all Australian made porous materials used for sound absorption, and in addition a large number of "foam" products have been tested. To make this information useful, various design procedures, which depend solely upon such data are being assembled. These procedures range over the design of ordinary liners for dissipative mufflers, procedures for estimating increase in transmission loss for acoustic baffles, and procedures for estimating random incidence absorption coefficients. This work is being carried out by Dr. David Bies.

In addition to the above activities the design of both reactive and dissipative type mufflers has been the subject of continuing investigation within the Department. The reactive device which depends upon the generation of higher order modes below their cut-off has motivated very careful consideration of the effects of flow upon the propagation of higher order modes. This work has been the subject of a Ph.D. thesis by Mr. Chris Fuller under the direction of Dr. David Bies. The work on the optimisation of dissipative mufflers is based upon an extension of the well known Morse-Cremer analysis which takes account of the effect of flow, and has been carried out by Dr. Manfred Zockel and Dr. David Bies. Currently, what has been learned from this work is being used in an attempt to develop an optimal muffler for a window type air conditioner.

Two former post graduates in the Department of Mechanical Engineering, Peter Swift and David Rennison, recently received the degree of Doctor of Philosophy with specialties in acoustics. Mr. Renzo Tovin has submitted his thesis for the degree of Doctor of Philosophy, and he is currently 'on the road' with the Hijacks now playing in Sydney. Mr. Chris Fuller plans to submit his Ph.D. thesis presently, and has taken a post for a year at Southampton. Dr. David Bies plans to spend six months study leave beginning in July 1978 in the United States, coming abreast of the latest developments in industrial noise control in that country.

## UNIVERSITY OF NEW SOUTH WALES, Graduate School of the Built Environment Master of Science (Acoustics) degree course.

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

The course is normally taken over four part-time sessions (two academic years). A new intake will be made in 1979.

Enquiries should be addressed to the Head, Graduate School of the Built Environment, UNSW, P.O. Box 1, Kensington, N.S.W. 2033 Australia. (02) 662 2301.

## INTERNATIONAL ACOUSTICS EVENTS

The following information on conferences and symposia has been supplied by:

International Commission on Acoustics (ICA)
Information Service
C/- Acoustical Commission of the Czechoslovak
Academy of Sciences
Plzenska 66, 151 24 Prague 5

### 1978

**Argentine:**

Spring 1978, Buenos Aires
"Symposium on Electroacoustics" and
"Symposium on Building Acoustics"
Details from:
Associacion de Acusticos Argentinos
Casilla de Correo 157
San Martin (Pcia. de Bs. As.)

**Belgium:**

Novembre 1978, Louvain
"Symposium: Isolation acoustique des parois legeres dans les moyens de transport"
Prof. P. Chapelle,
Secretaire de l'A.B.A.V.
rue de Houdain,
7000 Mons

**Hawaii:**

27 November to 1 December 1978
Joint Meeting: Acoustical Society of America and Acoustical Society of Japan

**United Kingdom:**

22 September, London
"Development of Language in Hearing Impaired Children"
Details from:
M. C. Martin, Hon. Secretary of the BSA
C/- R.N.I.D.
105 Gower Street
London WCIE 6AH

**United Kingdom:**

20 October 1978, Liverpool University
"Calibration and Standards in Audiometry"
Details from:
Miss E. C. Knox,
Myrtle Bank,
Clarke Street,
Airdria, Lanarkshire

### 1979

**Denmark:**

6-11 August 1979, Copenhagen
"Ninth International Congress of Phonetic Sciences"
Details from:
Prof. E. Fischer-Jorgensen
ICPhS Secretariat
Kongestein 45
DK-2830 Virum

**Poland:**

11-14 September 1979, Warsaw
"Internoise 79"
Details from:
Prof. S. Czarnecki
IPPT-PAN
Swietokrzyska 21
00-049 Warsaw

**United Kingdom:**

18-20 July 1979, Manchester University
"Conference of the British Society of Audiology. (BSA)"
Main topics: Paediatric Audiometry, Communication (incl. hearing aids), Noise induced hearing loss, Rehabilitation of hearing impaired adults, Vestibular tests
Details from:
M. C. Martin,
Hon. Secretary of the BSA,
C/- R.N.I.D.
105 Gower Street,
London WC1E 6 AH

### 1980

**Hungary:**

Spring 1980, Budapest
"5th Colloquium on Acoustics – Speech Ac."
by
Acoustical Communication of Hungarian Academy of Sciences,
Prof. T. Tarnoczy,
P.O. Box 132,
H-1502 Budapest 112

**Poland:**

September 1980, Warsaw
"Seminary of Acoustics"
Organized by:
The Polish Acoustical Society
ul.Matejki 48/49,
60-769 Poznan.

## FASE 78

The Second Congress of the Federation of Acoustical Societies of Europe is to be organized by the Acoustical Committee of the Polish Academy of Sciences and the Polish Acoustical Society in collaboration with the Institute of Fundamental Technological Research/IPPT-PAN/.

The Congress will be held in the conference rooms of the Palace of Culture and Science located in the centre of Warsaw. It will start on Monday 18th September 1978.

The Scientific programme will cover the following subjects:

1. *ACOUSTIC WAVES AND THE STRUCTURE OF MATTER*

- molecular acoustics of fluids

- acoustical investigation of the physical properties of solids
- acoustics of inhomogeneous media

2. *ULTRASONIC METHODS OF LOCATION AND RECOGNITION*

- nondestructive testing
- medical diagnostics
- geological prospection
- hydroacoustics

3. *OBJECTIVE AND SUBJECTIVE EVALUATION OF SOUND IN A LIMITED SPACE*

- concert halls and auditoria
- industrial halls
- urban areas

Authors should send offers of papers before 10 December 1977. Each offer should include the authors name and address, the title of the paper and a short summary. The papers will be published in the language of submission. For the optimum international accessibility of your paper the use of the English language is suggested. The verbal presentation during the sessions can be given in English, Russian, French or German – there will be simultaneous translation.

The Conference Proceedings will be issued to all participants at the beginning of the Congress.

There will be plenary sessions, round table discussions and three parallel technical sessions, with the following forms of paper presentation being foreseen:

- invited lectures
- contributed papers

Authors willing to present their papers in poster form will have 5 minutes to present their work during the session for contributed papers. Subsequently they will stay half an hour at their displays/booths of area about 4 $m^2$ to present the paper and discuss details with any interested participants. The materials for presentation may include figures, diagrams, photographs, numerical data, fragments of text etc.

The manufacturers of research equipment will have good opportunities and facilities for presenting their products. Companies interested in exhibiting are kindly requested to write to the Organizing Committee.

The registration fee is $85. It will cover the conference proceedings and the social programme/banquet included.

Final information concerning the Congress/registration forms, accommodation details, etc will be sent to all interested persons before the end of this year.

Address for correspondence:
FASE 78 Organizing Committee
IPPT-PAN, ul. Swietokrzyska 21
00-049 WARSZAWA, POLAND

## POST-PROFESSIONAL COURSE

The Graduate School of the Built Environment at the University of NSW is offering the following course:

**THE NSW ORDINANCE 70 NOISE CONTROL REGULATIONS – THE FIRST FOUR YEARS**
**November 9th-10th 1978**

An assessment of the effect these regulations have had on the design and construction of multi-family dwellings as well as an evaluation of their effectiveness in protecting residents from unwanted sounds. Both private sector buildings and public low-cost housing will be included.

Speakers include architects, builders, material and component manufacturers, local government officers and acousticians.

This two-day seminar will be of interest to all those concerned with the design, construction, supervision and approval of multi-family dwellings, and material and component manufacturers.

The course fee is $60 which includes copies of lectures, together with lunches, morning and afternoon teas, and a dinner. Full details are available from:

Mrs. R. Connors,
Secretary,
Graduate School of the Built Environment,
University of NSW,
P.O. Box 1,
Kensington, NSW 2033
(Telephone 02 662 2301)

# LETTERS

## MYTHS IN ACOUSTICS AGAIN

Dear Sir,

Further to the letter of Caleb Smith (The Bulletin Vol. 5 No. 1, 1977) on the use of strung wires to control auditoria acoustics, members may be interested to read Peter Parkin's Rayleigh Gold Medal Address which was published in J. Sound and Vibration 50, 163-182, 1977. For those who may have difficulty in obtaining a copy of the address I would like to quote one relevant part.

". . . in my more cynical moments I sometimes feel that the acoustics of auditoria are more a matter of public relations than anything else.

One awful warning of the difficulties of assessing the acoustics of concert halls is shown in what happened in the Royal Albert Hall in the 1890's. In his book "The Royal Albert Hall" (Hamish Hamilton, 1958) Mr. R. W. Clark says:

'Inside the Hall, things were hardly happier. The Electrophone Company, which operated a system by which subscribers could dial on an apparatus rather like a telephone and then listen to the events taking place in any of certain theatres and halls, installed their apparatus in 1896, Paying the Corporation £50 a year for the privilege. Yet what their subscribers heard was still subject to the persistent echo which during the 1890's had one of its periodic resurgences of notoriety. To cope with it, Wentworth Cole (the Manager) had wires stretched across the Hall and a length of rabbit netting suspended from each wire. 'There does not appear any doubt that these wires have proved effective in diminishing in a marked degree, if not altogether getting rid of the echo, and in effect bringing the sound of instruments and of voice, markedly nearer to the listener', he later reported. 'The opinion of the Honorary Stewards and others who have listened to music from different parts of the building, has been invited, with the result that the almost unanimous opinion is that a great benefit to the acoustic properties of the building has resulted'."

The awful warning is not the mere fact of trying the wires; they — if anything at all is certain about the acoustics of auditoria — could not possibly have had any effect, but is the "almost unanimous opinion" about the improvement."

As Parkin suggests, it seems that the conviction of the influential few is as important or even more important than the architectural details, in deciding the fate of a concert hall. Perhaps the wires would have continued to successfully transform concert halls if it hadn't been for Sabine and others who could show they had no measurable acoustic effect.

Yours faithfully,
Fergus Fricke
University of Sydney

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Dear Sir,

By this letter may I supplement published announcements, and extend to your distinguished society a cordial invitation to participate in the forthcoming joint meeting of the Acoustical Societies of America and of Japan, to be held in Honolulu, Hawaii, November 27 through December 1, 1978.

This joint meeting promises to provide an outstanding opportunity for scientific exchanges in all areas of acoustics. The technical program presently includes over 800 scientific papers. A comprehensive manufacturers' exhibit of acoustical instrumentation is also anticipated.

Members of your society will indeed be warmly received at the meeting, and we cordially invite your attendance. Detailed information, if required, can be obtained from the Executive Secretary, Acoustical Society of America, 335 East 45 Street, New York, New York 10017.

Sincerely yours,

JAMES L. FLANAGAN

President
Acoustical Society of America

## AUSTRALIAN NOISE AND VIBRATION CONFERENCES

There have now been a large number of conferences and symposia held in Australia that have had 'Acoustics' as a theme. Ron Barden has drawn up the following list of acoustical events since 1964. This provides an important record for the Australian Acoustical Society and should be of interest to many members.

