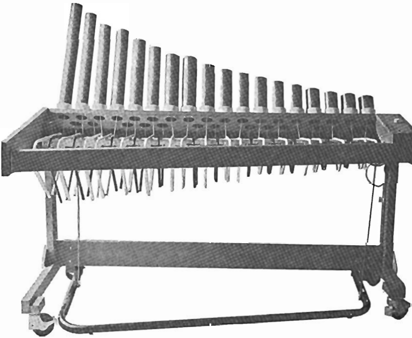
The Bulletin

AUSTRALIAN ACOUSTICAL SOCIETY

Vol. 12, No. 1 APRIL, 1984 Pages 1-28



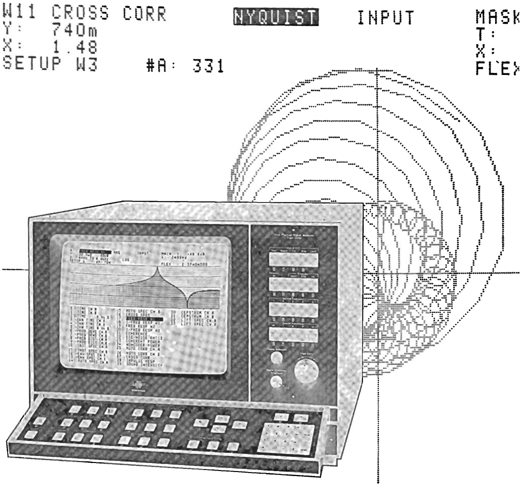
A New Musical Sound

Acoustics of the Alemba

Sounds made by Plants

Self-calibration of Microphones

2-channel FFT Analysis ...
... the Bruel & Kjaer way



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C/- School of Physics
The University of New South Wales
P.O. Box 1, Kensington, N.S.W. 2033

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* * * * * *

INFORMATION for CONTRIBUTORS

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

(a) Short articles which will appear as a Report or Technical Note;
(b) Long articles which may take the form of a discussion, review, tutorial or technical paper.

A referee's report will be sought for the latter.

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

Vol. 12, No. 2 — Long articles: May 21
Short articles: June 29
Vol. 12, No. 3 — Long articles: September 14
Short articles: October 19

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

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

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

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

Drawings and **photographs** may be prepared to any convenient size and will normally be reduced proportionally to single column width. Authors are requested to plan the proportions of diagrams so that they will fit preferably into a single column width. Drawings may be supplied with or without lettering. If lettering is added, please allow for the proportional reduction in size and thickness that will be necessary. In general, typed lettering is unsatisfactory.

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

Advertising information may be obtained from Cronulla Printing Co. on (02) 523 5954.

* * * * * *

SUSTAINING MEMBERS

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

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International Conference on "Developments in Marine Acoustics"

Sponsored by the Australian Academy of Sciences and the Australian Acoustical Society.

Call for Papers
4-6 December, 1984. SYDNEY, Australia
University of New South Wales.

Special Sessions:
(1) Interactions with the sea floor.
(2) Shallow water propagation.
(3) Acoustic Fluctuations.
Deadline for Abstracts: 29th June, 1984.

For further details contact:
Marshall Hall
R.A.N. Research Laboratory,
P.O. Box 706,
Darlinghurst, N.S.W. 2010

Science on Tape

A service which has existed for the medical profession for some time now is gaining popularity in the scientific field — the dissemination of information on audio casette. Black Inc Recorders, with recording studios in St. Leonards in Sydney, is active in this area and producer Allan Black reports increasing interest being shown by many companies who need further communication to their technical audience.

The present economic climate is also having an effect on seminar attendances and a greater reliance is being placed on getting it all on cassette, he said.

"The cost benefits derived by people in other states for instance, are enormous. They are able to digest information at their leisure and in some highly technical cases, because they can replay the tape, they're better off than the actual audience.

"Again, if a visiting scientist has only a couple of days in Sydney, some companies prefer to wheel him into our studios where we produce abbreviated versions of a seminar or workshop. This has the advantage of less organization and expense than a seminar and faster delivery of material; the speaker will get through his stuff in a quarter of the time because his actual audience will only be one or two people. This, of course, benefits the listener. Slides can be reproduced in book form to accompany the cassettes and the whole lot reproduced by the thousands for surprisingly small cost.

"When necesasry, we also have a service for recording and providing conference cassettes, at the conference. We can have cassettes for sale half an hour after the speaker finishes.

"One of the main advantages of the audio cassette is the listener plays it when he's ready to pay proper attention and therefore his intake is greater. He can replay complicated sections and when finished, put the cassette away for future reference."

Black Inc Recorders' studios are situated at 47 Chandos Street, St. Leonards 2065; telephone (02) 439 3033.

(Laboratory News, July 1983)

ANZAAS in A.C.T.

The Australian and New Zealand Association for the Advancement of Science (ANZAAS), after 96 years and 53 congresses, will for the first time stage a "Scientific Equipment and Services Trade Fair" in conjunction with its 54th congress next year; theme "The Horizons of Science".

The congress, a forum for researchers, practitioners and academics will be held at the Australian National University (ANU) in Canberra from May 14-18.

The exhibition will be set up in the gymnasium.

Up to 3000 delegates representing over 30 disciplines in natural and social sciences are expected to attend the lectures, forums, workshops, discussions and the exhibition during the week.

Tibor Vass on leave

Tibor Vass, Senior Lecturer, Department of Architecture was absent from WAIT in 1983, when he visited a number of Schools of Architecture in Great Britain, Canada and on the Continent. At the same time he continued his research into Hospital Planning, specifically in the area of Hospital Inpatient Unit Design.

In addition to the examination of the status of relevant Technology Subjects in Architecture Courses, Tibor took part in teaching in the Technology Area (mainly Acoustics) at Strathclyde University, Glasgow, in the third term and at the Toulouse University, France in part of first term.

Tibor also conducted two pilot studies in Hospital Ward Assessment; one in Glasgow (acoustic and thermal) and one in Toulouse (acoustic). In the case of the Toulouse Hospital, the initiated noise survey formed the basis of a research grant application to continue further research into Hospital Ward Design.

Tibor was also part of a strong Australian contingent at the 11th International Congress on Acoustics, in Paris in July.

—Michael Norton.

Occupational Safety and Health Research Projects

In November 1983 the Federal Minister for Employment and Industrial Relations, **Mr. Ralph Willis,** announced the establishment of a research grants scheme to be awarded annually for occupational safety and health research projects.

$200,000 has been allocated for the scheme in 1983-84.

Projects submitted for funding will be selected on the basis of their emphasis on occupational safety or direct relevance to improving the physical working environment.

It is envisaged that most projects will run from one to two years and will attract funding from $20,000 to $30,000. Projects of a shorter duration will also be considered.

Unfortunately details of this scheme reached the Bulletin too late for the 1984 awards (closing date 15 December 1983).

For further information, contact
Mr. Neville Betts
Director
Working Environment Branch
Department of Employment and Industrial Relations
(Phone (062) 45 9658)
CANBERRA, ACT 2600

● VICTORIA

SOUND FIELD IN FACTORY SPACES

Dr. Frank Fahy, ISVR, Southampton, England

Further to the seminar given in Sydney by Dr. Frank Fahy entitled "Sound Field in Factory Spaces", the Victorian Division in conjunction with Dr. R. Alfredson of Monash University, organised a repeat at the Engineering Lecture Theatre of Monash University. Comments from members were that it was a very practical, informative and well-illustrated talk.

Members interested in obtaining further information about the technical theory should contact Dr. J. I. Dunlop.

Victoria Division 1984 Meetings

The Programme Sub-Committee of the Victorian Division has organised the following technical meetings for the remainder of 1984:

July 20th:

Afternoon Seminar, 2-5 p.m.
"Noise within the Community".
Chairman: Stephen Samuels, ARRB.
Speakers: Andy Hede, EPA.
Jim Clements, Altona Petro. Chem.
Mark Williamson, City of Waverley.
Cost: approx. $10.
Papers will be bound into a "proceedings".
Venue: Australian Road Research Board.

September 19th:

Division AGM, 6-10 p.m.
An open forum on the future of the Acoustics profession. Includes dinner at the bistro.
Venue: The World Trade Centre.

October 9th:

Technical visit to the Aeronautical Research Labs., Department of Defence. Inspection of Acoustic emission, ultra-sonics, vibration and Modal Analysis etc.

November/December:

End of Year Function, to be arranged.

Two seminars are being run by the Victorian Division as part of its 1984 technical programme. The first was held on April 10 from 6 to 8 p.m. at Clunies Ross House and dealt with advances in building acoustics. The second seminar will be held on **Friday, 20th July** from 2 to 5 p.m. at the Australian Road Research Board and it will cover several aspects of community noise. **Stephen Samuels** at ARRB (03-235 1555) can tell you more. Members from other divisions would be particularly welcome so note these dates in your diary to assist in planning your next interstate trip.

H. Sin Chan

Annual General Meeting and end of the year function

The Annual General Meeting of the Society combined with the end of year function for the Victoria Division was held on November the 25th last, at the Royal Melbourne Institute of Technology Union "Glasshouse". Prior to the formal meeting 43 members and guests enjoyed an hour of conviviality and renewal of acquaintances over drinks, joined by several interstaters attending A/K and Council meetings at the Science Centre which gave the evening an international flavour. The Chairman, Graeme Harding, then introduced Lawrence Money, the "In Black and White" columnist with the Melbourne Herald, who in the ensuing 45 minutes gave a humorous account of strange things in print, unusual headlines, "bloopers", and other journalistic anecdotes which were warmly received. The evening concluded at about 11 p.m. with an enjoyable time had by all.

John Upton

● 3rd Applied Physics Conference

Australian Institute of Physics

Physics and Australia's Resources

First Announcement and Call for Papers

The conference will be held at Royal Melbourne Institute of Technology on 3rd-7th December, 1984, hosted by the RMIT Department of Applied Physics.

The deadline for receipt of abstracts is 25th May, 1984.

For further information contact:
Conference Secretary, Ken Cook,
Dept. of Applied Physics, R.M.I.T.,
GPO Box 2476V, Melbourne 3001.

● 12th Conference of the Australian Road Research Board

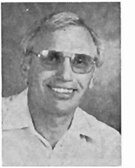
August 27-31, 1984, Hobart

The Australian Road Research Board (ARRB) is a co-operative venture between eight State and Commonwealth government departments interested in roads and road transport. The ARRB 12th Conference is the first to be held in Tasmania and will include over 100 refereed papers presented through three streams of simultaneous sessions covering all aspects of roads and road transportation. Several invited speakers, leading international authorities in their areas of expertise, will present keynote addresses. Conference activities will include technical tours, social events, social tours and will allow ample opportunity in both technical and social functions for informal delegate discussion.

For further information contact:
Australian Road Research Board,
PO Box 156 (Bag 4),
Nunawading, Victoria 3131.

● New B & K Appointment in Queensland

Bruel & Kjaer have announced the appointment of **Mr. Ted Pearce** as their Resident Queensland Sales Engineer.



Mr. Ted Pearce.

Ted Pearce has a Naval engineering background and, in addition to traditional acoustics, his many years experience in vibration measurement and analysis, particularly in regards to the rapidly expanding field of machinery health monitoring, will provide a valuable local expertise. He can be contacted on (071) 44-4060 and the new postal address is:

Bruel & Kjaer Australia Pty. Ltd.,
P.O. Box 227,
Mooloolaba, Qld., 4557.

Performing Arts Complex

The impressive looking Performing Arts Complex on the south bank of the Brisbane River is due for completion in October 1984 with the official opening by an as yet undisclosed "royal personage" in March 1985.

The complex is being built as an extention of the Queensland Cultural Centre. Its five levels will have a multitude of foyers, exhibition areas and theatres and a vast landscaped plaza.

With a combination of three levels the lyric theatre can seat 2000 (fixed seating). The parallel Concert Hall will seat 2000 (also fixed) and the Studio Theatre (formerly called the Experimental Theatre) will seat 450.

The complex will feature highly sophisticated electronic and production facilities, including simultaneous translation for six languages and closed circuit large screen TV allowing both theatres to be used for the same convention.

The Concert Hall will have an orchestra pit and four trumpeters balconies making it particularly suitable for ceremonial occasions.

From The Convention
November 1983

New Noise Laws in W.A.

The Minister for Health, Mr. Hodge, said that the key requirements of the regulations were:

- Employers to take all practical means to reduce noise levels so that worker exposure did not exceed an average of 90 dB"A" a day.
- Regular noise evaluation tests at the work place.
- Regular hearing tests for all workers exposed to a noise hazard.
- Where a noise hazard is shown to exist, the employer to either eliminate the hazard, reduce the noise level or reduce the worker's exposure.

Mr. Hodge said that the regulations had been a long time in coming and were framed after extensive consultations with health authorities, unions and industry.

The executive director of the Confederation of W.A. Industry, Mr. Basil Atkinson, said that industry would be faced with big costs in complying with the regulations.

They would involve a considerable amount of noise analysis, prevention and elimination by industry.

The W.A. Government has allowed factories and businesses 12 months grace.

Mr. Hodge said that the regulations were the most detailed of any State noise-abatement legislation. Employers who failed to comply faced fines of up to $5000 with further fines of $500 a day for repeated offences.

