The Bulletin

AUSTRALIAN ACOUSTICAL SOCIETY

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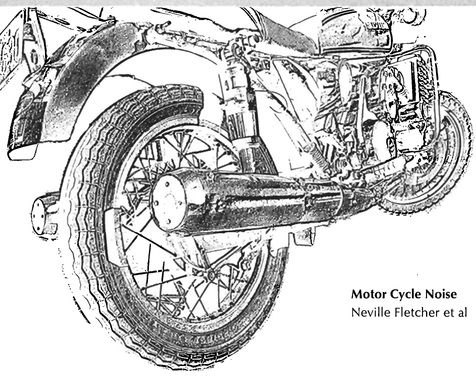

Motor Cycle Noise
Neville Fletcher et al

Loudspeakers
Roy Caddy

Acoustic Emission
Brian Wood

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BULLETIN OF THE AUSTRALIAN ACOUSTICAL SOCIETY

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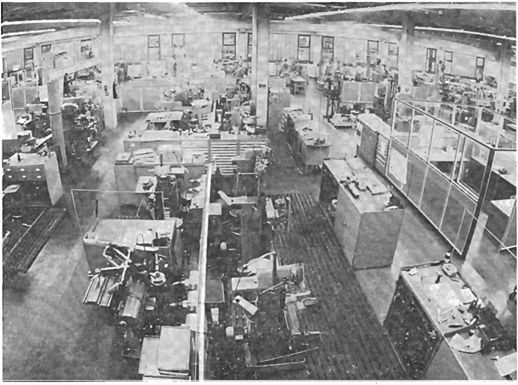
Cover photograph by Peter Elliston and Jane Campbell of U.NSW.

What does a really noisy factory look like?



Empty!

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EDITORIAL

Reactions to our April issue have generally been favourable, although nearly everyone wants to know how much the glossy paper is costing. As with everything these days, the answer is too much. However, we hope that the increased publishing costs with the new style will be justified by increases in the number of technical papers and other material published. We are aiming to cover as much as possible of the production costs with advertising revenue. To this end, we are pleased that Val Bray has agreed to act as our advertising manager. Val would like to receive suggested names for additional advertisers.

Although the Bulletin is being produced in New South Wales, the editorial team is conscious of the fact that it should be a national effort, or should at least reflect national activity. To that end, liaison officers have been appointed in each State to provide a steady stream of information relating to meetings, members' activities, future activities, technical notes and (continuing to be optimistic) papers for publication. With the present editors all residing in N.S.W., it will be easier to lean on members in that State to produce technical papers. That would be a pity as there are many workers in other States who could produce interesting articles relating to their interests. Articles may be submitted either to the appropriate liaison officer or to the Chief Editor.

As well as regular technical papers we would like to publish review papers, discussion and tutorial papers designed to edify those of us not in the same area of interest. We also need to bear in mind that the Society has a relatively large number of general members (approximately 20 per cent of total membership) who are not practising in acoustics but who are nevertheless very interested in many aspects of the subject. We need to cater for these readers on a regular basis. Could we urge all those members who have a flair or a yen for writing a straight-forward, informative article on his/her area of work to unsheath the pen and proceed forthwith to produce a masterwork. For this type of article we would like to see as many illustrations (with full captions) as possible, perhaps treated as an independent sequence in the style pioneered by Scientific American. (Additional staff will no doubt be needed to handle the flood of replies to our impassioned plea.)

In the People column of the April issue, it was reported that Professor Harold Marshall of New Zealand, who is a past member of the Australian Acoustical Society, had been made a Fellow of the Acoustical Society of America. We are now very pleased to learn that our President, Anita Lawrence, has also been made a Fellow of the Acoustical Society of America. Our heartiest congratulations go to both members for this recognition of their distinguished contributions to acoustics. These events raise the question: Why are there no Fellows of the Australian Acoustical Society? Although there is provision in our constitution for the election of Fellows, this option has lain dormant for a long time. The central problem is that no mechanism was laid down for an election process. The constitution merely gives the Council power to confer fellowships. A possible mechanism would be for each State Committee to make nominations annually for fellowships to Council who could then exercise their divine right to elect or otherwise. However, it has been suggested that, in these "enlightened" times the concept of a fellowship needs re-examination. Is this just a form of intellectual class distinction? Or, if it is an honour, would not a prize or similar award be more appropriate? Hopefully a solution to this and other membership problems will be forthcoming from the deliberations of the committee recently appointed by Council.

It seems that the long-established image of the laconic Australian, with his vocabulary confined mainly to "yep" and "nope", might also apply in the field of acoustics. One of our cherished hopes is to have an active Letters page but to date no-one has ventured an opinion or comment on anything at all. Maybe nothing deserves a comment but if anyone out there has an interesting thought, experience or gripe, please put it on paper and we will give you star billing. It would be a shame if we had to resort to the time-honoured Dorothy Dix method.

For those who are curious as to the origin of the pattern in the background of our masthead, this is a second-order beat pattern, generated by a small computer, consisting of a fundamental tone beating with a slightly out-of-tune octave tone. While the amplitude of such a pattern remains essentially constant, the pattern changes regularly producing a noticeable subjective effect (phase beats).

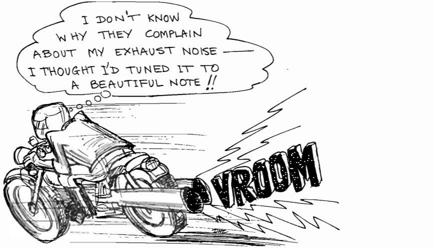
Howard Pollard

OVERVIEW OF THIS ISSUE

Our first paper is from Brian Wood on Acoustic Emission, one of the fast-growing new branches of acoustics. Brian's paper was given at the Acoustic Emission Symposium held in Sydney in November 1981. The elements of AE are covered in readable style and some interesting practical applications are described. An impressive feature of AE is the large scale activity that it inspires. Investigators need mountaineering experience in order to attach their myriad transducers to structures such as dams, bridges, oil refineries, television masts, etc.

Neville Fletcher and associates shatter our preconceived notions of what constitutes acoustical research in New England by tackling the shattering subject of motor cycle noise. The results are most interesting and confirm many of our subjective impressions. But, as one local motor cycle enthusiast remarked when he heard about this paper: "I hope they are going to tackle trucks and semis next." (See cartoon next page.)

Our third paper initiates a series of discussion papers that will be written in less formal fashion. Roy Caddy tackles a favourite subject, Loudspeakers, in his own very direct style. We have engaged a firm of solicitors who are eagerly awaiting the expected lawsuits that might arise from irate manufacturers.


I DON'T KNOW WHY THEY COMPLAIN ABOUT MY EXHAUST NOISE — I THOUGHT I'D TUNED IT TO A BEAUTIFUL NOTE !!
VROOM

AUSTRALIAN NEWS

• VICTORIA DIVISION REPORT

New Melbourne Concert Hall

On Wednesday 24 February members of the Victoria Division were shown over the new Melbourne Arts Centre Complex by the architects, Roy Grounds and Company. Of most interest to the members was the nearly completed concert hall. The acoustics in this hall were designed by Bolt Beranek and Newman and as no expense was spared should make it equal, acoustically to any in the world. However, members were even more fortunate to have the opportunity to speak to the people responsible for the acoustic design a few weeks later.

On Thursday 11 March Mr. Kim Kirkhope, Chairman of the Victoria Division introduced Mr. Bob Newman and Dr. Ted Schultz, both from Bolt Beranek and Newman to over 100 members and guests. Both gentlemen had come to Australia to test the results of their efforts in the acoustic design of the theatre complex.

Mr. Newman spoke first and discussed the performance of the main concert hall. He said that his company's main aims were to —

- — allow a clear view of the orchestra for all members of the audience.
- — to achieve a background noise environment of better than NC15.
- — to achieve a reverberation time of at least 2 seconds when the hall is fully occupied. He also added that his company used successful designs in America as models for the Melbourne Hall to ensure success.

The reason for allowing a clear view of the orchestra for all members of the audience was twofold. Firstly if the orchestra can be clearly seen the subjective assessment of the music made by the observer is apparently enhanced. Secondly, it is desirable that members of the audience are not "looking over a sea of people" which would detract from the total enjoyment of the music. To achieve this aim two sloping balconies are used with the top one taking full advantage of the maximum slope permitted by the relevant standards.

The second aim mentioned, to achieve an environment of about NC15, has been achieved and in fact, it may be better than NC13 in the empty hall.

The final aim was to achieve a reverberation time of at least 2 seconds when the hall is fully occupied. At the time of speaking to our Society, Mr. Newman did not know what the reverberation time would be as the hall was not yet completely finished. He did add however, that he was very pleased with it. He also pointed out that the use of concrete in the hall to enhance the reverberation time does not in any way lead to a harsh metallic sound as is sometimes said.

Mr. Newman also mentioned two features of the new concert hall. The first was the use of 700 m^2 of woollen banners which can be lowered to reduce the reverberation time by ½ sec. (for speech, pop music and rehearsals, for example).

The second was the use of oval perspex panels (or clouds) over the orchestra for acoustic reflection to the front audience and the stage. Oval panels were used instead of the usual round panels to provide sufficient area of coverage whilst still keeping the panels away from the hot overhead lights. Mr. Newman also described the method of orienting the panels using a spotlight and brought out the need for the orchestra themselves to hear the music they and their colleagues are playing. Mr. Newman concluded his talk by saying how gratified he was with the result to date.

Mr. Schultz then talked more specifically about the design of the concert hall. He mentioned the main aim of a concert hall is to enable a relationship to be established between each member of the audience and the orchestra. He then posed the question "Is designing a concert hall an art or a science?" and answered it by saying "both" and described some of the reasons for his answer.

Firstly as a Science

Noise such as traffic, mechanical services must be reduced to a minimum. The reverberation time for, say organ music, should be high (eg. 2.1-2.2 seconds) whilst for string instruments it should be lower (eg. 1.5-1.6 seconds). Any focussing of sound must be prevented and Dr. Schultz gave examples of some halls where the harps overpower the trombones in some listening areas. The Orchestra requires information back to ensure their communication to preserve the harmony of the music and no long delayed echoes must be present.

Secondly as an art

The reverberation time can be measured but Dr. Schultz asked what is the best reverberation time? Also how much early reflected sound is required by the audience? Dr. Schultz emphasised that the answer to problems such as these is no longer in the realm of science.

Dr. Schultz then discussed the general layout of the concert hall and defended the choice of a nearly square plan over the often talked about "shoebox" design. The "shoebox" design's best example is in Vienna and the acoustics in this hall are excellent. However, Dr. Schultz pointed out that the hall is very small (1600 *small* seats) and cannot be scaled up successfully to accommodate modern audiences.

The quare plan used in the Melbourne Concert Hall is in Dr. Schultz's opinion the best shape which provides both good acoustics as well as a good view of the orchestra.

Dr. Schultz then discussed the design of the acoustic reflectors and the woollen banners mentioned by Mr. Newman in some detail.

After these 2 presentations and an active question time the Chairman called up Mr. Ken Cook who thanked both guests for one of the highlights of the Victoria Division year.

I would like to add my thanks to our guests and on behalf of the Victoria Division thank the Directors of Roy Grounds and Company for their assistance and co-operation in organising these memorable occasions. We look forward to a very interesting opening season in the new Concert Hall shortly.

Sounds and Noises in Places of Worship

A disappointing attendance of 9 members were present on the 29th April to hear a talk by Peter Staughton, architect, on "Sounds and Noises in Places of Worship". Members who did not attend missed an entertaining audio and visual presentation of some great music as heard in some of the great churches of the world. Using tape recorder and slide projector Peter took us first to St. Mark's, Venice, to hear some music by Monteverdi using four antiphonal choirs on various levels. We then heard some organ music with distinct Spanish instrumental character as recorded in the Royal Chapel at Madrid.

Peter explained that for best music results churches required a "long tailing reverberation" and said he regarded a great church as being a work of architecture, a work of art, and a musical instrument.

Some of the great composers wrote music to be performed in a specific church or cathedral and to illustrate this we were taken to Kings College Chapel at Cambridge University. We admired Peter's very professional slides of the building exterior and interior (described as one of the most beautiful in the world) while listening to both organ and choir music composed specifically for and recorded in this space.

Accompanied by some music from Handel (great writer for large churches) we moved to the Round Church at Cambridge, Salisbury Cathedral and the intriguing octagon church at Ely and then to Canterbury Cathedral which is really two churches in one with the great length of the space presenting many acoustical challenges (or difficulties depending on one's viewpoint).

Across the Channel we visited Notre Dame with its fascinating front towers and magnificent flying buttresses and heard music dating from Louis IV time. On to Rome we viewed Michelangelo's beautiful dome of St. Peter's, spoilt in Peter's opinion by a later added facade.

We then moved to the Renaissance period and back to the U.K. to see a centralised classical church in Wren's St. Pauls and to hear the Dead March in Saul (recorded at Winston Churchill's funeral) and some intriguing trumpet sounds recorded in the famous Whispering Gallery.

We were reminded of some of our own beautiful churches such as St. Pat's (how many other churches in the world have three beautiful stone spires?) and urged to attend music performances in them. Bendigo Cathedral was described as one of the great Victorian buildings of the world.

Peter completed his talk by showing an example of his own work in the renovation of a lovely old church in Williamstown and stressed the importance of achieving a good inter-relation between light and sound so as to create the desired mood within the church.

John Lambert

• SOUTH AUSTRALIA DIVISION

Technical Meetings:

February 1982 — "A Quantitative Description of Properties of all Common Acoustical Uses of Fibrous Porous Materials" by Dr. David A. Bies, Reader in Mechanical Engineering and Director of the Acoustics Laboratory, University of Adelaide.

Synopsis—The requisite properties of porous materials may readily be measured using a simple impedance tube. In terms of these measured properties the quantitative description of all of the common acoustical uses of porous materials is possible.

For fibrous materials a further simplification can be made. The requisite properties may in turn be calculated from first principles; only the bulk density, the fiber diameter and the gaseous medium need be specified. For fibrous materials analytic expressions have been determined which now make possible straight forward design procedures for control of sound transmission through barriers and transmission in ducts.

The calculation of the statistical absorption of fibrous porous linings for reverberation control in enclosures is also straight forward. However, the relationship of the statistical absorption to the sabine absorption remains obscure because the sabine absorption depends on the geometry of the enclosure and is not a simple property of the lining alone.

Some results of interest in these matters which span a period of 28 years were presented by the speaker. *April 1982* — "Ultrasonics in Medical Diagnosis" by David E. Robinson, Head of the Advanced Techniques Section of the Ultrasonics Institute.

Synopsis — Mr. Robinson described the existing techniques used in Ultrasonic diagnosis together with a smorgasbord of clinical applications. He also discussed some new techniques which are being developed at the Ultrasonics Institute.

Greg Wild

• NEW SOUTH WALES DIVISION

Technical Meetings:

April 1982 — "Seismic wave propagation from blasting and its effect on surface structures with particular reference to the SAA blasting codes AS2187 1980 and CA23-1967" by J. L. Goldberg, Principal Research Scientist, CSIRO Division of Applied Physics, West Lindfield.

Summary — A programme of investigation into the response of structures by seismic wave propagation from blasting is being undertaken by Mr. Goldberg and his Vibration Group.

The aim of this work is to acquire a better knowledge of the reasons for damage and disturbance from blasting. With increased activity in Australia in mining and harbour deepening there is a need to formulate improved codes to ensure that the effects of blasting are minimised.

Mr. Goldberg's lecture described some of this work and indicated the progress made by his group in the past few years. Facilities used in his work were on display within the Division.

June 1982 — "Diagnostic Ultrasound in Medicine" by Dr. Robert Gill, David Carpenter, Dr. Laurie Wilson, Ultrasonics Institute, Sydney.

Summary — Ultrasound is now firmly established as a diagnostic tool in medicine. Ultrasound imaging has replaced x-rays and nuclear medicine techniques in some areas because it is safe and noninvasive, it produces complementary information to these techniques in other areas, and it has also opened up some totally new areas which have had a significant impact in medicine. In this talk, the principles involved were discussed briefly, and some examples of applications shown. This was followed by a tour of the Ultrasonics Institute, where research and development work is done on instruments, transducers, signal-processing techniques, and the biological effects of ultrasound.

N.S.W. Division Awards

Clause 3(f) of the Memorandum of Association of the Society states that one of the objects for which the Society is established is "To encourage the study of acoustics and to improve and elevate the general and technical knowledge of persons engaged or intending to engage in the science and practice of acoustics and for such purpose to donate or bestow on such terms and conditions as may from time to time be determined prizes or other awards or distinctions . . .".

The N.S.W. Division has agreed to present:

- an award for the best paper presented at a Technical meeting of the Division, and
- a prize for the best high school student essay on a topic in acoustics.

Details relating to each are in the process of being finalized.

The Hunter Valley expedition planned for March was cancelled due to lack of support. Perhaps the Barossa Valley will instil more enthusiasm.

The Division managed to mount an Acoustics Display at two recent "Careers Markets", organised by High Schools at Bankstown, 18 March and Fairfield, 29 April. This was a rewarding experience and the Division is now accumulating display material which will be on hand for these and other similar events.

John Dunlop

• WESTERN AUSTRALIA DIVISION

Technical Scientific Meeting . . .

