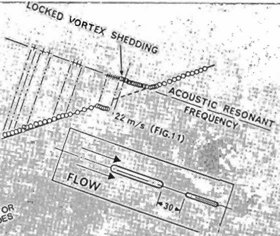
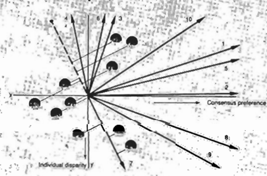
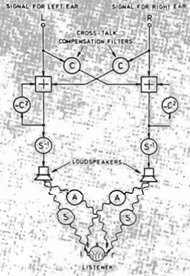
Acoustics Australia

Vol. 14 No. 1, April, 1986

AUSTRALIAN ACOUSTICAL SOCIETY



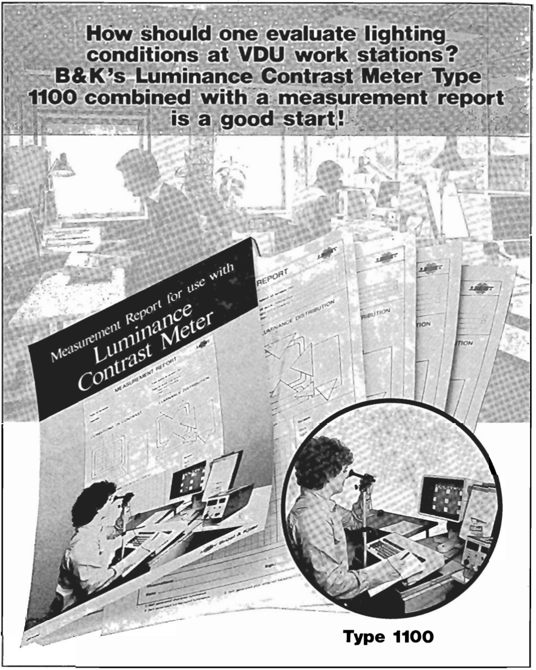




Computers in Acoustics

Microphone Sensitivity Calibration

Acoustic Resonances in Turbomachinery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Acoustics Australia

Vol. 14 No. 1 April 1986

CONTENTS —

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AUSTRALIAN NEWS —

AAS 1985 CONFERENCE

Approximately one hundred delegates participated in the 1985 AAS Conference on **Motor Vehicle and Road Traffic Noise** held on 24th-26th November. The venue was in the Blue Mountains west of Sydney although the rather damp weather inhibited enjoyment of the spectacular views and bush walks — however it did encourage attendance at the technical sessions. **Mr Peter Standen,** Director of the N.S.W. State Pollution Control Commission kindly presented the Opening Paper on behalf of the State Minister for Environment and Planning, the Hon. Bob Carr, whose planned arrival by helicopter was unfortunately cancelled. The Keynote Speaker, **Dr. Ariel Alexandre** of the O.E.C.D., Paris spoke on the topic of Strengthening Motor Vehicle Noise Abatement Policies. He pointed out that although the introduction of more stringent motor vehicle noise emission limits is proceeding slowly world-wide, here in Australia the limits will be 3 to 5 dB(A) **higher** than in the Common Market countries by 1988. Dr. Alexandre suggested three necessary components in traffic noise reduction —

- more stringent vehicle noise limits
- aggressive action against noisy driving behaviour
- local measures (route restrictions, etc.).

Incentives for low noise vehicles are a promising means of noise reduction — they may take the form of preferential treatment (allowing low noise trucks to travel in "quiet" areas), government purchasing preference, public information campaigns, etc. The O.E.C.D. is attempting to extend the concept of "friendly" vehicles globally, such vehicles are cleaner, safer and less noisy.

The *twenty-eight contributed papers,* were presented in two parallel streams — one dealing primarily with traffic noise and the other with the noise of individual vehicles. *Topics included* community response, research needs, the effect of vehicle noise regulations on traffic noise, ameliorative measures such as planning, prediction, traffic management and building attenuation, exhaust systems, passenger car and truck noise, and legislation and motor vehicle noise controls.

Lively discussion followed the presentation of most papers and this continued less formally during the coffee and meal breaks. An interesting technical exhibition was mounted adjacent to one of the meeting rooms and it was well attended.

It was a little disappointing that the conference was not better supported by AAS members, although it may have been thought by some to be a little too specialised — what was more alarming was the absence of all but a handful of delegates from the motor vehicle industry (dare one say from Ostrich Insurance?).

