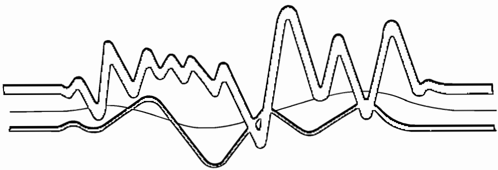
The Bulletin

OF THE AUSTRALIAN ACOUSTICAL SOCIETY

Volume 8, Number 2, August 1980



Addresses for Correspondence

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The General Secretary, Australian Acoustical Society, Science Centre, 35 Clarence Street, Sydney, N.S.W., 2000.

Correspondence to the Society on regional matters should be addressed to the appropriate Division Secretary as set out below:

N.S.W. Division (includes Queensland & A.C.T.): Mr. G. Patterson, C/ Science Centre, 35-43 Clarence Street, Sydney, 2000.
S.A. Division (includes N.T.): Mr. D.H. Woolford, 38 Lockwood Road, Erindale, 5066.
Vic. Division (includes Tasmania): Mr. W.J. Kirkhope, P.O. Box 130, Kew, 3101.
W.A. Division: Dr. I.H. Bailey, Department of Physics, W.A.I.T., Hayman Road, Bentley, 6102.

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Mr. R.J. Law, c/o 240 Victoria Parade, East Melbourne, Victoria, 3002.

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OF THE
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CONTENTS

- The Bulletin is published by the Australian Acoustical Society, Science Centre, 35-43 Clarence St., Sydney, NSW, 2000.

FROM THE PRESIDENT

At the time of writing this the ICA is still imminent and preparations are proceeding splendidly. The Executive Committee has worked very hard in recent weeks and a highly successful conference is expected in spite of some falling off in attendances from countries such as the UK and USA, who normally strongly support this Congress.

Recently there have been some interesting developments initiated by our National Academy of Science. The 32 National Committees of the Academy who have previously been mainly concerned with liaison with the international scientific unions, have now been given the additional responsibility of promoting the field of science in Australia.

The Academy sees value in a meeting between the representatives of Australian scientific socieities and chairmen of our National Committees for discussion on matters of mutual interest and the ways in which the committees can achieve their new role.

The meeting proposes to discuss:

1. Interrelations between the scientific societies, the National Committees and the Academy.

2. Ways in which the Academy, through its National Committees, can help to foster all fields of science in Australia and act as a more effective channel for inputs into national science policy.

3. Problems facing the scientific societies in Australia and ways in which they and the Academy can complement and support one another more effectively.

In the supporting information provided with the invitation to the Society to attend the meeting, the Academy specifically mentioned the problems of providing administrative support, publication of journals and liaison with overseas scientists - in the face of rising costs and reduced government support. The Academy also drew attention to the need for the scientific community to participate more effectively in the making of science policy and for the use of science in the development of government policies. Also mentioned was the need for public education on scientific matters and for improvements in scientific education.

Many of these matters are currently of concern to members of our Society who have recently been involved in implementing the Society's aims.

The initiative taken by the Academy promises to be of real value for the future of science and the scientific societies in Australia and I am sure will be welcomed by the scientific community in Australia.

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SUSTAINING MEMBERS OF THE AUSTRALIAN ACOUSTICAL SOCIETY

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

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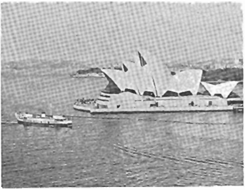
TENTH INTERNATIONAL CONGRESS ON ACOUSTICS

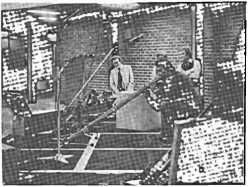
ADDRESS BY HIS EXCELLENCY SIR ZELMAN COWEN, A.K., G.C.M.G., G.C.V.O., K.St. J., Q.C., GOVERNOR-GENERAL OF THE COMMONWEALTH OF AUSTRALIA, ON THE OCCASION OF THE OPENING OF THE TENTH INTERNATIONAL CONGRESS ON ACOUSTICS IN THE SYDNEY OPERA HOUSE, WEDNESDAY 9 JULY 1980.

I am very pleased to accept your invitation to open this Tenth International Congress on Acoustics. This is the first to be held in Australia and in the southern hemisphere. As I open a variety of international congresses, I find myself saying this quite often, and it is always a happy event to welcome another group of specialists to Australia, many of whom will be coming here for the first time. For a congress held in the first year of the eighties, the general theme proposes itself: it is 'Acoustics in the Eighties'. You know, and I now know, that the range is vast and the applications far-reaching and exciting. I set myself the task of learning what an interested non-expert might learn about acoustics and the prospects and applications for this decade, and it has been a very interesting experience.



First, let me say that I am pleased that this ceremony takes place in the Concert Hall of this great and famous Opera House. I recently saw it described as "jewel" architecture by a distinguished British architect, and I think that it was intended to be praise and to refer to the special, the unique qualities of the building. Your expert eyes and ears will no doubt be asesssing it professionally and critically; I think that it is a fair judgement that, given the unusually difficult design criteria presented by its external shape, structure and design, the acoustical standard of this Hall is high and a success.

The acoustical design and quality of a great hall, a great music and theatre hall, is still said to be a combination of science and art. The pursuit of acoustic quality goes back a long way; I think of that great amphitheatre at Epidaurus where, spellbound, one afternoon, I sat and listened to a rehearsal of a play in a language I did not understand. I am told that the Greeks and Romans learned, no doubt empirically, that to hear well you also have to observe, to see the source of the sound well. Moving forward, we recall the work of Wallace Sabine, the physicist who founded the modern science of architectural acoustics. Sabine died long ago, at the



beginning of 1919, the year in which I was born. Sabine was asked to find a remedy for the acoustic deficiencies in the auditorium of Harvard's Fogg Art Museum, and out of his investigations grew the first theoretical base for rational sound engineering. The first building designed in accordance with his principles was the Boston Symphony Hall which was opened in 1900, and it is internationally regarded as a great acoustical success.

Sabine went on to serve as consultant for other significant buildings, and he handed on formulae well known in contemporary practice. In contemporary building, the process of design is seen as complex, and the architect has to bring together a team of consultants to inform and aid him. One of these, who is indispensable, is the acoustical consultant. The contemporary field of acoustical design has to take into account the internal spaces, their materials, and a complex of external factors. There are the besetting problems of traffic and other noise, and the need for sound isolation; there are problems associated with vibrations caused externally by traffic and internally by the functional characteristics and activities of the building, the air conditioning plant and building services. The demands for more complex services and their associated problems, the expansion of the range of building materials, changing building technologies, will all make more taxing demands on the acoustic profession for analysis of the properties of the materials and their performance, both in the short and long term life of the building. If, as is likely for the future, architects and designers of buildings will be called upon to design and build buildings which will meet a multiplicity, a variety of uses in their lifetimes, judgements will need to be made about their capacity to work tolerably well, in acoustic terms as well as others, for those uses.

A disintinguished Australian architect who has substantial involvement in the design of many buildings, including buildings which are required for major performances, has said to me that the history of the arts and sciences has shown that all the major breakthroughs have begun with a "passionate rebellion" against previous ways of thinking and approaching problems, and it will be no different in the future. Acoustical engineers will have to be prepared for the new fields of the '80's which human imagination and activities will no doubt create. It is predicted that in this decade much research will be devoted to the use of microelectric aids in defining accurately the total sound field within concert halls, and in determining how this is affected by the shape and internal direction of the hall.

I have spoken about noise in this context; let me say something more about it more generally and more specifically. We have problems of industrial and community noise, and of their effects on physical objects and on people. Concern with effects on people commands more attention, though vibration damage and its analysis are important considerations in various industries. Let me, however, speak more particularly of effects on persons. This has rightly attracted much public concern; there is, and should be a heightened concern with environmental standards and quality which embraces the working and the living and recreational environment. We know that industrial noise can cause suffering with possible permanent hearing damage and other effects, that it can lower productivity and affect industrial relations, that it may lead to accidents because of fatigue and poor communication, and that, indeed, it may extend beyond the industrial site and become a community problem, community noise. There can be no doubt that the dimensions of the problem are serious, in this country as elsewhere.

It is, of course, the responsibility and concern of many parties. I do not follow this out in detail: I direct attention to your specific concerns, to the role of the physicist and engineer. It has been suggested to me that there are various interesting approaches of significant promise for the eighties. Of these, one is the automation of heavy industrial processes made possible, at least in part, by the use of new electronic techniques. Here the microprocessor may be seen as an agent removing workers from unhealthy environments. Another is active noise cancellation by the production of out of phase signals which nullify the noise source, and this is mostly applicable to discrete, localised continuous sources. There is the modification of the source to dampen impulse type excitations more rapidly. Finally, we may expect substantial research in the coming decade on the development of new, quiet sources. It must be said that the most effective and economical approach is collaboration between researchers and manufacturers to ensure that noise reduction is considered at the design stage.