### SCHEDULE OF NOISE AND VIBRATION CONFERENCES AND SYMPOSIA HELD IN AUSTRALIA 1964-1976

| | Title of Conference/Symposium | Date | Location | Responsible Organisation | Convenor/Chairman |
|---|---|---|---|---|---|
| 1. | **Symposium on Noise** | Aug. 64 | Monash University | INSTITUTION OF MECHANICAL ENGINEERS AUSTRALIAN BRANCH | Barden R. G., Holmes J. G. |
| | *Contributors: Beirs D., Keeler A., King R., Lippert W., Morgan P., Reilly R., Ross J., Roberts A., Luxton R., Carr R., Wilkinson O., Weston H.* | | | | |
| 2. | **Second Australian Building Research Congress** | Aug. 64 | Sydney | EXPERIMENTAL BUILDING STATION | Anderson, G. W. |
| | *Contributors: Nickson A. F., Weston E.* | | | | |
| 3. | **Noise in Building** | July 66 | Sydney | BUILDING SCIENCE & TECHNOLOGY | Cowan H. J., Challis L. |
| | *Contributors: Higgs A., Lawrence A., Lippert W., Mehaffey W., Knowland P., Nickson A., Piesse R., Riley G., Taylor H., Weston E., Barden R.* | | | | |
| 4. | **Third Australian Building Research Congress** | Aug. 67 | Monash University | BUILDING RESEARCH COMMITTEE | Langlands I., |
| | *Contributors: Barden R., Carr R., Drysdale J., King R., Lawrence A., Lippert W., Giley G.* | | | | |
| 5. | **Applied Mechanics Conference** | 1967 | Adelaide | I. E. AUST., NATL. COMM. ON APPLIED MECHANICS | Hunt K. H., Crisp J.D.C. |
| 6. | **Symposium on Noise in Industry** | Feb. 68 | Adelaide University | DEPARTMENTS OF PUBLIC HEALTH & LABOUR | Wilson K. J. |
| | *Contributors: Barden R., Cramond W., Cumpston A., Davis H., King R., Reilly R., Rose J., Stafford R., Weston H., Wilson K.,* | | | | |
| 7. | **International Acoustics Symposium** | Sept. 68 | Sydney | AUSTRALIAN ACOUSTICAL SOCIETY | Pollard H., Rose J. |
| | *Contributors: Carter N., Challis L., Garinther G., Hodge D., McCommons R., Jones J., Jordon W., Knowland P., Lawrence A., Mather C., Stevenson C., Weston H., Wilkinson R.* | | | | |
| 8. | **Annual Conference of Institute of Health Surveyors.** | Aug. 69 | Toorak, Victoria | INSTITUTE OF HEALTH SURVEYORS | Hawthorn N. |
| | *Contributors: Johnson C., Lawrence A., Wilson K.* | | | | |
| 9. | **Applied Mechanics Conference** | 1969 | Melbourne | I.E. AUST., NATL. COMM. ON APPLIED MECHANICS | Hunt K. H., Crisp J.D.C. |
| 10. | **Noise Symposium** | Aug. 69 | Adelaide | A.N.Z.A.A.S. | Davis H. H. |
| | *Contributors: Copplestone J., Fuller C., Irvine J., King R., O'Keefe B., Randall R., Rose J., Taylor V* | | | | |
| 11. | **Australian Acoustical Society** | Oct. 69 | Sydney | AUSTRALIAN ACOUSTICAL SOCIETY | Weston E., Rose J. |
| | *Contributors: Irvine J., King R., Lawrence A., Madden J., Weston E., Green R., Wilkinson R.* | | | | |
| 12. | **Industrial Noise** | June 70 | Monash University | SAFETY ENGINEERING SOCIETY OF AUSTRALASIA | Carr R., Barden R. G. |
| | *Contributors: Carr A., Carr R., Riley G., Stafford G., Weston H.* | | | | |
| 13. | **High Density Living & Noise** | June 70 | Sydney | INTERNATIONAL BUILDING EXHIBITION | Lawrence A., Weston E. |
| | *Contributors: Challis L., Lawrence A., Irvine J., Knowland P.* | | | | |
| 14. | **Noise Zoning Conference** | Mar. 71 | Warburton, Victoria | AUSTRALIAN ACOUSTICAL SOCIETY | Barden R. G. |
| | *Contributors: Barden R., Bryant J., Challis L., Davern W., Fouvy C., Harper J., Hawthorne N., Knowland P., Lawrence A., Ledger F., O'Keefe B., Randall R., Rose J., Taylor H., Wilkinson R.* | | | | |
| 15. | **Industrial Noise Problems & Solutions** | Oct. 71 | Monash University | THE INSTITUTION OF ENGINEERS AUSTRALIA & INSTITUTION OF MECHANICAL ENGINEERS | Barden R. G. |
| | *Contributors: Barden R., Beynon T., King R., Prescord D.* | | | | |
| 16. | **Noise Legislation & Regulation Conference** | Terrigal, N.S.W. | | AUSTRALIAN ACOUSTICAL SOCIETY | Mason V. |
| | *Contributors: Cottier K., Ferrari J., Hunt M., Johnson C., Hemmings N., Knowland P., Lanteri A., Mather C., McCullough S., Mason V., Martin P., Moore V., Reilly R., Satory R., Sawley R., Steele W., Weston H.* | | | | |
| 17. | **Noise and the Environment** | Oct. 72 | Sydney | STANDARDS ASSOCIATION AUSTRALIA | Barden R. G., Mearns R. B. |
| | *Contributors: Bear V., Hawthorne N., Taylor H., Walton G., Weston H.* | | | | |
| 18. | **Noise and the Environment** | Nov. 72 | Melbourne | STANDARDS ASSOCIATION AUSTRALIA | Barden R. G., Mearns R. B. |
| | *Contributors: Hawthorne N., McMahon D., Snow R., Taylor H., Walton G.* | | | | |

| Title of Conference/Symposium | Date | Location | Responsible Organisation | Convenor/Chairman |
|---|---|---|---|---|
| 19. **Noise Symposium**<br>*Contributors: King R., Lawrence A., Reilly N., Stafford G., Wilson K.* | 72 | Adelaide | STANDARDS ASSOCIATION AUSTRALIA | Barden R. G., Mearns R. B. |
| 20. **Environment Conference**<br>*Contributors: Lawrence A., Taylor H.* | Feb. 73 | Sydney | DEPARTMENT OF THE ENVIRONMENT | |
| 21. **Noise and the Environment**<br>*Contributors: Barden R., Chenco G., Hawthorne N., Reilly R., Taylor H.* | 73 | Adelaide | STANDARDS ASSOCIATION AUSTRALIA | Wilson K., Mearns R. |
| 22. **45th ANZAAS Congress**<br>*Contributors: Barden R., Chenco G., Dubout P., Hawthorn N., Mather C., Taylor H.* | Aug. 73 | Perth | ANZAAS, STANDARDS ASSOCIATION OF AUSTRALIA, W.A. CHAMBER OF MANUFACTURES | Mather C. |
| 23. **Sound Sense Symposium**<br>*Contributors: Anderson J., Challis L., Keen K., Snow R., Weston H.* | Sept. 73 | Sydney | N.A.T.A. | Lane J. C., Taylor H. V. |
| 24. **Sound & Vibration in Pump Applications**<br>*Contributors: Aggett J., Addie G., McCormack J., Mearns R., Ross A.* | Oct. 73 | Sydney | AUSTRALIAN PUMP MANUFACTURES ASSOCIATION | Swift R. J. |
| 25. **Noise Shock & Vibration Conference**<br>*Contributors: Alfredson R., Andrews M., Beranek L., Berren T., Bhattacharyya A., Bies D., Bishop R., Bremhorst K., Brown G., Bull M., Chan S., Clarke N., Crisp J., Deb S., Dore R., Dransfield P., Dunlop J., Eshleman R., Fidel S., Frungle G., Gambling K., Hahn E., Harch W., Hooker R., Iyengar N., Jones R., Jullien Y., Ko Wah Man N., Koss L., Laki A., Lewis R., Longstaf B., McCormick M., McRae G., Macinante J., Mason D., Mazumder J., Mullick B., Nigam N., Parker B., Pandolai K., Patzke H., Patki G., Pattabiraman J., Prasad M., Pickles J., Price G., Raghaven K., Rao V., Randall R., Raymond W., Rennison D., Rice C., Rumble R., Rossiter P., Samuals S., Saunders R., Schafer B., Shankara T., Simandim S., Sokal Y., Stecki J., Stevens T., Sundararajan V., Taylor I., Triggs T., Tondl A., Ward W., Wilkins P., Yadav D., Yeh C., Yeh L.* | Sept. 74 | Monash University | MONASH UNIVERSITY<br>THE INSTITUTION OF ENGINEERS AUST<br>AUSTRALIAN ACOUSTICAL SOCIETY | Barden R. G., Crisp J.D.C. |
| 26. **Symposium on Noise**<br>*Contributors: Chenco G., Lawrence A., Moffatt J., Snow R., Taylor H., Weston H.* | Oct. 74 | Melbourne | N.A.T.A.<br>AUSTRALIAN ACOUSTICAL SOCIETY | Barden R.G., Mearns R.D. |
| 27. **Noise in Fluid Power Systems**<br>*Contributors: Alfredson R., Delcore J., Kemp D., Harding G.* | Nov. 74 | Monash University | FLUID POWER SOCIETY | Howe J., Dransfield P. |
| 28. **Industrial Noise Symposium**<br>*Contributors: Bull M., Chenco G., Karben E., King R., Stafford G., Taylor H.,* | April 75 | Adelaide | N.A.T.A. | Wilson K., Hunt G. V. |
| 29. **Industrial Noise**<br>*Contributors: Beynon T., McMahon D., Moffatt J., Moroney S.* | June 75 | Melbourne | VICTORIAN EMPLOYERS FEDERATION | Ramsay J. |
| 30. **Fifth Australian Building Research Congress**<br>*Contributors: Dubout P., Weston E.,* | July 75 | Melbourne | CSIRO DIVISION OF BUILDING RESEARCH | Blakey, F. A., |
| 31. **Conference Planning for Noise**<br>*Contributors: Carr R., Dubout P., Lawrence A., Mason V., Mather C., Rose J., Satory R., Weston H., Wilkinson R.* | Sept 75 | Medlow Bath, N.S.W. | AUSTRALIAN ACOUSTICAL SOCIETY | Carr R. J. |
| 32. **Symposium on Industrial Noise**<br>*Contributors: Chalk G., Hooker R., Macey D., Mason V., Middleton W., Rumble R.* | Mar. 76 | Brisbane | N.A.T.A. | |
| 33. **Acoustics**<br>*Contributors:* | Sept. 76 | Melbourne | AUSTRALIAN ACOUSTICAL SOCIETY | |
| 34. **Vibration & Noise Control Conference**<br>*Contributors:* | Oct. 76 | Sydney | THE INSTITUTION OF ENGINEERS AUSTRALIA | Macinante J. |

| Title of Conference/Symposium | Date | Location | Responsible Organisation | Convenor/Chairman |
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| Title of Conference/Symposium | Date | Location | Responsible Organisation | Convenor/Chairman |
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| Title of Conference/Symposium | Date | Location | Responsible Organisation | Convenor/Chairman |
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# PEOPLE AND PLACES

**OHM, GEORG SIMON** (1787-1854), German physicist, was born at Erlangen on March 16, 1787, and was educated at the university there. He became professor of mathematics in the Jesuits' college at Cologne in 1817, and in the polytechnic school of Nuremberg in 1833. In 1849 he was appointed conservator of the physical collection at Munich, and in 1852 professor of experimental physics in the high school of Munich, where he died of apoplexy on July 7, 1854. His writings were numerous, but, with one important exception, not of the first order. The exception is his pamphlet, published in Berlin in 1827, with the title *Die galvanische Kette mathematisch bearbeitet. This work, the* germs of which had appeared during the two preceding years in the journals of Schweigger and Poggendorff, has exerted a great influence on the whole development of the theory and applications of current electricity. (*See* ELECTRICITY.) The most important part of the pamphlet is summarized in what is now known as Ohm's Law. (*See* RESISTANCE, MEASUREMENT OF.) This work was so coldly received that Ohm's susceptibilities were hurt, and he resigned his post at Cologne. He eked out a precarious livelihood until appointed at Nuremberg. At this time his work began to be recognized, he was awarded the Copley medal of the Royal Society in 1841 and was made a foreign member of that society in 1842. In addition to a number of papers on mathematical subjects, Ohm wrote a memoir on interference in uniaxial crystals, and also a *Text Book of Physics* (1854).

BIBLIOGRAPHY – H. Von Fuchtbauer, *Georg Simon Ohm* (Berlin, 1939); E. Lommel, *Scientific Work of Georg Ohm* (Annual Report of the Board of Regents of the Smithsonian Institution, 1891) (1893).