June 1982 — Professor Brian Stone gave a talk at the Technical Scientific Meeting of the Australian Acoustical Society, Western Australia Division on Thursday 17th June. The topic was: "Some Methods of Reducing Vibrations in Machine Tools". — Vibration in machining poor surface finish, increased tool wear and excessive noise. The source of the vibration is often in the cutting process and may result from an instability called chatter. It is possible to achieve considerable improvements by using suitably designed tools and grinding wheels; also improvements to the structural response may give significant benefits. A review of some of the most cost effective methods was given and the magnitude of the improvements that may be obtained.

Research project . . .

A research project under way in the Department of Mechanical Engineering at the University of Western Australia is concerned with developing and validating statistical energy analysis techniques to provide engineering predictions for the estimation of random vibrations associated with practical piping systems. The project which is being carried out by Dr. Michael Norton and Mr. Lynn Kirkham with A.R.G.S. (formerly A.R.G.C.) support, is concerned primarily with experimental and analytical investigations of the effects of flanges, discontinuity in pipe wall thickness, and discontinuity in pipe wall material on the vibrational characteristics of cylindrical shells. The initial part of the project is concerned with a study of the various statistical energy analysis parameters (damping, modal density and coupling loss factors) which are essential to the subsequent development of analytical models for the vibration response prediction. The Department's newly acquired Hewlett Packard 5420 B Digital Signal Analyser (two channel spectrum analyser) is being used extensively in the project.

One day seminar . . .

A one day seminar on "Sound Intensity Measurement" was held at WAIT, Department of Architecture on the 20th May. The Seminar was organised by Les Southgate, W.A. State Manager of B. & K. Roger Upton, B. & K. Denmark, was very successful in delivering for an audience (18) with various backgrounds in acoustics, a very interesting lecture on the B. & K. Sound Intensity Analysing System before lunch. During the afternoon he conducted a session of practical demonstration during which he demonstrated the versatility of the B. & K. Sound Intensity Analysing System. WAIT provided an industrial vacuum cleaner with known Sound Power Levels (obtained by using Reverberation Chamber and Substitution Method) and Roger within minutes produced Sound Power Level figures, which for practical purposes were identical with those calculated by WAIT students (though Roger insisted that his figures were more accurate).

Tibor Vass

• AUSTRALIAN ACOUSTICAL SOCIETY ANNUAL CONFERENCE

"The Economics of Noise Control"
Tanunda, South Australia

24-25 February, 1983

CALL FOR PAPERS

ABSTRACTS
Abstracts will be received up to 31st July, 1982. They should not exceed one page in length but should provide sufficient information to allow for selection of papers.

ACCEPTED PAPERS
Authors will be notified of acceptance of papers by the end of August, 1982.

COMPLETE PAPERS
Must be received no later than 30th November, 1982. Papers should not exceed 8 pages on A4 size paper. Details of the required format will be provided at the time of notification of acceptance.

PRESENTATION
Authors will be allowed 20 minutes to present their papers followed by a 10 minute discussion period.
The theme of the Conference is:
"THE ECONOMICS OF NOISE CONTROL"
Commonly asked questions in the noise control field are: "What will it cost!" "What are the benefits!" and "What are the disadvantages!" Generally, decisions are made on the basis of economics.
Papers will be sought from insurance bodies, union and employer groups as well as from the research and applied engineering fields.

PROGRAMME
One keynote paper and 15 to 20 submitted papers are to be presented over 1½ days.

Invited Speaker: Dr. Eric Bender

ECONOMICS OF INDUSTRIAL NOISE CONTROL

Synopsis

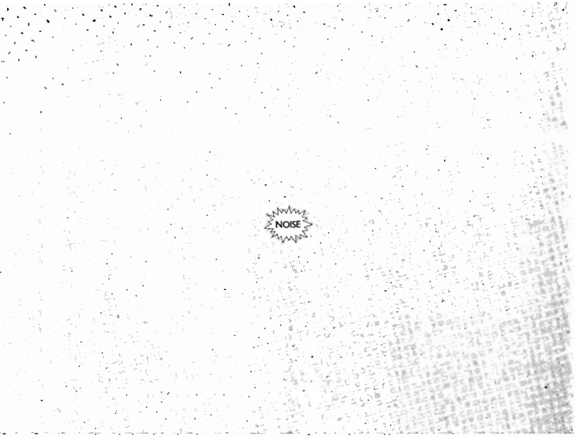
Studies to date of the cost of industrial noise control have been based primarily upon retrofit treatments that often involve cumbersome enclosures and or distributed applications of sound absorptive materials. Such studies have shown that the cost of control by these "barrier control" means and the cost of workmen's compensation for noise induced hearing loss are about equal. On the other hand experience has shown that noise control instituted at the design stage or control which achieves noise reduction by source modification can be an order of magnitude less expensive than barrier control.

Dr. Eric Bender, a Senior Consultant with Bolt Beranek and Newman Inc., of the United States, has for the last ten years been directly concerned with the economics of product noise control. He has recently been awarded the distinction of Fellow of the Acoustical Society of America for his leadership and work in the field of industrial noise control. Dr. Bender will deliver an invited lecture on the subject of "intrinsic" industrial noise control with emphasis upon the cost of alternative procedures at the Annual Conference of the Australian Acoustical Society hosted by the South Australian Division, at Tanunda, South Australia, on 24 and 25 February, 1983.

His talk will consider such matters of intrinsic control as necessary research and development costs and possibly higher production costs which must be amortised over the life of the product. He will show that when these costs are weighed against other currently accepted costs such as workmen's compensation for hearing loss that a significant cost saving may be expected. His talk will be illustrated with case studies.

Details: Dr. P. B. Swift, Pryce Goodale & Duncan Pty. Ltd., 65 Fullarton Road, KENT TOWN, S.A. 5067.

Receivers and Managers have been appointed for Advanced Acoustics Products (Aust.) Pty. Ltd. trading as Bruce Sheet Metal Service. It is the intention of the Receivers and Managers (Wallace McMullin & Smail, Melbourne) to continue trading whilst the financial position is assessed.



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ACI Fibreglass

BIGGER AND BETTER must be the adjectives to describe the first issue by the fifth production team. Even the Gossip — oops — PEOPLE column was bigger. If less errors by your People columnist is a measure of betterness then the column was better as well.

I know that many readers of this column only read it for the confessions of errors in the previous column. Yes, this column has such confessions; but life was never meant to be easy, so you have to read through the column to find my confessions.

* * *

Congratulations to DON GIBSON, M.A.A.S. who was appointed Chief of the Division of Energy Technology of the CSIRO. Prior to his appointment on May 25 Don was Acting Chief of the Division.

The fate of both the CSIRO Division of Building Research, Acoustics Section; and the E.B.S. have been in doubt.

From PAUL DUBOUT Sub-program Leader of the CSIRO D.B.R. Acoustics Section I have learnt that whilst there will be some administrative re-organisation of the division, there will be no shut door or closure, no heads to roll and similar. By the time I prepare the next column I hope Paul Dubout will have sent me sufficient information to inform readers of the situation.

Talking today to TED WESTON it seems the E.B.S. is not so fortunate. It appears that the E.B.S. has been allowed to wilt to the extent that it can now best be described as dying. Last year the Interdepartmental Committee called for "Expression of Interest" from organisations interested in taking over and running the E.B.S. Whilst two acoustical consulting organisations were interested in the acoustical laboratories and other organisations in the fine testing facilities; apparently no organisation of sufficient stature came forward to immediately interest the Interdepartmental Committee. So the E.B.S. languises on.

* * *

TED WESTON has left the E.B.S. and is now retired — doing some work — looking for work.

* * *

ALLAN HERRING, M.A.A.S., M.I.E. Aust. has commenced his own acoustical consulting practice as Allan Herring Acoustics, 3/14 Stone Street, South Perth. By agreement with Ron Carr, Allan will carry on or continue the previous practice of Carr Acoustics.

* * *

ANITA LAWRENCE has been elevated to Fellow of the Acoustical Society of America.

Anita is also in the news because she, and her husband Gerry left Australia in mid-June for a 6-month overseas visit. Whilst away Anita will be visiting acoustical laboratories in Europe and the U.K. and spending some time at the National Research Council in Ottawa as part of her Special Studies Programme.

* * *

STRENGTH TO STRENGTH. From Chris Day in New Zealand I hear that he has a staff of three working for him — plus Harold Marshall part time.

* * *

From Bob Fitzell I learn that PETER FEARNSIDE, M.A.A.S. is still in California, United States of America working with Jerry Hyde, and expects to stay until about September. Peter has found the different attitude to travel interesting — one job has Architectural, Mechanical and Civil Engineers and Acoustic Consultants at 4 most remote corners of the United States of America and job is dead centre about as far as you can actually get from everybody.

* * *

JOHN LAMBERT has just telephoned me to advise of his appointment as Manager, Noise Control Section, South Australian Department of Environment and Planning. John currently with the Environment Protection Authority in Victoria will move with his wife Margaret to Adelaide. Writing now, not as People's columnist but as Victoria Division Secretary I can tell you we will find it hard to find an adequate replacement on the Divisional Committee.

* * *

Now for the correction to the last issue. It is marvellous to be advised of correction to the People column; marvellous because it shows that somewhere out there somebody reads the column. JOHN SPILLMAN from Perth advises that Harold Marshall mentioned in the last column resigned from the Society in 1975.

* * *

CURIOSITY got the better of several members who telephoned me about the change of Knowland Harding Fitzell to Graeme E. Harding & Associates Pty. Ltd. For all those other curious people PETER KNOWLAND, BOB FITZELL, and myself remain good friends; only the name of my consulting company was changed. The previous name recognised the mutual friendship and co-operation of the three of us; but was changed because many people misconstrued the name as implying a legal partnership or similar. And about the change of address in the last issue; well due to a various set of circumstances we are able to stay where we are.

OBITUARY

HARVEY FLETCHER, one of the pioneers of modern acoustics, died 23 July 1981 at the age of 96. The early part of his career was spent at the Bell Laboratories where he helped develop sound recording methods, hearing aids, an artificial larynx, etc. His experiments in subjective acoustics led to the famous Fletcher-Munson curves for the frequency response of the ear. After his retirement as Director of Physical Research in 1949 he moved to Brigham Young University Utah where he continued his acoustical research. Some of his later work was on the analysis and synthesis of the tones from musical instruments. He was a foundation member and first president of the Acoustical Society of America.

West Australian members on the move . . .

DEREK CARRUTHERS, School of Architecture, University of Western Australia, will be on study leave from July 1982 to February 1983.

He will undertake a study of Concert Halls in Germany and Holland and attend the European Acoustics Congress in Gottingen in September (DAGA, FASE '82).

He will spend three months in the Martin Centre, University of Cambridge, working with Mike Barron on a project on the acoustics of British Concert Halls.

* * *

MICHAEL NORTON, of the Department of Mechanical Engineering, University of Western Australia, plans to go to England in September for the International Conference on Flow Induced Vibrations in Fluids Engineering. The Conference is being held at the University of Reading and is sponsored by B.H.R.A. Fluids Engineering.

* * *

VALERIE ALDER, Research Fellow, Department of Surgery, University of Western Australia, is going on study leave from early August 1982 to Frankfurt, Germany. She will be working at the "Max-Planck Institut fur Hirnforschung" with Professor Wassle on neurotransmitters in the retina. She will be also attending the International Congress of Ophthalmology at Eindhoven in Holland and she will be returning to Western Australia early in February 1983.

* * *

GRAEME YATES returned from the U.K. to work in the Physiology Department, University of Western Australia with Professor Brian Johnstone.

Prospective new member . . . ?

Professor BRIAN STONE arrived at the University of Western Australia from U.K. in December 1981 to take up his appointment to a chair in Mechanical Engineering. A graduate and PhD. of Bristol University, Professor Stone worked as a research engineer and section leader with the Machine Tool Industry Research Association (U.K.) for several years before joining the academic staff at Bristol, where he remained until taking up his new appointment. He has an enviable reputation for innovative research and practical industrial investigations in vibration dynamics; several of his patented inventions have been taken up by U.K. industry. A mathematical analysis of the movements encountered in variable speed cutting recently won him and a collegue the prestigious JOSEPH WHITWORTH PRIZE awarded by the Institution of Mechanical Engineers, U.K.

Professor Stone has been invited to give a keynote paper on the vibration characteristics of bearings at the C.I.R.P. Conference in Belgium this coming September. (C.I.R.P. is an international production engineering conference with about 500 delegates drawn from all the major manufacturing nations.)

* * *

SO REMEMBER, send news of interest to me: not just news but photographs of people, buildings, and all things of acoustic interest. Send them to me at Graeme E. Harding & Associates Pty. Ltd., 22a Liddiard Street, Hawthorn, Victoria 3122.

Graeme E. Harding

INTERNATIONAL NEWS

• Two New Acoustical Organizations

A new acoustical society has been established in **Portugal** and will be registered with the ICA. The address is as follows:

Sociedade Portuguesa de Acustica
Prof. Pedro Martins da Silva
Presidente
C/o L.N.E.C.
Av. Brasil, 101
1799 Lisboa
PORTUGAL.

A new acoustical organization was established in the German Democratic Republic in the year 1981 which is now registered with the ICA. The address is as follows:

Physikalische Gesellschaft der DDR
Arbeitsgruppe Akustik
Vorsitzender Prof. Dr. W. Kraak
C/o Technische Universitat Dresden
Helmholtzstrasse 18
8027 Dresden

The Deputy Chairman is Dr. Frohlich from the Academy of Sciences, Central Institute of Electron Physics, Berlin, the Secretary is Dr. W. Ahnert from the Institute of Cultural Buildings, Berlin.

The first meeting of the Acoustics Working Group was held in September 1981 in Berlin. According to its programme, the Acoustics Working Group is the representative of acoustics in the GDR. The work is done in nine sub-groups covering the following fields: physical acoustics, language communication, architectural acoustics, machine acoustics and aerodynamical acoustics, electro-acoustics, psycho-physical acoustics, musical acoustics, hydro- and geophysical acoustics, acoustics measurement. Colloquia and technical lectures will be organized to help to propagate available knowledge, also joint technical conferences are planned for all branches of the Working Group. The aim is to contribute to activities in the field of acoustics also on the international level.

• 11th ICA

The 11th Congress will be held in Paris (Hotel SOFITEL, Paris), July 19-27, 1983. The venue for the opening session will be the main theatre at the Sorbonne, in Paris. GALF (a group of French speaking acousticians), will be wholly responsible for the organisation of the Congress.

The Congress will deal with every aspect of acoustics and will be heralded by three smaller "Satellite" Symposia, held in:

MARSEILLE: July 12-13 on active sound absorption and acoustic feedback control;
LYONS: July 15-16 on acoustic radiations from vibrating structures;
TOULOUSE: Also July 15-16 on oral communication.

Message from the President of the 11th ICA, Professor R. Lehmann:

The 11th International Congress on Acoustics will be held in FRANCE, in the course of JULY 1983 and it is my own earnest desire that the near totality of all the world's acousticians attend regardless of origin or nationality, and converge on FRANCE for the occasion. Our Groupement des Acousticiens de Langue Francaise, or G.A.L.F., a body bringing together all French speaking acousticians, is responsible for the convening of this highly significant event and as such will do its utmost for it to be a success, so that every participant in the Congress goes home with unforgettable, heart-warming memories. We wish for nothing better, so won't you please come along and join us? Your presence alone will be ample recompense for our effort.

Details: 11th ICA, Secretariat SOCFI, 7 rue Michel-Ange, F.75016 PARIS.

• Summer Workshops in Digital Sound Synthesis and Processing — three one-week workshop sessions. Three one-week workshop sessions: August 2-6, 9-13, 16-20 BOSTON

Digital techniques are being more and more widely used in the recording industry and in research, for both the synthesis and processing of sound. Digital audio technology will become much less expensive in the next decade and its use will become widespread. These summer workshops provide a comprehensive hands-on introduction to this emerging field. Emphasis is on the practical application of digital audio technology. Participants will learn how to programme and use state-of-the-art digital audio signal processing systems. The course fee is $US375 for the one-week session. This includes tuition and course materials.

Details: Digital Music Systems, Inc., P.O. Box 1632, BOSTON, MA 02105.

• THE SOUTH AFRICAN ACOUSTICS INSTITUTE

ANNOUNCES a call for papers for an International Symposium on 6-8 October, 1982, at the Faculty of Medicine, University of Stellensbosch, Tygerberg, Cape Town.

Theme:

ACOUSTICS AND THE QUALITY OF LIFE.

Aim:

Highlighting and mobilizing the important roles that the various branches of acoustics may play in improving human existence.

Papers are invited on all aspects related to the above, including: Noise Pollution, Architectural, Music, The alleviation of hearing impairment and communication barriers, Ultrasound in Medicine. Details: Prof. C. J. du Toit, Faculty of Medicine, TYGERBERG 7505, Republic of South Africa.

NEW PUBLICATIONS

ENVIRONMENTAL IMPACT OF ROADS AND TRAFFIC

L. H. Watkins.
Transport and Road Research Laboratory, U.K.
265 pp., 1981, $A45.50 plus $1.00 postage.

CONTENTS: 1. An introduction to environmental appraisal. 2. Vehicle and traffic noise. 3. Vibration and low frequency sound. 4. Exhaust emissions. 5. Assessment of visual impact. 6. Roadside pollution. 7. Lorry nuisance. 8. Construction nuisance. 9. Environmental surveys. Index.

Available from D.A. Book Depot, 11-13 Station Street, Mitcham, Vic. 3132.

PHYSICS IN AUSTRALIA 1981

Australian Academy of Science.
139 pp., $7.50 plus $1.50 postage.