There is, and here I find it difficult to speak without strong feeling, the insistent, polluting problem of community noise. That which affects most citizens directly is transport noise. When we go from the shelter of a well isolated Government House to our beach house, I am appalled at the incessant noise of passing traffic, with thundering heavy transports and, in particular, the shattering noise of motor bikes. It is the case that for motor

traffic, noise emissions are being reduced by advances in engine transmission and tyre design, but there is a long way to go. There are the problems associated with world air traffic: the statistics reveal an extraordinary increase in air traffic over the last two decades, and seemingly, great increases yet to come. Modern design advances have dramatically reduced the noise of aircraft engines in terms of acoustic power; in the 1980's, I have seen it said that improvements are likely to consist of continuing refinements, rather than dramatic reductions in noise levels.

Transport looms large in community noise, and involves consideration of land use planning. There are other forms of community noise which create problems which will require further studies and investigation. There is need to establish by closer study, the health impacts of community noise on sleep patterns, on strees and on other aspects of bodily function. I think that this is one of the important problems of our time.

Let me turn now to other areas of development in acoustics, the science of sounds. Utrasonics is a rapidly expanding area of acoustics, with applications in both the medical and non-medical fields. Within the limits of a very imperfect understanding, I have been led into the field of echography. Ultrasound represents a unique and valuable way of investigating the structure of opaque objects; in the field of medical investigation of the human body, it represents a non-harmful, non-invasive technique at the levels which are used and required to visualise most soft tissue areas of the body. Research in this field began in the mid-1950's, and developed through the 1960's to the point at which clinical scanning was being carried out in a few specialized areas throughout the world. During the seventies, there were significant and substantial developments in ultrasound, and it has now established its standing as a clinically acceptable contemporary procedure. I am not qualified to trace the steps and developments, nor is it necessary at this time. In looking to the future, there is still a wide range of untapped information available from an ultrasound scanning beam. Computers are being used to process the information from scans, and these will play an even larger role in the future in characterising a particular type of tissue which is under examination. It should be possible to define benign and malignant areas of tissue being scanned. Other significant developments are indicated, and there will be an expanding role for medical ultrasound in pediatrics, as the head, the heart and the abdominal organs of the child are amenable to examination. There will be an expanding role in the diagnosis of breast tissues for specific diagnosis and for screening for cancerous lesions. As I was preparing for this occasion, the Commonwealth Minister for Productivity announced a substantial grant to fund the development of a sensitive ultrasonic scanner which will make possible the early detection of breast cancer. It was noted that it would also provide "a completely safe method" of patient examination, at a significant cost reduction over traditional x-ray methods. This grant supports work being done by medical and physics researchers in Queensland, and it is contemplated that the project will allow for the transfer of the results of the basic research to Australian industry for commercial development. Indeed, the record of work done in this field in Australia is impressive, and the Australian Society for Ultrasound in Medicine has undertaken the necessary tasks of training and accreditation of medical practitioners and sonographers in this rapidly expanding field, and ultrasound is now recognised as a sectional specialty of obstetrics and gynaecology, radiology and internal medicine.

I refer also to the use of ultrasound in the non-destructive testing field, where it has extensive applications in the detection of flaws in new composite materials which are becoming available in engineering and avionics fields. There are also sonar applications, and considerable developments in the use of large multielement transducer arrays for under-sea scanning.

Then there is the acoustic microscope which uses a very high frequency ultrasound transmitted through an object, and can give results which are not available through the use of an optical microscope. I have seen a recent report in the American press of a licensing agreement for the commercial production of an acoustic microscope which will penetrate through layers difficult or impossible to examine optically, and which can be used to examine properties of the object which are not available in the optical field. All of this opens up the prospect of applications in the fields of industrial materials, electronics and biological research.

I mention also a range of important researches in the aural and auditory fields, and I refer specifically to hearing aids. While over recent years they have become much smaller and more convenient, there have been few significant advances in their performance and the degree of assistance they can offer to the hearing-impaired. I understand that there has been limited progress in devising scientific methods for selecting the type of amplification to suit the specific needs of those with such impairment and in determining what is required, so that these needs may be met. In the next few years, it is anticipated that there will be significant progress in the development of much more sophisticated hearing aids which will alleviate impairment to a far greater degree. This will come about because of renewed research interest in the selection of amplification and in determining the requirements of hearing-impaired individuals, and this is linked with major advances in electronic technology and especially with the development of microprocessors. In Australia there has been active research in recent years conducted by the National Acoustics Laboratory, which is now cooperating with the University of New South Wales in the development of new and significantly different hearing aids.

I have culled from a mass of material made available to me, some of the promises of and some of the challenges to acoustics in the decade ahead. From my limited understanding, it is apparent that acoustics is an important interdisciplinary science, with applications in the life sciences, the arts, engineering and the earth sciences as well as in the physics of the earth and atmosphere. The "science of sounds" is a living and growing field of study which has a great impact on our daily lives in terms of safety, comfort, enjoyment, health and social well-being.

I welcome our visitors to Australia, and I express the hope that you will have a stimulating and productive meeting, and that you will take the opportunity to see something of Australia which lies beyond or apart from the specific concerns of this hard-working Conference. I have pleasure in declaring it open.

A REPORT FROM SYDNEY

All elements, including Sydney's fine weather, worked towards a very successful Tenth International Congress on Acoustics at the University of New South Wales during mid-July 1980.

Sponsored jointly by the Australian Acoustical Society and the International Commission on Acoustics, the Tenth ICA drew together more than 850 delegates and accompanying persons from over 35 countries, far exceeding the organisers' expectations.

OPENING CEREMONY

The Opening Ceremony was held in the Concert Hall of the Sydney Opera House, a most appropriate venue for a congress of acousticians.

After an organ recital by Mr. Michael Dudman, delegates were welcomed by Ray Piesse, President of the AAS, and Bob Beyer, Chairman of the International Commission on Acoustics.

The Tenth ICA was officially opened by Australia's Governor-General, Sir Zelman Cowen. In researching the field of acoustics in preparation for his address, Sir Zelman said he became very aware of the widely ranging applications of acoustics in our everyday lives.

Following Sir Zelman's address, delegates were entertained by a selection of "Songs from Around the World" presented by Sydney's renowned vocal octette, the Leonine Consort. The unaccompanied harmonies and interesting arrangements of the Consort's songs clearly revealed the Concert Hall's fine acoustics.

"An Interlude on Piano" was played by Mr. Julian Lee. Mr. Lee was then joined by the Leonine Consort, who together presented "An Australian Folksong Suite".

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TECHNICAL PROGRAMME

More than five hundred technical papers were presented in up to fifteen parallel sessions. One page abstracts of the papers were printed as Volumes 2 and 3 of the Congress Publications.

For each day of the Congress, a noted acoustician was invited to present a full paper in plenary session. The Invited Speakers' topics all related to the Congress theme "Acoustics in the 1980s", and included auditorium acoustics, noise propagation, physical and musical acoustics, audiology, community noise and opto-acoustics.

A number of Structured Sessions were also held. Papers were presented by known workers in various fields, including musical acoustics, underwater sound, non-linear acoustics, acoustic emission and medical ultrasonics. Two sessions were allocated for "Acoustics in Developing Countries".

The Structured Sessions were well attended and the format gave delegates an opportunity to discuss the topics in a workshop-type environment.

Papers presented by the Invited Speakers and during the Structured Session, appear as Volume 1 of the Congress publications.

ELEVENTH CONGRESS

At the Closing Ceremony, it was announced that the Eleventh International Congress on Acoustics will be in Paris in 1983 - sponsored jointly by the ICA and the Acoustical Society of France.

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10th ICA Proceedings available $20/set for Vols. 1, 2 and 3. Apply to: 10th ICA Secretariat, c/o Science House, 35-43 Clarence St., Sydney, NSW, 2000

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NEWS & NOTES

OBITUARY

ROBERT BRUCE KING

The Society records with deep regret the passing of Mr. Robert Bruce King, a Councillor for many years and foundation Chairman of the South Australian Division of the Society. He was 53.