*Reprinted from Encyclopaedia Brittanica.*

**JOULE, JAMES PRESCOTT** (1818-89), English physicist, was born on Dec. 24, 1818, at Salford, near Manchester. He owned a large brewery but devoted himself to scientific research. From the first he appreciated the importance of accutate measurement, and all through his life the attainment of exact quantitative data was one of his chief considerations. In 1840 Joule gave a quantitative statement of the law according to which heat is produced in a conductor by the passage of an electric current. He continued to study the relations between electrical, mechanical and chemical effects and was led to the discovery of the first law of thermodynamics. He determined the mechanical equivalent of heat in four ways. He found that to raise one pound of water 1°F (heat unit), 772 foot-pounds of mechanical work were required. In the C.S.G. system the mechanical equivalent, often called Joule's equivalent, is $4.184 \times 10^7$ ergs per gram-degree Centigrade (see *Brit. Assoc. Report,* 1845). In 1849 he presented to the Royal Society a Memoir which, together with a history of the subject, contained details and results of a long series of determinations. In addition, numerous other researches stand to Joule's credit – the work done in compressing gases and the thermal changes they undergo when forced under pressure through small apertures (with Lord Kelvin), known as the Joule-Thomson porous plug experiment the change of volume on solution, the change of temperature produced by the longitudinal extension and compression of solids, etc. Joule died at Sale on Oct. 11, 1889.

His scientific papers were collected and published by the Physical Society of London: the first volume appeared in 1884.

*Reprinted from Encyclopaedia Britannica.*

# Antiphon noise-a

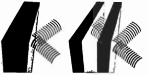
The best way to cut down the amount of noise in our environment is to attack it at the source, before it has had time to spread and become difficult to control. But selecting the correct noise control material for a particular source of noise (e.g. a machine or vehicle) often entails considerable difficulty. Even if one is quite knowledgeable about acoustics.

That is why we have prepared this guide, which covers most of our products. It is intended to help you select the combination or combinations of our products which will meet type of noise control material is not er combinations of different types of pro

You will notice that we have divic categories that are normally used whe lation of air-borne sound, absorption structure-borne sound. Some of our pr

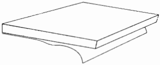
## Insulation of air-borne sound.

Every source of noise generates sound. Speaking very generally, one can say that air-borne sound is equivalent to air-borne oscillations propagated to your ear where they sometimes cause irritation. Noise. One way to reduce noise propagation is to screen the source with a wall. When the sound waves strike the wall, most of them bounce back towards the source. Only a part pass through.



This is insulation of air-borne sound. The sound-insulating capacity of a wall or a barrier increases with the weight per square metre and the frequency of the sound.

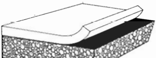
In order to avoid using an excessively heavy single sound-insulating wall, a double wall can be erected. In most cases (depending on frequency) a double wall gives better results.



For insulation of air-borne sound in light structures

Antiphon I 7.5-R is a noise barrier based on EPDM rubber. It is available with and without pressure-sensitive adhesive. It resists aging very well and is highly resistant to chemicals, solvents and mineral oil. Temperature range: −30°C to +110°C. Also suitable for compression moulding.

Antiphon I 7.5-R is intended for lightweight structures of wood, plastic and the like as well as structures made of sheet metal up to about 3 mm thick. It is used, to cite a few examples, in hoods for engines in boats and vehicles and for stationary machines. Also used on floors, doors and walls in engine compartments in vehicles of all types.

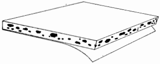


A barrier that creates a double wall

Antiphon AI 7.5-R is the same barrier as I 7.5-R, except that it is provided with a layer of flexible foam. Here, the foam functions simply as a decoupler between application surface and barrier.

This barrier is available with or without pressure-sensitive adhesive.

Antiphon AI 7.5-R is used primarily for heavier structures made of wood, plastic and sheet metal for example. Applications: see I 7.5-R.

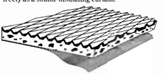


Decorative barrier which also functions as a sound-insulating curtain

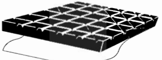
Antiphon I 7.5-P is made of vinyl and resists oil and chemicals. The barrier should be glued to the application surface. Ambient temperatures can range from −25°C to +100°C.

Used for structures on which an attractive surface is required. This barrier is highly flexible and easy to bend around corners and the like. Applications: see I 7.5-R.

The glass-fibre reinforced version of this barrier, Antiphon I 5.5-P, is intended for hanging freely as a sound-insulating curtain.



Also available with wear-resistant layer of black corrugated PVC, intended as a floor covering.



Inexpensive and effective barrier for insulating air-borne sound and damping structure-borne sound

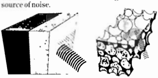
Antiphon LI 7.5-B is a bitumen-based barrier coated on one side with polyethylene film and on the other with pressure-sensitive adhesive (also available with heat-sensitive adhesive).

The film protects against solvents and mineral oil. Temperature range: −20°C to +120°C.

Used with structures of sheet metal up to about 3 mm thick, e.g. engine compartments; also vibrating machinery and kitchen sinks.

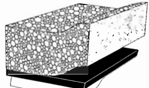
## Absorption of air-borne sound.

The noise that is reflected from walls, floors and ceilings in a room – large or small – is added to the direct air-borne sound emanating from a source of noise.



Reflected sound can be reduced by covering a sound-reflecting surface with a sound-absorbing material. Foam with open cells or mineral wool are suitable. When the sound waves pass through the absorbent, friction converts the sound energy to heat, thus reducing the noise.

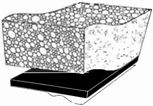
The sound-absorbing capacity of a material increases with the thickness of the material and the frequency of the sound.



Our least expensive absorbent

Antiphon LDA is a polyurethane foam absorbent provided with a damping pad for structure-borne noise and pressure-sensitive adhesive. Also available without pad or adhesive.

Withstands temperatures ranging from −30°C to +90°C. Used in environments in which ease of cleaning and fire-resistant properties are not important. Ideal, for example, for office machines and data processing installations.



Absorbent for areas with fire hazards

Antiphon LDA S is intended especially for environments that require an absorbent that is difficult to ignite. Fulfils the fire-protection standards of various automobile manufacturers.

Similar in other respects to Antiphon LDA

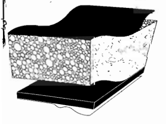
**SOUNDGUARD** *Acoustical Engineers* **PTY. LTD.**

# ıbatement guide.

-t your individual needs. Often, a single -enough and it is necessary to use -oducts.
ided our products into the three ıen discussing noise control: insu- _of air-borne sound and damping of products are intended only for ab- sorption, for example. Others are effective against both air-borne and structure-borne sound.

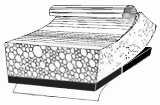
If you would like more information about any of our products, request the appropriate product sheets. If you are having difficulty in selecting the correct product using this guide, contact one of our specialists. He will be able to assist you in finding an economical solution to your noise problem. Regardless of what you are manufacturing.

<u>Attractive and easy to keep clean</u>
Antiphon LDA V 2 consists of absorption foam combined with a damping pad. This pad is coated with pressure-sensitive adhesive. Also available without damping pad and without adhesive.



The foam has a facing of strong, perforated PVC film which is easy to keep clean. The PVC film is available in several colours. Withstands temperatures between −30°C and +90°C.

Antiphon LDA V 2 is used, for example, for internal lining of vehicle cabs and personnel rooms.



<u>Noise absorbent which repels everything except noise</u>
Antiphon LDA S-E is built up of flame retardant foam with a facing of aluminized polyester film plus a damping pad with pressure-sensitive adhesive. The ambient temperature can range from −40°C to +120°C.

The chemically bonded (not glued) film is impervious. As a result, this absorbent is ideal for environments which impose stringent hygienic and cleanability requirements. Used, for example, for internal, fireproof linings in hoods and housings in engine compartments in boats, compressors, snowmobiles, oil burners, fans, machines used in the food industry, hospital equipment, etc.

Also available without damping pad. This variant, designated Antiphon LA S-E, is approved by automobile manufacturers, the National Swedish Institute for Materials Testing, the National Swedish Administration of Shipping and Navigation and Det Norske Veritas classification society for use in engine compartments in ships and automobiles for example.

## Damping of structure-borne sound.

Structure-borne sound, like air-borne sound, comprises oscillations, the only difference being that the oscillations are propagated through solid material such as steel, plastic, concrete or wood.

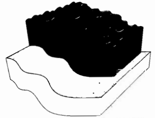
Structure-borne sound is generated, for example, by machinery. The oscillations are propagated to fixtures, e.g. hoods, and radiated to the air as noise. This is reduced by providing the sheet metal with a material that will dampen this type of sound or, even more effectively, by making

the structure out of such a material (MPM panels).

Both methods dampen structure-borne sound by converting oscillatory energy to heat. It is important that all damping materials follow the motion of the application surface. This is achieved by gluing the material to the surface or by building it into the structure.

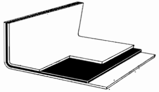
<u>Fast, inexpensive way to provide damping for plastic and sheet-metal structures.</u>
Antiphon pads 1 and 13 are coated with pressure-sensitive adhesive. Antiphon 13 dampens structure-borne sound somewhat better than Antiphon 1.

These pads have no odour. They resist aging well and withstand temperatures between −30°C and +90°C. They are impregnated to make them water repellant. Used, for example, for structures made of sheet metal up to 1.5 mm thick.



<u>The spray-on structure-borne sound dampener</u>
Antiphon D 444 is a water-based dispersion of synthetic resins and an extender. It is sprayed on to sheet-metal structures in order to reduce the amount of sound emanating from them. Dries in air. Resists water, solvents and mineral oils. Withstands temperatures of up to +60°C (+180°C for short periods).

Used on doors, ceilings and walls in fan rooms and vehicles for example. Also engine hoods, refuse chutes and within the shipbuilding industry.



<u>Metal panels with built-in damping</u>
Standard Antiphon MPM panels consist of two cold-rolled passivated and electrogalvanized sheets of steel with a sandwich layer of thermoplastic material. The panels are available in different thicknesses. MPM panels are also avilable in other materials, e.g. stainless steel and aluminium.

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MPM panels can be processed in almost the same way as ordinary sheet metal. They can be welded, bent, cut etc. without diminishing their damping properties. Moreover, MPM panels provide noise damping that lasts as long as the sheet metal itself – without maintenance.

Antiphon MPM panels are used as a structural material to provide damping of structure-borne sound and insulation of air-borne sound in vehicles, ships, boats, materials handling machines, construction machines etc. They are also used in combination with a sound absorbent in hoods for machine tools, presses and printing machines.

## Adhesive-coated sealants.

<u>Withstand heat, cold, salt water and chemicals. Available by the metre or ready-stamped</u>
Even if a structure has been provided with optimum noise control, *a tiny crack is all that is needed* to ruin everything.

Antiphon Seasoflex and Seasofite are intended specially for sealing structures – both with and without other types of noise control. This material has no odour, it is self extinguishing and displays excellent resistance to aging and various chemicals. Withstands temperatures ranging from −25°C to +90°C. Available by the metre or ready-stamped (any desired shape) in sheets of different thicknesses. Coated with pressure-sensitive adhesive.

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# BOOK REVIEWS

## APPLIED ACOUSTICS

G. Porges, Edward Arnold, London, 1977. 180 pp., ill., Index, bibliography. Price:$16.50 (soft cover).

The title is misleading as the book is mainly concerned with the derivation of theoretical expressions for the behaviour of sound in buildings and building services; theoretical expressions which are known to be of little practical use.

The book which is an inferior version of Kinsler and Frey (Fundamentals of Acoustics, Wiley, New York, 1950) consists of thirteen chapters. Expressions are derived for sound radiating from an omnidirectional point source, the mass law transmission loss through a wall, sound transmission through isolated duct discontinuities using the lumped element approach, absorption of resonant (but not porous) absorbers, reverberation time and sound level within a room and the transmissibility of a single spring-mass system.

Generally the author is uncritical of the limitations of the theories presented. For example, the only comment on the limitation of the Sabine equation for reverberation time in a room concerns the values of the average absorption coefficient for which it is valid. Nothing is mentioned about the room geometry or the distribution of absorption within the room. In the chapter on sound transmission the comment is made, after the derivation of an expression for the transmission of sound from one medium to another, that "This theory applies fairly well to the boundary between air and a thick rigid solid ..."