CONTENTS: The first of a series of quadrennial reports on the state of the various branches of science in Australia. Included are articles on the status of current branches of physics with complete summaries of institutions, personnel and projects throughout Australia. Of special interest to readers of this journal is the chapter on Acoustics by Jack Rose of NAL.

Available from Australian Academy of Science, P.O. Box 783, A.C.T. 2601.

STUDIO ACOUSTICS

M. Rettinger.
247 pp., 1981, $US35 plus $US2.50 postage.

CONTENTS: BASICS including sound insulation, reverberation, air-conditioning system noise levels. STUDIOS including control rooms; recording studios; large, small and miniature reverberation chambers. ELECTROACOUSTICS.

Available from Chemical Publishing Co., 155 West 19 St., Dept. 627, New York, NY 10011.

ACOUSTICS BULLETIN

Vol. 6 No. 4, Oct. 1981, 36 pp., £3.00 (Annual Subscription £10.00).

CONTENTS: News items, articles and a special feature on Speech Research including the following articles: Applied Acoustics and Speech Disorders by R. Beresford, Automatic Speech Recognition by R. K. Moore, Machines that Speak by J. N. Holmes, Speech Production Modelling by Celia Scully, Some Current Issues in Speech Perception by C. J. Darwin.

Available from The Institute of Acoustics, 25 Chambers St., Edinburgh EH1 1 HU, U.K.

The Acoustic Emission Systems of The 80's

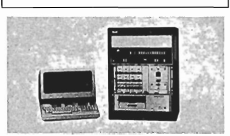
Use the technology of the Future NOW.

Successful acoustic emission (AE) applications within the metals industry are varied and numerous. AE technology has been employed in metallurgy and engineering mechanics to determine correlation between AE and material properties as well as deformation and fracture mechanisms. Other applications include pre-service and in-service testing of pressure vessels, pipes and manufactured components. In the industrial field, applications include mechanical properties testing of components and engineering structures, quality control inspection of manufactured parts and assemblies, weld testing, in-process weld monitoring and, in the case of spot-welding, feedback control of the process itself.

LOCAN I® Locator/Analyzer

LOCAN I is the only one/two channel AE System in its price range which offers numerical data handling and eight simultaneous output functions for graphic display. Now, the sophistication of a computerized system can be applied economically to small specimen work or production/quality testing. LOCAN I is compact, portable, has a built-in CRT and is surprisingly low-priced in comparison to systems that offer less.

TRODYNE SYSTEMS INCORPORATE MANY FEATURES AS STANDARD WHICH OTHER MANUFACTURERS EITHER OFFER AS OPTIONAL OR DO NOT OFFER AT ALL.



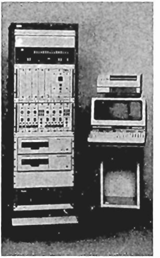
MINI "M"® (Compact MSCD) System

The MINI "M"® system is a lower cost, compact, table top version of the well known and proven Trodyne MSCD AE system. It provides data acquisition and analysis in either one or two dimensional applications and retains the salient features and versatility of the MSCD II. Improved packaging techniques allow either a four, six or eight channel system to be packaged with computer and floppy disc, common to the MSCD II, in one small cabinet.

This compact system incorporates software based upon the well proven MSCD II RTE software, the most extensive available today. The software allows the sensors to be used in either a "fishnet" configuration or in smaller independent groups or pairs. It also incorporates a high speed data collection mode, which is extremely important for use in fiber reinforced plastics (FRP) testing.

The MINI "M"® is also compatible with the IEEE 488 standard digital interface for the connection of hard copy, graphics and printing devices.

MSCD II®
Multi-Sensor Comprehensive Data System



Trodyne has purposefully selected the world renowned Hewlett-Packard family of peripherals for its high reliability and for its expeditious, efficient, worldwide supply and service network.

The MSCD II is a newly improved and updated version of the well-known and field-proven Multi-Sensor Comprehensive Data (MSCD) System. The original MSCD features, such as data set format, clearly defined parameters, exclusion logic, advanced noise discrimination techniques and the powerful real-time and analytical software are the main distinguishing characteristics that still remain.

The MSCD II improvements take advantage of a new generation of equipment and software. Incorporating the system operation under Hewlett-Packard's new Real-Time Executive (RTE) software package, we now offer modular software structure, FORTRAN IV source language, easy editing and system generation capabilities. The new dual Flexible Disk Drive utilizes double density diskettes, increasing both the capacity and speed of mass storage. The new and intelligent Graphics Terminal provides a multi-task keyboard, automatic plotting, block-mode of operation, off-screen storage with scrolling capability hardware pan and zoom facility and many other features found only in sophisticated terminals. The MSCD II is also compatible with the IEEE488 Standard Digital Interface, which makes the interconnection to modern printers, plotters and other devices easy and inexpensive.

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Acoustic Emission - A Stethoscope to Monitor Structural Integrity

Brian R. A. Wood

CSIRO Division of Mineral Physics

Lucas Heights Research Laboratories, Private Mail Bag 7, Sutherland, N.S.W. 2232

ABSTRACT: With the development of sophisticated electronics during the past few years, it is now possible to use acoustic data that were previously lost in background noise. One technique that is being exploited is acoustic emission (AE) monitoring; by careful use of AE, it is possible to gain valuable information on the structural integrity of both metal and composite structures. The technique can be used for non-destructive inspection during a proof test or during operation, or for long-term monitoring to schedule maintenance procedures and structural integrity. Acoustic emission has been successfully used on bridges, pipelines, pressure vessels, aircraft, as well as a wide range of large and small welded and fabricated components.

1. INTRODUCTION

Acoustic emission monitoring, the noise produced by a material which is undergoing stress, is a versatile and valuable non-destructive testing tool. It is not a new techniue — in fact it was probably the first warning technique — but usually it warns of a destructive incident. The creaking of timber before and when a branch or tree collapses is a typical early example. A more recent example would be the creaking of timber mine struts.

It has only been in the last twenty years that acoustic emission monitoring, as we knew it today, has been developed to its present form. The advent of solid state and more complex electronics has made it possible to develop techniques that can be applied usefully to industrial situations.

The AE technique has many non-destructive testing applications. For example, in a number of steels, stress wave emission (another description for AE) from localised areas of deformation can now be detected well before the most sensitive strain gauges can detect the yield point.

2. WHAT IS ACOUSTIC EMISSION?

Acoustic emission signals are stress or elastic waves generated when elastic energy is released during the deformation of a solid. The stress waves are essentially sound waves which travel with a characteristic velocity in the material. The signals may be small and occurring frequently so that they approximate a continuous noise signal, i.e. continuous emission, or they may be larger and less frequent so that they appear as bursts, i.e. burst emission. Practical applications of AE to non-destructive testing have been restricted to the monitoring of burst emission.

Continuous emission is thought to arise from submicroscopic events, such as dislocation movement. Theoretically, it should be possible to detect emissions, subject to thermal interference, which would be equivalent to the movement of a few atoms. However, at present, the smallest detectable emission involves the movements of clusters of 5 to 150 dislocations. Burst emission, on the other hand, is thought to result from larger scale phenomena, including the breakaway of clusters of dislocations from their pinning points, the formation of twins, the propagation of cracks, slip, the fracture of second phase particles and phase transformation.

The irreversibility of these phenomena suggests that they will not occur until the material commences to yield plastically. Emission has been detected at less than 10 per cent of the yield stress, and it is almost invariably detected before the nominal yield point. Earlier localised yielding will always occur in any "structure" because of the stress concentrations that result from manufacturing errors, design faults, or internal defects such as inclusions, cracks or voids. It is this localised yielding that enables the detection and location of the defects which are causing the stress concentration.

Because detection is possible at a general stress level which is less than yield, the technique is non-destructive. Since much small activity can be detected, defects can be identified in their very earliest formation. One of the major difficulties with acoustic emission is that, although defects of all sizes and forms can exist, if they are not under stress at the time of examination no emission will be generated and they will not be detected. A side effect of the phenomena is that known defects can be classed as active or passive by monitoring the generated emission under a known stress situation. This can be created in-service, enabling known defects to be categorised and unknown active defects located. This information could be of considerable value to designers and fabricators in critical situations and of economic advantage in identifying defects that require repair. However, great care is needed in this use of the technique.

3. HOW IS ACOUSTIC EMISSION DETECTED?

Acoustic emission is usually monitored by a piezo-electric transducer attached magnetically or mechanically to the surface of the structure. Any active defect in the structure will generate stress waves, which are detected by the transducers. Metal waveguides are used to protect the transducer from hostile environments. It is also possible to use a transducer which is tuned to a particular application and to achieve further filtering with electronic euipment (Fig. 1).

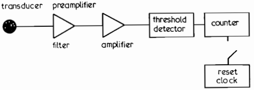

Figure 1: Block Diagram of Basic Acoustic Emission Instrumentation Ringdown Counting Method.

Useful emission occurs as bursts of elastic energy with frequencies ranging from several hertz to several megahertz. Although there may be significant bursts of energy in the audible frequency range, the most useful information is obtained by monitoring the higher frequency ultrasonic component of the burst, thus reducing the possibility of interference from low frequency external noise.

4. ANALYSIS OF DATA

The acoustic emission bursts detected by the transducer are converted into an electrical signal and, after amplification, this information may be evaluated in various ways.

First, the characteristics of the emission may be used to identify the source. Although this technique shows promise it is still far from being a practical tool; attempts are being made to identify sources from the signature analysis of the emission. Such sources of emission may be slip, twinning, hydrogen embrittlement, phase changes, crack growth, slag inclusion, cracking of microscopic carbides and movements of cascades of dislocations, etc. (Fig.2).

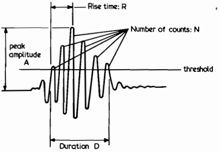

Figure 2: Parameters for Characterising an Acoustic Emission Event.

Second, it is possible to count the bursts as a function of time, as a cumulative count or as a burst rate. The burst may be described as a decaying sinusoidal oscillation whose frequency and duration depend on the resonance behaviour of the transducer assembly; the number of discernible cycles in the product will depend on the original size of the emission. If the crossovers of a set trigger level are counted, rather than bursts only, the count rate is more closely related to energy than to events. Note that the number of counts detected on acoustic emission counting equipment generally does not correspond to the number of pulses, but depends on the amplitude of the pulse (Fig. 3).

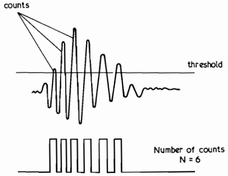

Figure 3: Ringdown Counting Method.

Third, the location of a source of emission in a two-dimensional body can be determined by standard triangulation technique using the relative arrival times of a specific burst at these separate transducers. For linear location, such as along the pipe or rod, two transducers placed at opposite ends of the region of interest are adequate (Fig. 4).

It is possible to gate the arrival times of the signals at the various sensors so that only those pulses emanating from a selected area will be fed into a counting circuit. This means that extraneous pulses originating at the loading points or support points of a structure can be eliminated.

5. THE USE OF ACOUSTIC EMISSION

Acoustic emission can be used on metals, ceramics, rock, timber, cement and, indeed, most materials. This versatility shows how widely AE can be used for fault-finding and proof-testing on such items as large structures, bridges, aircraft, dams, geological formations, pipelines and pressure vessels — to list but a few.

One of the earliest workers in acoustic emission, a German engineer named Kaiser, demonstrated what is now known as the Kaiser effect. If a material is stressed, and then that stress is removed, there will be no acoustic emission in any subsequent stressing until the original stress level has been exceeded. This means that it is very important that AE monitoring be done on the first pressurisation, i.e. at the proof-stress stage.

However, the Kaiser effect, although limiting the scope of AE monitoring in some cases, can improve it in other cases. If a material or object is proof-tested and then later repressurised, AE can be detected below the proof-test pressure. This indicates that there has been some recovery within the material, or that a stress concentration has formed, implying the formation or growth of an active defect. In some circumstances, correct use of AE monitoring would not only ensure confidence in the integrity of an item by substantiating the absence of AE during regular application of stress or pressure, but also signify the need for intensive inspection if it is present. Considerable saving can also be made owing to the ability of the technique to localise areas requiring detailed inspection.

Care should be taken in interpreting the Kaiser effect, for often parts or sections of the structure may be removed, modified or replaced; the activity from the new material associated with any replacement or modified parts may also generate emissions which mask the silence of the Kaiser effect. Any test loading should duplicate the service loading since any variation in procedure, e.g. the removal of ancillary equipment and supports, could lead to incorrect interpretation of the data.

6. MATERIAL EFFECTS ON ACOUSTIC EMISSION

Not all materials are suitable generators of acoustic emission. As mentioned earlier, acoustic emission has been recognised for years in the creaking of timber; it is also heard in the "cry" of tin. If a piece of tin or high-tin solder is bent, a crackling sound, known as the "cry", is heard. It is, in fact, the AE generated from the formation of twins, resulting from internal shear within the material. But bend a piece of clean, mild steel and the process is silent.

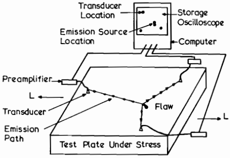

Figure 4: Flaw Detection by Acoustic Emission.

Different materials have very different acoustic characteristics. The successful use of AE tests is, in many situations, complicated by the characteristics of the material. In particular, clean high-toughness steels, such as those used for pressure vessels, are particularly quiet during deformation. As a simple generalisation, soft ductile steels that contain few inclusions are quiet, whereas high-strength, brittle steels are noisy. Although there are numerous exceptions to this generalisation, it is fortunate that the most commonly used constructional steels are noisy. Ceramic materials, such as cement and especially bricks, produce copious emissions before failure. Nevertheless, non-detection of a defect in a structure does not guarantee that one is not present. The potential success of any acoustic emission test should be evaluated on test samples of the relevant material before a decision is made on its use.

7. LIMITATIONS

At the present stage of development, it is not possible to be certain that AE techniques will locate a defect in a stressed structure. The chance of successfully locating a defect is wide-ranging and depends chiefly on a detailed knowledge of the material properties and the structural geometry.

As with other forms of non-destructive testing, failure of an AE test to detect a flaw does not guarantee the integrity of the structure. If the test finds no flaws, the operator can make only an estimate of the likelihood that it would have found a defect, had one been present, and not a direct estimate of the probability of integrity of the structure. The accuracy of this estimate is highly dependent on the operator's experience and ability.

In most applications, this rather unspectacular result is to be expected. Happily, gross defects are rare in most fabricated structures and often AE techniques have been used only after other non-destructive testing methods have been applied. A successful test, where success is defined as the locating of an unknown flaw, is thus very unlikely. However, the incidence of detection of unknown flaws must increase as AE becomes accepted and understood by those responsible for structural integrity.

A customer who is given a negative result (i.e. that AE test has found no flaws), can derive little assurance of integrity and must look to the results of other forms of non-destructive testing. A series of such vague and unspectacular results is highly probable and, in the absence of code requirements for AE testing, is likely to discourage potential applications and stifle its development as a non-destructive testing tool. It may be for this reason that the literature on AE applications is rich in reports of successful testing programs, but poor in reports of tests which produce inconclusive results, although these must surely be in the majority.

8. INTERPRETATION

The American Society for Testing and Materials has drawn up a standard specifying AE test conditions and classifying detected defects from the AE pulse rate. Sources are usually classified with respect to their acoustic activity and intensity.

8.1 Acoustic Activity

A source's acoustic activity is normally measured by event or emission count; a source is considered to be active if it is either of these; counts continue to increase with increasing or constant stimulation. It is considered to be critically active if the derivative of its event emission count continues to increase with increasing stimulation, or with time under constant stimulus.

8.2 Intensity Measure

An intensity measure of a source is its average amplitude per event. Also, the emission count per event, the emission energy per event, or other quantities that can be shown to be related to the amplitude of the signal, can be used as intensity measures. A source is considered to be intense if it is active and its intensity measure consistently exceeds, by a specified amount, the average intensity of active sources. The intensity of a source can be calculated for increments of the stimulus or of events. An intense source is considered to be critically intense if its intensity continuously increases with increasing stimulation, or with time under constant stimulus.

8.3 Typical Source Classifications

Sources considered to be critically active, critically intense or both are indicative of questionable structural integrity and, if possible, should be evaluated by other non-destructive testing methods. Sources considered to be intense are indicative of possible flaw growth and, if possible, should be evaluated by other non-destructive testing methods. Sources considered to be active but not intense, should be recorded for comparison with sources detected during subsequent examination. Sources considered to be of low activity and intensity usually require no further evaluation or subsequent correlation.

It must be emphasised that for a defect to be located by an AE test it must be active. If the stress distribution is such that at the time of monitoring a particular defect is not subject to a new maximum stress level above any previous maximum, then it will not be active and no AE will be generated, so it will not be detected. This is one reason why long-term monitoring is important. If the entire structure is monitored continuously, then its integrity can be monitored in real time and a factual history compiled. Also, the need to overstress to compensate for the Kaiser effect is reduced as pressure and temperature excursions and recovery will have both been recorded and monitored, and it may be possible to reduce the level of overstressing required to carry out a useful test program.

9. APPLICATIONS

The applications of AE divide into two main groups:
(a) long-term monitoring, and
(b) proof-testing and on-line testing.