Hearing loss happened gradually, so firms would be required to keep records of hearing tests on employees for 25 years.

Enforcement and inspection would be done by inspectors from the Public Health Department, as well as by health and safety officers already charged with these responsibilities under existing factory leglislation. Additional inspectors would be appointed.

From Safety Concepts
November 1983
monthly newspaper published
by Safety Concepts
Carlingford, Sydney

AUSTRALIAN ACOUSTICAL SOCIETY 1984 CONFERENCE

"Noise and Vibration Legislation in Australia"
University of Western Australia, Perth

1-2 November 1984

The W.A. Division of the Australian Acoustical Society invites submission of papers for presentation at the above Conference. Papers shall be in the following areas:

1. Environmental and occupational acoustic legislation;
2. Review or criticism of existing legislation or proposals for future improved legislation;
3. Experience or problems with the application of existing legislation.

Abstracts of not more than 200 words should be forwarded by 31 May, 1984, to F. R. Jamieson, Acting Secretary, W.A. Division, Australian Acoustical Society, 2 Beryl Avenue, Shelley, W.A. 6155.

Complete papers not exceeding 2,000 words must be received no later than 31 August, 1984. Details of the required format will be provided at the time of notification of acceptance of papers.

Changes of Address

Eden Dynamics Pty. Ltd. have moved to 28 Oatley Avenue, Oatley. Postal address: P.O. Box 64, Oatley, N.S.W. 2223. Tel. (02) 579-5566.

Since the move Eden Dynamics have acquired new equipment for the frequency analysis of vibration, enabling them to perform vibration monitoring and signature analysis on critical rotating machinery, as well as the more usual investigation of vibration in buildings, industry and dynamic balancing. As before, consulting services include the acoustic design of theatres, architectural acoustics, the design of acoustic treatment for buildings and building services, industrial and environmental noise and vibration control.

☆ ☆

After eleven years of unprecedented growth, the **Vipac Group** is relocating and consolidating its Melbourne operations as the foundation and core tenant of the Victorian Technology Centre, Cnr. Ingles Street and Normanby Road, Port Melbourne, Telephone (03) 645 2144. Vipac's new facilities include: acoustic chambers, anechoic room, solar simulator, engine test cells, environmental wind tunnel, boundary layer wind tunnel, air conditioning product development laboratory, appliance laboratory, computer centre.

New Members

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

Member: Mr. B. R. A. Wood (N.S.W.), Mr. R. A. Wills (Vic.).

Subscriber: Mr. W. G. Forrest (N.S.W.).

Subscriber awaiting processing of application for Member grade — Mr. Wan Kar Chan (W.A.), Mr. R. A. Godson (N.S.W.), Mr. D. N. Nicolaisen (N.S.W.), Mr. C. E. Tickell (N.S.W.), Dr. P. A. Wilkins (WA.).

Errata

D. H. Woolford: "Hearing Conservation in the Australian Broadcasting Corporation", Bulletin Australian Acoustical Society Vol. 11 No. 3, December 1983.

Page 111, para. 3.5 (2) (d) (iii) *should read* "transparent shields behind musicians in high risk areas".

INTERNATIONAL NEWS

FASE 84

The 4th Congress of the Federation of Acoustical Societies of Europe, FASE 84, will be arranged at Park Hotel, **Sandefjord, Norway, 21-24 August, 1984.**

The scope of the Congress is to stimulate the exchange of information and ideas among scientists and other people particularly interested in the two selected topics. Potential users will get an up-to-date review of the state of the art in these fields.

The main topics will be: Planning with respect to community noise, and acoustical methods in condition monitoring and diagnosis.

Several satellite symposia covering special issues within the two selected topics will be arranged in or near Sandefjord just prior to the Congress.

Papers will be presented in English, French or German.

For Australian participants, Scandinavian Airlines and Thai International operate a joint office in Sydney at 13-15 Bridge Street. There are four flights a week between Australia and Denmark with connections on to Oslo.

For further information contact FASE 84, ELAB, N-7034 Trondheim-NTH, Norway.

Noise and Vibration Control World Wide

For almost 15 years "NOISE AND VIBRATION CONTROL WORLD WIDE" has provided governments and industry around the world with a journal that presents practical solutions and up-to-date information on preventing and controlling unwanted noise and vibration.

Technical articles published in the journal are written by many of the world's leading authorities and examine all aspects of this increasingly important subject.

In this connection, an invitation is extended to submit a technical article for consideration in "NOISE AND VIBRATION CONTROL WORLD WIDE" in 1984. In general, articles should not exceed 1700 words and can be accompanied by up to four photographs, line drawings, illustrations, etc. Manuscripts should be typed in English, double spaced with wide margins. Two copies are requested.

Details of the general topics to be featured during 1984 are enclosed. If you are interested in providing a technical article please submit a brief outline of your chosen topic as soon as possible.

Further details: Christopher Dickenson, Managing Editor, 13-15 Creek Road, East Molesey, Surrey, KT8 9BE.

Ingerslev Receives DIN Award

Fritz Ingerslev, President of International INCE, was honoured recently by the German Institute for Standardisation (DIN). Professor Ingerslev received the DIN Silver Medal; the award which was given during the eleventh International Congress on Acoustics in Paris on 29th July, 1983 honours individuals who have made outstanding contributions to national as well as international standardisation.

The citation called particular attention to Professor Ingerslev's chairmanship of Sub-Committee 1 (Noise) of ISO Technical Committee 43 on Acoustics since 1968.

As an example of his technical leadership, the introduction of the concept of sound power as the fundamental measure of the noise emission of machinery was cited. Numerous national and international standards for determining the noise emissions of machines have been developed. The awarding of the medal was an expression of thanks from DIN for Professor Ingerslev's untiring efforts for acoustical standardisation and for his work to solve the worldwide problem of excessive noise which, in a densely populated country such as Germany, is of major importance.

Extract from I-INCE Newsletter No. 32

French Government Scientific Fellowships

The French Government is offering a limited number of Fellowships to enable Australians working in scientific fields to visit France for three to six months in the period February to December next year to further their experience through observation and participation.

Benefits

(a) Monthly allowance of around 2400FF.
(b) Economy class air travel from France to Australia.
(c) Registration fees.
(d) Internal travel.

Note

Travel to France from Australia is not provided.

Conditions

Applicants must be: Australian citizens, at least 25 years of age as at 1st January in year of tenure, possess appropriate academic qualifications, have practised a profession for at least two years, have some knowledge of French and present a detailed programme including advice of acceptance from a French institution.

Closing date

31st May, 1984.

Further information and application forms are available from:

The Secretary,
Department of Education and Youth Affairs
(French Government Scientific Fellowships)
P.O. Box 826,
Woden, A.C.T. 2606

Proceedings of 11 ICA

The Proceedings of the 11th ICA held in Paris in July, 1983 are now available.

The Proceedings of the main congress (8 vols.) is available for 600FF (8 vols.) or 100F for each volume; the Toulouse symposium (2 vols.) is 200FF (2 vols.) or 100F each; the Lyon symposium (1 vol.) is 100FF.

Orders should be directed to: Secretariat du G.A.L.F., Division TSS-CNET Lannion A-BP 40, 22301 Lannion Cedex, France.

Acoustical Society of Korea

The Acoustical Society of Korea, established in South Korea in 1981, is the official national organisation in acoustics. The purpose of the society is to collaborate with public bodies and other societies for their benefits by the rules in accordance with the establishment and operation of the Korea not-for-profit corporation law and is to contribute to the educational scientific and technological development and promotion of the theory and practice of acoustical engineering and the mutual communication with applied branches of engineering and related science.

Total number of members is approx. 240, the President is Prof. Il-Whan, Cha and the Secretary General is Soon-Hyub, Kim. The annual regular meetings of the Assembly are in August each year. Officers are: President, three Vice-Presidents, Secretary General, Director of Treasury of Academic Activities, of Publication and of Professional Activities.

The office of the Acoustical Society of Korea is
c/- Engineering Division,
Yonsei University,
Seoul 120, Korea.

Future Events

AUSTRALIA

1984

July 20, MELBOURNE
"Noise within the community"
Victoria Division Seminar 2-5 p.m.
Australian Road Research Board
Details: Stephen Samuels, Aust. Road Research Board (03) 235 1555.

August 27-31, HOBART
12th Conference, Australian Road Research Board
Over 100 papers, 3 simultaneous sessions covering all aspects of roads and road transportation.
Details: Australian Road Research Board, P.O. Box 156 (Bag 4), Nunawading, Vic. 3131.

September 19, MELBOURNE
Victoria Division AGM 6-10 p.m.
World Trade Centre
An open forum on the future of the Acoustics profession.
Details: Victoria Division, National Science Centre, 191 Royal Parade, Parkville 3052.

October 9, MELBOURNE
Victoria Division technical visit to Aeronautical Research Labs.
Details: See Sept. 19 item.

October 30-November 2, SYDNEY
7th International Conference on Computer Communication.
Conference theme: "The New World of the Information Society".
Details: Conference Secretary, G.P.O. Box 2367, Sydney 2001.

November 1-2, PERTH
Australian Acoustical Society 1984 Conference.
"Noise and Vibration Legislation in Australia".
Details: F. R. Jamieson, Acting Secretary, W.A. Division, A.A.S., 2 Beryl Ave., Shelley, W.A. 6155. (Also see page 6 this issue).

December 3-7, MELBOURNE
Australian Institute of Physics.
3rd Applied Physics Conference: "Physics and Australia's Resources". Royal Melbourne Institute of Technology.
Details: Ken Cook, Conference Secretary, Dept. of Applied Physics, RMIT, G.P.O. Box 2476V, Melbourne 3001.

December 4-6, SYDNEY
International Conference on Underwater Acoustics
Special sessions: (1) Interactions with the sea floor, (2) Shallow water propagation, (3) Acoustic fluctuations.
Details: Marshall Hall, Navy Research Laboratory, P.O. Box 706, Darlinghurst, N.S.W. 2010.

INTERNATIONAL

1984

May 6-10, NORFOLK, VIRGINIA
Meeting of the Acoustical Society of America.
Chairman: Harvey H. Hubbard, Acoustics and Noise Reduction Div., NASA Langley Research Center, Langley Station, Mail Stop 462, HAMPTON, VIRGINIA 23665.

June 12-15, STRASBOURG, FRANCE
Acoustic Propagation with Underwater Applications.
Details: M. Waton, Acoustique Moleculaire, U.L.P., 4 rue Blaisse Pascal, 67070 Strasbourg, Cedex, France.

August 21-24, SANDEFJORD, NORWAY
FASE 84 — 4th Congress of the Federation of Acoustical Societies of Europe.
Secretariat: FASE 84, Secr. Gen. J. Tro, ELAB, N-7034 TRONDHEIM-NTH, NORWAY.

August, MANCHESTER, U.K.
British Congress on the Education of the Deaf.
Details: Prof. Taylor, Dept. of Audiology and Education of the Deaf. The University of Manchester.

September 6-7, MERKSEM, BELGIUM
5th JAN PALFIJN Symposium European Conference on Echography. "Fetal abnormalities as detected by ultrasound".
Details: Mrs. H. Heye-De Decker, Gebr. Van Raemdonckstraat 46, 2060 Antwerp, Belgium.

October 2-4, CESKE BUDEJOVICE, CZECHOSLOVAKIA
23rd Acoustic Conference on Physiological and Psychological Acoustics, Acoustics of Speech and Music.
Organising Secretary: Mrs. Eva Dostalova, House of Technology, Gorkeho namesti 23, 112 82 Prague 1.

October 8-12, MINNEAPOLIS
Meeting of the Acoustical Society of America.
Chairman: W. Dixon Ward, Hearing Research Laboratory, University of Minnesota, 2630 University Ave., S.E. MINNEAPOLIS, MINNESOTA 55414.

December 3-5, HONOLULU
INTER-NOISE 84
Organised by INCE/U.S.A. in co-operation with INCE/Japan. Secretariat: P.O. Box 3469, Arlington Branch, Poughkeepsie, N.Y. 12603, U.S.A.

1985

April 8-12, AUSTIN, TEXAS
Meeting of the Acoustical Society of America.
Chairman: Professor David T. Blackstock, University of Texas, P.O. Box 8029, AUSTIN, TX 78712.

September 18-20, MUNCHEN, GERMANY
Enterprise 85. Organised by VDI, MUNCHEN.
Details from: Prof. E. Zwicker, Institut fur Elektroakustik der Techischen Universitat Munchen Arcisstr. 21, 8 Munchen 2.

June or September, DELPHI, GREECE
5th FASE Symposium on "Integrated Acoustical Environment Design".
Organised by the Hellenic Acoustical Society jointly with the Acoustical Society of Yugoslavia.
Details from: E. Tzekakis (5-FASE-85) 5, Agiou Seraphim Str. Thessaloniki.

October 1985, HIGH TATRA, CZECHOSLOVAKIA
24th Acoustical Conference on "Building and Room Acoustics".
Secretariat: House of Technology, Ing. L. Goralikova, Skultetyho ul., 881 30 Bratislava.

November 4-8
NASHVILLE, TENNESSEE
Meeting of the Acoustical Society of America.
Chairman: Robert W. Benson, Bonitron Inc., 2970 Sidco Drive, NASHVILLE, TN 37204.