Some subjects are treated descriptively but are equally uncritical. These chapters are on Loudness, Room Acoustics, Vibration and Transmission in Solids, Radiation of Sound and Noise Sources. For a book whose stated object is, "the practical application of acoustic theory", the inclusion of these descriptive treatments seems pointless, especially when they have no relevance to the theory presented.

The book is an unnecessary addition to the growing number of acoustics texts, though it may be of use to someone looking for "applications" of complex numbers. It contains no references and no information that has not appeared in previous text books. Its one advantage over other acoustics texts is its price.

*Fergus Fricke, Sydney University.*

## NOISE, BUILDINGS AND PEOPLE

D. J. Croome. Pergamon Press (International Series in Heating, Ventilation and Refrigeration, Vol. II), Oxford 1977. 613 pp., ill., index, bibliography. Price: unknown.

It seems that the modern trend in acoustics text books is a self-indulgent one. Noise, Buildings and People is an excellent book in most respects but it leaves one with the impression that the author has written about subjects that he is interested in, with little concern for his readers who presumably are meant to be from the Heating, Ventilation and Refrigeration fraternity. The book will become a very important reference for students and teachers of Building and Environmental Acoustics and possibly for acoustical consultants but it is highly doubtful if it will be used by the profession at which it is aimed.

The book is in three sections; Part 1 is an Introduction, Part 2 deals with Noise and its Control, and Part 3 deals with Some Fundamentals of Acoustics. The first part is in Rettinger's style with numerous quotations from people such as Robert Jungk, Yehudi Menuhin, Le Corbusier and George Bernard Shaw. The second part of the book includes a chapter on Man and the Acoustical Environment, which is a brilliant summary of the effects of noise on people, including interaction effects with other stressors such as heat, sleeplessness and alcohol. Noise Sources in Buildings is another chapter in Part 2. This chapter goes into considerable detail on some sources such as fans and air terminal devices but is very perfunctory on others, e.g. steam and gas turbines and cooling towers. No mention is made of standby generating plants. The chapter on Control of Airborne and Structure-borne Sound is also rather mixed with very little attention being given to Urban Planning though this is justifiable on a number of grounds including the one that the book is already over 600 pages in length. Case studies are given in this chapter as well as the following one on Some Acoustical Design Techniques for Buildings.

Part 3 of the book is also well written, though if the fundamentals are to be included it would seem more logical to include them at the beginning of the book or put them in an appendix. The chapter on The Behaviour of Sound in Rooms is an excellent review on current thinking in the design of auditoria and includes a case study of the Sydney Opera House as well as worked examples. The chapter seems out of place in this book (slightly expanded, it would make a valuable monograph for designers).

In summary, this is an important addition to acoustics literature which is clearly written, amply illustrated with photographs and diagrams, and well researched. Its greatest limitation is the lack of information on instrumentation and measurement. What emerges from the book is that we have some very precise knowledge about certain apsects of acoustics and some very imprecise information on other aspects. So while we may know the characteristics of noise sources and the conditions we require in buildings we often cannot link the two because predictions of sound propagation in the atmosphere and in structures are poor.

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**NOTE**

If you wish to review a recent publication on acoustics please let The Editor know and he will try to obtain a review copy for you.

Ed.

## SOCIETY LIBRARY

All documents and publications received by the Australian Acoustical Society are held in a section of the Library of the National Acoustic Laboratories, 5 Hickson Road, Millers Point, NSW, 2000 (telephone: (02) 20537).

The NAL Library also holds a number of films on aspects of acoustics and noise, and these are available for loan to institutions, associations and private individuals. Long term loans are possible in certain circumstances. Enquiries regarding a catalogue of films available should be directed to The Librarian, National Acoustic Laboratories, at the above address.

# STANDARDS REPORT

## SUMMARY OF INTERNATIONAL STANDARDS ON NOISE

This is a compilation of standards related to noise which are being prepared by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The major ISO Committees are ISO/TC43, Acoustics and ISO/TC 108, Shock and Vibration. Subcommittees and Working Groups of these parent committees are listed below. Within IEC, Technical Committee 29 on Electroacoustics is the parent committee concerned with acoustics. Standards on noise measuring instruments are the responsibility of IEC SC29C, Measuring Instruments. The work of this subcommittee is also listed below.

Where a national working group exists or when corresponding national standards exist or are in preparation, pertinent information is given in parenthesis following the information on the international group. This information has been compiled by the ASA Standards Secretariat.

## INTERNATIONAL SUBCOMMITTEE: ISO/TC 43/SC1,

### Noise

*DIS 4872:* Measurement of Airborne Noise emitted by construction equipment intended for outdoor use — method for checking compliance with noise limits.

*ISO 2204—1973:* Acoustics — Guide to the measurement of airborne acoustical noise and evaluation of its effects on man. (ANSI S1.13, Methods for the Measurement of Sound Pressure Levels.)

*Project:* Assessment of occupational noise exposure for hearing conservation exposure purposes. (Revision of ISO 1999.) (The national counterpart is ANSI S3-58, Hearing Conservation Criteria. Draft document being prepared.)

*Study Group B:* Calculation of the loudness of impulsive sounds. (The national counterpart is ANSI S3-51, Auditory Magnitudes. Draft Document being prepared.)

*Advisory Panel to TC 43/SC1:* Measurement of Noise from reciprocating internal combustion machines.

### INTERNATIONAL WORKING GROUP: WG2, Noise from Aircraft

*ISO 2249—1973:* Acoustics—description and measurement of physical properties of sonic booms.

*ISO/R 1761—1970:* Monitoring Aircraft Noise around an airport.

*ISO/R 507—1970:* procedure for Describing Aircraft Noise around an airport.

*DIS 3891:* Procedure for Describing Aircraft Noise heard on the ground.

(The national counterpart of WG2 is S3-44 (SI), Methods for Measuring and Evaluating Aircraft Noise.)

### INTERNATIONAL WORKING GROUP: WG5, Noise Emitted by Ships and Railways and Noise Inside Vehicles

*ISO 3381:* Measurement and description of noise inside railway cars.

*ISO 2922—1975:* Acoustics — measurement of noise emitted by vessels on inland waterways and harbours.

*ISO 2923—1975:* Acoustics — measurement of noise on board vessels.

*DIS 5128:* Measurement of noise inside motor vehicles.

*DIS 5129:* Measurement of noise inside aircraft.

*DIS 5131:* Noise level measurement of the operator's workplace on agricultural tractors and field machinery.

### INTERNATIONAL WORKING GROUP: WG6, Measurement of Sound Emitted by Machinery and Equipment

*ISO 3741—1975:* Acoustics — determination of sound power levels of noise sources — precision methods for broadband sources in reverberation rooms. (ANSI SI.21—1972, Methods for the Determination of Sound Power Levels of Small Sources in Reverberation Rooms.)

*ISO 3742—1975:* Acoustics — determination of sound power levels of noise sources — precision methods for discrete-frequency and narrow-band sources in reverberation rooms. (ANSI SI.21—1972, Methods for the Determination of Sound Power Levels of Small Sources in Reverberation Rooms.)

*DIS 3740:* Determination of sound power levels of noise sources — guidelines for the use of basic standards and for the preparation of noise test codes. (National document sent for first letter ballot.)

*DIS 3743:* Determination of sound power levels of noise sources — engineering methods for special reverberant test rooms. (National document sent for first letter ballot.)

*DIS 3744:* Determination of sound power levels of noise sources — engineering methods for free-field conditions over a reflecting plane. (National document sent for first letter ballot.)

*ISO 3745—1977:* Determination of sound power levels of noise sources — precision methods for anechoic and semi-anechoic rooms. (National document sent for first letter ballot.)

*DIS 3746:* Determination of sound power levels of noise sources — survey emthod. (National document sent for first letter ballot.)

*DIS 3747:* Acoustics — noise emitted by machinery and equipment — engineering and survey methods using a reference sound source. (In preparation by WG6.)

*DIS 3748:* Calibration and characteristics of reference sound sources. (In preparation by WG6.)

(For the above nine documents, the national counterpart of WG6 is ANSI SI-50 (S3), Measurement and Evaluation of Stationary Noise Sources.)

*DP 4871:* Noise classification and labelling of equipment and machinery. (ANSI S1.23—1976, Method for the Designation of Sound Power Emitted by Machinery and Equipment.)

(For the above document, the national counterpart of WG6 is ANSI S1-64, Noise Measurement Systems. Other pertinent national documents are ANSI S3.17–1975, Method for the Rating of Sound Power Spectra of Small Stationary Noise Sources and ANSI S1.13–1971, Methods for the Measurement of Sound Pressure Level.)

**INTERNATIONAL WORKING GROUP: WG7, Noise Assessment with Respect to Speech Communication**

*ISO TR 3352–1974:* Acoustics – assessment of noise with respect to its effect on the intelligibility of speech. (ANSI S3-49, Determination and Interference of Noise with Speech Intelligibility, ANSI S3.14–1977, Standard for Rating Noise with Respect to Speech Intelligibility.)

**INTERNATIONAL WORKING GROUP: WG8, Noise Emitted by Road Vehicles**

*Project:* Revision of ISO R 364–1964, Measurement of noise emitted by road vehicles.

*Project:* Survey method for the measurement of noise emitted by stationary motor vehicles.

(The national counterpart of WG8 is ANSI S3-41 (S1), Measurement and Evaluation of Motor Vehicle Noise.)

**INTERNATIONAL WORKING GROUP: WG9, Noise from Pneumatic Tools and Pneumatic Machines**

*DIS 3481:* Measurement of airborne noise emitted by pneumatic tools and machines – engineering method for the determination of sound power levels.

*DIS 3989:* Measurement of airborne noise emitted by compressor units including prime movers – engineering method for the determination of sound power levels.

Code for noise classification of pneumatic equipment for construction sites.

(The national counterpart of WG9 is ANSI S1-63, Measurement of Noise from Pneumatic Compressors, Tools and Machines.)

**INTERNATIONAL WORKING GROUP: WG10, Noise from Earth Moving Equipment**

*DIS 5132:* Noise emitted by earth-moving machinery measurement at operator's workplace.

*DIS 5133:* Determination of airborne noise emitted by earth-moving machinery to the surroundings survey method.

(The national counterpart of WG10 is the SAE Off-Road Vehicle Committee.)

**INTERNATIONAL WORKING GROUP: WG13, Noise Emitted by Rotating Electrical Machines**

*Project:* Revision of ISO/R 1680 Test method for the measurement of the airborne noise emitted by rotating electrical machinery. (The national counterpart of WG13, is IEEE Working Group 85, which has produced IEEE 85, Test procedure for Air-borne Noise Measurement on Rotating Electric Machinery.)

**INTERNATIONAL WORKING GROUP: WG14, Noise from Gas Turbines**

*Project:* Test method for the measurement of noise from gas turbines.

**INTERNATIONAL WORKING GROUP: WG15, Assessment of Fluctuating Noise**

The international work is in abeyance pending further studies.

(The national counterpart of WG15 is ANSI S3-51 Auditory Magnitudes. The committee is in the process of expanding the scope of ANSI S3.4, Procedure for the Computation of the Loudness of Noise.)

**INTERNATIONAL WORKING GROUP: WG18, Community Noise**

*Project:* Assessment of Noise with respect to community response (revision of ISO R 1996). (The national counterpart of WG18 is ANSI SI-62, Measurement and Evaluation of Outdoor Community Noise. A draft document is under consideration.)

## INTERNATIONAL COMMITTEE: ISO/TC 108, MECHANICAL VIBRATION AND SHOCK. WG8, Methods of Analyzing and Presenting Vibration and Shock Data

*DP 4865:* Analog and Digital Methods of Analyzing Vibration and Shock Data. (The national counterpart of WG8 is ANSI S2-66 Statistical Analysis of Vibration and Shock Data. This committee prepared ANSI S2.10–1971, Methods for the Analysis and Presentation of Shock and Vibration Data.)