Both applications give an indication of structural integrity. (Long-term monitoring provides a full and adequate data bank for the structure being monitored.) Most materials lend themselves to acoustic monitoring techniques. Paper, glass, ceramics, timber, metals, geological formations, concrete and composites may all be monitored by AE techniques. Each task requires specific techniques to overcome the many problems associated with AE monitoring and such work in Australia is well advanced. Some of the applications include:

Material defects

(a) The detection of areas of hydrogen embrittlement in steel slabs. As the hydrogen comes out of solution, the liberation and expansion of the gas can be detected and located.
(b) Corrosion phenomena have been monitored and, in some instances, quantified by monitoring the corrosion product formation and liberation in metallic and non-metallic structures.
(c) Variations in hardness in a large structure have been identified by AE techniques. More work is needed to make the technique reproducible.

Integrity testing

One of the largest fields of AE monitoring is weld integrity testing. It is possible to monitor the integrity of the weld at the time it is being laid down and also during its lifetime. A major application of AE monitoring is regular integrity testing of welds in pipelines.

Pipeline monitoring

Pipelines pose particular problems, especially in Australia where pipes pass through urban and suburban residential areas, recreation areas, rural areas, under water and through mountains. Often such pipelines receive unintentional damage which, for many reasons, is not reported. This poses particular problems for the pipeline authority in locating damaged areas. Acoustic monitoring will notify and locate such an event while monitoring material and weld integrity; with a little extra effort it is possible to control flow rates and processes by monitoring the AE from the product in the pipeline.

Pressure vessels

Acoustic emission first gained acceptance for the monitoring of pressure vessels. Many vessels have been more easily certified after being subjected to long-term AE monitoring. Some pressure vessels have been tested to failure and AE tests have identified the active areas and failure initiation points.

Structural testing

Acoustic emission techniques have been applied to timber, metal and pre-stressed concrete bridges. Techniques have been developed to monitor and test the tension cables, pre-stressing rods, aggregate bonds and welds of these structures.

Structures which undergo cyclic loading with and without thermal cycling exhibit creep and fatigue problems. Acoustic emission tests can be applied to monitor creep and fatigue in metal and concrete structures. If suitable laboratory investigations are made on the material being monitored it is possible to identify the stage of creep or fatigue describing the structure being monitored. Elastic and plastic regions can be identified from the acoustic event rate in some materials.

Steel towers, such as radio/television transmission towers and electricity power line supports, can be monitored. Careful study of electromagnetic radiation patterns and appropriate location of transducers and connecting loads will overcome interference.

Storage tanks

Storage tanks of various sizes and shapes present a different problem. Although the AE techniques used are well established, if the sound transmission paths within the vessel have not been understood and identified, serious location problems can be caused.

Chemical and petrochemical plants using alloy steel, stainless steel and fibre composite materials are well suited to AE monitoring and on-line pressure testing.

Civil engineering studies

Earth embankments and dam walls can be monitored successfully. The ability to detect acoustic activity in soils can be applied in many industries. It is possible to identify such stages as stable, little movement, moderate movement, considerable movement and impending failure from the emission from the soil. Packing density has an effect on the results and this should be monitored by a control sample.

Concrete dams, buildings, stacks and bridges can be monitored successfully using AE. The tilt of large dams can be monitored as the water level behind the dam rises and falls. Signal analysis can give an idea of the interface integrity between blocks in such structures.

Acoustic emission activity is evident before earth movements and earthquakes. However, inhomogeneity of the material owing to the large volumes involved and the varying attenuation properties of the rocks can give signal attenuation ranging from 2 dB per 100 metres to 100 dB per metre, usually in unknown combinations. If good coupling to the fault zone is possible, usable results may be obtained.

Timber analysis

Acoustic emission from timber is probably the oldest application of the technique. It is possible to use the technique to identify activity, fibre failure and matrix debonding, as well as areas of rot or fire damage or hidden knots or variations.

Aircraft industry

Considerable amounts of work have been done on aircraft. Some monitoring and inspection has been done on commercial aircraft, but most work is done on military aircraft. Australia is making a significant contribution to this area of work.

Mining

The mining industry has been a little slow to take up the obvious advantages of acoustic monitoring. Some work is being done in coal mines on earth movements, gas bursts and roof supports. However, since this type of work is too dangerous, few researchers will undertake such analyses. Extensive valuable acoustic monitoring of underground blasting has been made at Mt Isa.

Mining equipment and installations are little different to other machines when it comes to AE monitoring. The ropes, supports and welds in underground lifts, hoists, fans and on equipment such as draglines, bucket wheels and loaders, can be monitored successfully for integrity and defect location.

Electric arc furnaces

Crack initiation and growth has been monitored in the hearth and electrodes of electric arc furnaces.

Fibre re-inforced plastics

Fibre re-inforced plastics are difficult to test and evaluate useful life. The cherry pickers used by most electricity authorities are tested regularly and often rejected after 40 per cent of their useful life. Acoustic emission testing can adequately test the units and effectively provide an extended safe usage period for these booms.

10. CONCLUSIONS

Acoustic emission monitoring can be used successfully as a non-destructive testing tool to supplement, but not replace, other standard inspection techniques. The limitations of AE testing are not so great that the technique cannot be used on many structures. There is undoubtedly a large number of potential applications in Australian industry in which the technique can be used with economic benefit to locate defects. However, there is work to be done in three major fields.

First, the identification of sources of emission and the characterisation of their emissions. Data obtained to date are highly characteristic of the medium and the transducer. Perhaps the aim should be to get a transducer inside the material. The Yobell specimen of Scruby and Wadley at Harwell, is perhaps the closest approximation yet obtained. The research needs to be linked with studies of chemical composition and heat treatment to identify AE activity in relation to composition and microstructure.

Second, the macrostructural effects need to be investigated, together with the effect of structure shape, transmission path characteristics and internal cracking.

Third, there is a need to investigate further the Kaiser effect and quantify the recovery parameters to ensure worthwhile and useful test schedules.

Unfortunately, because short-term profits dominate industrial activity, this usually leads, in the long-term, to greater expense and often catastrophic results. It would be of considerable long-term advantage to set up an AE monitoring system in the plant and obtain real time structural integrity assurance and real time defect location. This type of system could also yield process data which would indicate areas for improved process control and result in an increase in product quality and quantity. Such an installation in a critical section of a plant would soon justify technically and economically its expansion to the entire plant.

An alternative strategy would be to use AE flaw location and monitoring techniques on a regular basis in areas of high stress. These tests can be made "on-line", thus avoiding plant shut-down. Having undertaken this type of surveillance, the maximum gain comes when the test program is repeated regularly — say annually — and a comparison made of present and previous results.

ACKNOWLEDGEMENTS

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Motor Cycle Noise in an Australian Context

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ABSTRACT: Traffic noise distributions for different classes of vehicles in a suburban area are compared. Heavy articulated vehicles are the major noise source but motor cycles are also extremely and unjustifiably noisy. All cycles in a small test population were found to comply with Regulations made under the N.S.W. Noise Control Act of 1975 (NCA 1975) but a significant fraction did not comply with Australian Design Rule 28. Correlation between the two measures of noise emission is not good. A further test of average exhaust noise for typical riding behaviour round a test course suggests that NCA 1975 procedures provide a good measure of average noisiness, though this may be underestimated for cycles of small engine capacity. Some further suggestions are made.

1. INTRODUCTION

Of all the forms of noise pollution affecting the community, that due to motor traffic is perhaps the most pervasive and annoying. Certainly airport and railway noise may be more extreme but each of these sources is localized and presents well-defined technical problems, while with motor traffic the sources are widely dispersed and behavioural problems are mixed in with technical ones.

The general problem of motor traffic noise was reviewed in detail not long ago by Delany (1974). It is not our purpose here to try to add substantially to existing knowledge but rather to examine certain problems in an Australian context and to describe the results of preliminary study bearing particularly on the increasing problem of noise from motorcycles.

The noise emission from motor vehicles in Australia is, in principle, limited by the requirements of Australian Design Rules 28 and 28A of 1976 and 1977 (hereafter referred to as ADR28 and ADR28A respectively), and in addition by various State Acts such as the New South Wales Noise Control Act, 1975 and its 1979 Regulations and amendments (hereafter referred to as NCA 1975). Broadly speaking, ADR28 and ADR28A refer to noise emission during an acceleration test under closely specified conditions, while NCA 1975 refers to exhaust noise under stationary conditions with the engine unloaded. Tests under ADR28 and 28A are relatively complicated because of their special site requirements while NCA 1975 tests are designed as simple kerbside checks on suspect vehicles.

It is clearly of interest to know the correlation between ADR28 or 28A and NCA 1975 measurements and the average noise emission from vehicles in use under Australian conditions, and it is also of interest to know to what extent vehicles in everyday use conform to the requirements of each of these sets of regulations. This study is therefore supplementary to the discussion in the preface to Australian Standard AS2240 (1979) which treats the correlations between different noise measurement procedures in more detail.

2. NOISE-LEVEL SURVEY

The measurements specified in ADR28 and ADR28A are designed to specify and limit the maximum noise emission from vehicles in motion. It is therefore of interest to compare the specified limits with the noise emission from vehicles in a typical situation where annoyance is appreciable but not extreme. The measurement site chosen was on the New England Highway where it passes through Armidale, with traffic climbing a moderate grade through a typical open suburban built-up area with little contribution from reflection from buildings and a speed limit of 60 km/h. The relatively light traffic level made the separation of contributions from individual vehicles a simple matter.

For convenience the traffic was classified into only four groups: (a) cars and light vehicles, (b) heavy vehicles, (c) heavy articulated vehicles and (d) motor cycles. The design limits specified in ADR28 for these classes are approximately (a) 84 dB(A), (b) 89 dB(A), (c) 92 dB(A) and (d) 86 dB(A) with these limits being reduced by about 3 dB in ADR28A for vehicles manufactured after about mid 1980. The limits specified for motor cycles are further subdivided according to engine capacity but we shall postpone consideration of this point until later.

Since the ADR tests specify that the measuring microphone be set up 7.5 m from the centre line of the path of the vehicle in an otherwise clear area, a test site conforming approximately to these requirements was chosen and measurements of maximum noise level were made on every vehicle passing during the measurement period. A subsequent measurement period extended the sample of motor cycles so that the numbers in the four categories were adequate for statistical analysis. The results are shown in Table 1.

TABLE 1
VEHICLE NOISE LEVELS IN dB (A)

Type	Number	ADR 28 limit	Measured mean	Standard Devn.
Cars and Light Vehicles	959	84	70.7	3.1
Heavy Vehicles	118	89	80.0	4.6
Heavy Articulated Vehicles	96	92	87.2	3.3
Motor Cycles	153	86	78.4	4.3

As they stand, these results look reasonably satisfactory in terms of the limits set, though more information can be extracted from the statistical distributions. Initially however we note that heavy articulated vehicles are clearly the major noise sources encountered and that, for their passenger and load-carrying capacity, motor cycles are much nosier than cars and rank closely with general heavy transport vehicles in the non-articulated range.

The histograms in Fig. 1 give the measured results in more detail. As expected, the distributions are more or less normal in shape (on these axes a normal distribution is an inverted parabola) except that the distributions both for cars and other light vehicles, and particularly for motor cycles, have tails extending to quite high noise levels. About 3 per cent of heavy articulated vehicles and nearly 10 per cent of motor cycles exceeded the ADR28 limit at the measuring point. A subjective assessment suggested that in most cases the excessive noise was caused by defective or modified exhaust systems.

3. MOTOR CYCLE NOISE

While heavy and articulated vehicles clearly pose major noise problems, they at least have the justification that they are transporting large loads and are generally confined to highways and industrial environments. Motor cycles, in contrast, generally carry only a single rider and are used in residential environments at all hours of the day and night. There are thus persuasive social arguments that their noise emission should be reduced to that applicable to passenger

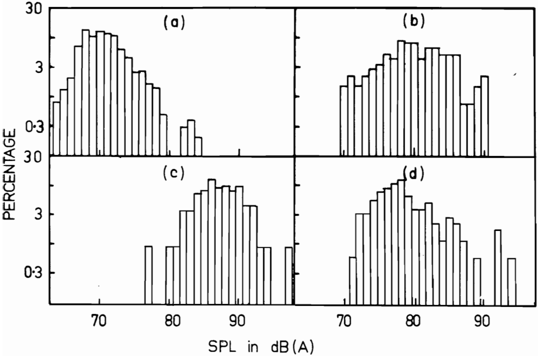

Figure 1: Histograms giving the percentage occurrence of measured noise levels within 1 dB classes for (a) passenger cars and other light vehicles, (b) heavy vehicles, (c) heavy articulated vehicles, and (d) motor cycles. Note that the percentage scale is logarithmic.

cars, though the technical problems and penalties in efficiency may in fact prevent this from being a feasible aim.

To examine the problem further, a selection of 34 motor cycles ranging in capacity from 90 to 1000 cm³, from 1 to 4 cylinders and of both 2 and 4-stroke design was tested against the requirements of ADR28 (using the sub-classification on engine capacity) and of NCA 1975. Measurements showed that 20 of the 34 cycles failed to meet the requirements of ADR28, 9 of these having obviously modified or defective exhaust systems. All cycles however met the limit of 100 dB(A) at 3000 rpm and 0.5 metres from the exhaust specified by the simplified form of NCA 1975.

The correlation between ADR28 and NCA 1975 sound levels, which is shown in Fig. 2, is interesting. The relationship is obviously quite nonlinear and, for the noisier cycles, the narrow NCA 1975 range from 94 to 98 dB(A) allows ADR28 noise levels ranging from 89 to 100 dB(A). Comparison of these levels for individual cycles with those measured during normal riding of the vehicle up a hill showed poor correlation in both cases, so this was then made the subject of a more detailed study to be described in the next section.

Finally, since the NCA 1975 test is very attractive for general monitoring use, an analysis was made, for the 34 cycles in the sample, of the correlations between exhaust noise measured at different engine speeds. These correlation coefficients are shown in Table 2

TABLE 2
CORRELATION COEFFICIENT (R) FOR EXHAUST NOISE AT DIFFERENT ENGINE SPEEDS (R.P.M.)

	2000	3000	4000	5000	6000
2000	1.00	0.96	0.95	0.92	0.86
3000		1.00	0.98	0.95	0.90
4000			1.00	0.98	0.94
5000				1.00	0.97

and are clearly all very high. This suggests that, since simplicity and availability of measurements are of more importance than absolute accuracy in community noise monitoring, it might be reasonable to specify noise requirements at one engine speed only, say 3000 rpm, rather than in the more complex way envisaged in the Act. A set of such equivalent noise levels is shown in Table 3. It is interesting that to a first approximation

TABLE 3
APPROXIMATELY EQUIVALENT NOISE LIMITS FOR MOTOR CYCLES, MEASURED IN ACCORD WITH SCHEDULE 3 OF THE NOISE CONTROL ACT 1975
ENGINE SPEED (R.P.M.)

2000	3000	4000	5000	6000
85	90	93	97	103
90	95	99	103	110
95	100	105	110	
99	105	110		

the relationship corresponds to an increase of 5 dB(A) for an increase of 1000 rpm in engine speed in only mild distinction with the 15 dB(A) increase for a doubling of engine speed quoted by Delany (1974).

4. TYPICAL CYCLE OPERATING NOISE

In order to assess typical operational noise emission from a vehicle, it is desirable that this be monitored during a considerable time and with differing road conditions and drivers. Such monitoring is more easily carried out for a motor cycle than for most other vehicles since the principal source of noise is the exhaust.

With this in mind a condenser microphone, protected by an appropriate nose-cone turbulence shield (Bruel and Kjaer 4135 half-inch microphone with UA0386 nose cone) was fitted in turn to each of a variety of motor cycles in a position similar to that specified in NCA 1975 but only about 0.2 m from the exhaust exit. The cycle carried an appropriate power supply and cassette recorder to record the microphone signal. Calibration was set by operating the engine at 3000 rpm while making a standard NCA 1975 measurement, and the recorder gain was then locked. This procedure automatically allows for the differences between individual microphone placings and relates the measurements directly to the NCA 1975 standard situation. The owner of the cycle then rode it over a standard course typical of traffic-free suburban conditions and occupying about 7 minutes of riding time. The cassette was then replayed through a data capture system to sample the A-weighted noise level at about one second intervals and a statistical analysis was made of the results. A simple listening test was used to confirm that turbulence noise was at no stage significant in comparison with exhaust noise. Four typical histograms are shown in Fig. 3, with NCA 1975 calibration marked in each case.

TABLE 4

MEASURED NOISE CHARACTERISTICS OF MOTOR CYCLES ON TEST COURSE

Cycle type	NCA 1975 level dB (A)	Mean level & S.D. dB (A)	Peak level dB (A)
Suzuki 125	90	99.0 ± 5.3	105
Yamaha 125	91	99.4 ± 5.2	105
Yamaha 175	90	91.7 ± 2.4	96
Suzuki 250	96	98.0 ± 3.8	102
Honda 250	90	95.5 ± 4.6	103
Honda 250	—	94.5 ± 2.5	101
Suzuki 370	94	96.3 ± 3.6	101
Yamaha 400	84	87.4 ± 2.2	93
Honda 500	90	93.4 ± 3.3	98
BMW 600	96	94.6 ± 4.4	101
Kawasaki 750	88	87.8 ± 3.7	97
BMW 900	89	91.6 ± 7.4	103

It is clear that the noise emission level has a rather wide range about its mean and that this mean is rather higher than the NCA 1975 level. Details are given in Table 4. Particular values are not necessarily typical of the particular cycle type quoted since muffler condition and rider habits varied widely. The NCA 1975 levels are, however, a good guide to the noise emission from these cycles, as is shown in Fig. 4, which gives the distribution of mean noise emission levels above the measured NCA 1975 levels. Leaving out of account for the moment the two small 125 cm³ cycles, which presumably had large noise levels because they were necessarily operated under nearly full-throttle conditions over much of the rather hilly course, the average excess is about 2 ± 3 dB(A). Within these limits and with the exception of the small cycles, the NCA 1975 levels are thus a reasonable indicator of average noise emission in typical operation. Indeed the correlation is remarkably good when the variation in cycle types and riding habits is taken into account.