1986

TORONTO, CANADA
12th ICA Congress (International Commission on Acoustics).
Secretariat: 12 ICA, 5007-44 Charles Street West, Toronto, Ontario, Canada M4Y 1R8.

May 12-16, CLEVELAND, U.S.A.
Meeting of the Acoustical Society of America.
Chairman: Arthur Benade, Case Western Reserve University, Physics Department, Cleveland, Ohio 44106.

May 1986, WIEZYCA, POLAND
3rd International Spring School on Acoustoopics and Applications.
Organised by the University of Gdansk.
Details from: Prof. A. Sliwinski, Uniwersytet Gdanski, Instytut fizyki Dosw. ul. Wita Stwosza 57, 80-952 Gdansk.

July 8-11, GYOR, HUNGARY
6th FASE-Symposium on "Subjective Evaluation of Objective Acoustical Phenomena".
Secretariat to be announced.

The Discovery of a New Musical Sound

Moya Henderson
42 Palmgrove Road
Avalon NSW 2107

ABSTRACT: A commission to write a piece of music for Düsseldorf sculptor, Helfried Hagenberg, based on his creation of 27 triangular shaped objects, was the trigger to discover and develop a new keyboard percussion instrument called the ALEMBA. The instrument consists of three chromatic octaves of "resonator-triangles" in the form of metal rods bent into triangular shape, each of which is coupled by a cord to a cylindrical resonator. The instrument is played by means of soft or hard beaters and is capable of making a range of sounds from harp-like to bell-like tones.

BEGINNINGS

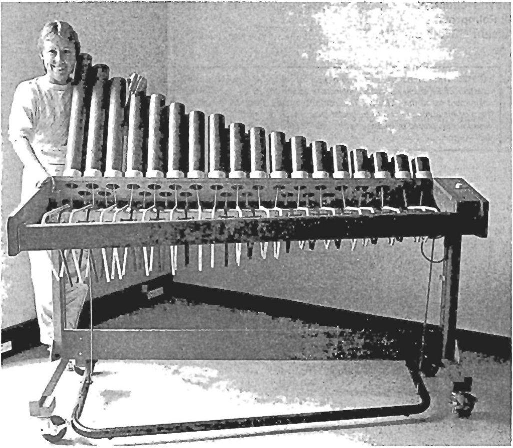
Usually the first question I'm asked about the *alemba* is how did I get on to the idea in the first place. I was in Cologne at the time, doing post-graduate courses in composition and music-theatre. After a concert of three of my music-theatre pieces, I was commissioned by a Düsseldorf sculptor to write a composition for one of his latest creations which comprised a fascinating array of triangular-shaped objects. In fact, there were twenty-seven of these objects, but as they had all been made out of identical lengths of steel rod, the variety in the actual pitches of the "triangles" was minimal — approximately a range of eight semi-tones! And in any case when triangles are played in the conventional way who is to know or care what pitch they are. The triangle in musical tradition is one of the classic non-pitched instruments. It belongs to that category that includes gongs, bells, drums, tambourines, cymbals, jaw-bones, wind-machines etc. There is of course a prestige rating for all instruments of the orchestra. Understandably the non-pitched instruments do not score too highly, but often the triangle is an object of ridicule. In the popular imagination it is the one instrument in the orchestra that a non-musician can play! I'm wondering if teachers themselves aren't responsible for this situation. So many people have presented themselves to me as ex-triangle players which is the standard euphemism for their being totally devoid of all musical aptitude — or at least so regarded by their junior school music teachers!

With all this in mind I wasn't sure that I wanted to get mixed up with an assortment of triangles, whatever their sculptural disguises. It was the "dare-like" challenge from my teacher, Mauricio Kagel, that clinched the decision to proceed. This was at the beginning of 1976. I suspended a triangle on a length of cord just outside my kitchen in Cologne in order to try out an array of kitchen utensils as beaters for the instrument because I was hoping to produce some new and unusual sounds. I had also cut a plastic mineral water bottle in half and, for no apparent reason, held the bottom half against the cord which was supporting the triangle. I struck the triangle and was amazed at what I heard. Unwittingly, and very simply, I'd set up the conditions for the emergence of a quite-new sound. Coincidentally the size of the bottle-resonator just happened to match the fundamental pitch of the triangle: a pitch which till then you wouldn't expect to hear anyway as the higher frequencies are intrinsically louder. I had struck the triangle with a "soft" beater and not the usual steel rod. This also was a necessary condition to produce the low, pure-sounding note which was amplified in the bottle resonator and ringing loud and clear. It was a beautiful sound and I *knew* I was on to something.

FURTHER DEVELOPMENT

I wish I could report that the discovery saved the piece which I'd called "Secco". In fact the work is best forgotten, and, in any case, we really need that unique sculpture on which to perform it. At the end of 1976 I returned to Australia and moved to Sydney to live the precarious existence of a free-lance composer. In 1977 I became irrevocably involved with triangles. I started making larger and larger specimens, each with a tuned resonator, and before long I had over three chromatic octaves of "resonator-triangles". It was this collection of instruments that I thrust into the lime-light in what could be described as the "Percussions-of-Strasbourg to-do" at the beginning of 1978. Here is not the place for admissions and accusations relating to the touring French group's rather shabby performance of my composition, "Alanbiq", which had been specially commissioned by Musica Viva, Australia. Suffice it to say that I was over-optimistic and under-experienced in dealing with such a project; the Percussions were over-tired and under-rehearsed; only Musica Viva was utterly blameless: their organisation was meticulous and their support and encouragement unflagging.

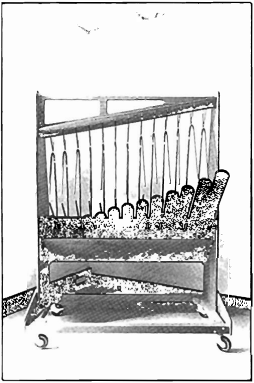
Perhaps there were those who thought that that would be the beginning and end of the triangles. But I felt that the new sound hadn't been given a fair voice



Sydney composer and inventor, Moya Henderson, with her new percussion instrument, the ALEMBA. (Photograph by Margaret Olah)

and I didn't like the idea of giving up anyway. So I applied regularly for funding to improve the instrument. The break-through came when I met Charles Smith, the president of the Inventors Association. There and then he recommended that I apply to the Department of Productivity (now known as the Department of Science and Technology) for a grant that would enable me to build a proper prototype of a single instrument that I eventually called the "alemba".

Whereas the resonator-triangles required several percussionists to play them, the alemba would have the configuration of a key-board percussion instrument and be playable by one performer. I received a grant of $10,000 from the Department of Productivity in June 1980 and was thus able to commission Carl Nielsen of Nielsen Design Associates to construct the frame of the new instrument for me. My job, then as now, was to make the set of triangles. This I did with the assistance of Albert MacDonald. We cold-bent each triangle on a machine invented by Albert's son Douglas. At about this same time I learnt from Dr John Dunlop (School of Physics, University of NSW) what a help it is to have a spectrum analyser on the scene and the triangle-bending technique became a far more controlled and scientific process. Use of the spectrum analyser led me to discover ways of "fine-tuning" the triangles. By fine-tuning I mean the system of internally tuning each note so that not only the fundamental but the octave above the fundamental sounds when the triangle is struck. A pitch that is controlled to this extent is a much more agreeable or harmonious sound for interaction with other instruments in the orchestra.



The bass alemba (photograph by Margaret Olah).

Once again the challenge was there simply to be met. The bass alemba was duly built thanks to the financial support of the Myer Foundation, APRA and the A.S. White Trust. Alan Forrester of Forrester Engineering (previously of Nielsen Design Associates) built the bass model which proudly made its concert debut under Sir Charles Mackerras in the Sydney Symphony Orchestra's performance of the "Symphonie Fantastique" on 29 August 1983.

Since the Berlioz, and thanks to Professor Neville Stevenson, the head of the Innovation Council of New South Wales, the alemba has been the subject of four mini-documentaries for different television networks including the BBC and the ABC. Then in November 1983, I was awarded one of the four Artist-in-Residence grants offered jointly by the Australia Council and the CSIRO. So now between the months of December '83 and March '84 I am installed at the West Lindfield division of the CSIRO, in the Acoustics section of the National Measurement Laboratory. The residency gives me a marvellous opportunity to improve the sound output of the bass alemba and investigate a better method of find-tuning the triangles. To help me I have some of the best brains in the country to consult with; I couldn't be happier about it all.

As for the future ... well, I'm hoping that interest in the alemba will be two-pronged. The instrument makes a gentle, harp-like, ethereal sound which should attract its own following of composers and listeners alike. Perhaps the more immediate interest is in the bell-like sounds produced especially by the bass alemba. Maybe it will be the answer to that ever-present problem confronting all orchestras, and opera house orchestras in particular. When Richard Bonynge heard the alemba he commented that he had been searching for years for such a bell sound. This encourages me to hope that opera orchestras will become my first customers.

(Received 20 January 1984)

THE ALEMBA IN ACTION

It wasn't really till the beginning of 1983 that the prototype of the treble alemba could be described as fully operational. In June of '83 I invited Michael Askill, the principal percussionist with the Sydney Symphony Orchestra and an old friend, to come and have a look and a listen to the instrument. Michael became intrigued with the bell-like sounds the instrument can make when struck with a hard beater. Within a few weeks he had arranged for me to take the instrument into the Opera House so that Sir Charles Mackerras could test it out on the Concert Hall stage. The outcome was that the treble alemba was given a trial-run in a performance of Janacek's "Glagolitic Mass". To cut right through the huge sound of the full orchestra the bell sounds have to be amplified, but everyone seemed very happy with the result and Sir Charles was even wondering if I'd be able to make a bass model for the Berlioz' "Symphonie Fantastique" which was due for performance in a few weeks' time.

It is our pleasure to present for the first time details of a new percussion instrument invented and developed by Sydney composer **Moya Henderson**. *In the above report, the way in which the instrument, christened the ALEMBA, came to be developed is described by the inventor. Then follows a technical article by John Dunlop on the acoustical principles involved.*

Born in New South Wales, Moya Henderson graduated from Queensland University with honours in music. She was appointed as resident composer to the Australian Opera Company during which time she became interested in music-theatre. Following the award of a scholarship to study in Germany, Moya Henderson studied music-theatre with Mauricio Kagel and composition with Stockhausen. While in Germany in 1976 she was commissioned to write a piece for Düsseldorf sculptor, Hagenberg, based on his creation of 27 triangular-shaped objects. Arising out of this work was the discovery of a new musical sound and its subsequent development into a new percussion instrument.

On returning to Australia Moya Henderson has combined part-time lecturing at Sydney University with composition including a number of commissioned works. Between November 1983 and March 1984 she has been an artist-in-residence at the CSIRO National Measurement Laboratory in Sydney undertaking further development of the alemba. — **Editor**

The Acoustics of the Alemba

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School of Physics
University of New South Wales

ABSTRACT: The ALEMBA is a recently invented percussion instrument which produces a unique and pleasing sound. The analysis has been made of the mechanics of this instrument and of the character of the sounds produced. The results reveal the source of the harmonious nature of the sounds and suggest that there is scope for further development of the range of sounds which may be produced.

INTRODUCTION

The *alemba* is a percussion instrument, similar in some respects to the xylophone, which also produces unique and pleasing tones. The instrument consists of a set of sound generators each made from a bent rod triangle coupled to a tuned air column resonator via a Mylar diaphragm, as shown in Figure 1. The triangles are struck with a soft mallet to produce in-plane flexural vibrations which are then selectively amplified by the resonator.

The pitch and character of the tones produced depend primarily on the dimensions and shapes of the triangles and there appears to be considerable flexibility in modifying the colour of the tone by changes to the triangle. To assist the inventor in specifying and controlling the tones produced an analysis was made of the vibration modes of the triangle and their relationship to the sounds of the instrument.

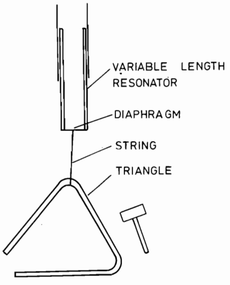

Figure 1: Schematic diagram of alemba sound mechanism.

FLEXURAL VIBRATIONS OF THE TRIANGLE

The flexural vibrations of a straight rod or bar are treated in most acoustic texts [1]. The frequencies of the vibration modes are non-harmonic and given by the formula

$$f \cong \frac{\pi c K}{8\ell^2}(3.0112^2, 5^2, 7^2, 9^2) \qquad (1)$$

for the free ended bar, or

$$f \cong \frac{\pi c K}{8\ell^2}(1.194^2, 1.988^2, 5^2, 7^2) \qquad (2)$$

for the bar clamped at one end. Here c is the velocity of compression waves in the material, K the radius of gyration of the cross section and ℓ the length of the bar. The free ended bar forms the bass of the xylophone and gives this instrument its characteristic tone. Vibrations of curved bars are more complex and are treated in more advanced texts [2].

The triangle appears to be a combination of straight bar and curved bar elements and thus of higher complexity. Measurements of an orchestral triangle frequencies have been reported by Rossing [3], which indicated fairly close agreement between the mode frequencies of the triangle and those of a rod of the same overall length. The triangles employed in the alemba differ markedly in shape from those of the usual orchestral triangle and hence a more thorough analysis of their mode frequencies was indicated.