Bruce King was a graduate of the University of Sydney and the Sydney Technical College. Later in 1965-1966 further studies at the University of Southampton gained for him the award of the Masters degree in Acoustics. After graduation he left Sydney for professional experience as an engineer in Broken Hill and Mount Gambier. In 1958 he was appointed to the staff of the University of Adelaide and during 1959 joined with Professor Harry Davis and Ron Barden to found the first Engineering Acoustics group in Australian Universities directly assisting industry and commerce in the solution of their acoustical problems. The foresight of Professor Davis set the scene for the development of the excellent laboratory facilities at the University of Adelaide enabling the in depth study of Acoustics and Vibration. Bruce King made an outstanding contribution to the design and commissioning of those facilities. In the late sixties he left the University to return to practice and formed the Consulting Engineering firm in Adelaide of R. Bruce King and Associates Pty. Ltd. Towards the end of the seventies he broadened his interest as Director of Vipac & Partners Pty. Ltd. As a leading consultant in sound and vibration he made an outstanding contribution to both practice and the advance of the learned society activity which has been so important to the fairly recent evolution of acoustics in Australia. Evidence of this stands in the record of his many interactions. He was a Fellow of the Institution of Engineers, Australia and a member of the Vibration and Noise Panel of the National Committee on Applied Mechanics of the Institution. Also he was a member of the Standards Acoustics Committee and Chairman of the Technical Committee dealing with Engineering Acoustics. He contributed numerous papers and willingly undertook the role of chairman of sessions at many conferences and seminars and coupled with this there was sustained work over many years towards the publications of the Standards Association of Australia making his all round impact great indeed.

His loss will be greatly felt by his many friends and professional associates in Australia and overseas. The Society extends to members of his family its deepest sympathy.

A.A.S. BULLETIN COMMITTEE

Statement of Income and Expenditure for Volume 7
Numbers 1, 2, and 3 of the Bulletin

INCOME	Vol.7 No.1		Vol.7 No.2		Vol.7 No.3		Total
Subscriptions	49.50		49.50		49.50		148.50
Advertising	1,023.00		1,128.00		1,068.00		3,219.00
Bank Interest	0.00		0.00		1.46		1.46
10th ICA Postage Subsidy	190.85		183.00		211.70		585.55
		1,263.35		1,360.50		1,330.66	3,954.51
LESS							
EXPENDITURE							
Stationary, Secretarial & Drafting Services.	229.62		199.17		243.92		672.71
Bulletin Printing & Envelopes.	542.25		626.00		744.00		1,912.25
Postage	272.53		266.88		363.55		902.96
Cover Design	10.00		10.00		10.00		30.00
Miscellaneous	2.50		0.60		0.00		3.10
		1,056.90		1,102.65		1,361.47	3,521.02
Surplus (deficiency)		206.45		257.85		(30.81)	433.49

INTERNATIONAL SYMPOSIUM ON PERSONAL HEARING PROTECTION IN INDUSTRY

Toronto, Canada, May 14-16, 1980

Dick Waugh of the National Acoustic Laboratories in Sydney attended the above conference. He comments as follows:

Earmuffs and earplugs are deceptively simple solutions to the problem of occupational hearing loss. Employers provide them, workers wear them, and the problem is solved. That things are not so simple was amply demonstrated in the 150 or so people who heard over 40 papers delivered at this three-day International Conference. It is impossible to cover the whole conference in a few paragraphs so what follows is a selective account of the papers specifically addressed to hearing protectors.

Measuring hearing protector attenuation is a fundamental problem that attracted a good deal of attention at the conference. Most national standards specify real ear techniques that define attenuation as the change in hearing threshold caused by wearing the protector being measured. Recent UK research has shown that direct attenuation measurements on cadavers and live subjects agree well with threshold-derived attenuation values. Small differences at low frequencies probably indicate an error in the threshold technique resulting from the masking effects of the subject's body noise, amplified and made more audible by wearing a hearing protector; small differences at high frequencies reflect the inability of ear canal sound measurements to take account of the sound that bypasses the canal altogether and reaches the inner ear by direct bone conduction - here a threshold technique is more accurate than one using a microphone.

A question that was raised several times was whether attenuation measured at low sound levels by the threshold technique will hold good at the high sound levels in which hearing protectors are normally worn. To my mind this was shown to be a needless worry several years ago by German research and that finding was confirmed and extended by results from the cadaver study mentioned above which showed that eight protectors provided linear attenuation up to 125 dB SPL.

Although France and South Africa use high sound level real ear techniques (based respectively on the masking of bone-conducted tones applied to the forehead and on loudness balancing), the consensus of opinion now favours the more straightforward threshold shift technique, which has recently been elevated to the status of an international standard.

Discrepancies of a decibel or two between different methods of measurement pale into insignficance, however, beside the great differences disclosed recently in the USA between laboratory and field measurements of earplug attenuation, the latter made by selecting workers from the shop floor and measuring the attenuation of the plugs they are wearing in a mobile test laboratory. Field performance less than half that shown by laboratory measurements has been a common finding in these studies. A similar but much smaller discrepancy exists for earmuffs. Protector deterioration plays some part in accounting for these differences but the major factor appears to be the difference between the fit achieved in the laboratory and in the work situation, where no experimenter is present to correct sloppy fitting techniques. One USA researcher reported the results of a systematic study of this effect and showed that leaving subjects to fit earplugs themselves after reading manufacturer's instructions produced results like those found in field studies, whereas supervising the fitting and correcting obvious failures produced results comparable to laboratory measurements. The same researcher showed that Australian attenuation measurements obtained by NAL agreed well with the USA field measurements and recommended that NAL results be used as a guide to the "real world" performance of hearing protectors. These results vindicate the approach of the Australian Standard on hearing protectors (AS1270), which imposes accelerated ageing tests on hearing protectors prior to measurement of attenuation and requires that subjects fit protectors themselves according to the manufacturer's standard instructions without experimenter assistance.

It is clearly a problem, therefore, to get people to wear hearing protectors properly but a question of over-riding importance, to which discussion turned again and again, was how to get people to wear hearing protectors at all. Even the best hearing protector can provide no more than 10dB of effective attenuation if it is worn for only 90% of the workday, so in high noise levels this problem can be as significant as physical deterioration or poor fitting. Moreover it is abundantly clear that people will not wear hearing protectors simply because they are provided by a beneficent management. One hearing protector manufacturer has therefore developed an excellent educational programme with separate kits for workers, supervisors and senior management. According to this company, the first two weeks of a hearing protection programme are critical and a major objective of the educational programme is to get wearers past this initial hurdle. Improved auditory comfort and reduction of non-audiory effects such as tension are claimed to be sufficiently rewarding to sustain wearing thereafter. If having such material to offer confers a marketing advantage, other companies may soon follow suit and expand their sales techniques accordingly. This will be a welcome development since it has been apparent for some time that wearer attitudes and cooperation rank in

importance with protector efficiency as factors determining the success of hearing protection programmes.

Comfort is another such factor. In some places it is now compulsory to wear hearing protectors, so uncomfortable devices are vulnerable to wearer-perpetrated modifications to improve comfort. Earplug flanges are trimmed off, earmuff shells are ventilated and headbands are sprung. The effects on attenuation are disastrous and it seems obvious that future hearing protector designs must place greater emphasis on comfort. Several contributors pointed out that we must get beyond the fetish that more attenuation is better; over-protection means a less comfortable device and unnecessary communication problems for the wearer which lead to outright rejection or the sorts of modifications mentioned above.

Feelings of isolation, difficulty in communication and impaired ability to detect and localise warning sounds remain signficant problems for many hearing protector wearers. Attempts to flatten the frequency response of ear muffs are being made in the UK by developing existing passive design princples and in America by incorporating active elements such as amplifiers in the design. An unconventional looking earmuff with a very flat frequency response has reached the prototype stage in the UK.

Single number noise reduction ratings for hearing protectors seem to be a mixed blessing. Indispensable for selecting protectors for noises of known dB(C) and dB(A) but unknown octave band levels they seem to be a source of some confusion, even among researchers. A common error is to suppose that all single number ratings relate the external and in-ear dB(A) levels, whereas some ratings - such as the SLC_{80} - relate the external dB(C) level to the in-ear dB(A) level. Readers familiar with the SLC_{80} rating will know that it incorporates a correction (subtracting a standard deviation from the mean attenuation) to ensure that the majority of wearers are adequately protected. In the USA, NIOSH has promulgated a Noise Reduction Rating similar to the SLC in concept but incorporating a 2 standard deviation correction and a further reduction of 3dB. By Australian standards these adjustments are unnecessarily stringent and one wonders if their real prupose is to correct for the unrealistically high basic attenuation data supplied by manufacturers in the USA.

Germany has incorporated the Australian SLC calculation procedure into a new hearing protector standard (DIN 32760), but with a 2 standard deviation correction. Since basic attenuation data obtained in Germany tends to be slightly higher than NAL data, the final result is likely to be much the same in both countries.

While I have concentrated on hearing protectors in this brief report, the conference also discussed other key topics such as noise measurement and monitoring audiometry. To my mind, however, the major theme of this conference was how to get hearing protection programmes to live up to our expectations of them; in the light of much that was said about current practice our expectations seem rather idealistic.

HIGHER DEGRESS IN ACOUSTICS-UNIVERSITY OF ADELAIDE

Four higher degrees were awarded by the University on 7th May, 1980 for work in acoustics and/or vibration.