## INTERNATIONAL SUBCOMMITTEE: ISO/TC 108/SC2, MEASUREMENT AND EVALUATION OF MECHANICAL VIBRATION AND SHOCK AS APPLIED TO MACHINES, VEHICLES AND STRUCTURES.

**WG3, Vibration and Stationary Structures.**

*SC2 N 17:* Instrumentation for the measurement of vibration in buildings.

*DP 4866:* Evaluation and measurement of vibration in buildings.

(The national counterpart of WG3 is ANSI S2-78, Vibration Levels of Structures.)

## INTERNATIONAL SUBCOMMITTEE: ISO/TC 108/SC4, HUMAN EXPOSURE TO MECHANICAL VIBRATION AND SHOCK. WG2, Whole Body Vibration

*ISO 2631–1974:* Guide for the evaluation of human exposure to whole body vibration.

*Proposed Addendum to ISO 2631:* Vibration and shock limits for occupants in buildings.

(The national counterpart of Working Group 2 is ANSI S3-39 (S2), Vibration Levels. ISO 2631 has been submitted for ballot as a proposed national standard.)

## INTERNATIONAL COMMITTEE: IEC/TC 19, ELECTROACOUSTICS. Subcommittee 29C, Measuring Devices.

**INTERNATIONAL WORKING GROUP: WG2, Free-Field Calibration for Microphones**

*Project:* Correction for free-field response of microphones.

*Project:* Calibration of half-inch standard condenser microphones.

(The national counterpart of WG2, is ANSI S1-54, Standard Microphones and their Calibration.)

**INTERNATIONAL WORKING GROUP: WG6, Ear Simulator for Insert Earphones**

*Project:* IEC ear simulator for the calibration of insert earphones.

(The national counterpart of WG5 is ANSI S3-37 (S1), Coupler Calibration of Earphones. The correponding national standard is ANSI S3.7–1973, Method for the Coupler Calibration of Earphones.)

**INTERNATIONAL WORKING GROUP: WG7, Equipment for Audiometry**

*Project:* Pure tone audiometers for general diagnostic purposes.

*ISO DP 6189:* Pure tone threshold audiometry on occupational noise-exposed people.

*Project:* Pure tone screening audiometers.

*Project:* Consolidated revision of IEC Publications 177 and 178.

(The national counterpart of WG7 is ANSI S3-35, Audiometers, Proposed ANSI S3.21–197x is being submitted to a second letter ballot and a revision of ANSI S3.6–1969, Specification for Audiometers, is being prepared for a second letter ballot.)

**INTERNATIONAL WORKING GROUP: WG9, Consolidated revision of IEC Publications 123 and 179**

*Project:* Consolidated revision of IEC Publications 123 and 179/179A.

(This national counterpart of WG9 is S1-45, (S3) Sound-Level Meters. This committee is working on a revision of ANSI S1.4–1971, Specification for Sound Level Meters.)

**INTERNATIONAL WORKING GROUP: WG19, Ear Simulator for circumaural Earphones**

*Project:* Artificial ear for the calibration of circumaural earphones. (The national counterpart of WG9 is ANSI S3-37 (SI), Coupler Calibration of earphones.)

**INTERNATIONAL WORKING GROUP: WG11, Integrating Sound Level Meters**

*Projects:* Intergrating sound level meters and personal noise dosimeters. (The national counterpart of WG11 is S1-45 (S3) Sound Level meters. A document on integrating meters is in preparation and proposed ANSI S1.25–197x on personal noise dosimeters has been submitted to three letter ballots.)

## PLUMBING NOISE

The International Organisation for Standardisation (ISO) has published a new standard on noise emission, ISO 3822/1 "Acoustics, Laboratory tests on noise emission by appliances and equipment used in water supply installations – Part 1: Method of Measurement".

## STANDARD ON NOISE IN AUDIOMETER ROOMS

On 19 May 1977 the American National Standards Institute approved a revision of S3.1-1960, "Background Noise in Audiometer Rooms." The title of the revision has been changed to read "American National Standard Criteria for Permissible Ambient Noise During Audiometric Testing." It has been designated S3.1-1977. The purpose of the standard is to set maximum permissible noise levels for audiometric testing with uncovered ears and with earphones set in MX-41/AR cushions. Octave and one-third octave band and spectrum levels are provided which will permit testing down to 0 dB HTL (ANSI S3.6-1969 Appendix F). The title was changed to its present form to more accurately reflect the purpose of the standard and to avoid the implication that the standard defined the characteristics of audiometric rooms other than to specify permissible ambient noise levels.

A prominent feature of the document is that it contains an Appendix which describes how the values given in the standard were determined along with the numerical values used for each factor. Thus, for example, should earphone cushions be used with different attenuation values than those assumed in the standard, the values provided in the standard can be easily and accurately adjusted to reflect the different attenuation values for the substitute earphone cushions.

The maximum permissible levels given in the standard have been compared to, and reconciled with, a number of independent efforts to derive the same numbers. The values given in the standard have stood these tests. Further, it has been verified that type I sound level meters of current manufacture are adequate to make the measurements.

The tabled maximum permissible levels are those for testing down to ) dB HTL. However, the working group recognized that some hearing testing programs (e.g., screening programs and others) would not need to test to such low hearing levels in order to meet the needs of those programs. Provision was made for that circumstance by the following statement quoted from the standard:

"Some testing programs may not require measurements at the sound pressure levels specified as reference hearing threshold levels in American National Standard S3.6-1969 but have objectives that can be met at higher test signal sound pressure levels. These programs do not require ambient background noise levels as low as those needed for testing to the reference threshold levels.

"The maximum allowable ambient noise levels for test conditions which exceed the reference threshold levels may be calculated by arithmetically adding the amount by which the minimum acceptable test hearing threshold levels exceed the reference hearing threshold levels at each test frequency."

## ASA ANNOUNCED THE AVAILABILITY OF TWO NEW NOISE STANDARDS

New standards on noise rating with respect to speech intelligibility and criteria for permissible ambient noise during audiometric testing have been published by the Acoustical Society of America. Both documents are American National Standards, having been prepared by Standards Committee S3 of the American National Standards Institute (ANSI). The Acoustical Society holds the Secretariat of the ANSI S1, S2 and S3 committees on Physical Acoustics, Shock and Vibration and Bioacoustics respectively.

The new standards are designated ANS S3.1-1977 (ASA Catalog No. 9-1977), Criteria for Permissible Ambient Noise During Audiometric Testing, and ANS S3 14-1977 (ASA Catalog No. 21-1977), Standard for Rating Noise with respect to Speech Intelligibility. Both documents are available for $7.00 each from Dept. STD, AIP Back Numbers Department, 335 E 45th St., New York, NY 10017. Orders not accompanied by payment will be subject to a $2.00 handling charge.

In addition to these documents, the Acoustical Society has available an index of Noise Standards covering standards published in the United States, International Standards and standards published in other countries. Also available is a noise standards package which includes key American National Standards concerned with noise.

The Society also has available 38 standards on noise, physical acoustics, bioacoustics and shock and vibration which are published by the American National Standards Institute.

Further information on all the above documents may be obtained from the Standards Manager, Acoustical Society of America, 335 E. 45th Street, New York, NY 10017.

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Doug Cato is a graduate of Sydney University and has been engaged in underwater acoustics research at the R.A.N. Research Laboratory, Sydney, for several years. His previous paper in The Bulletin was on, "Estimating the Environmental Noise of the New High Speed Hovertrains". (The Bulletin Vol. 4, No. 1, pp15-18, 1976)

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# NEW PRODUCTS

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The Type 1617 has an extended frequency range, 50 1/3 octave bands with centre frequencies 2 Hz to 160 kHz, and 41 overlapping 1/1 octave bands 2 Hz to 20 kHz. It contains a built-in interface to the proposed IEC standard to permit complete control by other instruments using the standard. An internal control system is able to program the averaging times of the measuring instrument to maintain the optimum BT product during a frequency scan.

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All 1/3 octave filters fulfil IEC 225–1966, DIN 45652, and ANSI SI.11–1966 Class III, while all 1/1 octave filters fulfil IEC 225–1966, DIN 45651, and ANSI S1.11–1966 Class II, which are the most rigorous standards for band pass filters.

For further information, contact Brüel & Kjær Australia Pty. Ltd., 33 Majors Bay Road, Concord, NSW, 2137. (02) 736 1755.

## PIEZOELECTRIC ACCELEROMETER WITH A BUILT-IN PREAMPLIFIER

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The case is made of titanium and is **internally isolated** from the signal which is carried in a 2 feet long low noise, 250°F, integral, coaxial cable terminated in a coaxial connector. The size is small: only 5/16" diameter by .40" high. The studded base, when ordered, is 1/8" long 6-32 UNC (standard) or 5-40 UNC (optional). The base is also available flat for cementing. The unit weighs less than 2 grams.

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For more information please contact John Morris Pty. Ltd., P.O. Box 80, Chatswood, NSW, 2067, (02) 407 0206.

# A METHOD FOR MEASURING LOW AMBIENT NOISE LEVELS

P. A. DUNSMORE

*SUMMARY*

*For certain audiometric tests it is necessary to ensure that the ambient noise level is sufficiently below the Minimum Audible Field (MAF) so as not to mask the true threshold of hearing. Even high quality noise measurement systems cannot, in themselves, measure down to these low levels. In this report the Principle of Energy Addition is combined with a consideration of the statistical nature of the noise to give an indirect method of measurement which is capable of detecting ambient noise levels to 10 dB below the MAF.*

## INTRODUCTION

Certain audiometric measurements require a low level of ambient noise in the test booth. During a hearing threshold test, for example, the ambient noise level must be so low that it does not mask an introduced signal. For such tests the hearing threshold for normal subjects, known as the Minimum Audible Field (MAF)[1], is used as a guide to acceptable ambient noise levels. To ensure a margin of 10 dB between the MAF and the ambient noise level it is necessary, at some 1/3 octaves, to be able to detect ambient noise levels as low as −14 dB. Even using good quality condenser microphone and specially selected amplification systems, the lowest ambient noise level which can be measured directly is about 5-10 dB, 1/3 octave. The main limitation is the electrical noise of the measuring equipment[2].

Previously the ambient noise level in the test booth has been taken as the ambient noise level outside the test booth minus the attenuation of the booth. However, this is only an approximate procedure since it ignores any sources of noise within the booth itself.

The method of measurement discussed below is based on the Principle of Energy Addition, viz. the power of the total noise equals the power of the electrical noise plus power of the ambient noise. An estimate of the ambient noise level is obtained from the difference between the power of the total and the electrical noise. Reasonable assumptions have been made about the statistical nature of the noise in order to minimise the duration of the power measurements. Basically these are that the 1/3 octave band noise is Gaussian and white. The total and the electrical noise power can be measured in about 25 sec. Thus, data to give an estimate of the ambient noise level over most of the audio spectrum can be obtained in about 8 minutes.

## OUTLINE OF RELEVANT STATISTICAL THEORY

Ambient noise in a test booth is essentially random and so is best measured using the technique of statistical estimation. This method of measurement requires the accurate determination of the power (mean square value) of both the total and the electrical noise. Ideally an estimate of the mean square value of random noise becomes more accurate as the measurement period increases, however, practical considerations, such as the drift of measuring instruments, slow variations in the properties of the noise and the inconvenience of a time consuming method of measurement (in the case where many bands must be measured) make a compromise necessary. Further, the duration of measurements can be limited to provide just sufficient accuracy to ensure that audiological tests are not impaired.

In order for the Principle of Energy Addition to apply it is necessary to assume that the noise, be it ambient or electrical, is stationary with zero mean and that the ambient and electrical noise are uncorrelated. It is further assumed that each noise is bandpass, white and Gaussian so that a manageable expression can be developed for the accuracy of a given estimate of mean square value.