5. CONCLUSIONS AND RECOMMENDATIONS

It was clear to all the people involved in the measurement programme that, though all the motor cycles tested fulfilled the legal requirements of NCA 1975, many of them were extremely noisy. It seems manifest that the limits specified under this act should be progressively and substantially tightened, probably by as much as 10 dB(A). The fact that this may require extensive modification of some cycles and even put others off the road should be regarded as necessary consequences of any effective legislation.

In addition it may be useful to recognise that cycles with small engine capacity appear to have average noise emissions much higher than the NCA 1975 levels because of their typical operation at much higher throttle settings. This tentative conclusion is based upon a lamentably small data sample, but it does seem to suggest that a revised Act should incorporate lower permitted noise levels for engines of small capacity, as does ADR28. Such a feature would in any case appear reasonable on general grounds.

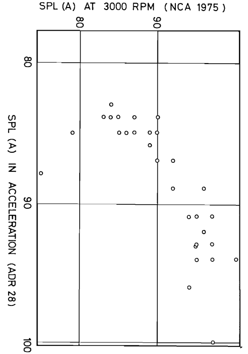

Fig. 2: Scatter diagram of the correlation between motor cycle noise levels as measured in an acceleration test (ADR 28) and a static test (NCA 1975).

Finally we turn to one other aspect of motor vehicle noise control legislation that appears worthy of comment. ADR28, ADR28A and NCA 1975 properly specify the use of general-purpose or precision sound level meters complying with the requirements of Publication 179 (1965) of the International Electrotechnical Commission (IEC 179). Such meters are accurate and reproducible within ±1 dB over the important part of the frequency range and their filter characteristics are closely controlled. Unfortunately they are expensive and this expense (more than $500) limits their availability and use.

We have seen, however, that the noisiness of many vehicles is gross and that furthermore the actual noisiness during operation may vary considerably. A rather less precise instrument of ready availability, together with a judicious allowance for possible error, might therefore be of assistance in controlling motor vehicle noise.

Such simple sound level meters are available from radio hobby shops for less than $50. They incorporate A and C filter weightings and fast and slow meter response. A check of two of these instruments

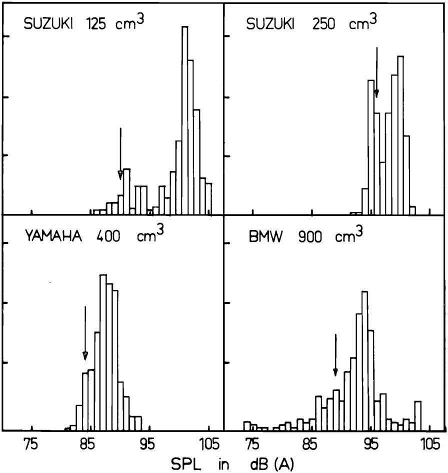

Figure 3: Histograms of exhaust noise level distributions for four typical motor cycles ridden around a suburban test course by their owners. The ordinate in this case is linear and the arrow in each figure shows the static 3000 r.p.m. noise level measured in accord with NCA 1975.

(Realistic 42-3019, randomly chosen and in condition as bought from the shop, against a properly calibrated high quality sound level meter showed an initial calibration error of less than 1 dB at 1000 Hz and agreement with it to within 1 dB(A) when measuring sound levels for several motor cycles in accord with NCA 1975. It is this second observation that is more significant since the frequency response of the simple meter may not be adequately accurate for use with pure-tone signals at other frequencies.

Obviously a comparably inexpensive calibrator is needed to ensure continued reliability, but this observation makes it feasible to require an exhaust noise check for all vehicles during registration inspection (hopefully in conjunction with much stricter standards) together with provision of such meters to all police traffic patrols for objective assessment of noise violations.

ACKNOWLEDGEMENTS

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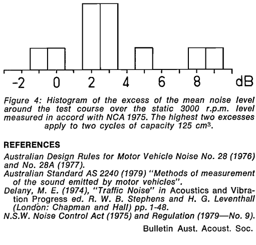

Figure 4: Histogram of the excess of the mean noise level around the test course over the static 3000 r.p.m. level measured in accord with NCA 1975. The highest two excesses apply to two cycles of capacity 125 cm³.

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LOUDSPEAKERS

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ABSTRACT: The weakest link in the sound reproducing system is the loudspeaker. Most manufacturers don't supply the important loudspeaker parameters. Most hi-fi salesmen don't know them anyway. What are they? How important is power handling capability? Should the loudspeaker be 5 or 50 cm diameter? Should the box be large or small, vented or closed? What about the resonant frequency? What is the damping? This article will discuss objective criteria for evaluating loudspeakers and help in the choice of a system.

1. INTRODUCTION

"This loudspeaker will handle 70 watts". Apart from the implied guarantee that the voice coil will dissipate continuously 70 watts of low frequency energy, such a statement tells you nothing about the loudspeaker. How much acoustical power will it deliver? Is it a 30 cm or 15 cm woofer — and is either preferred? Is it in a closed box or is it a vented enclosure? Which is better? These questions and many others apply especially to the "dynamic" loudspeaker, that is, a loudspeaker whose essential parts are shown diagrammatically in Fig. 1, set in a baffle and whose cone radiates directly into free air. This discussion will only deal with this generic system.

The other main type of loudspeaker, the horn, is rare and unless your loudspeaker is similar to the "Klipsch", large in physical size, complicated in box structure and probably mounted in a corner, then you don't have a true horn type loudspeaker.

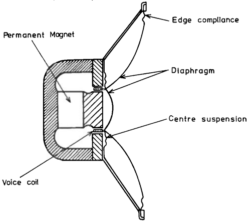

Fig. 1: Main features of an electrodynamic loudspeaker.

2. RESONANCE

Dynamic loudspeakers have cones that have mass, m_c. They must also have elastic suspensions to provide restoring forces: force per unit displacement is stiffness, s_c. Therefore they are like that "mass on the end of a spring" — they have a resonant frequency, f_r. This is an important constant for any loudspeaker.

3. ACOUSTIC EFFICIENCY

The overall efficiency, η (acoustic energy out to electrical energy in), of dynamic loudspeakers is low; 2 per cent is very good, 5 per cent excellent, 0.5 to 0.1 per cent normal. This results from the fact that the audio electrical signal energy must be changed to mechanical energy of cone vibration then to acoustical energy. The "radiation resistance" of the cone has a large mismatch with the acoustic impedance of the air.

In these days of inexpensive high powered transistorised amplifiers it might seem stupid to talk of efficiency, but the design factors that go to make up efficiency also show up in other important parameters of loudspeakers. Anyway, an efficiency of 1 per cent with an input of 7 electrical watts gives the same audible result as does 0.1 per cent from 70 watts.

4. LARGE OR SMALL LOUDSPEAKERS?

At frequencies about 10 times the resonant frequency of the loudspeaker, the efficiency η is proportional to[1]

$$[(Bl)^2A^2]/(R_c m^2) \qquad (1)$$

where B is the magnetic field, l is the actual length of wire of the voice coil in this field, R_c is the voice coil resistance, A, cone area and m_c mass of the cone.

This leads to the deduction that apparently the area of the cone has only little effect on the efficiency. For a given cone material, the mass of the cone (and coil) is about proportional to the area of the material!

So why not have small loudspeakers? First, the smaller the cone area the greater the cone excursion for a given acoustical output power. Since the driving coil must be in a uniform magnetic field, then the smaller the cone the larger the field — and a magnetic field is expensive. Also the system is a mechanical one and the suspension could easily be driven into non-linear displacements, resulting in distortion. Again, the voice coil can become too heavy compared with the cone mass itself and so the system efficiency drops compared with a larger cone. Further, the amplitude of cone movement radiating a given acoustical power varies inversely as the square of the frequency. At 100 Hz the amplitude is 4 times that at 200 Hz; at 50 Hz 16 times that at 200 Hz! So small cones are out for anything but low acoustical output.

5. EFFECT OF COIL RESISTANT

The quantity l^2/R is relatively fixed too. Suppose we halve the diameter of the wire but fill the same volume with this new wire. The number of turns increases by 2 along the length and by 2 in thickness, so l has increased by 4, l^2 by 16. But the cross-section of the wire has decreased by 2, its resistance has increased by 4. Its length has increased by 4 so its new resistance is 16 times the old resistance!

So efficiency goes up with B^2 and B is expensive. Bl's of about 10 are about the best that most manufacturers aim for with a voice coil of 8 ohms nominal resistance.

For frequencies below the resonant frequency, f_r, the efficiency drops off at the rate of 12 dB per octave so the lower frequency limit of a loudspeaker is roughly its resonant frequency. But let's be careful about what is meant by the resonant frequency of a "loudspeaker system".

6. THE CLOSED BOX

The resonant frequency, f_r, of a loudspeaker, in isolation, is given by

$$f^2_r = (4\pi^2 m_c c_c)^{-1} = s_c/(4\pi^2 m_c) \qquad (2)$$

c_c, cone compliance, is the inverse of cone stiffness, s_c.

But a loudspeaker unit has to be mounted in some way to stop the waves from the front of the cone interfering with the waves from the rear of the cone.

The simplest way to do this is to put the loudspeaker in an airtight box. Now the cone has to compress and rarefy this enclosed air. The box is an acoustical compliance with a stiffness s_B. This adds to the stiffness of the cone suspension and the formula becomes

$$f^2_B = (s_B + s_c)/(4\pi^2 m_c) \qquad (3)$$

f_B is the resonant frequency of the loudspeaker box system, which is obviously higher than that of the isolated loudspeaker. It is this frequency that enters into the calculation for the lower frequency limit of the system.

So, to get a reasonably low frequency limit in small boxes, the cone mass must be increased. The box stiffness becomes the limiting factor since stiffness is inversely proportional to box volume. Lowering the stiffness (making the suspension more sloppy) of the loudspeaker cone helps little. Of course increasing the cone mass decreases the efficiency — more electrical power in for the same acoustical power out.

A loudspeaker manufacturer should state the equivalent volume, V_c, of his loudspeaker. V_c is proportional to the compliance of the suspension and allows us to calculate the effect on the resonant frequency of the system for different box volumes, V_B. V_B is proportional to the compliance of the box. Generally we are interested in the ratio of these two volumes. The compliance of a loudspeaker-box system, c_t, is given by

$$c_t = c_c(V_B V_c)/(V_B + V_c) \qquad (4)$$

and the inverse of this value can be substituted for $(s_B + s_c)$ in equation (3).

7. LOUDSPEAKER DAMPING

A loudspeaker is a mechanical system that is meant to reproduce speech and music, that is, transients, not just continuous sine wave tones. This means that the system should be damped to reduce overshoot and spurious oscillations near the resonant frequency (boom). A measure of damping is the Q_T of the system (see Box 1). A Q_T of 0.5 means the system is critically damped. The system, when suddenly displaced and released, returns to rest in the minimum time without overshoot. A Q_T greater than 0.5 means that a transient will result in overshoot, the system will not return to zero displacement in minimum time. The greater the Q_T, the less the damping, the greater the boom.

For a loudspeaker system

$$Q_T = (2\pi m f_B)/[r + (Bl)^2/(R_c + R_w + R_a)] \qquad (5)$$

where r is the mechanical dissipation of the system.

The second term of the denominator is due to the fact that the voice coil vibrating in a magnetic field generates a back emf and current which, flowing in the circuit provides mechanical dissipation as well. R_w is the resistance of the wires joining the amplifier to the loudspeaker system, something often overlooked, and R_a is the internal resistance of the driving amplifier. In these days of transistor amplifiers with lots of negative feedback, R_a can be taken as zero. "r" is small, as should be R_w so

$$Q_T = 2\pi m f_B R_c/(Bl)^2. \qquad (6)$$

Once again, a low Q_T requires expensive B*l*.

Small "long throw" loudspeakers illustrate the application of equation (6). These loudspeakers have small cone areas, so to generate adequate acoustic outputs they must vibrate over large amplitudes at the lower frequencies (the inverse square frequency effect). To repeat, if the excursion of the cone is to be linear with driving current the coil must always move in a uniform magnetic field. There are two ways to get this, a short coil in a long magnetic field — and resonable efficiency — or a long coil in a short magnetic field with low efficiency. Since *l* is the length of coil actually in the magnetic field it follows in the latter case that some of the coil is outside the magnetic field (i.e. "wasted" coil resistance) leading also to a high value of Q_T. Unless mechanical damping is introduced boomy bass (if any) is the result.

Fig. 2 is a graph with normalised frequency on the abscissa; the ordinate is the relative response of the system at a particular frequency compared with a frequency much greater than the resonant frequency. Each curve is for a particular Q_T. The loudspeaker with a Q_T of 2 shows high efficiency at resonance — it also means undamped boom at any transient and poor response to frequencies near resonance. A Q_T of 1 gives almost flat frequency response but there is a small ripple and it is underdamped. A Q_T of 0.7 yields the maximally flat response while the critically damped value ($Q_T = 0.5$) yields a response 6 dB down at resonance. This fact gives a reasonable excuse to use tone controls on power amplifiers to supply the extra 6 dB — if the amplifier can do so without distortion and the loudspeaker can handle the extra power and the amplitude of vibration. Note the effect of a $Q_T = 0.1$. This would be a highly efficient loudspeaker, a large B*l*. Its response is 20 dB down at resonance. It could be enclosed in a small box if the rise at resonance were acceptable OR it could be used in a horn type enclosure because its response is close to the "constant resistance" response that is needed for "horn loading".

Another way of looking at the curves is to see what would happen to the response of a loudspeaker if its B*l* is kept constant and mechanical damping could be introduced to improve the performance.

BOX 1

Quality Factor, Q

The term Q grew up in the early days of radio transmission and reception. A circuit consisting of an inductance or coil (L) and capacitance (C) when connected electrically has a natural or resonant frequency given by:

$$f_r^2 = (4\pi^2 LC)^{-1}.$$

But coils are of wire which has resistance, resulting in the dissipation of energy when currents flow in the system.

The prime importance of resonant circuits is to tune in wanted radio frequencies and tune out unwanted ones. The ratio $2\pi L f_r/R$, where R is the resistance of the inductance in a series LCR circuit, gives the magnification of the input voltage applied to the circuit to that appearing across the inductance at resonance. Since the bigger the ratio the better the result, the term quality or *quality factor* was applied to this ratio. The term quality factor was shortened to Q: the bigger the Q, the better the coil.

Since mechanical quantities have analogous electrical quantities: mass analogous to inductance, compliance [= (stiffness)$^{-1}$] to capacitance and dissipation to resistance, similar equations and similar ideas can be used.

Musical instruments, vibrating mechanical systems, have high Q's, they vibrate at precise frequencies. If a system having a Q greater than about 5 is shock excited, it will vibrate at its natural frequency, decaying to approximately 5 per cent of its original amplitude in about Q vibrations. This is precisely what we don't want with loudspeakers.

The equations of motion show[4] that the Q of a vibrating system must be 0.5 for the system to be critically damped. That means that if the system is shock excited, it will return to its original position in the minimum time

$$Q_{crit} = \frac{\text{system mass} \times 2\pi \times \text{resonant frequency}}{\text{dissipation}} = 0.5$$

The same argument holds for the ratio between your car's mass-suspension resonant frequency and the shock absorber dissipation!

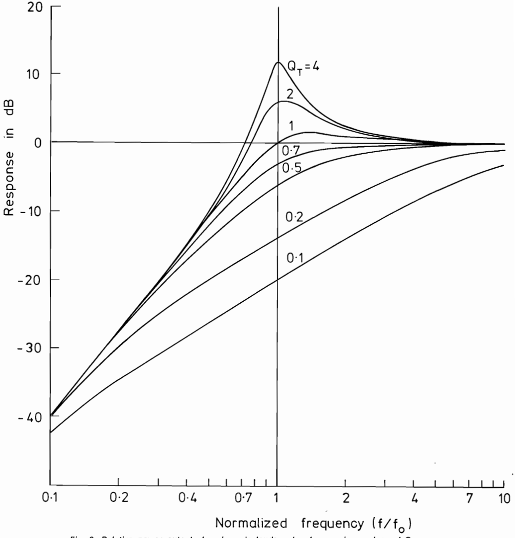

Fig. 2: Relative power output of a dynamic loudspeaker for various values of Q_T.

Fig. 2 also shows how to manipulate a loudspeaker with a Q_T less than 1, for maximum frequency range. Adjust the box volume to yield a Q_T, for example, of 1. The system drops off below resonance at 12 dB per octave, but the penalty is — the system will take a time interval equal to one period of the resonant frequency longer than the critically damped system to come to rest after the application of a transient. It is no longer a transient!