Recipients were:

A.D. Jones, Ph.D. M.P. Norton, Ph.D.
C.H. Hansen, Ph.D. C.E. Hyland, M.Eng.Sc.

All of these are members of the Society having joined the South Australian Division although Michael Norton has since transferred to the Victorian Division.

Adrian Jones has been granted leave of absence by his employer in South Australia to spend approximately a year at the NASA Langley Research Centre in Virginia, U.S.A. commencing May 1980.

Michael Norton is working at the C.S.I.R.O. Division of Mechanical Engineering, Highett, Victoria.

Colin Hansen is employed at Bolt, Beranek & Newman Inc. in California as an Acoustic Consultant in industrial noise control.

Chris Hyland is an Engineer with the Public Buildings Department in South Australia.

The Time Distribution of Impulse Noise in an Enclosure.

Robert Bullen & Fergus Fricke

Architectural Science Department
University of Sydney

SUMMARY

Impulse noise is an important cause of speech interference in industrial buildings and a significant source of annoyance in commercial and domestic buildings. Existing, steady state, theory is inappropriate for estimating noise levels in enclosures resulting from impulse sources, except for L_{eq}, valves. An alternative theory is presented in which the percentile levels in a room are given as a function of reverberation time and the time between impulses.

1. INTRODUCTION

For many years absorbing materials have been added to rooms to reduce noise levels. Theoretically, in many cases, there is little to be gained by adding absorption because either the receiver is in the free field or the amount of absorption in the room is already large so that the cost of any further noise reduction is very high. Subjectively, however, a doubling of the amount of absorption in a room has an important effect, where transient and quasi-steady (e.g. impulse sounds that are rapidly repeated) sounds are involved, even when the receiver is in the direct field.

This subjective change has either been ignored or vaguely attributed to unknown psycho-acoustic effects [1] [2], while in reality there is a physical explanation dealt with in this paper for all or part of the subjective improvement. A further explanation, [3], for the difference between objective and subjective assessments lies in the instrumentation used which is rarely capable of assessing the characteristics of rapidly varying noises.

Most industrial plants have noise sources which generate impulse sounds, [5], which range from the clattering of parts on a conveyer to the intense and regularly repetitive impacts of power presses. Progress in quietening these sources has been slow, despite the high noise levels involved, because of factors such as lack of technology, cost, and the need to maintain productivity and operating convenience in existing machinery. Any progress in controlling impact and impulse noises, away from the machine, in order to improve communication would therefore seem important. The following theoretical treatment and experimental verification is a first attempt at predicting noise levels in rooms due to rapidly repeated impulses.

The sound intensity level and the sound pressure level which result from an infinite sequence of impulses in a reverberent environment will be considered. The impulses will be assumed to be identical, to occur at equally-spaced time intervals T, and to have a width λ where $\lambda << T$. The reverberation characteristics will be assumed to be in accordance with standard room-acoustic theory, as described in Reference 2. Thus, the following theory will describe the behaviour of broad-band impulses in a comparatively "normal-shaped" room more accurately than it will describe other situations.

It is desired to find the sound level, and the sound pressure, which is exceeded for a given proportion of the time. This level will give some indication of the extent of interference with speech and other communication, [4], as well as the possibility of medical effects. The effect of changing the reverberation time of the environment will be considered.

2. PERCENTILES OF THE SOUND INTENSITY LEVEL

The sound field in the enclosure will be described in terms of the propagation of a large number of "sound particles" (or "phonons"). The sound level will be proportional to the number of phonons which reach the receiver per unit time. In a diffuse field, which according to standard room acoustic theory will exist in the enclosure, this will in turn be proportional to the total number of phonons in the room.

If n phonons are emitted in a pulse at time t = 0, the number of phonons from this pulse which are still in the room at time t will be $n\ e^{-t/\tau}$, where $\tau = R/(6 \ln 10)$, and R is the reverberation time of the enclosure. For a sequence of pulses, separated by a time T, the total number of phonons in the room at a time t after one pulse will be

$$\sum_{i=0}^{\infty} n e^{-(t + iT)/\tau} = n e^{-t/\tau}/(1 - e^{-T/\tau})$$

assuming that the sequence has extended over a time much greater than τ.

The mean number in the room overall times is

$$1/T \int_0^T n\,(e^{-t/\tau}/(1 - e^{-T/\tau}))dt = n\tau/T$$

which is exactly the number of phonons resulting from a source steadily emitting n phonons in a time T.

Taking the intensity corresponding to n phonons being in the room as a reference level, let I be the intensity relative to this level and F(I) be the proportion of time for which the intensity is greater than I. The time t(I) at which the intensity is equal to I is given by

$$I = e^{-t(I)/\tau}/(1 - e^{-T/\tau})$$

If t<t(I), the intensity is greater than I. Thus, F(I) = t(I)/T, and

$$I = e^{-T\,F/\tau}/(1 - e^{-T/\tau}) \qquad (1)$$

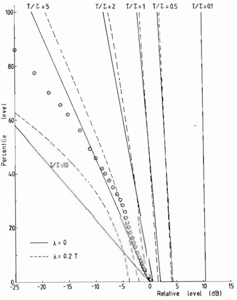


Fig. 1 Percentile levels of sound intensity level in a room with a rapidly repeated impulse source

It will be seen from equation (1) that if $T/\tau >> 1$, the denominator in the expression for I approaches 1, and the value of I for a given F approaches that which would be obtained by considering each impulse separately. Equation (1) is shown graphically for some values of T/τ in Figure 1.

This expression was tested using pulses of white noise (filtered in an octave-band about 2KHz) of width 0.1 s. in a room with a reverberation time, R = 2.3 s., with $T/\tau = 5$. RMS conversion was performed by a B and K measuring amplifier on "fast" response. The reference level was determined by measuring the level of steady-state noise of the same intensity as the pulses. The results are shown in Figure 1. The term "percentile level" refers to the probability that the intensity is greater than the given level. Departure from the expected curve at high values of F are probably due to the fact that the level of each pulse was not constant, due to the speaker response and the inherent randomness of the white noise.

3. PERCENTILES OF THE INSTANTANEOUS SOUND PRESSURE LEVEL

It will be assumed that the mean pressure in the pulse, at least after it has suffered a number of reflections from the room walls, is zero. Let the RMS pressure of the pulse, measured at 1 m from the source in a free field, be P_o, and the width of the pulse be λ. It will be assumed that $\lambda << T$ and $\lambda << \tau$. The sound pressure in the room at time t resulting from a pulse which began at t = 0 will be the sum of the pressures from a number of reflections of the pulse, with travel times between $t - \lambda$ and t. The number of such reflections is [2]

$$N_t = 4\,\pi\,c^3\,\lambda\,t^2/V \qquad (2)$$

where V is the volume of the enclosure and c the speed of sound in it. The RMS pressure in each of the reflected pulses is

$(P_o/ct)e^{-t/2\tau}$. It is assumed, as is usual in room acoustics, that the phase of these reflections is random, i.e. that the total pressure is the sum of N_t random samples from a population with zero mean and standard deviation $(P_o/ct)\,e^{-t/2\tau}$.

The assumption that N_t is large implies

$$\text{that } \lambda >> \frac{V}{4\pi c^3\,t^2}$$

Even for $t = \lambda$, this will usually hold. Thus the probability density for the total pressure will follow a Gaussian distribution with variance

$$V_t = N_t (P_o/ct)^2 \; e^{-t/\tau}$$

$$= \frac{4\pi c\lambda P_o{}^2}{V} \; e^{-t/\tau}$$

Considering now a sequence of such pulses, the pressure will be the sum of the pressure from all pulses, whose variances will be $V_{t + iT}$, where $0 \leq i < \infty$ and t is the time since the beginning of the last pulse. The distribution of pressures is thus Gaussian, with variance

$$V_t' = \sum_i V_{t + iT}$$

$$= \frac{4\pi c\lambda P_o{}^2}{V} \; \Sigma e^{-(t + iT)/\tau}$$

$$= \frac{4\pi c\lambda P_o{}^2}{V(1-e^{-T/\tau})} \; e^{-t/\tau} \qquad (4)$$

The mean value of V_t' over a period is

$$\frac{4\pi c\lambda P_o{}^2}{VT}$$

Thus, the probability density for the pressure is

$$P_t(p) = (2\pi V_t')^{-\frac{1}{2}} e^{-p^2/2V_t'} \qquad (5)$$

If all times $0 \leq t < T$ are considered equally probable, the overall probability density for the sound pressure is

$$P(p) = 1/T \int_0^T P_t(p) dt$$

$$= (2\pi)^{-\frac{1}{2}} \; T^{-1} \int_0^T V_t'^{\,-\frac{1}{2}} \; e^{-p^2/2V_t'} \; dt$$