TRIANGLE MODE FREQUENCIES

A finite element analysis technique was used to determine the mode frequencies of bent rod triangles of differing dimensions and geometries and is reported more fully elsewhere [4].

Two sets of modes, corresponding to in-plane and perpendicular to plane vibrations, were realised by the analysis. Only in-plane vibrations appear relevant to the alemba, and the shapes of these modes are shown in Figure 2 together with those of a straight bar or rod, from which it can be seen that there is a close correspondence between the modes of the straight rod and those of the bent rod triangle. The main divergence is a distortion of the mode shapes in the curved regions of the rod at the triangle corners, particularly for the triangles with small radius corners. The modes are numbered 0, 1, 2, 3, ...; mode 1 corresponding to the fundamental of the free ended bar, mode 0 being a rotation generated in the triangle analysis.

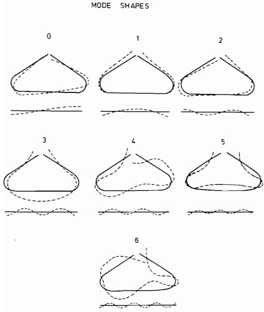

Figure 2: Mode shapes of in-plane flexural vibrations of a bent rod triangle and a straight rod.

The frequencies of the modes depend primarily on the triangle rod dimensions — its total length, diameter and material properties — it being found that the mode frequencies of similar triangles of different sizes are similar, being related through the physical constants of equation (1).

The remaining triangle parameters which can be altered are the radius of curvature at the corners and the angles of the triangle. The effects of changes to these parameters are indicated in Figure 3 which shows the relevant mode frequencies of isosceles triangles of different base angles and corner curvatures fabricated from a 12.6 mm diameter steel rod 1 m long. Also indicated on the figure are the mode frequencies of a straight rod of the same length and material as the rod in the triangle.

The results of Figure 3 indicate that considerable alteration of the straight rod mode frequencies has been produced by bending the rod into the form of a triangle. The results also indicate some empirical relationships between the mode frequencies and the geometry of the triangle. For example, as the triangle base angle increases from 30° to 60°, the frequencies of the modes tend to increase: an increase in corner curvature leads to an increase in frequency for some modes (3 and 4) and to a decrease in others (5 and 6).

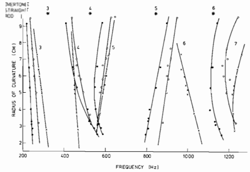

Figure 3: Mode frequencies of in-plane vibrations of a bent rod triangle of differing corner curvatures and base angles (O = 30°, 0 = 45°, X = 60°). Other dimensions are ℓ = 1 m, diameter = 12.6 mm, acoustic velocity of steel = 5180 ms^{-1}. Also shown (*) are the mode frequencies of a 1 m long straight rod.

THE ALEMBA

The sounds emitted by the alemba result from the coupling of the in-plane flexural vibrations of the bent rod triangle to the air column resonator. The resonator is tuned to the frequency of the mode 3 overtone of the triangle and is the dominant tone emitted. The triangle lower modes (2, 1 and 0) are effectively suppressed from producing sounds, but higher order modes may couple quite strongly depending on the mode shape at the point of suspension and its frequency in relation to that of the resonator.

The pitch of the sound produced is controlled by the total length of rod in the triangle, and the dimensions and material property of the rod. The relative spacing of the overtone frequencies and hence colour of the note is a function of the triangle geometry — the base angles and corner curvatures.

The alemba utilises triangles with base angles of approximately 45° and corners of about 6 cm radius of curvature fabricated from 12.6 mm diameter bright steel rod. The fundamental frequency of each tone (mode 3 of the triangle) is tuned to a note of the 12 tone chromatic scale. The triangles are struck on their closed side with mallets of various hardnesses as with the xylophone.

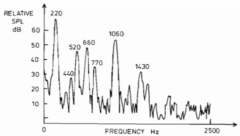

Figure 4: Frequency spectrum of alemba note A_3.

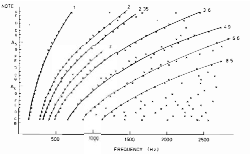

Figure 5: Alemba note spectra. The fundamental frequency components of each note are joined by a line and labelled 1. The overtones in each note are similarly joined and the ratios of the overtone frequencies to the fundamental frequency indicated.

ALEMBA SOUND SPECTRUM

The spectrum of a typical alemba note is shown in Figure 4, indicating the basic anharmonicity of the overtones. The spectrum lines of the different notes are illustrated in Figure 5, the intensities of the different overtones being indicated by the thicknesses of the lines connecting them. From Figure 5 it can be seen that there is good consistency of timbre across the range of the alemba notes, indicating the similarities of the different triangles employed. There are some slight differences in the colour of the notes at opposite ends of the scale, for example the third overtone gets progressively weaker going up the scale, being entirely absent from the higher notes. The first overtone shows the opposite effect.

The frequency ratios of the overtones in each note can be related to the in-plane vibrations of the triangles used. For example the A_3 triangle, fundamental 220 Hz has a length of 1.03 m, radius of curvature 6 cm and base angles of approximately 45°. The vibration mode frequencies from the third mode upwards for a similar triangle used in the analysis are (from Figure 3) 255, 495, 590, 900 and 1180 giving overtone ratios of 1, 1.94, 2.3, 3.52 and 4.62, which may be compared with the measured frequencies of 220, 439, 518, 660, 798 and 1078 with ratios 1, 2.0, 2.35, 3.0, 3.6 and 4.9. There is some discrepancy between the frequencies of the analysis and those of the triangle; this might be accounted to material modulus differences. There is however generally good agreement in the overtone ratios between the calculated and measured values, the differences that exist being attributed to deviations of the shapes of the alemba triangles from those used in the analysis model. The anomalous spectral line at 660 Hz was observed to be generated by the resonator (it being the third harmonic) and not by the triangle, probably by non-linear coupling of the fundamental to the diaphragm.

The colour of the notes may be described in terms of the musical intervals of the JUST scale. For example, the first overtone is an octave above the fundamental ($2\times$), the second overtone an octave and a minor third (2×1.2), the third overtone an octave and a fifth (2×1.5), the fourth overtone an octave and a flattened seventh (2×1.67) and the fifth overtone two octaves and a minor third (4×1.2).

The timbre of each note struck may be varied by striking the triangle at different positions to accentuate or suppress different modes. For example the first and fourth overtones may be accentuated by striking the triangle off centre as is suggested by the shapes of these modes shown in Figure 2. The use of mallets of different hardness also has a significant effect on the sounds produced. For example, a soft mallet is used to produce an unusually harmonious sound whereas a hard mallet excites the higher order overtones which are generally non-harmonic producing bell-like dissonant sounds.

CONCLUSION

The *alemba* produces an interesting and novel sound. The origins of these sounds are the in-plane flexural vibrations of bend rod triangles coupled to air column resonators. The pitch and colour or timbre of the sounds produced are controlled by the dimensions of the triangles — by their sizes, the curvature at their corners and their angles.

The results of finite element analysis of triangle vibrations provide a series of empirical relationships showing the effects of triangle corner curvatures and base angles. These together with some quantitative relationships on the effects of rod dimensions and material properties may be useful in designing an alemba triangle to produce a specified sound. In its present state of development the sounds produced by the alemba are characterised by overtones which have related musical intervals to the fundamental. These sounds are rather unique and pleasing, but there would appear to be considerable scope for extending the range of sounds.

REFERENCES

1 Kinsler, L.E. and Frey, A.R. "Fundmanetals of Acoustics", J. Wiley (1962) p. 55.
2 Shanley, F.R. "Strength of Materials", McGraw Hill (1957) p. 326.
3 Rossing, T.D. "Acoustics of Percussion Instruments Part 1", The Physics Teacher (1976) p. 546-555.
4 Dunlop, J.I. "Flexural Vibrations of the Triangle", Acustica (1984) in press.

(Received 10 December 1983)

Sounds Made By Plants

A Novel Application of Acoustic Emission Analysis

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ABSTRACT: Plant organs emit acoustic signals which can be analysed. A considerable body of circumstantial evidence indicates that these signals are a consequence of sap cavitation. By analysing acoustic emissions we can distinguish some plants which are more able to withstand water stress than others. This information enables us to identify the more drought resistant species. The cause of the different responses between species has yet to be explained.

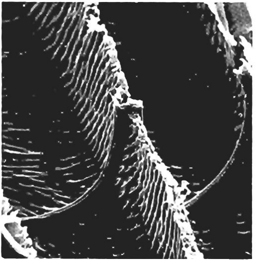
PREAMBLE

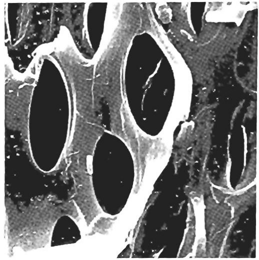
Plants lack the range of sound-producing structures found in amazing diversity in the animal kingdom. Indeed one might be surprised that plants have the capacity to generate acoustic noises at all. In nature, sounds are produced when plants are subjected to wind, particularly in the form of creaking, rubbing and swishing sounds. Such sounds as these are of the type one might expect of non-living systems subjected to stress and strain. There seem not to be specialised structures for sound production or its detection. There is a popular notion that sound vibrations might serve as a means of communication between humans and plants and presumably between plants themselves but this seems unfounded. It is even difficult to see how in evolution any benefits could have arisen through natural selection if communication was possible. Plants cannot respond or escape to anything like the same extent as animals where communication has obvious evolutionary advantages. There is no good evidence that growing plants benefit from human vocalisation. A possibility remains however that plants might derive some useful signals during impending drought because we know that the sap conduction system produces acoustic vibrations if it is subjected to excessive tensions arising from an inadequacy of water. The notion that liquids can withstand tensions at all is mystifying to those unfamiliar with the topic so we will explain our investigations from the beginning.

EARLY WORK

Our research developed along the ideal sequence in science, which is rather rarely encountered in practice, observation, prediction then discovery. Experiments were being performed to investigate the uptake of water into leaves suffering from severe water deficits. One would expect that as the water deficit decreased there would be a progressive decrease in the rate of water uptake. In effect, as a leaf became less "thirsty" the more slowly it might be expected to "drink". However several leaves suffering from severe water deficits tended to absorb water ever more *rapidly*, despite the absorption of water. Eventually however there was the anticipated decline in rate of uptake [4]. Since the driving force on the water must have decreased, it was deduced that some adjustment must have taken place in the conducting system itself. The repair had somehow been made at 1 °C, the temperature at which each experiment was performed, chosen to reduce living processes to a low ebb.

On the basis of these experiments it was deduced that conduction must have been disrupted by cavitation, a purely physical process, in which a bubble suddenly emerges within a liquid-filled pipe, effectively embolising it and so preventing conduction. Cavitation could then be reversed later by the renewed supply of cold water because the low pressure bubble emboli would be replaced automatically by water at atmospheric pressure. In this way the number of pipes available for water conduction increased once more so as to more than compensate for the reduced water deficit. Accordingly it was predicted that cavitation must have taken place during the imposed drought and thought it would be worth trying to detect the shock waves produced acoustically.





THE SAP CONDUCTING CONDUITS (VESSELS) OF RICINUS COMMUNIS, *THE CASTOR BEAN.*

Figure 1a: Longitudinal view of two parallel vessels showing the perforation plates between xylem vessel elements and heavy pitting of the lateral walls which enable sap to move laterally between vessels. The diameter of the vessels is about 0.2 mm.

Figure 1b: Close-up view of the bordered pits in the walls of the vessels. The thick walls of the vessel support fragile pit membranes (the remnants of the primary cell wall) across each pit. Some of the pit membranes have been ruptured during preparation of the material enabling their flimsy structure to be seen clearly. The pores in the membrane are sufficiently fine to prevent gas transport providing the membranes are wet.

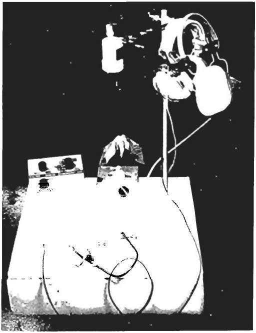


Figure 2: A simple portable apparatus for the detection of vibrations produced during cavitation. A leaf is suspended by a stiff wire from the armature of a transducer consisting of a modified microphone. Acoustic emissions from the leaf are detected by the transducer. Extraneous noises are removed in amplification stages. Cavitation can be monitored manually using headphones or automatically using a pre-set signal detector. The apparatus is screened from ground vibrations by resting it on a shock-absorbent platform.

We (Dr Richard P.C. Johnson and J.A.M.) decided to set up a detection system to test this prediction. We expected only a small vibration to be produced when each microscopic tube (Figure 1a) cavitated. Our equipment was little more sophisticated than a sensitive record player with preamplifier and a magnetic transducer to hold the gramophone stylus. We substituted a pointed wire for the gramophone stylus and simply impaled a leaf on it. Our test plant was *Ricinus communis*, the castor bean. As the fresh leaf lost water it slowly wilted and produced a large number of "clicks" which we monitored on an oscilloscope. Clicks were produced more rapidly if the leaf was illuminated with an incandescent light bulb because radiation enhanced the rate of water loss which tends to be very protracted in low illumination [5].