8. THE VENTED BOX

The second popular loudspeaker enclosure is the Helmholtz or vented enclosure. There is a vent or tunnel or pipe connecting the inside of the box to the outside air. (This vent acts as an acoustic inductance.) Thiele[2] shows that there is an optimum relationship among the constants — the box volume V_B, the equivalent loudspeaker volume, V_c, its resonant frequency, f_c, and the box/vent resonant frequency, f_v, which yields a maximally flat and critically damped acoustic response. The optimum values are such that the two resonant frequencies f_c, f_v are the same, the volume of the box is 0.707 that of the loudspeaker's equivalent volume and the Q_T is 0.38. The system response drops off at 24 dB per octave below f_r. Good loudspeakers for vented boxes must have strong magnetic fields and strong magnetic fields are expensive.

9. INCREASING THE DAMPING

Can Q_T be reduced easily? If $(Bl/R)^2$ is limited and m is limited by the cone having to be stiff enough to vibrate to radiate the claimed power, f_r could be reduced by making the loudspeaker suspension floppy. But the equivalent volume rises. So while you can find loudspeakers with a Q_T of 0.38, they might have a resonance of 25 Hz and equivalent volume of 200 litres! So for the optimum vented enclosure a volume of 140 litres is required. Hardly a bookshelf type loudspeaker.

If we start defining the loudspeaker for size of box we want, say, 70 litres, a resonance of 35 Hz and a cone mass of 30 grams, we would need a B*l* of about 13 to get a Q of 0.38. All this suggests that most loudspeaker units on sale are deficient in bass response and damping. The above remarks are based on a 25 cm diameter loudspeaker.

Thiele's tables show that to decrease the box volume and yet keep smooth response means decreasing Q_T even more. Lampton and Chase[3] give curves for vented enclosures showing necessary Q_T values down to 0.32!

10. LOUDSPEAKER CONSTANTS

Summing up so far. To know anything about a loudspeaker we should know:

- the Q_T of the loudspeaker
- cone mass m_c
- cone compliance c_c or stiffness s_c or equivalent volume V_c
- *product* of B and *l* NOT just B
- voice coil resistance R_c
- resonant frequency f_r
- effective cone area A.

Then the first statement of this article will begin to mean something. Loudspeaker manufacturers seem loath to give out such vital statistics — and to keep to them. One company I know published figures, then found it couldn't keep to them. Another two companies I have found give details of some of their products.

11. WHAT ABOUT THE TREBLE FREQUENCIES?

But everything so far only applies to low frequencies! An ordinary loudspeaker fails to obey equation (1) when the circumference of the cone becomes greater than about twice the wavelength (in air) of the emitted sound. Corrugating the cone helps to increase the frequency range — the cone doesn't vibrate uniformly over its whole surface area at higher frequencies. The cone "breaks up" and only the cone near the voice coil vibrates at the higher frequencies.

The fashionable method to obtain wide frequency response is to use 2 or 3 (or more) loudspeakers to handle the different frequency ranges. Each loudspeaker is handed its own frequency band by use of passive splitting networks inserted between the power amplifier and the loudspeakers. Of course if you want to be extravagant you can have active splitting networks, that is, splitting networks before the power amplifier stage and use one power amplifier per loudspeaker!

12. WOOFER MID-RANGE AND TWEETER

Multiple loudspeakers introduce further power handling limitations, generally unknown to buyer and seller. Symphonic music has little power in the frequency range above 2000 Hz. These frequencies are, however, very important. Your 70 watt loudspeaker will not dissipate 70 watts at any frequency throughout the whole frequency range. If you try that out you will burn out all but the woofer or low frequency loadspeaker. You might even burn it out as well! The standard loudspeaker test signal is a noise signal with a frequency power envelope of Fig. 3. Maximum power per unit bandwidth occurs at 150 Hz. 3 dB down points are at 50 and 350 Hz. The envelope is down 12 dB at 1000 Hz, 20 dB at 2000 Hz and 32 dB at 5000 Hz. If anyone designed a loudspeaker system to handle white noise, then the loudspeaker handling the top octave would have to handle half the input power! Even pink noise for a 70 watt system of overall bandwidth 30 Hz to 16 kHz would mean 8 watts in that top octave. MORAL: Never test loudspeakers with white or pink noise. Also beware feeding electronically generated or altered music into the usual loudspeaker system.

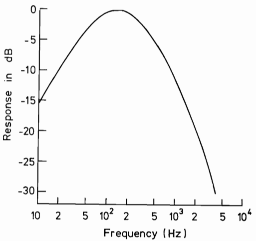

Fig. 3: Frequency-power envelope of loudspeaker test signal.

To return to our 70 watt example. While the woofer might handle 70 watts, the tweeter (the highest-frequency unit) will probably handle 70 milli-watts. To get acoustic power above 2000 Hz means systems specially designed to do so. To repeat, don't expect a 70 watt loudspeaker to handle even 7 watts in the higher frequencies. It will give you two burned out loudspeakers instead. Remember also that transients are wide bandwidth impulses. Avoid loud recurrent transients.

To conclude — beware the loudspeaker advertisement. But I don't know where you can learn the truth about that loudspeaker system!

However, see Appendix 1.

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2. A. N. Thiele, "Loudspeakers in Vented Boxes", Proc. IREE (Australia), **22**, p. 487 (1961 Aug.), also J. Audio Eng. Soc. **19**, pp. 382-392 (1971 May) and pp. 471-485 (1971 June).
3. M. Lampton and L. M. Chase, Audio, Dec. 1973, pp. 40-52.
4. A. P. French, Vibrations and Waves, Nelson.

APPENDIX 1

To choose a loudspeaker take your spouse — or friend — and a couple of good records or tapes to the salesroom. My two recommendations are "Les Patineurs" Meyerbeer arr. Lambert, National Philharmonic Orchestra, cond. Rich Bonynge, W.R.C. R04210 to test the bass response and "Fantasia" in C Major D760 (Wanderer), Schubert, Sviatoslav Richter pianoforte, W.R.C. S-4924 to test damping and smooth frequency bandwidth.

Listen for several minutes on one set of loudspeakers — don't jump from one to another. Using the first record check to see if the bass drum sounds different from the tympani and all the bass notes are separate. Listen to see if the percussion group instruments are crisp. Make sure the tone controls start at flat. However a small bass boost is allowable. Then compare with another set.

The piano is a percussion device. When the Schubert is played, note whether you can hear the pedal being used, that the whole of the frequency range is coherent. Some loudspeakers emphasise just one band of mid-range frequencies (to give presence!).

Note your choice and go away and ponder. Go to another shop. Each pushes a particular brand. Try not to be influenced by price — but be prepared to pay.

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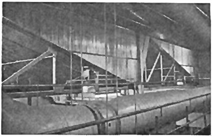

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Damping and Absorption	machinery housings; in-plant enclosures	Foam Damping Sheet	109
Absorption	business machines; enclosures; pipe wrapping; lining sound trapping labyrinths; anechoic chambers	Soundfoam/Embossed Soundfoam	102 101
Absorption and Barriers	machinery enclosures; business machines; yacht and recreational vehicle generators; appliances	Soundmat LF/Embossed Soundmat LF/Film Facings	110 103/110
Absorption with special surface treatments	near liquid spray equipment; cleanable surface applications; marine applications	Soundfoam/matte film finish Soundfoam/fabric facing Soundfoam/Tedlar® Soundfoam/metalized Mylar® Soundfoam/tufted fibre	103 116 103 103 116
Absorption for vehicle cabs	headliners and side panels for cabs for off-highway vehicles and similar applications	Cabfoam Soundfoam/perforated vinyl	104 103
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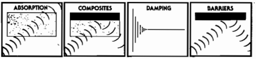

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TECHNICAL NOTES

NOISE ATTENUATION

Noise in duct systems can be a major industrial, social and environmental problem. Engine exhaust pipes, air conditioning and ventilation ducts and power station stacks are familiar examples of where gases and noise are being moved from place to place. Although adequate methods are available for eliminating high frequency noise, the low frequency components are difficult and expensive to eliminate. In addition, the elimination of low frequency noise often imposes major increases in energy use because more pressure is required to move the gas through the silencer. This often results in a larger fan and motor being required.

Recent advances in electronics have enabled new methods of attenuation to be considered which do not restrict the flow, do not increase energy use and are particularly suitable for low frequencies. The Division of Energy Technology is investigating a method called active attenuation. This entails measuring the signature of the noise at one point in the duct and then introducing downstream a secondary sound of the opposite signature. This "anti-noise" signal attenuates the original, unwanted noise.

Experimental work at the Division has commenced with periodic, random and transient noise sources being studied. It is hoped to achieve a reduction of up to 15 dB (subjectively 50-75 per cent) with a broadband noise of 30-700 Hz. The next stage will be to introduce flow into the duct. Turbulent pressure fluctuations in the flow will make noise attenuation more difficult to achieve.

(From CSIRO Minerals & Energy Bulletin, April 1982)

SINGERS' PITCH DRIFT

Many of us have had the excruciating experience of sitting through an interlude of unaccompanied singing, conscious that the pitch was wandering and dreading the inevitable discord that would occur when the accompaniment restarted. Like most people, I would have automatically attributed this sort of disaster to lack of skill on the part of the singers, but a recent chance reading of an article by Donald E. Hall* suggested to me that the subtleties of the musical scale may quite readily *compel* a perfectly skilful choir to lose pitch.

The sample that Hall gives is the following:

It may not be great music, but it is not unbelievably bad. It describes a sequence of five chords in which one note, marked by a tie, is sustained into the next. Our perfect choristers skilfully adjust the other notes on the new chord to give the proper frequency ratios to the note sustained from the old. If, for example, we take the middle C of the first chord to have a frequency of 1, the A of the second chord will have a frequency of 5/3. The D of the 3rd chord will consequently be $(5/3) \times (2/3) = 10/9$, giving the G of the 4th chord a frequency of $(4/3) \times (10/9) = 40/27$. This G carries over to the final chord resulting in a frequency for the middle C there of $(40/27) \times (2/3) = 80/81$!

That is, by the faultless singing of this simple 5-chord progression, the pitch has been forced down about 1/5 semitone, and clearly the process could be repeated any number of times to make the drop more and more painfully obvious.

So next time you hear singers, or other musicians who have to make their own frequency decisions, going off pitch, consider that not all the blame may be theirs. Some of it may be inherent in the decision taken centuries ago to call a 2:1 frequency ratio an octave and divide it into 8 (or 12) parts.

*Hall, D. E., "Musical Scale Tunings", American Journal of Physics, Vol. 42/7 (1974), pp. 543-552.

Dennis Gibbings

HEAVEN IS HOTTER THAN HELL

The temperature of Heaven can be rather accurately computed from available data. Our authority is the Bible: Isaiah 30:26 reads, *Moreover the light of the Moon shall be as the light of the Sun and the light of the Sun shall be sevenfold, as the light of seven days.* Thus Heaven receives from the Moon as much radiation as we do from the Sun and in addition seven times seven (forty-nine) times as much as the Earth does from the Sun, or fifty times in all. The light we receive from the Moon is a ten-thousandth of the light we receive from the Sun, so we can ignore that. With these data we can compute the temperature of Heaven.

The radiation falling on Heaven will heat it to the point where the heat lost by radiation is just equal to the heat received by radiation. In other words, Heaven loses fifty times as much heat as the Earth by radiation. Using the Stefan-Boltzmann fourth-power law for radiation

$$\left(\frac{H}{E}\right)^4 = 50,$$

where E is the absolute temperature of the Earth, 300K. This gives H as 798K (525°C).

The exact temperature of Hell cannot be computed but it must be less than 444.6°C, the temperature at which brimstone or sulphur changes from a liquid to a gas. Revelations 21:8: *But the fearful, and unbelieving . . . shall have their part in the lake which burneth with fire and brimstone.* A lake of molten brimstone means that its temperature must be below the boiling point, which is 444.6°C. (Above this point it would be a vapour, not a lake.)

We have, then, temperature of Heaven, 525°C. Temperature of Hell, less than 445°C. Therefore, Heaven is hotter than Hell.

(From Applied Optics, **11***, No. 8, A14, 972)*

* * *

PHONETIC ACOUSTICS

Much to my pleasure I appear to have started a whole cacophony of noises by remarks on the different sounds made by British and French drums. I now know from correspondents that, unbelievably, German pistols go *piff-paff,* theoretically to suggest an echo, and that guns say *pan-pan* in French, *pick-puff* in Polish and *bakvoom* in Japanese. One man says that French saucepans also go *bling,* but omits to say in what circumstance. As they strike someone's head?

Roger Owen, a lecturer at City of London Polytechnic, has been conducting research among his students who, he says, were restrained with difficulty from spending an entire teaching period producing multilingual drum-beats, blasts, thuds, squeaks, and so on. I am indebted to him for my now extensive knowledge of the subject, starting with drums.

Japanese drums normally go *pam-pam* but brass drums go *don*, unlike Korean brass drums which say *koong*. So much for drums. The rest is a selection from the onomatopoeic students.

Greek dogs bark *ghaff-ghaff* and a Japanese falling into water sounds *japong,* in contrast to a Frenchman who goes in with a *ploof.* English bottles pouring out, go *glug-glug* but in China a bottle will go *glob-glob*, curiously different from its near neighbours in Indonesia going *krook-krook*. Spanish bottles are distinguished by a subtle extra sound, perhaps due to the solera system. They say *tot-tot-to*.

Ending on a military note, Mr. Owen's Italian informants say that artillery in their country fires with a *poom* or a *tchouf*, but he adds that a cap pistol bought by his son in Siena and fitted with extra loud caps, went, according to the packet, with a super *bum*.

(From New Scientist)

* * *

ULTRASONIC SYSTEM FOR MURRAY

The Australian Mineral Development Laboratories (Amdel) is producing an ultrasonic river flow gauging system for the South Australian Engineering and Water Supply Department.

The system will be used in the lower Murray River to monitor flow variations and produce a continuous record of flow rates.

The ultrasonic method is considered superior to mechanical or electronic methods.

As there are no moving parts it does not obstruct the river, affect the environment or require maintenance.

Also the technique is suited to the low velocities of the Murray.

The method involves measuring the difference in travel time for ultrasonic pulses travelling upstream and downstream between two points.

Transducers which transmit and receive the ultrasonic pulses are usually placed on opposite banks of the river and at an angle of 30-60 degrees to the direction of flow.

From these the velocity at a particular depth averaged over the width of the river can be calculated. Because the velocity profile can be affected by several conditions it is necessary to measure at several depths to obtain a sufficiently accurate measurement of total flow.

The system being built requires an accuracy in the velocity measurements of about 0.1 mm/s, which means the average travel time of the ultrasonic beams is to be measured with an error of less than five nanoseconds.

It is proposed to use a system with pairs of transducers at four depths. A microprocessor will control the operation of the system, determine the velocities and calculate the total flow every hour.

(From The Australian Physicist, **19***, 65, Apr. 1982)*

* * *

HOW STEREO STIMULATES THE BRAIN

Why do people prefer stereo music to monaural music?

It may be that stereo stimulates more nerves in the brain, according to Dr. Manfred R. Schroeder, a physicist associated with Bell Laboratories in New Jersey. "The more stimulation of the nerves, the greater the enjoyment," he says.

Recent studies have clearly demonstrated that a listener derives most pleasure from music when the sounds reaching each of his ears are as dissimilar as possible. This creates, says Schroeder, the "acoustic space that most listeners find so satisfying." How does this translate into greater nerve stimulation?

According to Schroeder, it appears that nerve signals reaching the brain from the ears can actually work at cross-purposes. If the signals are similar enough and if they arrive at nearly the same time, stimulation of brain nerves can actually be inhibited. Such may be the case with monaural music, which presents almost identical sounds to both ears.

Since stereo, on the other hand, delivers different sounds to each ear, the auditory nerves send different messages to the brain. As a result, more brain nerves are stimulated.

Schroeder emphasizes that this is still a theory, based on only a few studies. But he disagrees with the view that people have developed an "ear" for stereo music only since the development of high-fidelity stereo equipment. "Have people enjoyed colour only since the invention of colour television?" he asks. "There was always colour in nature. It's the same with sound. Noises — birds, the wind, thunder, even airplanes — surrounded us with sound long before stereo was invented."

(From Science Digest **89***, No. 5, 25 (June 1981))*

ACOUSTICS IN 1638

In these days of sophisticated equipment, it is a chastening experience to read how the greats of yesterday made fundamental discoveries of natural laws with the simplest of apparatus. The Dover reprint of Lord Rayleigh's famous tome "The Theory of Sound", has an excellent historical introduction by R. B. Lindsay (the editor of JASA). In discussing Galileo's contributions to acoustics, Lindsay writes:

At the very end of the "First Day" of Galileo's "Discourses Concerning Two New Sciences", first published in 1638, the reader will find a remarkable discussion of the vibrations of bodies. Beginning with the well known observations on the isochronism of the simple pendulum and the dependence of the frequency of vibration on the length of the suspension, Galileo goes on to describe the phenomenon of sympathetic vibrations or resonance by which the vibrations of one body can produce similar vibrations in another distant body. He reviews the common notions about the relation of the pitch of a vibrating string to its length and then expresses the opinion that the physical meaning of the relation is to be found in the number of vibrations per unit time. He says he was led to this point of view by an experiment in which he scraped a brass plate with an iron chisel and found that when a pure note of definite pitch was emitted the chisel cut the plate in a number of fine lines. When the pitch was high the lines were close together, while when the pitch was lower they were farther apart. Galileo was actually able to tune two spinet strings with two of these scraping tones; when the musical interval between the string notes was judged by the ear to be a fifth, the number of lines produced in the corresponding scrapings in the same total time interval bore precisely the ratio 3:2. The presumption is that if the octave had been tuned the ratio would have been 2:1, etc.