Putting $x = V_t'$, $dx = -(x/\tau)dt$

$$P(p) = \tau(2\pi)^{-\frac{1}{2}} \; T^{-1} \int_{\frac{1}{2}(AP_o)^2}^{\frac{1}{2}(BP_o)^2} x^{-3/2} \; e^{-p^2/2x} \; dx$$

$$\text{where } A^2 = \frac{8\pi c\lambda}{V(1-e^{-T/\tau})}$$

$$\text{and } B^2 = A^2 \; e^{-T/\tau}$$

$$= (2/\pi)^{\frac{1}{2}} \; (\tau/T) \int_{\frac{\sqrt{2}}{BP_o}}^{\frac{\sqrt{2}}{AP_o}} e^{-\frac{1}{2}p^2y^2} \; dy$$

putting $y^2 = 1/x$

$$= (\tau/pT) \; [\Phi \, (\frac{p}{BP_o}) - \Phi \, (\frac{p}{AP_o})] \qquad (7)$$

where $\Phi(x) = 2\pi^{-\frac{1}{2}} \int_0^x e^{-t^2} \; dt$

If F(p) is the proportion of the time for which the pressure is greater in modulus than p,

$$1 - F(p) =$$

$$\frac{2\tau}{T} \int_0^p \frac{1}{x} \; [\Phi \, (\frac{x}{BP_o}) - \Phi \, (\frac{x}{AP_o}) \,] \; dx$$

$$= \frac{2\tau}{T} \int_{\frac{p}{AP_o}}^{\frac{p}{BP_o}} \Phi(x) \; \frac{dx}{x} \qquad (8)$$

The integral in equation (8) can be evaluated numerically and the results are shown in Figure 2 for a pulse width of 0.1 s., and a room volume of 83 m^3, using P_o as the reference pressure.

The predictions of equation (8) were tested using the experimental system described above, and the results are shown in Figure 2.

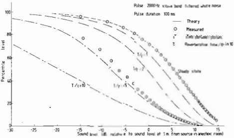


Fig. 2 Percentile levels of sound pressure level in a room with a rapidly repeated impulse source.

The measured pressures were normalised by measuring the RMS pressure at the receiver when the source emitted continuous white noise. The predicted distribution of pressures in this case was calculated using theory very similar to that above, and the predicted RMS pressure was set equal to the measured value. Predicted and measured distributions of the pressure in this "steady-state" case are also shown in Figure 2.

The agreement between predicted and measured distributions is good, except at low pressure levels. It is believed that the discrepancy here could have been caused by background noise.

4. CONCLUSION AND SUGGESTED FURTHER WORK

Using simple theory, all percentile values of sound intensity, and of sound pressure, resulting from an impulsive source in a reverberant environment may be predicted with reasonable accuracy. It will be noted from Figures 1 and 2 that this theory implies that a reduction of the reverberation time will have a significant effect on the lower percentiles, but not as much on the higher ones. This finding may be important in cases where the degree of speech interference caused by the noise is critical.

The present work is to be extended in order to deal with random impulse amplitudes occurring at random intervals. Verification of the work is also being attempted in factories and workshops where data can be obtained before and after acoustic absorbing materials are added.

1. T.W. EMBLETON, I.R. DAGG, G.J. THIESSEN, "Effect on Environment on Noise Control", Noise Control, 5, 369-383, 1959.

2. H. KUTTRUFF "Room Acoustics", (Applied Science, London, 1973).

3. R.B. WILKERSON, "Sound Level Meter and Dosimeter Response to Unsteady Noise Levels", Noise Control Engineering, 4, 68-75 (1975).

4. K.S. PEARSONS, "The Effect of Time-Varying Traffic Noise on Speech Communication and Annoyance" Noise Control Engineering, 10, 108-119 (1978).

5. A. AKAY, "A Review of Impact Noise", J. Acoust. Soc. Amer., 64, 977-987 (1978).

GOSSIP

Readers of this Column will know that the Department for the Environment in Queensland has been seeking a noise control officer for many many months. Recently they appointed Dr. Tom Stubbs to be Chief Noise Control Officer. Apparently Tom is not an acoustician (presumably because the Department could not get an acoustician), but rather a scientist in general and an administrator. Recently he was in Melbourne visiting his sister organisation the Environmental Protection Authority, the Royal Melbourne Institute of Technology and similar bodies, to learn amongst other things what sort of instruments he should order for his department.

The State Pollution Control Commission in New South Wales is running very short of acousticians these days since Athol Day left them to join his old firm, Wessberg Martin Pty. Ltd. So far as we know, the S.P.C.C. now has John Mazlin fulfilling all roles requiring an acoustician.

The readers of Australian Standard AS1269 S.A.A. Hearing Conservation Code will know that reference is made in a footnote to a publication of the National Acoustic Laboratories titled Attenuation of Hearing Protectors. This very useful publication gives the mean and standard deviation of the attenuation of dozens of hearing protectors at frequencies from 125 Hz to 8 kHz. But have you ever tried to obtain a copy; I rang the Australian Government Publishing Service and was told that they have many enquiries for the publication but that it was out of print within two months of being published. Further I was told that it could not and would not be republished no matter how many enquiries were received or how many times it was referred to in Australian Standards until the Director of the National Acoustic Laboratories authorised it. Yes you guessed it, Ray Piesse, the Director of N.A.L. had no knowledge that the booklet was out of print.

How does an acoustical consultant demonstrate that his opinions and judgement is right. Well you see in Melbourne there has been a controversial proposal to establish a new railway line from Station Pier to Webb Dock. Controversial because it would virtually run along the beach front and so be unsightly and noisy etc. etc. The railways retained Vipac and Partners to advise them of the likely noise nuisance; so how did they determine the likely noise nuisance? They ran a diesel locomotive and 10 carriages down the proposed track; acoustically that is with the aid of tape recorders and loudspeakers. This done several times they assessed the communities response to the train noise by telephoning the E.P.A., and enquiring as to how many complaints they had received about noise from trains running along the beachfront. No complaints were received by the E.P.A.! After all that work the Government has since announced that they will not be proceeding with the railway presumably for political reasons.

Talking about Vipac, most readers will know that the Vipac group consists of at least three companies. Vipac and Partners being the consulting company, Vipac Laboratories being the laboratory measurements company and the newest, Vipac Instruments Pty. Ltd. headed by Andrew Walker, being their instrument sales organisation. Vipac Instruments handle instruments by Spectral Dynamics, Dymac, and B.B.N. Instruments. Andrew who is not an acoustician but who has a background in electronics and process control tells me that you can meet him at their stand at the I.C.A., and that Vipac Instruments will operate their own services department so that they can offer purchasers full sales and service.

Sound Attenuators Australia Pty. Ltd. have finally shifted to their new address at 39 Koornang road, Scoresby. Finally we say because the strike which they had by their factory employees which started last Christmas spread to include a black ban on the new factory site so that they were unable to move until the strike was settled.

With all this battery operated noise and vibration measuring equipment there is a temptation to run some of it off your car battery if only to save spending ones brass on all those gold tops. If you do, be careful; that well known brand of instrument does not include a fuse in the external power supply circuit so that if the main switching transistor decides to give up the ghost and take eight more transistors with it you have a $300.00 repair bill. And no, it is not covered by warranty as you are supposed to know from your good sense that you should provide an external fuse rated to the instrument; and no, there is nothing in their instruction manuals about the need for a fuse.

Keeping the peace is the title of a new little booklet produced by the Environment Protection Authority. This little booklet could have many uses for many people but you would have to get a copy to see just what it is like; we understand that it is free, certainly we got our copies for free. The book discusses sound and noise, the decibel scale, noise and hearing, sources of noise including traffic, industrial, entertainment, construction, domestic noise, measuring noise including an explanation of L_{90}, L_{10}, etc., preventing

hearing damage, improving the environment, etc.

When measuring noise levels it is frequently advantageous to be able to listen to what the sound level meter is listening to. For many years we have been forced to use an old pair of airforce headphones as the commonly available high fidelity earphones have too low an impedance to be connected directly to a sound level meter. The only readily available high impedance earphones of high quality are of the "Open Air" type which are quite unsatisfactory both because you can hearing everything else through the open air structure as well as what you want to hear and because in any low level situation feedback occurs and you get deafened by the howl from the headphones. At last after many years of looking and contemplating writing to various manufacturers etc., we have discovered the Beyer headphones type DT-100 which have an impedance of 2000 ohm per capsule, have pretty good sound isolation characteristics and best of all have a low frequency response way way better than the old steel cans that we used to use. These headphones are available from Rank Electronics Pty. Ltd. in a variety of impedances from 4 to 2000 ohm per capsule.

Did you see the very nice profile of Anita Lawrence in the recent issue of 'The Australian Standard'? Well done Anita.