Though we have improved the amplification subsequently and also introduced automatic acoustic filtering and recording, the essential technique has remained unchanged (Figure 2). Characteristically, clicks are produced slowly from a water saturated leaf and then build up to a crescendo which then declines towards zero as the leaf wilts severely over several hours. Click production ceases long before a leaf is dry enough to produce the crisp crackling sounds which characterise drying leaves.

THE CRITICAL SIGNIFICANCE OF CLICK PRODUCTION

What then were the further implications of this discovery? The whole question of the mechanism of water transport through the woody tubes (xylem) has been a perennial problem for at least 150 years. By comparison with human efforts to pump water from deep bores by suction it was thought that plants could not possibly utilise suction to raise the watery sap through tall tree trunks. A search for powerful pressure pumps in plants was unsuccessful. Then at the turn of the century Dixon and Joly (1894) proposed their cohesion hypothesis which took about fifty years to gain virtually universal acceptance. According to this theory the failure by man to use suction effectively is accounted for by the presence of small gas nuclei trapped within the system. These can expand when subjected to powerful suction and so disrupt the liquid continuum. In plants it is now argued water is insufficiently pure to more nearly approach the enormous tensions theoretically possible. We now recognise that the theoretical strength of cohesion is mainly attributable to the hydrogen bonds which hold water molecules together in the liquid state.

Following the general acceptance of the cohesion hypothesis the importance of surface tension in cell and conduit walls was also recognised. Surface tension acts as a valve in allowing evaporation of liquid water into the atmosphere while preventing the entry of air. Seemingly the system was secure and the basic mechanism of water transport in plants had been satisfactorily explained.

At this point it is appropriate to give some quantitative parameters. The greatest vertical height a column of water can be drawn by a suction pump in the presence of a gas space corresponds to the atmospheric pressure which at sealevel can sustain a water column of height 10.013 m. On this basis it is rash to use suction pumps on bores deeper than about 10 m; also any tree growing taller than 10 m would appear to confound this suction mechanism. Since the tallest trees (*Sequoia gigantea* and

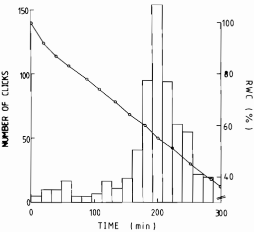


Figure 3: The relationship between cavitation clicks and time as a leaf of Acer pseudoplatanus *is allowed to lose water. Clicks (per 16 minute) are plotted against time (min) in the form of a histogram. The change in leaf water content is monitored as % Relative Water Content which is 100% when the leaf is fully saturated.*

Eucalyptus regnans) grow over 100 m tall and have occasionally to suck their water from dry soil in addition, any mechanism must account for well over 100 m vertical lift, which suction is about 10 bar (1000 kPa). However trees like mangroves were known to require suctions exceeding 20 bar to extract fresh water from the seawater which bathes their roots, and during drought, soil suctions might develop between 60 and 100 bar. Despite these enormous suctions, corresponding to a vertical suction of 600 to 1000 m of water, it was thought that the cohesion theory provided an adequate explanation for the mechanism: indeed there was no known alternative!

FURTHER EXPERIMENTATION

What our experiments seemed to show was that in fact cavitation might occur much more readily than might be expected as the basis of cohesion hypothesis. Certainly clicks, detectable from *Ricinus* plants before the first signs of wilting were apparent, suggested that the system was by no means so secure as had been supposed. Before we could be sure of this we had to show that clicks did indeed correspond to cavitation. A whole series of experiments, some on isolated vascular systems in which non-conducting cells had been removed, showed the following:

- Clicking could be induced by enhancing water stress by evaporation (radiation, wind, etc).
- Clicks were stopped if water was introduced into the xylem system.
- Clicks were produced by whole plants in drying soil.
- The capacity of plant tissues to produce clicks was restored slowly when water was supplied.
- Vacuum pretreatment was particularly effective for rapid restoration of the capacity to click, presumably because it extracted the gas from the large potential emboli in the tissues directly [8].
- Pressurisation of tissues under water restored the capacity to produce clicks but was less effective without the vacuum pretreatment [8].

A number of negative results are also of interest:

- Clicks of the same magnitude were *not* produced by the tissues if they were subjected to mechanical stress of bending.
- Click production did not seem to increase if the xylem sap under tension was subjected to radiation from radioactive sources.

These results did not prove that "clicks" are caused by cavitation but provided very strong circumstantial evidence in support. There was no alternative detection system available for comparison with the acoustic technique.

SAP TENSION LIMIT AND PLANT SURVIVAL DURING DROUGHT

Our more recent work was given a powerful boost when we began to measure the tensions at which cavitation took place. Quantification of the process required the solution of several technical problems. Eventually these were resolved by building into the amplifier an active electronic frequency filter with variable Q factor: the best signals were generally in the vicinity of

500 Hz which is inconveniently close to human speech so that acoustic isolation proved essential. An electronic filter was introduced to remove all signals below a threshold selected using headphone monitors. No ideal threshold was found by which noise interference and genuine clicks could be sharply separated.

One of the most serious problems lies in measuring xylem sap tensions. One method relies on a pressure chamber which can squeeze water from plant cells into the xylem conduits. By keeping part of the plant xylem exposed and under observation it is possible to measure the positive pressure which must be applied to the cells to squeeze water out through the xylem. When the pressure is removed the cells subject the xylem sap to suction once more which is numerically identical with the positive pressure applied under test. The method depends on the xylem conduits being filled with sap but if they had suffered cavitation this would not be the case. The volume of the xylem is not sufficiently large to be a problem but the disruption of xylem columns during test was both serious and uncontrollable.

In practice we overcame these problems using a single leaf in two sequential tests. During the first test the leaf was subjected to water stress and clicks were counted as it lost weight. Water was then restored to repletion and then a pressure chamber was used to monitor xylem tensions at frequent intervals as the leaf was weighed as it lost water a second time. Finally, using leaf weight as a common denominator, it was possible to plot sap tension against the numbers of clicks per increment of tension (1 bar). This plot gives the range of tensions at which cavitation begins and the tension when cavitation occurs most extensively [1, 3, 9].

When results from these researches were studied our initial conjectures were verified. Cavitation occurred at quite low tensions in *Ricinus*, our main test plant, and the plant seemed to suffer total disruption of its water conduction system (i.e. clicks ceased) between suctions in the range 10 to 15 bar. Clearly mangroves living in seawater must not cavitate so easily because suctions exceeding 20 bar were essential to extract fresh water from seawater. Furthermore the pressure chamber had been used by its discoverers, Scholander et al [12], to measure tensions in mangroves up to 60 bar. As we have accumulated more results it has become apparent that the more drought-resistant plants have a much more extreme cavitation range (30 to 60 bar) whereas in *Ricinus* and drought-intolerant plants such as *Lycopersicon* (tomato) ranges were much lower (3 to 12 bar). This work has raised interesting questions as to the importance of xylem sap vulnerability and the capacity to survive water stress and drought. We are presently accumulating information over more species.

Acoustically it seems that the "click" we detect depends on energy stored when the walls of the xylem tubes, which have been distorted inwards by sap under suction, are allowed suddenly to relax. A bubble appears suddenly as the walls are released and energy is released as a range of vibrations. It seems probable that the frequencies detected most successfully are those least absorbed by the plant tissues intervening between the vascular system itself and the detector. We have used pairs of probes simultaneously to find the number of monitors necessary. Apparently vibration transmission

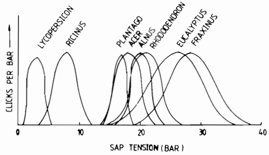


Figure 4: Relationship between cavitation and sap tension curves from leaves of various species. Each curve illustrates diagrammatically results from several leaves from a selected species. Ricinus, Lycopersicon *and* Plantago *are drought-susceptible herbs. The other species used were woody trees or shrubs which are more drought-resistant.*

through the xylem is excellent and a single detector gives an adequate sample of clicks from a whole *Ricinus* plant 2 m tall. More detectors might be required to give an adequate pattern for a large tree.

Presently we do not know exactly how cavitation is initiated. There seemed to be three main possibilties:

1 Physical damage of the tubes themselves.
2 Gas, such as air, is drawn through a fine pore in the wall.
3 A nucleus within the conduit fluid may retain a microscopic unwettable bubble which can expand when the tension is sufficiently great.

We have not yet been able to distinguish between **2** and **3**, but **1** has been eliminated because it is possible to restore cavitation capacity several times more or less completely. If the tubes were damaged the number of clicks should be fewer from each drying cycle. Many of these experiments have been made on dead but preserved vascular tissues. These click quite normally when subjected to drying, confirming the simple physical nature of the click-producing process.

RECENT AND FUTURE DEVELOPMENTS

- Advances are being made by surveying the incidence of cavitation in a wide range of wild plants, crops and trees. It is hoped to further document the apparent correlation between resistance to cavitation and resistance to drought and saline conditions [1,9].
- Recent experiments indicate that cavitation does not arise from spontaneous nucleation of the sap within the xylem tubes. Instead a critical situation is reached at which air is pulled through the porous walls of the conduits. Assuming that the sap has a similar surface tension to water, calculations indicate that pores about

0.2μm would allow cavitation at sap tensions of 7 bar. Of course a single pore of this dimension would be sufficient to trigger the disruption in a conduit [2, 3].

The importance of surface tension is also indicated by experiments in which air pressure is used to force liquid from lengths of stem. Butanol-water with a surface tension about half that of water allows air to be forced through the stems at half the pressure required to dislodge water. Furthermore if butanol is introduced into the tubes when cavitation is in progress the rate of click emission is increased. Since the absorption of fluid should reduce tensions and suppress cavitation it seems that this effect is overcome by the reduction in surface tension (unpublished work).

- Recent experiments by Tyree and Dixon [10] indicate that ultrasonic detection of acoustic emission resembles the results obtained using audio frequencies. One potential benefit of this approach might be improved suppression of background noise.
- A longer term goal is the direct and continuous measurement of xylem sap tensions. Plant water relations could be studied much more precisely than by the present intermittent sample techniques based on the pressure bomb. Such measurements require the suppression of cavitation. If it can be suppressed we should be able to make instruments which are not disrupted at tensions which are commonplace in plants but are still beyond our present technology.

REFERENCES

1 Crombie, D.S. and Milburn, J.A. "The physiology of xylem sap cavitation in different ecotypes: a preliminary survey", (Abstr.). Federation of European Societies of Plant Physiology (Santiago di Compostela) (71 J) 292-293 July (1980).

2 Crombie, D.S., Milburn, J.A. and Hipkins, M.F. "The effect of cavitation of xylem sap on pressure chamber measurements of plant water potential", Planta. In press.

3 Crombie, D.S., Milburn, J.A. and Hipkins, M.F. "Maximum sustainable xylem sap tensions in *Rhododendron* and other species", Planta. In press.

4 Milburn, J.A. "The Conduction of Sap. I. Water conduction and cavitation in water stressed leaves", (Planta (Berl.) 65, 34-42 (1966).

5 Milburn, J.A. and Johnson, R.P.C. "The Conduction of Sap. II. Detection of vibrations produced by sap cavitation in *Ricinus* xylem", Planta (Berl.) 69, 43-52 (1966).

6 Milburn, J.A. "Cavitation in *Ricinus* by Acoustic Detection: Induction in Excised Leaves by Various Factors", Planta (Berl.) 110, 253-265 (1973).

7 Milburn, J.A. "Cavitation Studies on Whole *Ricinus* Plants by Acoustic Detection", Planta (Berl;) 112, 333-342 (1973).

8 Milburn, J.A. and McLaughlin, M.E. "Studies of cavitation in isolated vascular bundles and whole leaves of *Plantago major L*", New Phytol. 73, 861-871 (1974).

9 Milburn, J.A. "Water flow in plants (Integrated Themes in Biology)", Longmans London & New York (1979).

10 Tyree, M.T. and Dixon, M.A. "Cavitation Events in *Thuja occidentalis L*", Plant Physiol. 72, 1094-1099 (1983).

11 Zimmermann, M.H. and Milburn, J.A. "Transport and Storage of Water". In: Encyclopedia of Plant Physiology. N.S. Eds. Lange, O.L., Nobel, P.S., Osmond, C.B. and Ziegler, H. 12B, 135-151 (1982).

12 Scholander, P.F., Hammel, H.T., Bradstreet, E.D., Hemmingsen, E.A. "Sap pressure in vascular plants", Science, 148, 339-346 (1965).

(Received 6 December 1983)

ACOUSTIC EMISSION FROM PAINT FILMS

It is generally accepted that paint must adhere firmly to underlying surfaces to protect them effectively from weathering and corrosion. Thus adhesion tests are important in the development and testing of new paints and painting processes, and a number of physical adhesion tests have been devised by the paint industry. While such tests give an idea of overall adhesion quality, they are less useful for providing information on specific mechanisms of adhesive failure and the factors influencing debonding. That is why new methods for testing paint adhesion are constantly being sought and assessed.

A promising new technique, which relies on analyses of **acoustic emissions during tensile testing** of painted panels to determine paint-film quality, is being assessed by at least two groups, one at the University of Duisberg and the other at Imperial College, London. The work of the latter group, under **Dr R.D. Rawlings** of the Department of Metallurgy and Material Sciences, is outlined below.