It seems plain from a careful reading of Galileo's writings that he had a clear understanding of the dependence of the frequency of a stretched string on the length, tension and density. There was, of course, no question then of a dynamical discussion of the actual motion of the string: the theory of mechanics had not advanced far enough for that. But Galileo did make an interesting comparison between the vibrations of strings and pendulums in the endeavour to understand the reason why sounds of certain frequencies, i.e., those whose frequencies are in the ratio of two small integers, appear to the ear to combine pleasantly whereas others not possessing this property sound discordant. He observed that a set of pendulums of different lengths, set oscillating about a common axis and viewed in the original plane of their equilibrium positions present to the eye a pleasing pattern if the frequencies are simply commensurable, whereas they form a complicated jumble otherwise. This is a kinematic observation of great ingenuity and illustrates the fondness of the great Italian genius for analogy in physical description.

Howard Pollard

* * *

PIANO AS FOURIER ANALYSER

Find a piano. Hold down the damper pedal. Shout "hey" into the region of the strings and sounding board. Listen. Shout "ooh". Try all vowels. The piano strings are picking up (in somewhat distorted form) and then preserving the Fourier analysis of your voice. Notice that the recognisable vowel sound persists for several seconds.

Frank Crawford in "Waves"

NEW PRODUCTS

CSR LAUNCHES NEW NOISE REDUCTION BAFFLES

Rockwool Insulation for a long time has been recognised as an effective sound absorber for controlling unwanted noise. Applications have often been low ceiling office type areas, but difficulties with controlling "noise pollution" in large, high ceiling factories and buildings have never been easy to overcome. Bradford Insulation, part of the Building Materials Division of CSR Ltd., now offers a noise reduction solution which is not only acoustically efficient, but attractive too.

Bradford Insulation's N.S.W. Sales Manager, Mr. Leo Rufus, says, "The Bradford Fibertex Acoustic Baffle is an extension of the well known Bradford Rockwool and Fiberglass batt insulation. It's been specially developed to provide excellent sound absorption particularly in the middle and high frequency range where much hearing damage occurs. Bradford Acoustic Baffles are suspended verticlly from the ceiling either in a parallel or perpendicular pattern. Both patterns absorb sound which would otherwise echo off the roof or walls. The open grid pattern achieved by the vertical hanging of the baffles provides access to lighting, and plumbing on roof mounted services, while also permitting air to circulate. At the same time the baffle arrangement hides unsightly roof surfaces and the clean, painted surface provides an attractive textured finish at roof level. The baffles can be installed at various heights and spacings to build up to any desirable pattern.

"Fibertex baffles have been proven in sound reverberation chambers, following the Australian Standard Method of measurement, and are particularly effective in reducing noise in canning and bottling factories, machine shops, industrial plants as well as in high noise buildings such as enclosed swimming pools, gymnasiums, bowling alleys and skating rinks," Mr. Rufus says. Installation is done by attaching baffles directly to an aluminium U-channel fixed to the roof or by individually suspending the baffles from the roof using S-hooks and galvanised wire.

Further details of the Bradford Fibertex Acoustic Baffle can be obtained by contacting the CSR Bradford Insulation office near you or Colin Forster, (02) 237 5683.

BUILDING ACOUSTICS ANALYZER

A new microcomputer controlled serial analyser for the automatic measurement and subsequent calculation of the common quantities of interest in building acoustics is announced by Bruel & Kjaer.

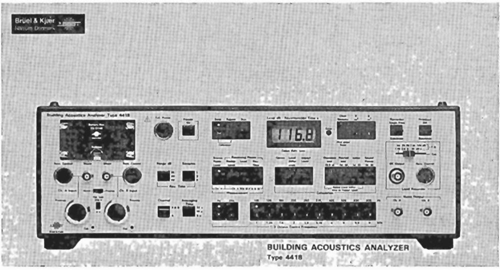
The 4418 performs all the jobs of its predecessor (the 4417) and much more. From the measured data the Type 4418 can calulate 39 important spectra according to both national and international standards, i.e., ISO (both current and draft standards), DIN, NF, NEN, ASTM, ASTI and ONorm, in contrast to the 9 ISO calculations which the 4417 could perform. Other capabilities of the 4418 include the calculation of octave and dB (A) values from measured third-octave data, repeated measurements at the same frequency (useful for facade measurements) and an Auto Calibration facility.

The lightweight (7 kg : 15 lb.) and battery operated 4418 is primarily intended for the control of sound insulation in new buildings but can also be used for noise control and for investigations of building materials, auditoria and concert halls.

When used with a minimum of accessories (i.e., a microphone and a sound source) the 4418 can be programmed to measure and retain in its memory data for 3 sound pressure level spectra and 1 reverberation time spectrum.

When used with a rotating microphone boom or an array of microphones and a multiplexer, the 4418 can perform spatial averaging automatically.

From the measured data and the entered values of the room's volume and the room's (or wall's) surface area, the 4418 can calculate any or all of 39 important spectra in 20 third-octave bands covering the frequency range 100 Hz to 8 kHz. The results can be presented digitalliy on the 4418's liquid crystal display, graphically via a level recorder, printed via an alphanumeric printer or stored on a digital cassette recorder.



NEW PRODUCTS

LEQ-METER TYPE 2221/22

Two new Integrating Sound Level Meters are presented by Bruel & Kjaer, Denmark. Innovative use of modern electronic design has made it possible to package a precision type integrating Sound Level Meter in a small pocket-size housing.

Besides measuring L_{eq} and SEL to precision standards, they also feature "slow" (2222) or "fast" (2221) max. hold facilities as well as max. peak readings.

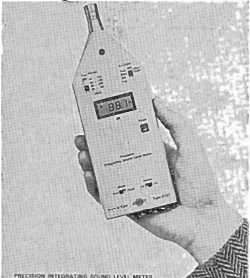
The 60 dB dynamic range properties within each of the four measuring ranges ensure that also high peak levels are accurately measured. Digital read-out and a minimum of control knobs make the meters extremely easy to use.

The digital display also indicates conditions of overload, under-range, battery and A or linear weightings.

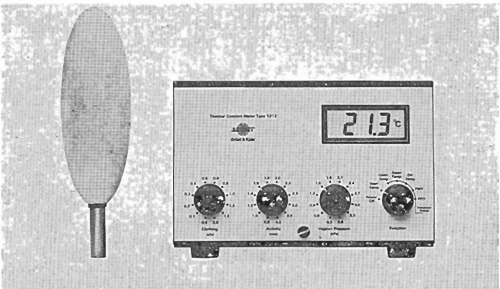
The new Sound Level Meters are equipped with a high-sensitivity prepolarized condenser microphone.

* * *

NEW JOURNAL A new quarterly publication has been announced: Journal of Low Frequency Noise and Vibration, which will feature fundamental research papers, case studies, preliminary and experimental results and letters. Editor: Dr. H. G. Leventhall, University of London. Publisher: Multi-Science Publishing Co. Ltd., 42/45 New Broad St., London EC2M 1QY. Annual subscription £40. Sample copies available on request.



PRECISION INTEGRATING SOUND LEVEL METER
Type 2222



THERMAL COMFORT METER
Type 1212

THERMAL COMFORT METER TYPE 1212

Most of us spend more than 90% of our lives in artificial thermal environments, and of course we should like to be comfortable. The new Thermal Comfort Meter Type 1212 from Bruel & Kjaer is a unique measuring instrument which takes account of the fact that our response to the thermal characteristics of the surroundings depends not just on air temperature, but also on five other quantities. These are: radiant temperature, air velocity, humidity, the thermal insulation provided by clothing, and the metabolic rate (which is a function of physical activity). The instrument functions by integrating the influence of three of the environmental parameters (air and mean radiant temperature, air velocity) using a compact transducer which contains a heat source and behaves thermally like a human being. When clothing, activity and vapour pressure values are dialled into the 1212, the effect on people's thermal comfort of the environment being measured is shown numerically on a liquid crystal display. Comfort may be indicated as Predicted Mean Vote (from —2,2 to +2,2 on a thermal-sensation scale) or Predicted Percentage of Dissatisfied. Both these thermal indices are employed in Draft International Standard ISO/DIS 7730. The Thermal Comfort Meter Type 1212 can also be set up to display Operative Temperature, Comfort Temperature, Equivalent Temperature and Difference Temperature.

The Thermal Comfort Meter is battery operated, and optional accessories include a mains power supply and single-channel and two-channel graphic recorders.

BOOK REVIEW

Physik der Geige

(Physics of the Violin)

by Lothar Cremer.

Published by S. Hirzel Verlag, Stuttgart, 1981, in German. Reviewed by Robert W. Harris.

Assistance with translation by P. G. Holland.

This book written by Professor Cremer shows again the very thorough and complete approach which one expects from German authors. The book is divided into three main sections — the string; the instrument case; and the radiation of sound.

The treatment of the string starts off by representing it as a simple single-degree of freedom discrete system and then develops the theory for a thin string which is excited at a point. The forms of the solution to the resulting wave equation are then used to obtain expressions for the transverse forces on the bridge of the violin, and the theory further extended to include simple damping. There is only a very short discussion on the limitations of a linear theory of string motion and it is strange that the author does not expound more on this aspect and cite such workers as Oplinger. Experimental and theoretical work on the free vibration of a struck string are then considered, which is used as a starting point to develop normal mode theory and the representation of an arbitrary motion by the superposition of normal modes. The effect of a static deflection associated with the constant friction of the bow is then considered. Distributed viscous friction is introduced and the effects of bow pressure are discussed leading to a criterion of minimum bow pressure.

The logical development of the subject continues by discussing constraints due to boundaries with particular reference to the violin bridge using an impedance approach. A string is not a simple line so the effects of torsion on an actual string resulting from bow friction is considered, including the effects of intermittent excitation. An impedance approach is used to describe the interaction of the bow with the string in producing torsional waves. The next logical step in the development of the theory of an actual string is the consideration of bending (flexing) and the role of the bow in this facet. Finally the section on the stretched string concludes with a description on the use of analog computers to study the vibration of the strings; a description on the use of the impulse response; and a description on the treatment of the string as an integral rather than a differential equation.

The analysis of the body starts off by considering the vibration of the bridge. The vibration patterns have been investigated using holographic techniques. The coupling of the bridge to the violin body is developed using impedance techniques. Initially the body is represented as a system with a few degrees of freedom. The acoustical properties are described in terms of Helmholtz resonators. The coupled vibration of cover and base is then incorporated into the model and actual measurements are presented. The simple several degrees of freedom model is then extended to consider the cover and base as flat plates capable of flexure and then the treatment is extended to allow for curvature in the cover and base. Following a treatment of the acoustic response of the inner space of the violin, including the coupling of this space to the cover and the base, some experimental observations of the vibration modes of the cover and the base using holographic techniques are presented.

The radiation of sound from the violin is first analysed for the case when the dimensions of the source are small compared with the wavelength of the sound. Monopole, dipole and quadrupole sources are treated and it is indicated how they apply to violins. The situation is then considered when the dimensions of the source are comparable with the wavelength of the sound. The synthesis from two point sources is developed and the shading of the source by both the body of the violin and the player are considered using primarily experimental data. The situation is finally considered when the dimensions of the source are large compared with the wavelength of the sound which introduces the concept of a "critical" frequency (coincidence effect). Finally, a short discussion on the effects of room acoustics concludes this comprehensive work on the physics of the violin.

STANDARDS

The Acoustics Standards Committees have been active during 1981-82 and have recently published the following new standards:

AS 2499 Acoustics — Method for laboratory measurement of airborne sound attenuation of ceilings (two-room method).

AS 2533 Acoustics—Preferred frequencies for acoustical measurements (revision of AS Z33).

Work is in progress in various stages on the following standards:

1. Glossary of acoustic terms (revision of AS 1633 — to be issued for public review shortly).
2. Pure tone audiometers for advanced audiological use.
3. Sound level meters (revision of AS 1259, Parts 1, 2 and 3 — to be published shortly).
4. Background noise levels for audiometer rooms.

5-11. Acoustics — Determination of sound power levels of noise sources (revision of AS 1217 into 7 parts as follows:
- Part 1—Guidelines for the use of basic standards and for the preparation of noise test codes (issued for public comment as DR 82052).
- Part 2—Precision methods for broad-band sources in reverberation rooms (issued for public comment as DR 82053).
- Part 3—Precision methods for discrete frequency and narrow band sources in reverberation rooms (issued for public comment as DR 82054).
- Part 4—Engineering methods for special reverberation test rooms (to be issued for public comment shortly).
- Part 5—Engineering methods for free field conditions over a reflecting plane (to be issued for public comment shortly).
- Part 6—Precision methods for anechoic and semi-anechoic rooms (to be issued for public comment shortly).
- Part 7—Survey method (to be issued for public comment shortly).

Note: The draft revisions of AS 1217, Parts 1 to 7, will be based on International Standards ISO 3740 to 3746, which have the same designation.

12,13. Guide for the use of sound measuring equipment (MP 44):
- Part 2—Equipment for frequency and time analysis of sound signals (to be issued for public comment shortly).
- Part 3—Equipment for integration of sound signals (issued for public comment as DR 82012).

14. Taperecorders for recording and replaying acoustical signals in acoustical measurement systems (to be issued for public comment shortly).
15. Pressure calibration of microphones by reciprocating techniques.
16. Audiometers (revision of AS Z43, Part 1, and AS 1591, Part 6 — to be published shortly).
17. Mechanical coupler for the calibration of bone vibrators used in hearing aids and audiometers (revision of AS 1591.4).
18. Instrumentation for Audiometry.
    Part 5—Wide band artificial ear (revision of AS 1591, Part 5).
19. Methods of measurement of airborne noise emitted by rotating electrical machinery (revision of AS 1081).
20. Electro-acoustical characteristics of hearing aids — hearing aids with automatic gain control circuits.

21,22. Methods of measurement of electro-acoustical characteristics of hearing aids. Hearing aid equipment not entirely worn on the listener. Magnetic field strength in audio-frequency induction loops for hearing aid purposes.

23. Hearing conservation (known as SAA hearing conservation code) (revision of AS 1269) (issued for public comment of DR 82008).
24. Hearing protection devices (revision of AS 1270) (to be published shortly).
25. Test methods for air duct sound attenuators (issued for public comment as DR 82107).

26. Methods for assessing and predicting speech privacy and speech intelligibility (issued for public comment as DR 81312).
27. Method of measurement of the reduction of airborne sound by the facades of buildings.
28. Noise rating for acoustic environment (revision of AS 1469) (issued for public comment as DR 81247).
29. Building siting and construction against aircraft noise intrusion (revision of AS 2021).
30. Method for laboratory measurement of airborne sound transmisison loss (revision of AS 1191) (to be issued for public comment shortly).
31. Ambient sound levels for areas of occupancy within buildings (revision of AS 2107) (issued for public comment as DR 81128).
32. Noise assessment in residential areas (revision of AS 1055) (to be issued for public comment shortly).
33. Methods for the measurement of road traffic noise (issued for public comment as DR 82108).
34. Noise from mechanical equipment in buildings.
35. Recommended noise levels emitted by vessels on waterways in ports and harbours.
36. Method of measurement of airborne sound emitted by lawn mowers and edge cutters.
37. Method of measurement of sound pressure levels for stationary compressors.
38. Measurement of sound power level of compressors and pneumatic tools and machines.
39. Noise rating — classification of pneumatic tools and machines.

While in cases of a number of draft standards such as Hearing Conservation (AS 1269) Hearing protection devices (AS 1270), considerable volume of public comments has been received by the Association at the public comment stage, the response for other standards at public comment stage from the members of Australian Acoustical Society apart from the representatives of the Society already actively participating in the committee work cannot be considered as "encouraging". The Association will appreciate the Society bringing to the notice of the Acoustics profession the availability of more than 40 Australian Standards covering various topics in Acoustics. The members of the Acoustical Society responsible for teaching Acoustics to students at various tertiary levels are requested to bring to the attention of their students the availability of these standards.

In this work of preparation of Australian Standards, considerable assistance is being derived from the work of ISO Technical Committee 43, Acoustics and IEC Technical Committee 29, Electro-acoustics.

Australia through the Standards Association of Australia, participates in this work. In a number of cases significant contribution to the work of the above ISO and IEC committees has been made by the members of the Association's Acoustics Committees.

The Standards Association of Australia owes a depth of gratitude to the members of the Australian Acoustical Society holding various positions throughout Australia giving their time and expertise in working on the various Acoustic Standards Committees, responsible for publishing these standards.

Enquiries and suggestions relating to current Australian Standards and draft standards on which work is in progress, as reported above, may, where necessary, be addressed to the Director General, Standards Association of Australia, P.O. Box 458, North Sydney, N.S.W. 2060. Comments on draft standards issued from time to time including DR 82052, DR 82053, DR 82054, DR 82107 and DR 82108, which are currently available free of cost from the Association for public comment and published standards are invited from the members of the Australian Acoustical Society, which will be used by the Acoustics Standards Technical Committee as a basis for further modifications or changes to the above. The work of the various Acoustics Standards Technical Committees is being supervised by the Acoustics Standards Committee, for which Dr. R. G. Barden, Consulting Engineer, has been the Chairman from its inception.

R. NAGARAJAN
Engineer Secretary
Acoustics Standards Committee
Standards Association of Australia
May 1982

PUBLICATIONS by AUSTRALIANS

Continuing our listing of acoustical publications by Australian authors (some of whom have not yet joined the Society!), we are indebted to Anne Quill of RANRL and Marion Burgess of U.NSW for regular journal checks, and to Toni Benton of U.NSW for arranging the references for publication. We hope to reach 1982 by the next issue.