Remember I want to hear all the bits of gossip from all states of Australia and the rest of the world. Send them to me at Knowland Harding Fitzell Pty. Ltd., 22a Liddiard Street, Hawthorn, Vic., 3122. Of course you all know by now that John Spicer has joined me here in Melbourne but those keen to note the latest should note that our telephone number is 819 4522.

Graeme E. Harding

LETTERS

Sir,

It was interesting to read the different views on the future role of the Bulletin expressed by the Editor and the President in the last issue of the Bulletin.

My sympathy is with the Editor. I know of eleven people, four NSW and seven Victorian members, who know the heartache of trying to generate copy for the Bulletin. It is a never ending battle against apathy. How many times do you have to remind people that the Bulletin exists for their use. It is depressing to a keen Committee to have to resort to foreign society press releases to fill up spaces in our national magazine.

For our Bulletin to succeed in any one year, there must be a keen editorial committee determined (i) that it will appear on time (ii) that it will be presentable and (iii) that it won't be a financial liability. The first two are essential if we are to obtain advertising revenue, and advertising revenue is essential if the Bulletin is to pay for itself. No honorary editorial Committee is satisfied if there isn't interesting, spontaneous copy from members to fill the gaps between advertisements. One frustrated editor once called Western Australia Division the perfect anechoic termination; no matter what the stimulus there is no response. Why hasn't someone expressed an opinion about the new Australian Association of Acoustical Consultants? Why don't more consultants write up little case histories? Many people have said Jim Watson's note on painted acoustic tiles was the most interesting article they have read in the Bulletin.

The Bulletin reflects the well-being and enthusiasm of the Society. It is relevant, just viable and very vulnerable. There is never a significant back-log of copy for the next issue. Contributors can be confident their articles will be published promptly, provided they meet the published deadlines. If our Society becomes learned and professional and stuffy, so will the Bulletin. For the time being it is alert, sympathetic to new ideas and ready to serve the most exalted and the most humble members of our Society equally.

Our Society is too cosmopolitan and too small to support a learned society journal at present. Let us develop a strong, highly relevant, news and views bulletin for the benefit of members, and have it publish the technical articles that come along. Let us not strive for the status of a Learned Society Journal, for the sole benefit of the minority of members in the academic and research community that suffer from that dreadful "publish or perish" syndrome.

D.C. Gibson
Melbourne

Dear Sir,

It has come to my notice that Mr. Athol Day has left the N.S.W. State Pollution Control Commission to return to private industry and I feel compelled to acknowledge his contribution to acoustics, particularly in the Government and Local Government sphere of N.S.W.

Athol was a foundation member of the Government regulatory body for noise control in this State and while there were times when I have been in conflict with some of his decisions, I respected his position and the necessity for the protection of the "sleeping" public.

A person who makes a major contribution to any worthwhile cause should not go unnoticed. With this in mind I say well done Athol Day.

Caleb Smith

TECHNICAL NOTES

RESEARCH ON ANNOYANCE FROM ROAD TRAFFIC

J.F.M. BRYANT
Principal Research Scientist
Australian Road Research Board

Engineering and the social sciences meet and establish a somewhat uneasy relationship in environmental science. It is not the first meeting of these disciplines, of course; in industrial health, ergonomics, industrial design and many other fields in which technology affects the health, comfort and well-being of individuals engineering has had to consider human responses to its technical proposals and achievements. Latterly, with the pervasive growth of the motor vehicle, road transportation has become an important subject of debate and often controversy.

The response of each discipline to the challenge has been characteristic; the engineers say that, if they are told what human and social characteristics they should design for, they will provide acceptable designs. The social scientists, suspecting the motives of the engineers, point to past history and say that any more of the same will make life intolerable. Meetings of engineers, psychologists, sociologists and environmental scientists which attempt to work out a common approach to these problems are therefore noteworthy.

One such meeting was organised recently by the Australian Road Research Board (Seminar on Measuring Social Behaviour in Road Researh, April 1980). The object of the workshop was to provide a forum for the discussion and testing of methods of evaluating responses to environmental by-products of road transportation systems. Of particular interest to acousticians was the consideration given to traffic noise and the annoyance caused by it. Over the past few years, ARRB has sponsored research into traffic noise measurement and the evaluation of annoyance conducted by researchers in the University of Queensland. Noise levels and annoyance have been measured on freeways in Brisbane and on arterial roads in that city and also in Sydney and Melbourne by Dr. Lex Brown, a member of the Society and by Dr. Henry Law.

Dr. Brown presented a paper to the workshop on the measurement of dose-response relationships for environmental factors, using road traffic noise as a paradigm. The physical data, representing the noise dose, were gathered in the usual way with a magnetic tape recorder, edited and analysed to provide various measures of noise exposure, e.g. L_{10}(18 h), for each neighbourhood. The response measures were obtained by social surveys, using interviews and carefully constructed and tested questionnaires with samples of residents. The principal measure of the subjective effect of noise was a seven-point, semantically labelled annoyance scale, 'How much does traffic noise in this area annoy you?' Traffic noise has other effects that may not be reflected directly in expressed annoyance, e.g. interference with communication or with sleep, the shutting of windows and the extent of use made of different rooms in a house. In the study referred to, information on fourteen variables was sought concerning the effects of noise ranging from expressed opinions about traffic noise and reported interference with activities to respondents' actions regarding the noise - by no means an exhaustive list.

While it is reasonable to assume that there is an increasing dose - response relationship for each individual, these are unlikely to be the same for all; some people are much more susceptible to noise than are others, with different thresholds of annoyance and different response rates to increasing noise. Grouped responses disguise such effects, nor can an individual's response be predicted from such grouping. Over a range of more than 15 dB in mean L_{10} (18 h) percentage responses indicating average annoyance increased to only a slight extent with increasing levels of noise; such regressions have limited value in predicting group response, owing to the large scatter of results, and little or none for the individual case.

Much of the difficulty in defining the dose-response relationship, particularly for the individual case is due to the intervention of factors correlated to the variation in intensity of stimulus. It has been consistently reported that individual susceptibility to noise and individual opinion of the neighbourhood as a place to live are significant predictors of response. This was found to be so in the present research and, in addition, two other factors were identified, i.e. location of activities within the dwelling in relation to the noise-source and the type of house, whether set high or low, whether isolated or part of terrace or block.

Henry Law, a psychologist, was chiefly interested in the analysis of multivariate responses to complex stimuli such as traffic noise and, in a paper with C.W. Snyder, outlined a linear structural-relations model that might be useful in the unravelling of the complicated situations described by Brown. The model is intended to reveal the linear simultaneous or independent associations among latent variables in terms of the observable indicators. The analysis is thus intended to verify the hypothesised causal connections between variables such as those depicted in Fig. 1 (taken from Law and Snyder). In this model ζ are independent variables (freeway noise, physical conditions, e.g. internal house noise, times at

home, etc., and human attributes, e.g. hearing sensitivity, attitude to neighbourhood etc.) defined by the x measures which also include error terms δ. The measurement model for the input dose is the vector:

$$x = \Lambda_x \zeta + \delta$$

On the response side, psychological and behavioural effects n are reflected in measures y which are also subject to error ε. The response model is thus

$$y = \Lambda_y + \varepsilon$$

The object of the ensuing analysis is to determine the latent variables together with information on the extent to which these variables are measured by the observed variables and the relationship between the latent variables themselves. In this way it would be possible to distinguish between annoyance and frustration or to determine the relative strengths of traffic noise and human attributes in their effect on psychological and behavioural effects.

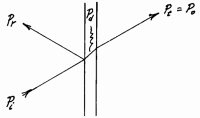
Experience in road research indicates that sophisticated treatment of data obtained in environmental studies, particularly of traffic noise, using complex models and multivariate hypotheses, is necessary if adequate understanding of these important aspects of engineering design is to be achieved.

The proceedings of the workshop are available from ARRB, P.O. Box 156 (Bag 4), Nunawading, 3131.

ACOUSTIC ATTENUATION OF WALLS AND ENCLOSURES

In this discourse we discuss the desirable properties of materials to provide high acoustic attenuation, and compare the requirement for a wall with that of an enclosure.

1. Isolated Infinite Wall



For an isolated infinite wall separating a source and a receiver we have the following relationships.

Given that Pi = the incident sound power
Pr = the reflected sound power
Pt = the transmitted sound power
Po = the output sound power
Pd = the dissipated sound power
Pt = Po

then Pi = Pr + Pd + Pt

then ρ = Pr/Pi = sound power reflection co-efficient
= r^2 where r is the sound pressure reflection co-efficient
= 1 - α where α is the sound power absorption co-efficient

δ = Pd/Pi = sound power dissipation co-efficient

τ = Pt/Pi = sound power transmission co-efficient

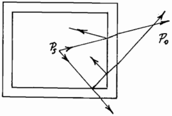
= 10↑(-TL/10) where TL is the transmission loss in dB

Then ρ + δ + τ = 1

and Po = τPi

Thus the transmitted sound power approaches zero as the transmission co-efficient approaches zero and is independant of ρ and δ so that for example a sheet of steel with low δ and τ, and high ρ is an effective isolating wall. Dense thick rockwool with low τ and high ρ and δ also provides an effective isolating wall.