An estimate of the mean square value of the noise is obtained by squaring and then time averaging the noise signal over a fixed period. The estimate can be written

$$\Psi_x^2 = \frac{1}{T} \Sigma_O^T x^2(t)\, dt$$

where x(t) is the noise signal and T is the integration time. The estimate is itself a random variable with a Chi-square distribution[3]. However, for large bandwidth-integration time products, as in this case, the distribution is very close to Gaussian with a mean equal to the true mean square value and a coefficient of variation (standard deviation/mean) given by[4]

$$V = \frac{1}{\sqrt{BT}}$$

where B is the bandwidth of the noise. The definition of bandwidth is significant and the appropriate one is statistical bandwidth which for a 1/3 octave filter is 0.336 times the centre frequency[5] compared to a half-power point bandwidth of 0.231 times the centre frequency.

## INSTRUMENT TO MEASURE MEAN SQUARE VALUE

An instrument called a Noise Integrator has been developed to obtain an estimate of the mean square value of random signals. In fact it produces a count proportional to the estimates of the mean square value. Thus.

$$\text{Count} = 1000\Psi_x^2$$

where the noise signal is expressed in volts. The Noise Integrator consists of a squarer which is based on a four quadrant multiplier, a voltage to frequency converter, a stage which divides the pulse frequency by the integration period and finally an accumulator. The integration period can be varied from 1-999 sec. The maximum input voltage is 10 V peak.

Most instruments of this type suffer from non-linearity and drift with temperature. However, the square root of the count (which is proportional to the RMS value of the input signal) is in error by less than 0.5% with respect to a sinusoidal input over the range 0.5 — 10 V peak. Drift becomes negligible after about an hour of operation e.g. counts vary by only ±4 in 12,500 during the two hours following the first hour of operation for a sinusoidal input of 5 V peak at 1 kHz. The drift is mainly in the output offset voltage of the four quadrant multiplier and this can be compensated for by deducting the count for which the input signal is zero from the actual count.

The performance of the Noise Integrator when applied to random noise is evaluated by comparing an estimate coefficient of variation obtained from a sample of 25 estimates of mean square value, with the theoretical coefficient of variation obtained from a sample of 25 estimates of mean square value, with the theoretical coefficient of variation. A suitable noise signal is provided by a B&K 1402 random noise generator. This is then passed through a 1/3 octave filter and amplifier in a B&K 2121 frequency analyzer and finally is measured by the Noise Integrator, set to a 1 sec integration period. The estimate coefficient of variation itself has a coefficient of variation which can be shown[5] to be approximately 1/7. The 95% confidence limits of the estimate coefficient of variation are then placed at 1.96 times the standard deviation (V/7) either side of the true coefficient of variation. As can be seen in Fig. 1, the estimates of the coefficient of variation fall within the expected region.

## COLLECTION OF DATA

Data required to determine the ambient noise level in the booth consists of estimates of the mean square value of the total and the electrical noise. The electrical noise of the microphone by an equivalent capacitance because the difference between the noise level when using the microphone and the noise level when using the capacitance may easily exceed the difference between the total and the actual electrical noise levels. Instead, the electrical noise is measured by isolating the microphone in an elastically suspended container which has good transmission loss. The signal from the B&K 4145 1 inch microphone passes via a B&K 2619 preamplifier out of the booth to a B&K 2120 frequency analyzer, set to 200 Hz high pass, to a B&K 2606 measuring amplifier, with a bandwidth of 22.4 Hz to 22.4 kHz, then to the Noise Integrator. The highpass and broadband filters reject frequencies outside the range of interest so that as much gain as possible is available for the required 1/3 octave band. Measurements are made in the following order: the estimate mean square value of the 124 dB, 240 Hz pistonphone calibration tone, the estimates of the mean square value of the electrical noise for all 1/3 octaves and finally the corresponding estimates of mean square value of the total noise. The integration period is fixed at 10 sec. This more rapid consecutive, rather than alternate, method of measurement, is acceptable because the drift of the apparatus is very slight over the 4 min period which separates corresponding total and electrical noise measurements for each band. After the calibration tone has been measured the gain of the amplifier chain is increased by a factor g (or G dB), appropriate to the measurement of electrical noise. If the level of the total noise is sufficient to require a reduction of say 10 dB in the gain then the count is scaled up by a factor of 10 and the gain is assumed to be the same as for the electrical noise.

The ambient noise level in the booth is measured under two conditions (i) the base condition (the booth is as quiet as possible) (ii) working condition (the neon light in the booth and the air-conditioning to the control chamber are on).

## NATURE OF THE NOISE

A necessary condition for the previously listed assumptions about the nature of the noise (be it total or electrical) to be valid is that the estimate coefficient of variation of the estimate mean square value at each of several values of the bandwidth-integration time product lies within the expected limits. The results, presented in Fig. 2, show that agreement is good for 1/3 octave bands of centre frequency 400 Hz and above.

For lower frequencies the noise tends to be non-stationary and hence cannot be measured properly using this method. However, since the level is usually higher it can be measured in the normal way.

## ANALYSIS

The statistics of the idealised noise signal can now be applied to the total and electrical noise. Thus, $\hat{\Psi}_t^2$ the estimate mean square value of the total noise signal has a Gaussian distribution for which 95% confidence limits lie at 1.96 times the standard deviation either side of the true mean square value. That is

$$1 - 1.96\,V < \frac{\hat{\Psi}_t^2}{\Psi_t^2} < 1 + 1.96\,V$$

where V is the coefficient of variation of $\hat{\Psi}_t^2$. By rearrangement, limits for the true mean square value may be expressed in terms of the estimate. Thus with 95% confidence

$$\frac{\hat{\Psi}_t^2}{1+1.96V} < \Psi_t^2 < \frac{\hat{\Psi}_t^2}{1-1.96V}$$

A similar expression can be derived for the electrical noise. Using the Principle of Energy Addition and these limits, the maximum 95% confidence limits for $\Psi_r^2$, the mean square value of the ambient noise, are given by

$$\frac{\hat{\Psi}_t^2}{1+1.96V} - \frac{\hat{\Psi}_e^2}{1-1.96V} < \Psi_a^2 < \frac{\hat{\Psi}_t^2}{1-1.96V} - \frac{\hat{\Psi}_e^2}{1+1.96V}$$

By considering the mean square sound pressure to be proportional to the mean square value of the corresponding noise signal the counts supplied by the Noise Integrator can be referred back to sound pressure levels. Thus the ambient SPL in dB is given by

$$P_a = 10\log_{10}\left(\frac{\Psi_a^2}{\Psi_r^2}\right) - G + 124$$

Note that the mean square value of the calibration tone $\Psi_r^2$ is taken as equal to $\hat{\Psi}_r^2$ since there is a negligible spread in the values. The 95% confidence limits for $\Psi_a^2$ lead to corresponding limits for $P_a$ and the results are presented in Fig. 3. The upper 95% confidence limits are joined to give a maximum ambient noise level contour for both base and working conditions.

## SIMULATED AMBIENT NOISE MEASUREMENT

A small error in the measured electrical noise level gives rise to a much larger error in the calculated ambient noise level. For instance, if the microphone is not sufficiently well isolated from the ambient noise then the measured value of the electrical noise will be higher than the true value. This gives a low estimate of the ambient noise level. Thus in order to determine the significance of such systematic errors the method is used to measure a known, simulated ambient noise level.

A broadband noise is purposely created in the booth by driving a medium range speaker with white noise. High, medium and low noise levels are established in the booth and the 1/3 octave band levels are measured in two separate ways: by the Noise Integrator technique and by reading the meter in the normal way. The speaker noises and the ambient noise are measured with the booth in the base condition. The three levels of white noise supplied to the speaker are separated by 25 dB. The results are present in Fig. 4. The solid lines are the levels estimated by the Noise Integrator, where the error bars are the 95% confidence limits, and the triangles, circles and squares are high, medium and low levels of the speaker noise respectively, as measured on the meter of the frequency analyzer B&K 2121. Each meter reading is an average. Fluctuations are about ±2 dB at 250 Hz, ±0.7 dB at 1 kHz and about ±0.3 dB at 10 kHz.

For the high and medium levels of speaker noise the estimates from the Noise Integrator technique are almost parallel and separated by the required 25 dB. The meter measurements are in good agreement. At the low noise level, the estimate from the Noise Integrator technique is still quite close to that expected from the speaker response but many of the meter measurements deviate considerably from this because the true ambient noise signal is affected by the electrical noise of the measurement system. The medium and low speaker noise level curves are closer than expected at lower levels because here ambient noise (see Fig. 4) adds to speaker noise. This is particularly noticeable at lower frequencies.

The value of the Noise Integrator technique is demonstrated by the accurate measurement of a speaker response at very low levels (below 10 dB for all frequencies, at which the output of the speaker is almost inaudible). The results which it provides are certainly more accurate than those found in the normal way from meter readings. This verification of the measurement method permits reasonably confidence to be placed in the previously determined estimates of ambient noise level.

## CONCLUSION

A method for measuring ambient noise levels in quiet locations, such as audiometric booths, has been developed which is both fast and accurate. It can be used for 1/3 octave bands of centre frequency 400 Hz and above. An application of the method has been to the determination of suitable operating conditions for a test booth. It has been found that in order to maintain a margin of 10 dB between the MAF and the ambient noise level, the test booth must be in the base condition, i.e. the air-conditioning must be turned off.

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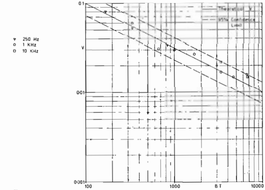
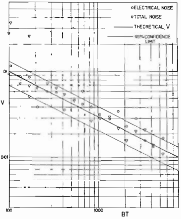


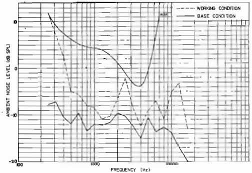

**FIGURE 1.**

Comparison of the estimate coefficient of variation of the estimate mean square value of 1/3 octave band white noise with the theoretical value.



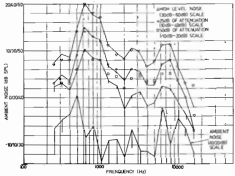

## FIGURE 2.

Comparison of the estimate coefficient of variation of the estimate mean square value of 1/3 octave band electrical and total noise with the theoretical value.




## FIGURE 3.

The upper of 95% confidence limits for 1/3 octave band ambient noise levels.




## FIGURE 4.

Simulated ambient noise measurements.

# REVIEW OF AMBIENT NOISE IN THE OCEAN: NON BIOLOGICAL SOURCES

DOUGLAS H. CATO

*SUMMARY*

*The ambient background noise is a major limitation on the many uses of sound in the ocean. Apart from the biological noise there are two main sources of prevailing noise. The first is a broad band noise generated by the wind at the sea surface by a mechanism that is not understood. The second is traffic noise: the noise of distant shipping, usually evident from frequencies of a few Hertz to a few hundred Hertz. Both these components, however may be obscured by the almost white noise from heavy rain on the sea surface. This paper reviews the present state of knowledge of ambient noise from non biological sources, with particular reference to waters near Australia, and discusses methods of predicting the noise. Because ambient noise varies considerably with environment, existing prediction methods, derived with the North Atlantic, are not applicable to waters near Australia.*

## INTRODUCTION

As sound is the most effective form of radiation in water it has become our main means of transmitting information through the ocean. Many applications, generally referred to as SONAR have been developed since the first use of sound in the ocean towards the end of last century. Apart from the well known echo-sounder, modern applications include the detection of fish and the estimation of fish abundance, the detection of ships and submarines for the purposes of naval defence, and the probing of the sea floor and the sub-bottom layers in mineral exploration. In all these applications, the signals must be detected against the background noise, and a major component of this background (sometimes the only component) is the ambient noise. Here ambient noise is taken to mean all observable noise at a position, apart from that due to the measuring system.

Sound exists in the ocean in at least as much diversity as in our own environment, and sound pressure levels are comparable to those in a noisy urban district. This is perhaps to be expected, since the generation of sound of a certain pressure level requires far less energy (about 1/3500) in water than in air. Once generated, the sound spreads with much less absorption, propagating to distances two orders of magnitude greater than in air for the same absorption attenuation. Thus a much larger area of sources contribute to the ambient noise in the ocean than in the atmosphere. Propagation conditions in the ocean vary considerably with the consequent variation in the ranges at which sources can contribute to the ambient. In a deep ocean basin, where propagation loss is low, contributions from sources at distances of thousands of kilometres may be possible.