The hard-working conference organising committee was ably supported by officers of the N.S.W. State Pollution Control Commission to whom sincere thanks are given.

Anita Lawrence, Convenor.

SOUTH AUSTRALIA

August Technical Meeting

On 22 August, 1985 **Dr. S. A. T. Stoneman** from University College Swansea, U.K., spoke on an experimental investigation of vibration caused by flow excited acoustic fields in an axial flow compressor.

A hitherto unrecognised source of rotor blade vibration has been observed in tests on axial flow research compressors for an aero engine. The excitation has been shown to be the result of resonant waves propagating circumferentially around the annulus. The source of excitation of the acoustic resonance is vortex shedding from the blades. An experimental investigation has been undertaken of this phenomenon, using a low speed, single stage axial flow compressor test rig. A suite of computer programmes has been developed to record, transform and present test data.

September Technical Meeting and AGM

Peter Straughton presented a visual and audio feast of the architecture of great churches and the music which has been recorded in them. He regards a great church as being a work of architecture, a work of art and a musical instrument. His discussion included churches and cathedrals of England, France, Spain, Netherlands and Australia with recorded music of Bach, Handel, Couperin, Mozart, Tallis and Gobons.

This meeting was held on 19 September, 1985 and was followed by the Ninth Annual General Meeting of the South Australian Division. Following the retirement of **Peter Brook** the Divisional Committee remains the same and now has three vacant places.

VICTORIA

November Function

The End of Year Function of the Victorian Division was a dinner held, once again, at the popular Rumpoles Cinema Restaurant on 15 November, 1985. The members were delighted with the congenial (and noisy) atmosphere.

WESTERN AUSTRALIA

November Technical Meeting

On 14 November, 1985 a Forum on a Review of the Noise Abatement (Hearing Conservation in Workplaces) Regulations 1983 was held. This was a joint meeting with the AAS, the Occupational Health Society of Australia and the Australian and New Zealand Society of Occupational Medicine.

The objectives of the meeting were to increase the awareness of the document and to encourage practitioners in hearing conservation to submit well considered comments on the regulations. Three members of the Commission, **Mr. P. Shaw** (Executive Director, Department of Occupational Health, Safety and Welfare), **Mr. B. McCarthy** (Manager, Industrial Relations, Confederation of W.A. Industry) and **Mr. R. Reid** (Secretary, Trades and Labour Council, W.A.) presented short addresses. These were followed by time for audience participation and discussion.

56th ANZAAS CONFERENCE

This will be held in Palmerston North, New Zealand from 26 to 30 January 1987. It will give an opportunity for much interdisciplinary as well as specialist discussion and will convey a strong impression of the contribution of science to society to the general public. This is an important aspect of any ANZAAS Congress and is especially valid in the present difficult times for scientific endeavour.

Sectional programmes will be mainly scheduled during the mornings of the Congress week. A series of "Interest Groups" have been established for programming purposes which include:

- Physical and Mathematical Sciences
- Technological and Biochemical Sciences
- Biological Sciences
- Health Sciences
- Social Sciences
- Environmental Sciences
- Community Sciences
- Education and Communication Sciences
- Youth ANZAAS

The organisers have placed emphasis on an inter-disciplinary approach to programme content. Hence the programme for the first part of each afternoon will consist of a number of concurrent General Symposia presented by invited speakers of high international standing, from Australasia and beyond.

Further details:

56th ANZAAS Congress,
P.O. Box 5158
Palmerston North,
New Zealand.

Exchange Agreements

The Society has received information on Exchange Agreements arranged by the Academy of Science. The date for applications for 1986-1987 has passed (it was 1st February) but there is plenty of time for 1987-1988.

One exchange programme is with the Japan Society for the Promotion of Science and provides support for short-term visits by senior scientists and for post-doctoral fellowships, which are up to twelve months. The other programme is with Academia Sinica (Beijing) for either short-term or long-term visits. These exchanges can be for individual scientists or groups (max. 6) who have a specific programme or project.

Further details:

International Relations Section
The Australian Academy of Science
G.P.O. Box 783
Canberra, A.C.T. 2601

Noise Labels

From 1 March 1986 all new air-conditioners with cooling capacity greater than 12 kW will be required to have a noise label specifying the output sound power.