2. For an enclosure around a Source



If we allow

ρ, δ, τ are the properties of the wall of the enclosure as defined above.

Pi as the integrated source sound power W.

Po as the integrated transmitted power W.

Then unlike the isolated wall where the reflected power Pr is lost and does not con-

tribute to Po we must recognise that because we are integrating all the acoustic power transmitted through the enclosure walls we must account for the transmission of the reflected power. An examination on an energy basis will show that the only energy loss mechanism is the dissipation loss; if this loss is high the transmitted power is low.

i.e. $Po = (1 - \delta)Pi$

As the dissipation co-efficient δ for acoustical materials is not commonly listed it may be inferred indirectly from the available absorption co-efficients and transmission loss data.

Given $\rho + \delta + \tau = 1$

by transposition $1 - \delta = \rho + \tau$

Subsitute $1 - \alpha$ for ρ to give $1 - \delta = 1 - \alpha + \tau$

i.e. $Po = (1 - \alpha + \tau)Pi$

Therefore the desirable properties for the walls of a highly sound isolating enclosure are high sound absorption and low transmission co-efficient (high transmission loss). Note that α and τ are not independant variables so that τ cannot exceed α to give a negative Po.

Thus an un-damped steel sheet enclosure with both low α and low τ is not as effective an enclosure as a combination panel with high α and low τ.

Graeme E. Harding

DIVISION REPORTS

REPORT TO ANNUAL GENERAL MEETING 1ST MAY, 1980

1. PROGRAMME

For the year the Division has held eight functions. These have included a visit to the ABV2 television studios, two workshop study groups each to examine and comment on a draft Australian standard, a joint meeting with the Audiological Society on audiology and acoustics in hearing conservation, a wine tasting and dinner, a joint meeting with the Mechanical Branch of the Institution of Engineers on the suppression of vibrations in the Melbourne underground rail loop, a site visit to Museum Station and track works of Melbourne Underground Rail Loop Authority and this evening's visit to the acoustic facilities of the Department of Applied Physics, Royal Melbourne Institute of Technology.

In addition, the Division was the host for the Society one-day conference in September last year on "Building Acoustics Design Criteria". It was a successful meeting and was attended by 64 people from various parts of Australia. The Division was also the host for the Society Annual Dinner which followed the Annual General Meeting of the Society.

It has been pleasing to see members with varied interests attend the meetings which were beneficial for Society members to meet and discuss matters of common concern with members of kindred societies. The Division extends thanks for the planning and organizing of functions to Messrs. Fouvy, Chenco, Barnes and Koss of the Programme Sub-committee.

2. ADMINISTRATION

I would like to extend thanks to Mr. Jim Kirkhope, Divisional Secretary, for his tireless and efficient efforts, without whose devotion I feel certain the Division would not properly function. I would also like to thank Mr. Reg McLeod, Registrar and Treasurer, and Mr. Louis Fouvy, Committee Minute Secretary. The Committee functioned as a whole in unison and through the efforts of the various sub-committees.

3. MEMBERSHIP

Over the previous few years the membership of the Division had been rather static. However over the year just completed there has been a significant increase in membership, and thirteen additions have resulted, a pleasing achievement.

4. THE BULLETIN

The Division continued to assume full responsibility for production of The Bulletin. Following the issue of Volume 7 No. 2, Dr. Robin Alfredson stood down as Editor, and I wish to thank him for his time and efforts.

The post of Editor was taken up by Mr. Rob Law, Volume 7 No. 3 was issued in December 1979, and Volume 8 No. 1 has been distributed in April. A notable achievement has been that the three issues for the year have been distributed on schedule, and that the Bulletin Committee through its careful planning and efforts has been able to declare a small surplus.

I wish to thank the Editor, Mr. Rob Law and his committee of Messrs. Harding, Davy, Gibson, Koop and Lambert for their worthy achievements. It would truly assist them in their task if members were able to increase the volume of material for publication.

K.R. Cook
Chairman
Victoria Division

Basic Combustion Noise Research: Theories, Experiments and Scaling Laws.

S.L. Hall

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The experiments, theories and scaling laws developed from fundamental research studies of the combustion noise process are reviewed.

1. INTRODUCTION

Combustion noise, although a well-known phenomenon, is attracting research attention because it is now considered as a pollutant. Unlike many chemical pollutants, noise has an instant effect upon bystanders. Combustion noise takes two forms: combustion-driven oscillations (or instability) and combustion roar. Combustion instability is a phase-coherent, fixed-frequency feedback oscillation associated with the acoustic mode of the combustor. The periodic oscillations can cause structural damage as well as producing an unbearable environment. Historically, combustion instability has received much greater attention than combustion roar. Putnam (1971) has provided a comprehensive book on the subject.

Noise is generated in combustion systems for two reasons: (1) except for some small-scale devices, all practical burners have turbulent flames; and (2) heat is liberated during the burning process. Practical combustors are usually turbulent because the rate of heat release per unit volume is greater than a laminar system can achieve. The imbedding of a chemically-reacting process in a turbulent field produces different noise characteristics than non-reacting turbulent fluids. Combustion roar is essentially the interaction between the basic chemical combustion process and the turbulence required for mixing and efficient burning. Thus, the study of combustion-generated noise involves the disciplines of physical chemistry, turbulence and acoustics.

This report reviews the combustion roar theories, laboratory measurements and resultant scaling laws produced by research scientists.

2. THEORETICAL AND DESCRIPTIVE MODELS

The first attempt to mathematically quantify combustion roar was made by Bragg (1963). He envisaged the turbulent flame as a collection of "eddies" or "turbules" acting as monopole, or omnidirectional, sources of sound. These eddies would have their own heat-release rate statistically independent of other eddies. The rate at which the total combustion volume is expanding or contracting is the net sum of the individual eddies. Bragg developed the following equation for sound power based on the monopole-source model of sound generation by turbulent flame:

$$P = \frac{(\rho_u)^2 \ (E-1)^2 \ S_L \ U^3 \ r_j^{\ 2} \ \alpha}{16 \ \bar{\rho} c} \qquad (1a)$$

This equation was reduced by Thomas and Williams (1966) to the form:

$$P = \left[\frac{d^2V}{dt^2} \right] \frac{\bar{\rho}}{4\pi\bar{c}} \ . \qquad (1b)$$

Bragg's theory of combustion noise was based on the wrinkled (laminar) flame concept of a turbulent flame. Strahle (1978) criticizes the following aspects of Bragg's theory:

(i) it does not follow from the conservation laws of fluid mechanics;

(ii) it speculates a net monopole radiation without any rigorous mathematical backing; and

(iii) it can produce errors if equation (2) is used.

Strahle and Shivashankara (1971, 1972, 1974) obtained semi-empirical expressions for acoustic power and efficiency by using a Lighthill-type wave operator. The resultant scaling laws will be presented under Section 4.

From their experimental results, Smith and Kilham (1963) postulated that a turbulent flame could be represented acoustically by a distribution of monopole sources caused by fluctuating heat-release rates. Cummings (1971) comments that Bragg's theory is at variance with the results of Smith and Kilham (1963). Kotake and Hatta (1965) treated the flame front as a discontinuity and applied various equations of fluid dynamics. They deduced that flow velocity turbulence generates the movement in the flame front, which gives rise to pressure fluctuations that propagate as noise. Thomas and Williams (1966), Gaydon and Wolfhard (1970), and Hurle et al (1968) visualise flame noise as being generated by "turbulence balls" which produce pressure waves due to the expansion of the hot products of combustion. Strahle (1978) improved the aeroacoustics approach originally used in his 1971 paper by using a variable speed of sound formulation. Chiu and Summerfield (1974) developed a complex mathematical treatment comparing the distributed reaction zone theory and the wrinkled laminar flame model, both based on the monopole-source theory. Essentially they used the convected wave equation to account for source convection within the flame zone. Unfortunately, Kilham and Kirmani (1978) point out that the resultant source terms are difficult to determine experimentally.

The work of Toong et al (1965, 1972, 1974) deals with combustion instability due to acoustic-kinetic interactions. They mathematically couple the heat-release rate (monopole source), the burning rate (monopole) and the stress tensor (quadropole due to velocity, temperature and density fluctuations) to the acoustic wave equation. All terms are sound generation terms; some are also amplification terms.

3. EXPERIMENTAL

Smith and Kilham (1963) produced the first reliable data on broad-band flame noise. They systematically investigated small laboratory-scale turbulent premixed flames. They measured the variation of sound intensity, frequency spectra and directionality with burner diameter and flow parameters.