The three main sources of ambient noise in the ocean, at least in the frequency range from a few Hertz to about 50 kHz, are that generated at the sea surface by the wind, the noise of distant shipping, and the biological noise. This paper reviews the present state of knowledge for non biological sources of noise, with particular reference to the waters near Australia. Methods of predicting the ambient noise in these waters are also discussed. Because the ambient noise is very dependent on environment, existing prediction methods, derived from work in the North Atlantic, are not applicable to waters near Australia.

## HISTORICAL REVIEW

The first scientific investigation of ambient noise in the ocean commenced in 1941, and was conducted by several research organisations in the United States and Britain, mainly in the coastal waters of these two countries. The work covered the frequency range 100 Hz to 25 kHz and resulted in the classic publications by Knudsen, Alford and Emling (refs 1 and 2). They identified three main sources of noise;

a) noise generated at the sea surface which they considered to be due to wave motion,
b) noise from marine life,
c) ship and other man made noise.

They found that the broad band surface generated noise was usually the prevailing noise in open water and established empirical relationships between noise and sea state, which have become known as the "Knudsen spectra". These took the form of an average spectrum for each sea state, each having a spectral slope of −5 dB per octave, and showing a 3 to 4 dB increase in noise level for each doubling of wave height. Considerable variation was observed, however, in the noise level for a particular sea state. Knudsen, Alford and Emling gave only a small amount of data on ship and man made noises, mostly confined to busy harbours. Considerable data, however were reported on biological noise, showing how, in some areas it was a prominent component of the ambient noise while in others it was rarely significant. They also reported that rain, hail, surf, movement of gravel on the bottom, and creaking and breaking of ice contributed to the ambient, but no quantitative data were given.

The next major work was that by Wenz (ref 3) who, in the light of considerable new data from both shallow and deep water off the USA and frequencies down to 1 Hz, refined the interpretation of ambient noise in terms of its component spectra. He introduced the concept of "traffic noise" which he defined as that due to the sum effect of many distant ships, which are too distant for an individual contribution to be significant. He noted that the dependence on wave height or sea state was often not observed at frequencies below 200 Hz and sometimes even below 500 Hz, and attributed this to the presence of traffic noise at these frequencies. A typical ambient noise spectrum would thus be the composite of a sea surface generated noise which would be dominant above 500 Hz, and traffic noise which would be dominant below 100 Hz. The noise from 100 to 500 Hz would contain contributions from both traffic and sea surface noise in amounts depending on actual ship traffic conditions and the sea state. Wenz also refined the shape of the surface noise spectra, showing that there was a broad peak at about 500 Hz. Some further sources of noise were discussed by Wenz: thermal agitation noise which was considered to be well below other noises except at frequencies above about 30 kHz, noise from water turbulence, and seismic noise.

Research following Knudsen, Alford and Emling, and Wenz, has refined our understanding of the sources of noise which they identified. The main areas of measurement have been the North Atlantic, the Mediterranean, the Pacific Ocean of the coast of North America, waters near New Zealand, and the waters near Australia, New Guinea and the Indonesian Islands.

## THE NOISE GENERATED AT THE SEA SURFACE: WIND-DEPENDENT NOISE

*Relationship between the noise and wind speed*

This is the prevailing noise of the ocean. It has a broad spectrum and is significant from 1 Hz to well over 25 kHz, although it may be obscured by traffic noise or biological noise over some of this frequency band. Although early workers considered this to be the noise of the wave motion, later work has shown it to be more directly related to wind speed than to wave height or sea state. Although the wind is responsible for generating the waves, there is no simple relationship between the wind speed and wave height at any instant. If the wind were to start blowing over a calm sea, small scale capillary waves would appear almost immediately, but it may take many hours for the large scale gravity waves to develop to the full height corresponding to the wind speed, and these would persist well beyond the cessation of the wind. Experiments have generally shown that the noise varies with the wind speed rather than the wave height. For example, Perrone (ref 4) cross correlated wind speed and wave height measured in deep water near Bermuda and found that the waves lagged the wind by about 6 hours. Cross correlation of noise and wind speed, however, showed that the noise lagged the wind by 0 to 1 hours. In addition, correlation of noise and wave height showed that the waves lagged the noise by 6 hours. This and other experiments have generally shown a significantly higher correlation coefficient between wind speed and noise than between wave height and noise. Mean wind-dependent noise spectra determined from measurements in waters near Australia (ref 5) are shown in Fig. 1. Measurements from other parts of the world show similar spectral shapes, but actual noise levels may vary with position and time. Also few measurements are available elsewhere at frequencies below 100 Hz because of the difficulties of separating the wind-dependent noise from traffic noise. The Australian measurements had an upper frequency limit of 10 kHz. As these spectra approach 10 kHz, they approach the slope of the spectra measured by Knudsen, Alford and Emling (ref 2) which extend to 25 kHz. The best estimate of wind-dependent noise above 10 kHz for Australian waters is taken as an extrapolation of the measurements beyond this frequency using this spectral slope. The resulting levels are 2 to 3 dB higher than the average measured by Knudsen, Alford and Emling.

Probably the most accurate empirical determination of the relationship between noise level and wind speed was measured by Piggott (ref 6) in the shallow water of the Scotian Shelf. From 8000 samples of noise and wind speed he obtained plots like those shown in Fig. 2 which are reproduced from his paper (ref 6). Each data point gives the mean noise level ± two standard deviations for a particular wind speed. For frequencies above 200 Hz, Piggott found that the dependence of noise on wind speed could be represented as a linear relationship between noise spectrum level, L, and the logarithm of the wind speed U, of the form

$$L = A + 20\, n \log_{10} U$$

where A and n are parameters which depend on frequency but not on wind speed. This can be more simply stated as

$$p = a U^n$$

where

$p$ = rms sound pressure in a 1 Hz band, and
$L = 20 \log_{10} P$,
$A = 20 \log_{10} a$

At frequencies below 200 Hz the noise level decreased to a constant level with decreasing wind speed, as shown in Fig. 2. At these lower frequencies, the line of best fit to the data is obtained as the sum (of the intensities) of a non-wind-dependent background noise and a wind-dependent noise whose level increases linearly with the logarithm of the wind speed. These two noise components are shown as the dashed lines in Fig. 2. This is a fairly accurate means of separating the wind noise component from the non-wind-dependent component, which, as will be shown below, is traffic noise.

*Wind noise dependence on position and season*

Although the above relationship between noise and wind speed provides a good fit to Piggott's data, it cannot generally be applied to other areas unless the parameters A and n are allowed to vary. Crouch and Burt (ref 7) showed that this relationship could be applied to deep water measurements near Bermuda with different values of A and n, and their levels were more than 12 dB below Piggott's at 1120 Hz. Some of this difference may have been due to the greater depth of the hydrophones. Even Piggott's results showed a seasonal variation in the mean depth of about 6 dB over the 12 month period, a variation comparable to that due to a two change fold change in wind speed. Piggott suggested that this might be caused by varying propagation conditions due to seasonal variation in water temperatures. Wenz (ref 3) also observed both a seasonal variation of about 8 dB, and a variation with position of up to 13 dB, in the measured noise at a particular wind speed and frequency.

Not only does the measured wind-dependent noise vary with position, but so also does the rate at which the noise increases with increasing wind speed. This latter point is illustrated in Fig. 3 which shows the parameter, n, plotted as function of frequency for six studies in various parts of the world. Each study represents a series of measurements in the one area, except for the Australian results which were obtained from about 30 positions in open waters in the Tasman, Coral, Arafura and Timor Seas and the east Indian Ocean. A wide variation in the value of n is apparent, and note that in waters near Australia and New Zealand, n is significantly less than in North Atlantic Ocean. It may seem surprising that noise generated at the ocean surface should show such a dependence on environment. However, the noise that is measured depends not only on the nature of the source but also on the propagation conditions of the region. Although there is, as yet, no explanation for the wide variation of n in Fig. 3, it seems likely that it is a propagation effect. There is a general trend of decreasing values of n with improvement in propagation conditions. For example, the absorption of sound is less in waters near Australia and New Zealand than in the North Atlantic (refs. 11, 12).

*Wind noise dependence on depth*

Lomask and Frassetto (ref 13) demonstrated that wind-dependent noise decreased with increasing depth by measuring the noise while slowly descending in a Bathyscaph to the bottom of the Mediterranean Sea at a depth of 3000 m. At 240 Hz, the noise level decreased, with some fluctuation, at an average rate of about 5 dB per 1000 m. Urick, Lund, and Tulko (ref 14) measured the variation with depth to 3700 m at a fixed position near the Virgin Islands, while Perrone (ref 15) used bottomed hydrophones down the side of a sea mount. The limited amount of data makes it unreliable to generalise other than to say that wind-dependent noise above about 200 Hz decreases with depth. However, the data may be summarised as showing a drop in level of 5 to 10 dB over the first 1000 m, followed by a decrease of 0 to 5 dB per 1000 m at greater depths, up to a maximum of 20 dB over the complete water column (for frequencies from about 200 to about 3200 Hz). It should be noted that the parameter determining the depth dependence is the depth of the receiver, not the water depth. The data of Perrone (ref 15) and also of Arase and Arase (ref 16) have been interpreted as indicating a dependence on water depth. However, since bottomed hydrophones were used in their experiments, the results are ambiguous – the observed effect could have been due entirely to the dependence on receiver depth. Later work, however, has resolved this ambiguity. Measurements at more than 30 positions near Australia where water depths varied from 26 to 6700 m, showed that the wind noise at a constant receiver depth of 25 m was dependent of water depth (ref 5). Thus wind-dependent noise varies with receiver depth (refs 13, 14) but not with water depth (ref 5). Wenz's prediction curves give wind-dependent noise levels in shallow water (less than 200 m) which are 6 dB higher than in deep water. In the light of more recent work, this difference should apply to receiver depths rather than water depths.

*Models of wind-dependent noise*

In spite of the considerable amount of research on wind-dependent noise, the actual mechanism of noise generation is not understood. Even empirical relationships between noise level and wind speed are not general in their application. Part of the difficulty in modelling, theoretically, the generation of wind noise is that much is yet to be learnt about the dynamics of the sea surface.

Figure 4 illustrates some possible mechanisms of noise generation by the wind. In the first, noise is radiated from the turbulent pressure fluctuations that result from the flow of the wind across the sea surface. Although the difference in acoustic impedance between air and water results in a reduction in intensity of about 30 dB in transmission through the interface, this is offset by the fact that sound pressure levels in water are about 30 dB higher than in air for the same intensity. The water presents an almost rigid surface to air-bourne sound waves, with the effect that a normal incident wave is reflected with almost a doubling of pressure amplitude at the surface, and this, of course, must be matched by the pressure on the water side of the interface. Issacovitch and Kuryanov (ref 17) have considered this mechanism, suggesting that it may be the dominant source at frequencies below 100 Hz, but the predictions of their theory do not compare well with measurement.

The second mechanism of Fig. 4 involves a second order effect of the surface wave motion – the interference of progressive wave trains. Although this mechanism has received the most attention, it suffers from the disadvantage of being associated with the surface wave motion rather than the wind speed. Longuet-Higgins (ref 18) showed that pressure fluctuations from this effect would persist to the ocean depths, in constrast to the simpler pressure fluctuations induced by wave motion, which decay rapidly with depth. A number of workers have developed theories but none can be said to adequately predict the noise observed. Perhaps the most likely theory is that by Kuo (1968, ref 19) based on the small patches of capillary waves that ride on the forward crests of the larger scale gravity waves. The capillary waves can be thought of as a direct consequence of wind action. His theory has some interesting results but does not go far enough to predict noise levels. Later work by Hughes (1976, ref 20) using more recent models of the sea surface wave field, provides theoretical estimates of the noise produced by this mechanism. His main conclusion is that the mechanism fails to account for the observed noise above 10 Hz but may well provide the necessary energy below 10 Hz.