For paint-film research, steel panels are prepared by various methods and are coated with paints of interest. The coated panels are then tensile tested to fracture in an Instron machine at a strain rate of 4 $\times$ $10^{-4}s^{-1}$. Acoustic emission during tensile testing is monitored by means of a clip-type PZT transducer (150 kHz resonant frequency) attached to the panel midpoint. Through suitable electronics, the ringdown counts and event counts are measured as a function of strain and the amplitude distribution of events is obtained. So far, a typical automotive finish has been investigated. This has included tests of panels with the complete four-part automotive system including topcoat as well as panels with the individual components of the system, i.e., steel alone, phosphated steel, phosphated steel plus anodic electrocoat primer, and phosphated steel plus primer plus surfacer coating.

The amplitude distribution of acoustic events during a tensile test was deconvoluted through computer analysis by assuming that the distribution was due to several breakdown mechanisms, each with a specific energy (amplitude) and each of which could be approximated by a Lorentzian distribution peaked at a specific amplitude. As a result, four processes with peak amplitudes at 22, 26, 35, and 47 dB were identified. The peak at 22 dB was correlated with cracking of zinc phosphate crystals. Adhesive failure of the bond between the zinc phosphate layer and the mixed iron phosphate–zinc phosphate layer was correlated with the peak at 26 dB. The peaks at 35 and 47 dB were correlated with gross cracking and peeling of the upper paint layers.

The results of the foregoing research were obtained with paint films that had not been exposed to the environment. However, research is well in progress in which such tests are being carried out on films exposed to water. Rawlings feels that the acoustic emission approach will be equally informative in determining the adhesive characteristics of such films. Perhaps in the future, in place of speculation about how well paint films will adhere, the films themselves will tell us, if we listen carefully.

P.A. Clarkin
in J.Acoust.Soc.Am. 73, 1394 (1983)

Self-Calibration of Your Own Microphone and Sound Level Meter

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ABSTRACT: Anechoic rooms are not totally necessary for free-field calibration of microphones using the reciprocity principle. It is possible to obtain satisfactory absolute microphone sensitivities in suitable outdoor locations, using simple inexpensive electronics.

INTRODUCTION

Pistonphones only calibrate the pressure microphones for which they have been designed to match. They cannot calibrate any other microphone. How do you know the pistonphone's calibration is correct for your microphone? How do you calibrate a cardioid microphone?

Of the two methods of calibrating microphones absolutely using the reciprocity principle, the pressure calibration method suffers from the same limitations as the pistonphone. The free-field method needs an anechoic room — or does it?

THEORY

The free-field method [1] uses one loudspeaker, the microphone to be calibrated and another instrument which must be able to act both as a microphone and a loudspeaker. The method appears simple enough. The loudspeaker provides a sound source and the microphone and loudspeaker-microphone are set at the same distance from the source and their open circuit output voltages measured (Figure 1).

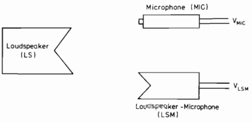


Figure 1: Schematic arrangement of the first set of measurements using the reciprocity method for microphone calibration. V_{MIC} and V_{LSM} are the output voltages of the microphone and loudspeaker-microphone respectively.

The loudspeaker microphone (LSM) is then fed with a current I, set at a distance d from the microphone (MIC) and the open circuit voltage of the microphone (V'_{MIC}) measured (Figure 2).

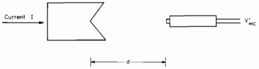


Figure 2: Schematic arrangement for the second set of measurements using the reciprocity method for microphone calibration. I is the current feeding the loudspeaker-microphone, V'_{MIC} is the output voltage of the microphone (MIC) and d is the separation.

The formula for the free-field sensitivity, K, is then

$$K = (2\lambda d V_{MIC} V'_{MIC} / V_{LSM} I r)^{1/2} \qquad (1)$$

where r is the specific acoustic impedance of air, and λ is the wavelength of the exciting sound. This is a rather formidable formula with 3 voltages in the millivolt range, one AC current and a wavelength. An AC current is a horror to measure accurately by analog meter. But suppose we put a resistor R in series with the loudspeaker-microphone and measure the voltage, V_{LSMR}, across the resistor. Use the same meter system to measure all four voltages, two by two, substitute $\lambda = c/f$, $r = c\varrho$ (c is the velocity of sound in air, ϱ the density of air and f the test frequency) and the formula looks like this:

$$K = \left(2\frac{d}{f} \cdot \frac{V_{MIC}}{V_{LSM}} \cdot \frac{V'_{MIC}}{V_{LMSR}} \cdot \frac{R}{\varrho}\right)^{1/2} \qquad (2)$$

V_{MIC}/V_{LSM}, V'_{MIC}/V_{LMSR} are ratios so the absolute accuracy of each voltage is *not* required, only the ratios are needed to be shown accurately. One per cent resistors are "off the shelf"; d and f are reasonably easily determined, only ϱ might be a bit "sticky". If the voltage reading on analog meters can be kept to the top half of the scale and the readings made to an accuracy of 2% of full scale deflection, add 2% for the density and 2% for the indefiniteness of the position of the sound source of LSM and the RMS accuracy looks like $\pm 4\%$ or 0.4 dB. Calibrate the meter over its whole range and the accuracy appears to be about $\pm 3\%$ or 0.3 dB. All that is needed apart from the equipment is the anechoic chamber.

A SUBSTITUTE CHAMBER

The back yard of my home seemed quiet enough. Using the rotary clothes line as a suspension I could get the microphones about 1.8 metres above the ground, which was grassed with buffalo, a coarse porous cover. The sound sources could point towards garden and vegetable beds growing dahlias, roses, beans, carrots. A few leafy trees were in the background against the fences — all material to absorb and scatter — not hard reflecting surfaces. The nearest fence (on the side of the equipment) would be about 6 metres and the nearest neighbour's back door about 15 metres. Two questions arose. Could the yard substitute for an anechoic chamber? Could the measurements be made with easily built, reasonably simple, equipment?

MEASURING EQUIPMENT

The loudspeaker originally used (LS in Figure 1) was a Foster 150 mm 160 K03 in a box about 240 mm cube. LSM was a Magnavox 4A (100 mm) in a box of external dimensions 240 mm long and 145 mm square cross section. This latter loudspeaker was chosen because, in this box, it would work down to 300 Hz, was reasonably small and yields an acoustic output (SPL) of about 94 dB at a distance of 1 m for an electrical input of about 2 watts.

A very simple AC voltmeter [2], preceded by a simple discrete component amplifier with a fixed gain of about 50 times and an input gain control, was assembled. A similar fixed gain amplifier (100 times) was built, as well as a simple Wein bridge oscillator of frequency about 1000 Hz and a small power amplifier. Later, an active unity-gain narrow band filter was added and the whole mounted into a large aluminium chassis.

The original experiments in the back yard were encouraging. Repeating them on the lawn fronting the University of NSW yielded strange results until I recognised that parts of the camera tripods used to suspend the equipment could act as very efficient reflectors. The clothes line did not provide such surfaces.

The final mechanical system consisted of two collapsible tripods of 3m pieces of extruded aluminium, 20 mm × 10 mm cross section (curtain track), with a similar section as cross bar to carry the loudspeakers and sound detectors. The large loudspeaker was replaced by a second 4A unit (no great difference was noted in the experimental results with the change).

The instruments chosen for calibration were an ECM 270 Sony cardioid electret microphone, a cheap Osoku sound level meter and a GR precision sound level meter.

EXPERIMENTAL PROCEDURE

The experimental procedure was as follows. One 4A loudspeaker was used as the reciprocal transducer and set 800 mm from the other loudspeaker. This latter was excited with a constant signal of about 2 watts power input. The output of the loudspeaker microphone (LSM) was fed to the 100 times amplifier, through the filter, to the voltmeter, and the "gain" of the voltmeter adjusted to yield full scale deflection. The LSM was then shifted by 100 mm increments till it was 1300 mm from the loudspeaker, meter readings being taken at each setting.

The microphone (MIC) was then substituted for the LSM at the same distances and the corresponding meter readings noted using the same overall system gain.

The LSM was then set facing the microphone and excited with the same electrical power as fed to the original loudspeaker. The voltage across the nominal one ohm resistance in the loudspeaker line was applied to the voltmeter and the voltmeter gain readjusted till the meter read full scale. The microphone output was fed through the 100 times amplifier to the voltmeter. The same distances used in the first set of measurements were used in this set between the LSM and MIC.

The readings at each distance were then used to calculate the microphone sensitivity, K, using eq. (2). Air density was obtained by neglecting any variation from standard atmospheric pressure and correcting for temperature alone.

The value of R was found from a wheatstone bridge calibration. Note that no voltage reading was known absolutely. Only relative readings were used.

Two sets of experiments on the university front grass area yielded sensitivities of 2.3 ± 0.2 mV and 2.4 ± 0.2 mV. A home back yard result gave 2.4 ± 0.2 mV.

The Osoku noise level meter (NSM) was set on its 100 dB range. Since its output is about 0.25 V at 94 dB the readings from this instrument went straight to the filter. The same procedures were used to calibrate the (NSM). Using a calibrated voltmeter to set up a sound pressure level of 94 dB according to the microphone calibration, yielded a deflection of 93.5 dB on the Osoku. The GR sound level meter when calibrated first with a pistonphone indicated 94.7 dB when its experimental reading yielded 94 dB.

A B and K small sound level meter was calibrated in the same way. It yielded a meter reading of 95 dB when the calibration said a sound pressure of 94 dB was incident on the microphone. A 94 dB pistonphone gave a deflection of 94.7 dB on the B and K meter.

CONCLUSION

With these results I suggest that reliable check calibrations of microphones and sound level meters within 1 dB can be obtained without the use of anechoic chambers. The process does not depend on the use of expensive "absolute" millivoltmeters.

(Received 4 October 1983)

REFERENCES

1 H. Olsen, J. Audio Eng. Soc. Vol. 17 No. 6, pp 655-658 (Dec. 1969).
2 G.W. Short, Wireless World, Dec. 1969, p. 578.

Book Reviews

BIOACOUSTICS — A COMPARATIVE APPROACH

Edited by Brian Lewis

Academic Press, London, 1983, 493 pp ($78.20 with 25% discount available to members of the Society from Academic Press, P.O. Box 300, North Ryde, N.S.W. 2113)

The editor's intention in this book is to bring together a collection of reviews from both sides of the vertebrate-invertebrate division in biological acoustics in such a way as to show the common nature of the problems faced and the solutions developed by evolutionary processes. The book is therefore directed both to research workers who find themselves on one side or other of the division, and a little more incidentally to other people who would like an introductory survey spanning the whole field. I write spanning advisedly, since the book wisely does not try to be encyclopaedic but rather selects particular topics for treatment in considerable depth.

The book is international in flavour, with seven authors from the United Kingdom, seven from other countries in Europe and four from the United States. It is well referenced and up to date, with a bibliography of some 1100 papers, most of which are from the decade 1970-1980. It is also quite clearly written for biologists, particularly those working in or close to the field of bioacoustics, and for these people it should provide a wealth of useful information and comparative insight. It will, however, be up to each individual reader to arrive at his own global view of the subject, since each of the chapters keeps quite closely within the defined limits of its own subject area and it is really only in the introductory chapter, and then only briefly, that any integration of the field is attempted. This difficulty is perhaps inevitable in a multi-author volume such as this, and the editor is fully aware of it. Perhaps we have not yet reached that stage in the development of the subject when a twentieth century Helmholtz can expound the whole state of our knowledge with authority. Until that time and that individual arrive, this volume is at least a step in the right direction.

The book begins wih a chapter by Axel Michelsen on the biophysical basis of sound communication followed by one by J. D. Pye on techniques for studying ultrasound. Chapter 9 by Brian Lewis treats directional cues for auditory localization, there is a nice chapter 13 on hearing and sound communication under water by A. D. Hawkins and A. A. Myrberg, and the final chapter 14, again by J. D. Pye, discusses echolocation and countermeasures. These are the more general and more physically oriented chapters and should be interesting reading for anyone with a general concern for the subject.

The remaining chapters are more biological, and particularly neurobiological, in their treatment and deal with more closely defined subjects. Three chapters deal with the control of sound production in insects, birds and mammals, but say little about the physical mechanisms of sound production. Three chapters deal with receptor mechanisms at the cellular level, and three more deal with central nervous system processing in insects, non-mammalian vertebrates and vertebrates respectively. It is clear that a great deal of work has been done in all these areas in recent years, but the phenomena and structures being studied are so complex that in many cases few simple general principles have yet emerged. Perhaps one is wrong in hoping for simplicity in biological systems — they may be inherently complex in all their processes, with the balance changing from one embodiment to another — but at least the complexity is being steadily measured and documented, and this compact survey summarizes the present state of our understanding.

For the biologist concerned with any branch of animal acoustics this book should be required reading. For more generally interested scientists, particularly those with a background in the physical sciences, the densely Latinate prose of the more biological chapters will cause problems. I suspect that they will have to consult a dictionary, as I did, to find the meaning of words like trabeculation, and that sentences like "The subgenual nerve innervates the posterior sensilla of the subgenual organ and the distal part of the organ probably gives rise to the intermediate organ and crista acustica of the tettigoniids and to the main process of the gryllids" will require a second reading. However it is not really for these people that the book was written, though chapters 1, 9, 13 and 14 will give them some taste of the subject.