A. PAPERS

1980

Ultrasonic Speed, Compressibility and Structure Factor of Liquid Cadmium and Indium.
Almond, D. P. (U.K.), and Blairs, S. (School of Metallurgy, The University of N.S.W.).
Journal of Clinical Thermodynamics, Dec., 1980, **12** *(12), 1105-1114.*

New Approaches to the Acoustic-Phonetic Component of a Speech Recognition System.
O'Kane, M.
Dept. of Eng. Phys., Australian National University, Canberra, Australia.
Aust. Comput. Sci. Commun. (Australia) **2** *(1), 69-83, Jan., 1980.*

On the Acoustic Emission Due to the Fracture of Brittle Inclusions.
Rose, L. R. F.
Aeronautical Research Laboratories, Melbourne.
Journal of Non-Destructive Evaluation, **1** *(3), 149-155, Sept., 1980.*

Reduction of Aerodynamic Blade Noise in a Rotary Lawn Mower.
Shepherd, I. C., and Gibson, D. G.
Division of Mechanical Eng., CSIRO, Vic., Australia.
Noise Control Engineering, **14** *(3), 110-118, May/June, 1980.*

1981

Spatial Impressions Due to Early Lateral Reflections in Concert Halls: The Derivation of a Physical Measure.
Barron, M. (U.K.), and Marshall, H. (School of Architecture, Auckland, New Zealand).
Journal of Sound and Vibration, **77** *(2), 211-232, July, 1981.*

On the Hydrodynamic and Acoustic Wall Pressure Fluctuations in Turbulent Pipe Flow Due to a 90° Mitred Bend.
Bull, M. (Dept. Mech. Eng., Adelaide University, S.A.), and Norton, M. (Div. Mech. Eng., CSIRO, Vic.).
Journal of Sound and Vibration, **76** *(4), 561-586, June, 1981.*

Comparative Reliability of Warble Tone Thresholds Under Earphones and In Sound Fields.
Byrne, D., and Dillon, H.
NAL, Sydney.
Aust. Journal Audiology, **3** *(1), 12-14, May, 1981*

MD-Generated Noise Produced by Turbulent Pressure-Fluctuations in the Atmosphere Near the Ocean Surface.
Cato, D. H.
RAN Res. Lab., Darlinghurst, Australia.
Journal of the Acoustical Society of America, **70** *(6), 1783-1784, 1981.*

Solitary Waves in the Lower Atmosphere.
Christie, D. R., Muirhead, K.J., and Clarke, R. H.
Inst. of Advanced Studies, A.N.U., Canberra, Australia.
Nature (GB) **293** *(5827), 46-49, Sept., 1981.*

Four PB Word Lists for Australian English.
Clark, J. E.
School of English and Linguistics, Macquarie University, N.S.W.
Aust. Journal Audiology, **3** *(1), 21-31, May, 1981.*

Transient Vibrations of Elastic Panels Due to the Impact of Shock Waves.
Coleby, J., and Mazumdar, J.
Dept. Applied Mathematics, University of Adelaide, S.A.
Journal of Sound and Vibration, **77** *(4), 481-494, Aug., 1981.*

The Relative Variance of the Transmission Function of a Reverberation Room.
Davy, J. L.
Division of Building Research, CSIRO, Melbourne.
Journal of Sound and Vibration, **77** *(4), 455-479, Aug., 1981.*

Flanking Path Identification in Buildings.
Epstein, D., and Fricke, F.
Dept. Arch. Science, Sydney University.
Acoustic Letters, **4** *(12), 256-262, June, 1981.*

The Economics of Industrial Noise Control in Australia.
Gibson, D. C., and Norton, M. P.
CSIRO, Division of Mech. Eng.
Noise Control Engineering, **3** *(126-135), 1981.*

Survey of the Perceived Needs of Hearing — Impaired Adults in Queensland.
Hyde, M., Pattison, E., and Serman, G.
Centre for Human Development Studies, Mt. Gravatt CAE, Qld.
Aust. Journal of Audiology, **3** *(1), 5-10, May, 1981.*

Factors Affecting the Detection of Hearing Impairment in Children.
Milhinch, J. C.
301 Broadway, Reservoir, Vic.
Aust. Journal Audiology, **3** *(1), 16-20, May, 1981.*

Acoustic Reflection from Estuarine Pycnoclines.
Penrose, J. D., and Beer, T.
Dept. of Phys., W.A. Inst. of Tech., Bentley, W.A.
Estuarine, Coast and Shelf Sci., **12** *(3), 237-249, 1981.*

Primary Auditory Neurons—Non Linear Responses Altered without Changes in Sharp Tuning.
Robertson, D., and Johnstone, B. M.
Dept. Physiology, University of W.A.
Journal of Acoustical Society of America, **64** *(4), 1096-1098, April, 1981.*

Transmission and Reflection of Higher Order Acoustic Modes in a Mitred Duct Bend.
Shepherd, I., and Cabelli, A.
Division Mech. Eng., CSIRO, Melbourne.
Journal of Sound and Vibration, **77** *(4), 495-511, Aug., 1981.*

Optimum Tuning and Damping of a Dynamic Vibration Absorber Applied to a Force Excited and Damped Primary System.
Thompson, A.
Dept. Mech. Eng., University of Adelaide, S.A.
Journal of Sound and Vibration, **77** *(3), 403-415, Aug., 1981.*

Some Notes on the Clavichord.
Thwaites, S., and Fletcher, N. H.
Dept. Physics, University of New England, N.S.W.
Journal of Acoustical Society of America, **69** *(5), 1476-1481, May, 1981.*

The Physics of the Singing Voice. Measurements on the Voices and Vocal Apparatus of Trained Singers, and Their Interpretation.
Troup, G. J.
Phys. Dept., Monash University, Vic.
Phys. Rep. (Netherlands), **74** *(5), 379-401, Aug., 1981.*

A Three-Dimensional Geometrical Noise Model for Traffic Noise Simulation.
Wang, N.
Dept. of Mech. Eng., University of Newcastle, N.S.W.
Journal Acout. Soc. Jpn. (E), **2** *(1), 1-4, Jan., 1981.*

B. REPORTS

1980

Approaches to a Quantitative Analytical Description of Low Frequency Sound Absorption in Seawater.
Whelan, D. J., Materials Research Labs., Ascot Vale.
Rept. No.: MRL-R-791, Sep., 1980.

A Review of Some Physical and Chemical Factors Affecting the Attenuation of Low Frequency Sound in Seawater.
Whelan, D. J., Materials Research Labs., Ascot Vale.
Rept. No.: MRL-R-782, July, 1980.

Intermediate Frequency Sound Absorption in Seawater: The Role of Magnesium Sulphate.
Whelan, D.J., Materials Research Labs., Ascot Vale.
Rept. No.: MRL-R-777, Jun., 1980.

Noise in the Textile Industry.
Plate, D. E. A., CSIRO, Belmont, Vic.
Noise in the Text. Ind., Publ. by CSIRO Div. of Text Ind., Belmont, Vic., 1980, pp. 21-28.

The Deep Ocean Sound Channel in Areas Around Australia.
Whelan, D. J., Materials Research Labs., Ascot Vale.
Rept. No.: MRL-R-791, Sep., 1980.

1981

Maximum Entropy Estimates of the Wavenumber Power Spectrum of Acoustic Data from a Linear Array of Equispaced Sensors.
Gray, D. A., Weapons Systems Research Lab., Adelaide.
Rept. No.: WSRL-0196-TR, Feb., 1981.

Proposed Acoustic Emission Location System for a Full-Scale Fatigue Test.
Scott, I. G., Areonautical Research Labs., Melbourne.
Rept. No.: ARL/MAT-TM-378, Apr., 1981.

NDI of Composite Materials.
Scott, I. G., and Scala, C. M., Aeronautical Research Labs., Melbourne.
Rept. No.: ARL/MAT-TM/379, Jul., 1981.

Resonance Tests on a Piper PA-32R Tailplane Before and After Damage.
Goldman, A., and Quinn, B., Aeronautical Research Labs., Melbourne.
Rept. No.: ARL/STRUC-TM-328, Apr., 1981.

FUTURE EVENTS

AUSTRALIA

1982

August 18, SYDNEY
N.S.W. Division A.G.M.
Panel Discussion: A.A.S. — Professional Body or Learned Society
6 p.m. U. of N.S.W., Kensington.

August 20-26, MELBOURNE
17th Annual Conference of the Australian Psychological Society
Details: Dr. Jean Russell, Psychology Dept., Melbourne State College, 757 Swanston Street, CARLTON, Vic. 3053.

August 23-27, MELBOURNE
11th Australian Road Research Board Conference
Details: Ms. Margaret Holdsworth, Conference & Publications Co-ordinator, Aust. Road Research Board, 500 Burwood Highway, VERMONT, Vic. 3133.

August 31-September 2, PERTH
Seminar on "Condition Monitoring in Industry" — West Australian Institute of Technology
Days 1 and 2: Thermography, Ultrasonics, Oil Analysis, Electrical Equipment Monitoring, Strain-Gauging, Vibration Condition Monitoring and Performance Monitoring.
Day 3: Continuous Workshop Demonstrations; Management Session emphasising Planning, Control, Management and Cost/Benefit Analysis.
For further information write to: Mr. Bevan Bessen, Wait-Aid Ltd., Kent Street, SOUTH BENTLEY, W.A. 6102.

September 15, ADELAIDE
Technical meeting, S.A. Division
"A Caused Solution to Extraneous Noises in Telephonists' Head Sets".
Mr. A. Driscoll.

September 26-October 2, SYDNEY
Deafness Awareness Week—A.A.S. Events.

September 30-October 1, SYDNEY
Transport and Communications Conference.
Details: Mr. B. E. Jacka, Executive Officer, Australian Academy of Technological Sciences, Clunies Ross House, 191 Royal Parade, PARKVILLE, Vic. 3052.

November 17, ADELAIDE
Technical meeting, N.S.W. Division
"Inservice Vehicle Noise Regulations".

December 10-11, SYDNEY
N.S.W. Division
Public Forum — Aircraft Noise
Friday evening: Public Address. Saturday morning: Workshop, visit to Tempe Public School. Saturday afternoon: Australian Acoustical Society A.G.M.

1983

February 24-25, SOUTH AUSTRALIA
A.A.S. Annual Conference
"Economics of Noise Control"
Weinthal Conference Centre, TANUNDA
Members intending to attend should notify Dr. P. B. Swift, Pryce Goodale and Duncan Pty. Ltd., 65 Fullarton Road, Kent Town, S.A. 5067.

July
Environmental Engineering Conference
Details: The Conference Manager, The Institution of Engineers, Australia, 11 National Circuit, BARTON, A.C.T. 2600.

INTERNATIONAL

1982

August 16-18, KTH, STOCKHOLM, SWEDEN
Acoustical Society of Scandinavia Meeting
Details: Acoust. Soc. of Sweden, Dept. of Speech Communication, KTH, S-100 44 Stockholm 70.

September 1-3, SINGAPORE
Western Pacific Acoustical Conference
Australian Acoustical Society and the Acoustical Society of Japan
Details: The AAS/WPRAC Sub-Committee, c/o N.A.L., 5 Hickson Road, MILLERS POINT, N.S.W. 2000.

September 9-10, EDINBURGH, U.K.
Auditorium Acoustics
Details: Institute of Acoustics, Mrs. C. Mackenzie, Secretary, 25 Chambers St., Edinburgh EH1 1HU, U.K.

September 14-17, GOTTINGEN, GERMANY
3rd FASE Congress, jointly with DAGA 82
The Congress will cover: Speech research, Room and Building acoustics, Acoustic streaming, Nonlinear acoustics, Physical Acoustics.
The DAGA '82 will cover: Electroacoustics, Psychological Acoustics, Measuring technics, Noise. etc.
Secretariat: Prof. M. R. Schroeder, III. Physikalisches Institut, Burgerstr. 42, D-3400 Gottingen.

September 20-22, KRAKOW, POLAND
Noise Control 82
Conference theme is Practice of Noise Control
Details: The Organising Committee, Noise Control 82, Institute of Mechanics and Vibroacoustics, Al. Mickiewicza 30, paw. B-2, 1p., 30-059 Krakow, Poland.

October 4-8, STRBSKE PLESO, CZECHOSLOVAKIA
21st Acoustical Conference on Noise and Environment
Secretariat: House of Technology, Ing. L. Goralikova, Skultetyho ul., 881 30 Bratislava, Czechoslovakia.

October 6-8, CAPE TOWN, SOUTH AFRICA
International Symposium, South African Acoustics Institute
Theme: "Acoustics and the Quality of Life"
Topics: Noise pollution, Architectural, Music, The alleviation of hearing impairment and communication barriers, Ultrasound in medicine, Current research.
Details: Prof. C. J. du Toit, Faculty of Medicine, University of Stellenbasch, P.O. Box 63, TYGERBERG 7505, South Africa.

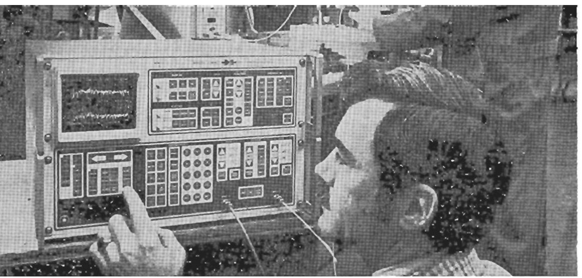
October 18-22, TORONTO, CANADA
Annual Symposium of the Canadian Acoust. Association with internat. seminar on various aspects of vibration.
Secret.: J. Manuel, 5007-44 Charles Str., W. Toronto, Ont., Canada, MY4 1R8.

November 8-12, FLORIDA, U.S.A.
Meeting of the Acoustical Society of America.
Chairman: Joseph E. Blue, Naval Research Laboratory, P.O. Box 8337, Orlando, Florida 32856.

December 14-17, SINGAPORE
First International Conference on Industrial Pollution and Control.
Topics: Air pollution and control, water pollution, noise pollution, industrial health, industrial waste and treatment system.
Details: The Conference Secretary, Dr. Raymond B. W. Heng, Senior Lecturer, Dept. of Mechanical and Production Engineering, National University of Singapore, Singapore 0511.

1983

May 9-13, CINCINNATI, U.S.A.
Meeting of the Acoustical Society of America.
Chairman: Horst Hehmann, 119 Glenmary, Cincinnati, OH 45220.



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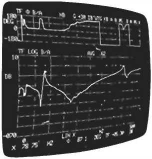

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5 Hawksburn Road, Rivervale, W.A. 6103. Phone: 361 7311. Telex: AA93065

June 20-25, TURIN, ITALY
Congress of the International Commission on Biological Effects of Noise.
Secretariat: TNO Research Institute for Environmental Hygiene, P.O. Box 214, 2600 AE Delft. Secretary, ir. Jan van den Eijk.

July 13-15, EDINBURGH
Internoise 83.
Secretariat: Institute of Acoustics, 25 Chambers Street, Edinburgh EH1 1HU.

July 19-27, PARIS, FRANCE
11th ICA—International Congress on Acoustics.
Satellite Symposia:
July 12-13, MARSEILLE, Active Sound Absorption and Acoustic Feedback Control.
July 15-16, LYON, Acoustic Radiations from Vibrating Structures.
July 15-16, TOULOUSE, Oral Communication.
Details: Secretariat SOCFI, 7 rue Michel-Ange, F.75016 PARIS.

July 29-August 1, STOCKHOLM, SWEDEN
Music Acoustics Conference.
Principal themes of the conference will be acoustics of stringed instruments and singing.
Details: Stockholm Music Acoustic Conference 1983, C/o Dept. of Speech Communication KTH, S-100 44 Stockholm 70.

August 1-6, UTRECHT, NETHERLANDS
10th International Congress on Phonetic Sciences.
Contact: Organizing Secretariat, C/o QLT Convention Services, Keizeasgracht 792 1017, EC Amsterdam.

August 1-6, TOKYO, JAPAN
4th World Congress of Phoneticians.
Contact: Secretariat, Phonetic Society of Japan, 12-13, Daita-2, Setegaya, Tokyo-55.

September 4-7, LONDON
4th Conference of the British Society of Audiology.
Details: above society, M. C. Martin, The Secretary, 105 Gower Street, London WC1E 6AH.

September, PARIS
Information Processing Congress.
Contact: M. Hermieu, 6 Place de Valois, F 75001 Paris.

October, HIGH TATRA, CZECHOSLOVAKIA
22nd Acoustical Conference on Electroacoustics and Signal Processing.
Preliminary Information: Acoustical Commission of Czechosl. Academy of Science, Secr. Dr. I. Januska, Provaznicka 8, 11000 Prague 1.

November 7-11, SAN DIEGO
Meeting of the Acoustical Society of America.
Chairman: Robert S. Gales, Code 5152, Naval Ocean Systems Centre, San Diego, California 92152.

1984

May 7-11, 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.

August 21-24, SANDEFJORD, NORWAY
FASE 84 — 4th Congress of the Federation of Acoustical Societies of Europe.
Topic: Solving todays noise problems — technological and political aspects; Planning with respect to environmental noise; Acoustics in Condition Diagnosis.
Secretariat: FASE 84, Secr. Gen. J. Tro, ELAB, N-7034 Trondheim-NTH.

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, HONOLULU, U.S.A.
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TORONTO, CANADA
12th ICA Congress (International Commission on Acoustics).

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