The third mechanism of Fig. 4 concerns the breaking of small scale waves which is a direct effect of wind action, since both the small scale waves and their breaking follow very soon on the application of wind to a smooth surface. Above a certain wind speed (about 3 m/s) some of the breaking results in air entrainment and the effect is visible as white caps. Banner and Phillips (ref 21) have investigated this form of breaking and found that it is far more widespread than the occurrence of white caps. They have also shown that separation occurs in the air flow over the region of breaking – a possible source of noise which should be included in the first mechanism. Possible sources of noise associated with the breaking of small scale waves are

a) the turbulence of the breaking region
b) the impact (splash noise) of the breaking region onto the undisturbed surface
c) the oscillation and bursting of the bubbles resulting from air entrainment.

No models of noise generation by this mechanism appear to have been published, although it appears to be a likely cause of the wind-dependent noise. It is possible to hear "splash noise" from a region of breaking if a hydrophone is sufficiently close to the surface. In addition, the spectrum of splash noise (ref 22) has a similar shape to the mid frequency part of the wind-dependent noise spectrum.

In any mechanism of noise generation by the wind it seems likely that the surface roughness would play a secondary role because it would affect the wind action on the surface. It also seems likely that different mechanisms would be the dominant source in different frequency bands. For example, Figs. 1 and 3 suggest different mechanism above and below 100 Hz.

Some models (ref 23, 24) have considered only the propagation side of the problem, i.e., they have assumed a uniform distribution of sources over the surface without considering the mechanism of noise production. These do however, provide some insight into the nature of the sources as, in order to fit measured data on the directivity of the ambient noise field (summarised by Urick, ref 24), the sources in the models would need to have some directionality. Although there is considerable spread in this data, there is some indication that the sources may be dipoles with maximum radiation downwards.

## LOW FREQUENCY, NON-WIND-DEPENDENT NOISE: TRAFFIC NOISE

This component of the ambient noise is usually evident at frequencies from a few Hertz to a few hundred Hertz when winds are low to moderate, depending on the relative levels of the traffic noise and the wind noise.

Wenz (ref 3) defined *traffic noise* as the combined effect of the noise from distant shipping where the noise from any one contributing ship would not be significant nor detectable. Because so many sources contribute, traffic noise is usually not obvious as such, that is, it does not have the distinguishing characteristics of noise from a single ship. It is probably analogous to the background noise in an urban district which cannot readily be associated with a particular source, as opposed to the noise, say, near a busy road.

Given the source strength of an average ship, and the average propagation loss in deep water, Wenz calculated that the noise at 100 Hz from 100 ships at a distance of about 900 km would be similar to the average non wind dependent noise levels observed in the North Atlantic. As a doubling of this distance would mean a reduction of only about 6 dB in this noise level, it is apparent that ships at distances of thousands of kilometres could contribute to the traffic noise in a deep ocean basin. Wenz also noted that the non-wind-dependent noise spectra usually showed a negative slope similar to that of ship noise. It thus becomes less significant with increasing frequency, so that the wind noise usually becomes dominant above 100 to 500 Hz.

Piggott's method (ref 6) of analysis of sea noise data (described above) provides a fairly accurate determination of the non-wind-dependent noise spectrum at the position of measurement. Crouch and Burt (ref 7) used a similar method of analysis on data measured in deep water near Bermuda. The spectral slopes of the non-wind-dependent noise obtained by Piggott of −7.5 dB/octave and by Crouch and Burt of −6 to −7 dB/octave are comparable to the spectral slopes of about −6 dB/octave of ship noise at close range (Urick, ref 24). As propagation loss, in general increases slightly with frequency (mainly because the attenuations due to absorption and to reflection from the bottom increase with frequency) traffic noise spectral slopes should be slightly higher than that of close range ship noise.

Because of the nondescript nature of non-wind-dependent noise it has been difficult to verify that the source is in fact distant shipping. Wenz at least showed that the hypothesis was feasibly and there has been some indirect supporting evidence arising out of later experiments. For example, Dyer (ref 25) developed an analytical model for the statistical fluctuation of traffic noise. Using known shipping distributions in the North Atlantic, he calculated the standard deviation in traffic noise at 60 Hz which compared favourably with that measured at this frequency near Bermuda (ref 15). There are more than 1000 ships underway in the North Atlantic at any time so that traffic noise levels would be continuously high, providing no opportunity in this ocean to test the hypothesis for a wide range of shipping densities and propagation conditions. Such an opportunity arose from the measurements near Australia, and the results provided substantial support for the traffic noise hypothesis (ref 5).

Figure 5 shows the mean non-wind-dependent noise levels measured in three regions near Australia. Temporal and spatial fluctuations of ± 5 dB about the mean spectrum were observed in each region. Also shown is the Wenz's "usual deep water traffic noise" for the North Atlantic. The highest traffic noise levels near Australia would be expected in the Tasman Sea because of the considerable amount of shipping parallel to the coastline and the good propagation conditions. A model of traffic noise in this sea predicted levels comparable to those observed. The observed levels are also comparable to those of the North Atlantic. Non-wind-dependent noise measured at various positions in the east Indian Ocean showed lower levels than in the Tasman Sea, as would be expected from the lower shipping densities. Levels are lower still in the Pacific Ocean near New Guinea, and are consistent with both lower shipping densities and poorer propagation conditions than in the Indian Ocean.

In the shallow Arafura and Timor Seas north of Australia, it was calculated that traffic noise should not be significant, even at the lowest wind speeds, because of the very low shipping densities and high propagation loss in the region. Measured mean noise levels in these seas for low wind speeds (less than 5 m/s) were about 20 dB below the mean traffic noise levels in the Tasman Sea, and consistent with that expected for wind noise alone. The lowest measured levels were comparable to the wind noise spectra for a speed of 1 m/s in Fig. 5. The low frequency non-wind-dependent noise therefore varies in accordance with the wide range in propagation conditions and shipping densities around Australia, and thus provides substantial support for the traffic noise hypothesis.

It is interesting to note that, since ocean basins provide the conditions required for good sound propagation, it only needs a reasonable spread of shipping for traffic noise to be evident throughout the ocean basin — perhaps the most widespread form of noise pollution. In this respect the Arafura and Timor Seas are unusual — they appear to be one of the very few open sea areas where noise has been measured and traffic noise is not significant.

## OTHER SOURCES OF NOISE IN THE OCEAN

While wind-dependent noise and traffic noise are the prevailing components of the ambient, other sources may be significant from time to time.

*Rain noise*

Rain on the sea surface produces high noise levels under water over a broad frequency band, the noise of a heavy rain storm exceeding the highest levels observed from traffic noise and wind-dependent noise. Heindsmann, Smith and Arneson (ref 26) measured noise spectrum levels of between 73 and 80 dB re 1 $\mu$Pa over the frequency band 50 Hz to 20 kHz for a heavy rain storm — almost white noise over this frequency band. Bom (ref 27) produced empirical relationships between noise level and rain fall rate in various frequency bands for measurements in a lake.

The noise spectrum of a heavy rain storm passing over the hydrophone is shown in Fig. 1.

*Seismic noise*

Wenz (ref 3) first suggested that some sea noise might be seismic in origin, but at the time there were practically no data available to test this idea. Recent measurements of sea floor motion have been used by Urick (ref 29) to calculate the resulting noise in the water. Although the assumptions in these calculations limit the validity of the results, it seems feasible that seismic noise might be significant at very low frequencies, say below 1 Hz and possibly below 100 Hz (with levels decreasing with frequency) in positions where other noises are low.

Underwater volcanoes produce intermittent noises at frequencies of a few Hertz, and some have been located by using the acoustic signals received at different positions (ref 29).

*Noise under ice*

Under an extensive sheet of stable ice, noise levels may be exceptionally low because the water surface is shielded from the wind. On the other hand, the cracking of the ice and collisions of ice flows can be responsible for quite high noise levels. An account of the noise under ice in the Antarctic is given by Kibblewhite and Jones (ref 30).

*Thermal agitation*

Mellen (ref 31) has calculated the noise from thermal agitation of the mediun. It rises at about 6 dB/octave, the spectrum level at 100 kHz being about 25 dB re 1 $\mu$Pa. This noise, therefore, would be significant only at frequencies above about 30 kHz.

*Noise from surf*

The roar of the noise from surf on a beach may be the dominant low frequency noise close to the beach, but beyond a few kilometres it is usually obscured by other noises.

*Noise from drilling rigs*

The recent development of off-shore drilling platforms has provided another potential source of noise in the ocean, although no data is available at present.

## PREDICTION OF AMBIENT NOISE IN WATERS NEAR AUSTRALIA

The prevailing ambient noise spectrum from non-biological sources may be estimated by summing (the intensities) of the appropriate wind-dependent component spectrum from Fig. 1 and traffic noise component spectrum from Fig. 5. The wind-dependent component applies *irrespective of water depth,* and for shallow hydrophones. Noise levels will be lower at deep hydrophones, and an estimate of the reduction in level may be obtained from the discussion above, under the heading "Wind noise dependence on depth". The errors of estimate for the wind-dependent noise are about ± 3 dB for frequencies above 200 Hz and ± 6 dB below 200 Hz. The traffic noise spectra in Fig. 5 are mean values, a temporal and spatial fluctuation of ± 5 dB about the mean may be expected in each region. In the shallow, shelf areas of the Arafura and Timor Seas, traffic noise is insignificant compared with wind noise, and so may be ignored. The only measurement of traffic noise in the Coral Sea shows levels similar to those of the Indian Ocean, and this is not inconsistent with shipping densities and propagation conditions in the region. In the absence of further data the Indian Ocean spectrum could tentatively be used for this sea. No data appear to be available for waters south of Australia.

Rain on the sea surface will produce approximately white noise spectra over the audio frequency range. The spectrum in Fig. 1 shows the highest levels likely to be observed. Prediction of levels for intermediate rates of rain fall may be obtained from ref 27.

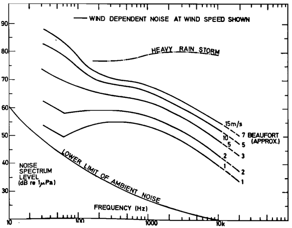



FIGURE 1

Empirical wind-dependent noise spectra determined from measurements in waters near Australia (ref 5). Also shown are the highest levels expected from heavy rain, and the lower limit of prevailing noise (after Wenz, ref 3). The broken lines indicate extrapolation using the spectral slope at these frequencies determined from ref 2.

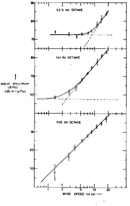



FIGURE 2

Measured noise levels on the Scotian shelf plotted as a function of the logarithm of the wind speed (from Piggott, ref 6). The wind-dependent and non-wind-dependent component spectra are shown.

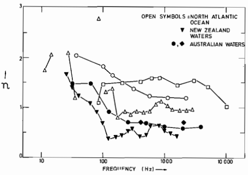



FIGURE 3

The parameter, n, indicating the rate of increase of noise level with wind speed, plotted as a function of frequency. Sources of data:
open squares: Narragansett Bay, Rhode Is. (ref 8)
open circles: Scotian Shelf (ref 6)
open triangles: Deep water, Bermuda (ref 7)
filled triangles: near New Zealand (ref 10)
filled circles: around Australia (ref 5)
filled diamonds: Indian Ocean (ref 9)

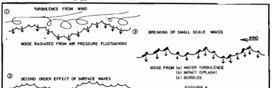



FIGURE 4

Models of the mechanism of wind noise generation at the sea surface.

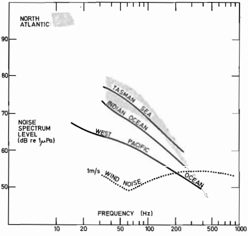



FIGURE 5

Traffic noise measured in three regions near Australia (ref 5) and Wenz's "usual deep water traffic noise" for the North Atlantic (ref 3). In the Australian results, actual levels fluctuate ± 5 dB about the means shown. Wind noise for a wind speed of 1 m/s is also shown.

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