The book is nicely produced and I found only a few typographical errors. The only discrepancy likely to cause any problem is the redefinition, by some of the authors, of the Q of a resonance curve to be the 10 dB relative bandwidth rather than the 3 dB relative bandwidth. Some use a subscript to indicate this change but some do not, and some use the normal 3 dB Q. The units are commendably metric, and usually S.I., throughout.

As the editor points out, the choice of topics to be included in the book was a personal one, and another book of comparable size and with the same title could be produced having very little overlap with the present volume. Some people will inevitably find their special interest omitted — there is nothing on cochlear mechanics, for example — but perhaps they will gain from reading about someone else's specialty.

NEVILLE FLETCHER

RAY METHODS FOR WAVES IN ELASTIC SOLIDS

J. D. Achenbach, A. K. Gautesen, H. McMaken

Pitman Books, Boston, 1982.

The background behind this book is the investigation of defects in solids by the measurement of the effects of a defect on the propagation of elastic waves. This is a difficult problem due to the fact that several different modes of wave propagation can concurrently exist and the boundary conditions around a defect (the emphasis being on cracks) are complicated. The authors develop the arguments for the use of geometrical ray theory and establish the limits of such an approach.

The book makes extensive use of mathematics, and a knowledge of vector algebra and simple tensors is required. Many of the mathematical techniques involved other than the customary ones used on vectors, are included in appendices at the end of appropriate chapters. Important parameters such as scattering coefficients for elastic waves impinging on cracks have been computed and plotted, however, no details of the computer programmes have been included so the calculations cannot be simply repeated by interested investigators. A trend in many books is to include sufficient details on numerical procedures even to the extent of programme listings, and it is a shame that this book did not adopt such a practice.

The book has seven chapters, and a brief review of them will give a better idea of the scope of the book. The Introduction (Chapter 0) discusses very briefly the concept of ray propagation and scattering of elastic waves by a simple crack. Chapter 1 develops the theory behind wave propagation in elastic solids by first introducing elasticity theory, and then using this to develop the wave equation and the concept of vector and scalar potentials to specify the transport of energy by elastic waves. Chapter 2 considers how wave propagation can be treated as integral relationships instead of the differential equations of

(Continued on Page 28)

Screams and Gurgles from the Acoustics Lab

One of the delightful aspects of working in a University is that one can indulge in fanciful research projects with very little accountability. Another is that there are plenty of people who can be coerced into either undertaking some of the research or being subjects for research.

These "Architectural Laboratory Animals" have certain advantages over the common laboratory rat. They can answer questions verbally and they don't have to be fed. On the other hand they are not easy to train and, if examination paper answers are anything to go on, they are not always reliable. One of the unknown factors about Architectural Laboratory Animals is how well they model other laboratory animals and humans.

In some research on aural perception of distance undertaken this year by **Kristin Young,** it appears that Architecture and Psychology animals are no different. Subjects from the Department of Architecture and Psychology were played prerecorded sounds over headphones and asked to make judgements about the distance of the source away from the dummy recording head.

The reason for the research was to obtain information about the way in which people make judgements of the acoustics of auditoria and, in particular, how judgements of "Intimacy" are made. But the work turned out to be valuable in other ways as well. Specifically, architecture students are not significantly different to students from other Faculties . . . in their ability to judge distance aurally anyway.

Another interesting discovery made about architecture students was that their ability to hear speech in noisy surroundings was negatively correlated with their Higher School Certificate score. Although the correlation coefficient was fairly low (only about 10% of the variation in an individual's ability to hear words correctly could be explained by variations in the H.S.C. score), work on the perception of sound is not renowned for the high correlation coefficients found. Maybe, in future, workers in this field should add "ability to pass examinations" to the list of factors affecting speech intelligibility and noise annoyance. But before they do they should also look at the relationship between H.S.C. score and the cultural and ethnic backgrounds of students.

Good idea! We can do that with next year's batch of Architectural guinea students.

FERGUS FRICKE
Dept. of Architectural Science
University of Sydney

(Reprinted from Architectural Science Dept. Newsletter, No. 17, January 1984)

Recorded waveforms in LP disks

Sound is a "constant velocity" phenomenon (for a non-dispersive medium). That is, for a given intensity of sound, the product of frequency and amplitude is constant over the whole spectrum. To cut a gramophone disk under these conditions would be disastrous because the amplitude of cut in the low frequencies would be too great.

The old 78 rpm disk used a recording characteristic which had a "turnover point" at 300 Hz. Crudely, below that frequency the recording characteristic changed from constant velocity to constant amplitude. This meant that the intensity of the signal presented to the cutting head dropped off at 6 dB per octave below that frequency. The resultant loss in recorded intensity was made up by an inverse network in the replay amplifier which followed the pick up.

With the advent of the LP disk and after much infighting, the world-wide recording characteristic and corresponding replay curve known as the RIAA characteristic was adopted. This, to cut down high frequency record replay hiss, boosts the high frequencies in the recording process, changing from a constant amplitude with increasing frequency above about 2000 Hz. This means a boost of 6 dB per octave

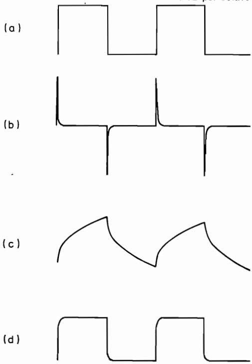


Fig. 1

to the signal applied to the cutting head. The turnover frequency at the low frequency end is moved up to 500 Hz.

As a test of the ability of a pick up to follow transients, a 1000 Hz square wave is used by some equipment reviewers in their tests. This does not mean that the pick up has to follow a 1000 Hz square wave cut in the record groove. Rather, a 1000 Hz square wave is fed to the recording pre-emphasis network, its output feeds the cutter head and the pick-up traces out the groove cut by the cutting stylus.

What are the waveforms presented to the cutting head and the waveform that the cutting stylus traces out in the record groove?

The accompanying copies of oscilloscope traces give the answers. Fig. 1 (a) is the square wave feeding the system, 1 (b) the waveform feeding the cutter head, assuming a first class cutter head. 1 (c) is the shape of the groove sliced out by the cutting stylus. In practice, at the outside of an LP disk, a 1000 Hz signal has a wavelength of about 0.4 mm and the amplitude of cut would not exceed 0.001 mm.

Fig. 1 (d) is the resultant waveform after the signal has pased a recording pre-emphasis network, and, an amplifier followed by a "de-emphasis" network. (This actual waveform reveals a 3 dB down point of 15,000 Hz over the whole process due to imperfections of the experiment.) But the photograph does show that the overall LP recording and replay process introduces little phase distortion between input and output waveforms if high quality recording and replay equipment is used.

This is not the case with most analogue magnetic tape recorders where the pre-emphasis necessary to give an overall flat response introduces considerable phase shifts in the higher frequencies. Digital tape recorders should not suffer this defect.

But of course this is the day of the compact digital disk (CDD). So the above waveforms are of historical interest only. Or are they?

Those interested in the technical side of the CDD are referred to Philips Technical Review, Vol. 40, No. 6, 1982.

ROY CADDY

Less stops — better fuel consumption

Every time a car stops at a traffic light around 40 ml of extra fuel is consumed. Even in apparently freely flowing traffic occasional stops can account for 10% of the fuel used on urban arterial roads. At the CSIRO Division of Energy Technology, a study is being made of a system of dynamic advisory speed signs to eliminate this waste.

Traffic signal systems are making increasing use of computers to minimize delays and stops while coping with the daily peak maximum flows. The driver in Australia, however, receives no instructions on what speed to drive in order to pass through the next traffic lights "on the green" although in a few cities in western Europe such advice is given.

The Division's project is aimed at quantifying the benefits of a driver advisory system for maintaining a uniform economical speed (i.e., less fuel, stops, emissions, noise, collisions and the same or lower travel time) and then designing a system to add to existing installations. Computer runs and road tests so far have given a saving of up to 15% in fuel consumption and 50% in number of stops.

(Minerals & Energy Bulletin, CSIRO, July 1983)

The quieter mower arrives

The Victa Vortex Mower, made under licence to CSIRO, has finally arrived in hardware departments and onto the lawns of Australian suburbs.

It is the result of research and development over a period of eight years by Victa Ltd. in association with the CSIRO Division of Energy Technology (formerly the Division of Mechanical Engineering).

Indeed it is down under(neath) where the design advance can be seen — not winged keel certainly, but turned-up fins in a vortex-action blade disc.

This produces a swirling action that generates a high-velocity airstream to fling the clippings through a narrow chute into the back of the catcher.

To cut and catch grass, wet or dry, the motor needs to spin at only 2700-3000 revs per minute compared with 3400-3800 rpm for Victa's popular Mustang model.

It is the slower blade action which is responsible for most of the noise reduction. A meter positioned 7.5 m. from a Victa Vortex (the standard distance for measuring mower noise) running at its normal cutting speed of 3000 rpm registers a maximum of 71 dBA, a significant 7 dBA lower than the Mustang in full cry. In fact, the Vortex already complies with the level set for all mowers produced in N.S.W. from 1987.

Another feature of the mower is a new 160 c.c. two-stroke, air-cooled engine developed by Victa engineers.

The company thinks the mower has excellent export potential, and hopes to claim a share of the overseas market — some 7 million power-driven lawnmowers are produced annually around the world.

Managing Director Mr. Bob Dunkerley believes a strong domestic market is a prerequisite for supplying world markets. Earlier this year Victa celebrated its 30th anniversary as its four millionth mower came off the production line.

From C.S.I.R.O. Industrial Research News 161, November 1983

The Bionic Ear

An outstanding product of Australian high technology, the bionic ear, is about to hit the international market following an injection of funds from the Australian Industry Development Corporation into the Sydney-based company, the Nucleus Group.

The AIDC has bought equity to the value of $5 million in the group, proven in the medical products market through its heart pacemakers.

The successful development of the bionic ear represents years of research and development, initiated by a University of Melbourne team led by Professor Graeme Clark and brought to its present stage by the Nucleus Group.

The bionic ear — technically, the multi-channel implantable hearing prosthesis—is designed to bring hearing to the profoundly deaf, for whom conventional hearing aids are inadequate.

It comprises a 22 channel cochlea device implanted behind the ear, a pocket-sized speech processor and a diagnostic and programming system used to program each patient's speech processor.

From The Australian, 6 April, 1984

New Products

STOREHOUSE
A MAJOR RECORDING ADVANCE FROM RACAL

Racal Recorders Ltd. have announced a major development in magnetic tape recorder technology. STOREHORSE, a large portable wideband instrumentation recorder, is designed to handle accurately and efficiently vast quantities of data.

STOREHORSE incorporates many advanced and innovative features not previously available in this type of equipment. It is expected to find wide application in aerospace, industrial, acoustic and medical research, defence, communications and data archiving.

Key features of this high performance recorder include Automatic Calibration and Equalisation (ACE) and self diagnosis of performance giving early warning of possible system malfunction. Extensive microprocessor control has resulted in a recorder that, unlike conventional machines, does not require qualified staff for setting up and maintenance.

STOREHORSE is a 42 track recorder with 15 inch coaxial spools compatible with ½ inch and 1 inch magnetic tape. It can be used in any combination of the three standard data recorder/replay formats - DR (direct recording), FM (frequency modulated), and HDDR (high density digital recording). All record and replay functions can be controlled and monitored from the front panel using an integral push-button keyboard and visual display unit.

An important breakthrough in the design of STOREHORSE is, for the first time, the reduction of setting up time for several hours to less than three minutes.

The settings for each circuit can be stored in a built-in memory and recalled whenever it is required to record or replay with a given set of conditions.

The VDU is used to display all the major machine characteristics of STOREHORSE as well as monitoring all input and output signals. By using the information on the display together with a few very simple controls, operations such as tape search, channel sequencing, replay shuttling, comparison or recall of recorded data, can be undertaken with ease.

Fully IRIG/ISO compatible, STOREHORSE can be used as a 7, 14, 28 or 42 track recorder. Recording sequentially on one track at a time at the lowest speed of 15/32 in/sec gives 131 days on continuous use. Tape speed is variable between 15/32 in/sec and 120 in/sec.

In the DR mode, STOREHORSE can operate in the Intermediate Band to 600 kHz and Wideband to 2 MHz. FM recording covers Intermediate Band to 40 kHz, Wideband 1 to 80 kHz, and Wideband 2 to 500 kHz. HDDR recording is to 36,000 bits per inch using Delay Modulation Bi-Phase L or NRZ codes.

For further information contact Mike Clark or Mike Evans at Racal Electronics Pty. Ltd., 47 Talavera Road, North Ryde, 2113. Tel. (02) 888-6444.

Long-Range Tachometer Probe

A new Tachometer Probe, MM 0024, has recently been introduced by Bruel & Kjaer. The Probe is a small, handy device designed to facilitate the remote triggering of vibration analysis and balancing equipment in synchronism with rotating and reciprocating machine parts. A special benefit is that it can operate up to 800 mm. from the target, and thus at a safe distance from moving parts or otherwise hazardous environments.