Thomas and Williams (1966) produced spherically-expanding flames which conclusively verified that such flames act like monopole sound sources. The pressure in the radiated sound wave was proportional to the time rate of change of the volumetric rate of gas expansion during combustion, see equation (2). Hurle et al (1968) extended the results of Thomas and Williams to a turbulent premixed flame by recognizing that the rate of generation of free radicals within the reaction zone was also fundamentally related to the rate of combustion. They developed an optical technique which measured the changes in intensity of the emission of free radicals (C_2 and CH) which are confined almost exclusively to the inner reaction zone in hydrocarbon/air flames. Narrow-band spectrum filters isolated all wavelengths other than those for the C_2 and CH emission; a photmultiplier was used as an optical detector. A definite correlation was established between the measured sound pressure and the rate of change of combustion rate in the flame. Price et al (1969) extended the experimental technique of Hurle to turbulent diffusion flames. Chillery (1975) confirmed the observations of Hurle et al (1968) for single and double premixed flame systems over a limited frequency range.

Roberts and Leventhall (1973) measured sound, flame speed and flow velocity fluctuations for gaseous premixed flames. They found that the major noise source was the fluctuations in the flow velocity, not the "turbulence balls" of combustible gases generating pressure pulses as they burn. Roberts and Leventhall (1977) used the classical gas-dynamics equation to relate pressure and velocity across the flame front:

$$\rho_2 = \rho_1 \left[1 + \gamma_1 M_1^2 \left(1 - \frac{U_2}{U_1}\right)\right] \qquad (2)$$

where the subscrips refer to pre- and post-flame conditions, respectively. In experiments with town gas, Roberts and Leventhall claim good agreement with values for the pressure drop across the flame front quoted by Gaydon and Wolfhard (1970). Using cross-correlation measurement techniques, they have essentially verified Hurle's (1968) claim that the acoustic pressure generated by a flame was proportional to (dI/dt), the time derivative of the intensity of emission of light of a certain wavelength from free radicals present in the flame reaction zone. It then follows that (dI/dt) is a measure of the rate-of-change of the flamefront area and as such is related to the flow velocity fluctuations reaching the flamefront.

Strahle and Shivashankara (1973, 1974) extended the study of Smith and Kilham (1963) to slightly larger burners and a wide range of flow velocities. Sound pressure, directionality and frequency spectra were obtained for three hydrocarbon-air mixtures. Shivashankara et al (1974) used direct photography, centred on the emission of CH radicals from the active reaction zone, to measure the volume of the reaction zone. Shivashankara et al (1975) confirmed the results of Hurle et al (1968) that acoustic pressure corresponds to the time derivative of free radical emission intensity from turbulent flames. Their experiments led to the conclusion that the noise sources are primarily located in the luminous flame brush.

Kumar (1975) tested premixed and non-premixed turbulent jet flames both in an anechoic chamber and in a hard-walled bay. The structure of the flames was studied with still photographs and high-speed movie film. The sound pressure, waveshape, directionality and frequency spectra was measured. He found significant differences between the two flame types both in their structure and their noise characteristics.

Gupta and Beer (1978) studied noise emission from "inverse" diffusion coannular jet flames using natural gas/air and helium/air. Good correlation was obtained between mean temperature and velocity, and fluctuating pressures and velocities with the overall noise emission.

Ramohalli (1979) reverses the usual process and uses measurements of the acoustic radiation from the reaction zone to obtain information on the structure, mechanics and overall characteristics of turbulent combustion.

4. NOISE SCALING LAWS

Scaling laws result from attempts to identify the important parameters and find a power-law relationship between the parameters. Bragg (1963) reduced his equation for sound power from a monopole sound source model, see equation (1), to:

$$P \propto U^3 S_L d^2. \quad (3)$$

All subsequent noise scaling laws have been based on experimental data. Smith and Kilham (1963) deduced that:

$$P \propto (U S_L d)^2. \quad (4)$$

The experimental results of Hughes and Roberts (1976) produced exponents very similar to Bragg's:

$$P \propto U^{2.8} S_L^{1.2} d^{2.3}. \quad (5)$$

Shivashankara et al (1973) found that:

$$P \propto U^3 d^2 \quad (6)$$

for fuel-rich flames. Their experimental data for fuel-lean flames produced the following, more complicated, expression:

$$P \propto U^{2.7} d^{2.8} S_L^{1.4} F^{0.4}, \quad (7)$$

$$\text{where } F = \frac{\phi\left(\frac{F}{1-F}\right)_{stoic}}{1 + \phi\left(\frac{F}{1-F}\right)_{stoic}} \quad (8)$$

Scaling laws for thermo-acoustic efficiency are obtained by dividing the acoustic power by the thermal input. The thermal input is the product of the mass flowrate of the reactants, the fuel mass fraction and the heating value of the fuel per unit mass. Shivashankara et al (1973) obtained:

$$\eta_{ta} \propto U^{2.7} d^{2.8} S_L^{1.4} F^{0.6} \quad (9)$$

for their fuel-lean flames.

Giammar and Putnam (1971) derived the following expression, which comes directly from equation (1):

$$\eta_{ta} = \left(\frac{\gamma-1}{4\pi}\right)(E-1)\left(\frac{S_L}{c}\right)\left(\frac{u'}{c}\right)^2 \quad (10)$$

Strahle and Shivashankara (1974) used dimensionless groups to obtain:

$$\eta_{ta} \propto Da_1^{0.92} \; Re^{-0.14} \; F^{-1.4} \; M^{2.72} \quad (11)$$

from the data of Shivashankara et al (1973). Strahle (1978) presented slightly different exponents in his review paper on combustion noise:

$$\eta_{ta} \propto Da_1^{0.92} \; Re^{-0.09} \; F^{-1.26} \; M^{2.68}. \quad (12)$$

He claims a standard deviation of ±1.5dB over a range of acoustic power of 40dB. The relative insignificance of the Reynolds number indicates that transport processes do not dominate the noise generation process. For turbulent flames, the large-scale energy-carrying eddies appear to dominate the noise process.

All the experimental work leading to the various scaling laws were performed on bunser-burner type, premixed, hydrocarbon-air turbulent flames. The obvious differences in the scaling laws are possibly due to variations in flame size. The ratio of the wavelength to flame size can influence the directionality of the radiated noise pattern since the wavelength (λ) affects the radiated pattern in accordance with λ's size to the burner geometry. Also, the wavelength influences the turbulent structure and the frequency content of the flame noise.

5. CONCLUSIONS

Noise from open, turbulent flames is physically caused by the fluctuating heat-release rate, which appears to be influenced by turbulence. Efficient combustion requires turbulence for good mixing of the reactants and high heat generation. Thus, the design of relatively quiet burners requires the elimination of "excess" turbulence as well as the elimination of acoustic feedback and amplifying systems.

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INFORMATION FOR CONTRIBUTORS

Items for publication in the Bulletin are of two types

(a) Shorter articles - which will appear typically under the heading 'News and Notes'

(b) Longer articles - which will appear as refereed technical articles.

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

Vol. 8 No. 3 Longer articles: Mid September; Shorter articles: Mid October
Vol. 9 No. 1 Longer articles: Mid January; Shorter articles: Mid February.

Articles may be sent directly to the editor or via the local State Bulletin representative.

There are no particular constraints on "shorter articles" except that they should be of relevance to the Society and be received on time.

Attention to the following matters will assist when processing "longer articles".

(i) Length - typically from 3 to 4 pages when printed.

(ii) Title and Authors Address - the title should be concise and honestly indicate the content of the paper. The author's name and that of his organisation together with an adequate address should also appear for the benefit of members who may wish to discuss the work privately with the author.

(iii) Summary - The summary should be self contained and be as explicit as possible. It should indicate the principal conclusions reached. That should be possible in less than 200 words. Many more members will read the summary than will read the paper. Everybody seems to be busy these days.

(iv) Main Body of the Article - This should contain an introduction, and be followed by a series of logical events which lead finally to the conclusions or recommendations. The use of headings greatly assists the reader in following the logic of the paper. The conclusions should of course be based on the work presented and not on other material.

(v) References - Any standardised system is acceptable - for example those used by Journal of Sound and Vibration, Journal of the Acoustical Society of America, or The Institution of Engineers, Australia. Page numbers and dates are important, particularly when referencing books.

(vi) Tables and Diagrams - As a general rule, Tables are best avoided. Diagrams may need to be redrawn during the editorial stage. They ought to be totally self explanatory, complete with a title, and with axes clearly labelled and units unambiguously shown.

The papers generally will be subject to review but this is not intended to discourage members. The author no doubt would prefer to have any anomaly drawn to his attention privately rather than to gain notoriety by having errors published widely.