The MM 0024 generates a modulated infra-red beam and has a small indicator to confirm correct orientation with the target. Light reflected back from a piece of self-adhesive reflective tape attached to the rotating or reciprocating part produces a well-defined pulse-train corresponding precisely to the cyclic movement of the subject. This provides a stable constant-magnitude trigger signal directly suited for triggering B & K equipment such as the Portable Balancing Sets Types 3517 and 9537, Tracking Filter Type 1623 and Stroboscope Type 4912.

The Probe is equipped with a combined signal/power cable for coupling the probe to these battery-powered instruments, and a thread for attaching it to a tripod or magnetic foot.

Recorder Control Unit Type 7509

The Recorder Control Unit Type 7509 together with a front loaded Application Package, enables spectra, time functions and control settings from Bruel & Kjaer Analyzers to be plotted by the X-Y Recorder Type 2308. The plots can be made to a preferred paper format and are in a fully annotated form which is suitable for direct inclusion in a report — no need to have the results redrawn and no need to write out all the control settings.

Two Application Packages are available: BZ 7075 for the Digital Frequency Analyzer Type 2131 and the Sound Intensity Analyzer Type 2134 (which is a part of the Sound Intensity Analysing System Type 3360) and BZ 7078 for the Narrow Band Spectrum Analyzer Type 2031 and the High Resolution Signal Analyzer Type 2033.

Format modes

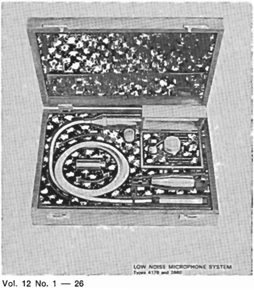
Four format modes are available for presentation of the measured data.

A single spectrum using the "Fast" writing speed may be plotted in ten seconds whilst a fully documented plot using "Slow" may take two minutes.

The X-Y Recorder Type 2308 may be fastened horizontally or vertically to the top of the Recorder Control Unit Type 7509 by means of the mounting brackets provided. Type 7509 is connected to the analyser via an IEC/IEEE interface cable and to the X-Y Recorder Type 2308 using the cables supplied, and the cabling is the same no matter what combination of analyser and Application Package is employed.

Condenser Microphone System for Very-low-level Acoustic Measurements

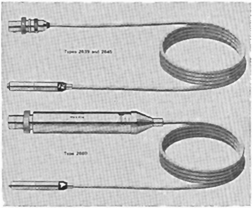
To facilitate measurements of very low sound pressure levels, Bruel & Kjaer has developed a condenser microphone system consisting of one-inch diameter Condenser Microphone Type 4179 and Microphone Preamplifier Type 2660. This system is unprecedented in low-noise performance; the typical noise floor for the complete system is -2,5 dB(A), allowing measurements to be made down to levels of -5 to -15 dB in the third-octave bands between 20 Hz and 12,5 kHz. The frequency response is in accordance with IEC 651, Type 1 requirements, and the system is well-suited for laboratory hearing research, measurement and monitoring of very low background noise levels, and sound pressure and sound power level measurements of very-low-level sources.



BRUEL & KJAER:

Microphone Preamplifiers

For precision acoustic measurements with condenser microphones, three new microphone preamplifiers have been introduced to the Bruel & Kjaer instrument range. The preamplifiers have very low inherent noise, are robust, and are designed for use under a wide range of environmental conditions. **Type 2639** accepts ½" microphones directly and 1", ¼" and ⅛" types via adaptors. It is intended for precision acoustic measurements in accordance with IEC, ISO and ANSI requirements. **Type 2645** is similar in design and application to the 2639, but in addition includes a facility for insert voltage calibration of 1" and ½" condenser microphones in acccrdance with standards requirements throughout the world.



Types 2639 and 2645 are available in two forms: delivered either in a mahogany case together with various accessories or alone in a plastic case. **Type 2660** may also be used with the complete range of B & K Condenser Microphones, but has been specially designed for use with a new very-low-noise 1" condenser microphone Type 4179. This system is unprecedented, with a very-low noise floor of -2,5 dB(A).

New Publications

Journal of Technical Physics (in English)
Polish Academy of Sciences
Vol. 23, Nos. 3-4, 1982.
Included in the Contents:
T. Feuer and W. Karmowski, Holographic measurement of displacement of a rigid body.
Z. Dzygadlo and A. Krzyzanowski, Dynamics of longitudinal motion of an aeroplane with a deformable control system.

Royal Institute of Technology, Stockholm
E. Jansson and K. Karlsson: Sound levels recorded within the symphony orchestra and risk criteria for hearing loss.
J. Sundberg: Chest wall vibrations in singers.

New Zealand Acoustical Society
Papers from 7th N.Z. Acoustical Society Conference, 1983.

Telecom Australia
Review of activities 1982-83.

Canadian Acoustics
Vol. 12, No. 1, January 1984.
W. A. Cole: Prospects for the application of high technology to hearing aids.
J.-Y. Trepanier and A. C. C. Warnock: L'effet du volume d'une salle sur la mesure des coefficients d'absorption du son.
D. A. Benwell: Activities of ISO TC43/SC1 "Noise", WG19, "Occupational Noise".
It is noted that there is now a new Editor-in-Chief, John Bradley, of the Division of Building Research, National Research Council.

Revue d'Acoustique
No. 66, 1983.

Includes: **D. Juve and P. Roland,** Two dimensional intensity probe measurements in the near field of a subsonic jet; together with a number of papers from the colloquium EUROMECH 154 dealing with ultrasonic measurements.

The Australian Journal of Audiology

Vol. 5, No. 2, November 1983.

Archives of Acoustics (in English)

Polish Acoustical Society

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PUBLICATIONS by AUSTRALIANS

1982

The Three Dimensional Cavity Resonator.
G. BIGG.
Dept. Appl. Math., Univ. of Adelaide, S.A. 5001
J. Sound. Vib. **85 (1),** 85-103 (1982).

A Criterion for Predicting the Annoyance due to Higher Level, Low Frequency Noise.
(1) N. BRONER. (2) H. LEVENTHALL.
(1) Vipac & Partners Pty. Ltd., Victoria, Australia.
(2) Atkins Res. & Dev., Epsom KT1 5BW, England.
J. Sound. Vib. **84 (3),** 443-448 (1982).

Cumulative Spectra, Tone Bursts, and Apodization.
J. D. BUNTON, R. H. SMALL.
School of El. Eng., Univ .of Sydney, N.S.W. 2006
J. Audio Eng. Soc. **30 (6),** 386-395 (1982).

The Barrier Attenuation of Garden Fences.
C. G. DON, J. G. WEGNER.
Dept. of App. Physics, Caulfield Inst. of Techn., Victoria 3145
Appl. Acoust. **15 (6),** 429-444 (1982).

Formulation of the Maximum Signal-to-Noise Ratio Array Processor in Beam Space.
D. A. GRAY.
Dept. Def. Support, WSRL, Defence Res. Centre, Salisbury, Adelaide, S.A.
J. Acoust. Soc. Am. **72 (4),** 1195-1201 (1982).

Comments on "Sound Propagation Through an East Australian Current Eddy". [J. Acoust. Soc. Am. 63, 1381-1388 (1978)].
M. HALL.
RANL, P.O. Box 706, Darlinghurst, N.S.W. 2010
J. Acoust. Soc. Am. **72 (4),** 1316-1318 (1982). (Letter).

Multiplier/Detector for SAW Spectrum Analyser.
P. J. HALL.
Dept. of Physics, University of Tasmania, G.P.O. Box 252C, Hobart, Tasmania 7001
Electronics Letters **18 (16),** 699-700 (1982).

Refined Finite-Element Analysis of a Clad Fiber Acoustic Waveguide.
(1) A. J. JENNINGS. (2) G. K. CAMBRELL.
(1) Telecomm. Aust. Res. Lab., Melbourne, Victoria.
(2) Monash Univ., Melbourne, Victoria.
IEEE Trans. Sonics Ultrasonics **29 (5),** 239-248 (1982).

The Validity of Aided Thresholds.
J. MACRAE.
Audiology Res. Sect., NAL, 5 Hickson Rd., Sydney, N.S.W. 2000
Aust. J. Audiology, **4 (2),** 48-54 (1982).

A Scale Model Investigation of Sound Radiation from a Large Aperture in a Building.
(1) D. J. OLDHAM. (2) Y. SHEN.
(1) Dept. of Arch. Sc., Univ. of Sydney, N.S.W. 2006
(2) Dept. of Bldg. Sc., Univ. of Sheffield, S10 2TN, England.
Appl. Acoust. **15 (6),** 397-409 (1982).

Reply to "Comments on 'Sound Propagation Through an East Australian Current Eddy'" by Marshall Hall.
(1) P. SCULLY-POWER, D. BROWING. (2) P. NYSEN.
(1) New London Laboratory, NUSC, New London, Connecticut, 06320, U.S.A.
(2) Tabtek Electronics Pty. Ltd., 159 Kent St., Sydney, N.S.W. 2000.
J. Acoust. Soc. Am. **72 (4),** 1319-1321 (1982).

Logarithmic Converter.
(1) C. VELAYUDHAN. (2) V. K. GOVINDAN.
(1) Dept. of El. and Electronic Eng., Univ. of W.A., Nedlands, W.A. 6009
Int. J. Electr. **53 (4),** 381-386 (1982).

Experimental Investigation of a Random Repeated Impact Process.
(1) L. WOOD. (2) K. P. BYRNE.
Eng. Dept. G.M.H. Ltd., Port Melbourne, Victoria 3207
(2) School of Mech. and Ind. Eng., The University of N.S.W. 2033
J. Sound. Vib. **85 (1),** 53-69 (1982).

1983

The Environmental Aspects of Structural Response to Blasting Overpressure.
E. J. ANCICH.
Vipac & Partners Pty. Ltd., Victorian Technology Centre, Melbourne.
Resources Industry, **22 (8),** 15 (1983).

Scattering of Phonons by the Strain and Rotation Fields of Crystal Defects.
R. A. BROWN.
School of Math. and Physics, Macquarie Univ., N.S.W. 2113
J. Phys., C. Solid State Phys. **16 (6),** 1009-1029 (1983).

Time-of-day Corrections in Measures of Aircraft Noise Exposure.
BULLEN, R. B.; HEDE, A. J.
Nat. Acoustic Labs., Millers Point, Australia.
J. Acoust. Soc. Am. **73 (5),** 1624-30 (1983).

Modeling of Acoustic Propagation across Warm-Core Eddies.
LAWRENCE, MARTIN W.

Royal Australian Navy Research Lab., Edgecliff, N.S.W. Aust.
J. Acoust. Soc. Am. **73 (2),** 474-485 (1983).

Crack Detection in Cover Plated Steel Guides using Acoustic Emission.
G. G. MARTIN, P. GRUNDY.
Dept. of Mat. Eng., Monash Univ., Clayton 3168
Non-Destr. Testing — Aust. **20 (1),** 27-32 (1983).

Performance of Stochastic Gradient Descent Adaptive Beam-forming using Soanar Radar.
Dept. Def. Support, Weapons Syst. Res. Lab., Def. Res. Centre, Salisbury, S.A. 5001
IEE Proc., F. Comm. Radar Signal Processing **130 (1),** 147-151 (1983).

BOOK REVIEWS (Continued from Page 22)

Chapter 1 and this leads onto the important concepts of reciprocity and intensity.

Chapter 3 considers wave propagation in a half-space and from this the phenomenon of mode conversion at the boundary is considered in detail including the generation and propagation of Rayleigh surface waves. Chapter 4 introduces elastodynamic ray theory. Geometric rays describing wave propagation arise at the high frequency asymptote where the wavelength of the elastic wave is very much less than the characteristic dimensions, and any small deviations from this requirement are allowed for by correction terms. Wavefronts are defined as the surfaces of constant phase and the curves normal to these wavefronts are rays. Caustic surfaces are introduced being defined as the envelopes of rays producing a focus (spherical aberration in optics) and it is shown that ray theory cannot apply on these surfaces.

Chapter 5 deals with the diffraction of a plane wave by the edge of a semi-infinite crack. The effects are described in terms of special diraction coefficients. Chapter 6 considers the more difficult problem of scattering by a finite crack and involves in the theory the concept of the crack opening displacement (COD). Chapter 7 develops a geometrical theory of diffractions with particular reference to stress-free cracks. Chapter 8 indicates how the theory may be extended to consider diffraction from a crack having a uniform COD.

Robert W. Harris

HEARING CONSERVATION FOR STEELFOUNDERS

Steel Castings Research and Trade Association, East Bank Road, Sheffield S2 3PT, U.K., 1982, 52 pp., £5.00.

This booklet is a valuable source of information for noise specialists and includes chapters on: Types of ear protectors, Selection of ear protectors, Dispensation of ear protectors, and Promoting the use of ear protectors. There are four Tables including a survey of information about ear muffs and a table of suppliers of ear protectors. Four appendices contain detailed information on: British standard attenuation data for 65 ear protectors, A classification of personnel, Equivalent continuous octave band sound pressure levels for occupational groups, and a number of tables of ear protectors suitable for different groups of personnel.

SCRATA also has available (1) A colour video cassette of 14 minutes' duration entitled "You will never get used to deafness", consisting of the stages of deafness, purchase price £50.00 or hire charge £10.00. (2) A microcomputer disk which contains data relating to available ear protectors and a programme which assists in the choice of the most appropriate device.

Howard Pollard

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A. ARTICLES