Environmental Noise Control Manual

This manual has been released by the Member for Planning and Environment **Mr Bob Carr.** The manual sets out which agency has the responsibility for handling particular noise complaints and how these should be dealt with. Recent amendments to the Noise Control Act have increased the powers of Local Councils, Police, and the Maritime Services Board. The Manual is designed specifically to help these authorities fulfil the increased responsibilities now placed upon them. Copies (at $30 each) are available from:

State Pollution Control Commission
157 Liverpool Street
Sydney 2000

(See Book Review in this issue.)

Australian Standards

The following Australian Standards have been released recently.

AS 2824 Non-Destructive Testing — Ultrasonic Methods — Evaluation and Quality Classification of Metal Bearing Bonds.

This standard specifies six classes of quality and sets out methods for the assessment of the quality of the bond between the bearing and its backing material.

AS 1710 Ultrasonic Testing of Carbon and Low Alloy Steel

This is a revision of the Standard covering the non-destructive testing and quality grading of steel plate. It sets out the methods for ultrasonic manual testing of steel plates of uniform thickness, in the range 5 mm to 180 mm.

AS 2822 Methods of Assessing and Predicting Speech Privacy and Speech Intelligibility

This standard applies to speech communication in various spaces (such as intelligibility in auditoria, class rooms, conference rooms and offices) and to speech privacy conditions in various spaces (such as offices, conference rooms, hotels, motels, dwellings and schools). It may also be used to assess intelligibility of a voice reinforcement system in an auditorium.

AS 2021 Aircraft Noise Intrusion — Building Siting and Construction.

This standard relates to guidelines for determining whether the extent of aircraft noise intrusion makes indoor spaces unacceptable for the activities to be, or being accommodated, the extent of the noise reduction required to provide acceptable noise levels for the activities and the type of building construction necessary to provide the necessary noise reduction.

FROM THE PRESIDENT

There have been two letters published recently in Acoustics Australia expressing concern that the Council is acting contrary to its published guidelines and the Society's Articles as regards admission of applicants without recognised tertiary qualification to the grade Member. As a Member who was admitted through the above "gate" I can assure members that I have carefully watched membership grading to ensure that the overriding requirement of an adequate understanding and experience of the applicant's chosen field of acoustics is assessed, regardless of whether the applicant has a degree or diploma or not.

At my suggestion the organisers of the Toowoomba conference are arranging for a bush barbecue in lieu of the normal formal conference dinner. The idea is to provide a better opportunity for delegates to mix, relax and talk. This first conference in Queensland, needs the support of all members, so start organising now!

Graeme Harding.

NEW MEMBERS

We have pleasure in welcoming the following new members whose gradings have now been approved.

Subscriber

Victoria Mr. J. W. Searle.

Member

New South Wales
Mr. B. D. Dick, Mr. A. C. Stewart.
Mr. S. Hlistunov, Mr. M. Maffucci.

Queensland Mr. F. H. Kamst.

Western Australia Mr. A. Zaknich.

EDITORIAL—

It is with pleasure that we announce the official formation of the new **Queensland Division** of the Society. Now that the preliminaries and the formalities are over, we look forward to receiving a stream of regular news concerning acoustical activities in the northern state. We wish all the office-bearers and members the very best for the future.

A number of articles relating to the use of computers in acoustics has appeared in both the last and current issues. We are greatly indebted to our consulting editor, **Dr. Robert Harris,** for organising this set of articles.

With regard to the writing of **articles** for Acoustics Australia, the average length for a printed article is 4-5 pages including diagrams. Occasionally we receive a manuscript that is considerably longer than this. In order that we can print 3 or 4 articles each issue, and to try to live within our budget, the editorial committee has decided not to accept articles longer than five printed pages unless exceptional circumstances warrant the printing of a long article. If an article is accepted that exceeds five printed pages, the author or his institution will be asked to bear the cost of the additional typesetting and diagram plates. We regret the need for these restrictions: if we could double the number of our advertisers then all our problems would vanish!

Howard Pollard

LETTERS —

The "Grandfather" Clause

There have been two letters recently in Acoustics Australia discussing the so-called "Grandfather" clause for admission to the grade of Member of the Australian Acoustical Society (AA Vol. 13 No. 2 and Vol. 13 No. 3).

The clause referred to is Clause 16(d) of the Society's Articles. It states that a person may be elected to the grade of Member if they satisfy the Council "that notwithstanding the lack of recognised educational qualifications he is suitable for election as a Member by reason of his verified practical or theoretical experience in the field of acoustics".

This has been interpreted by the Council of the Society in its "Guidelines for admission and grading of members" as membership gate MD (The Bulletin Vol. 11 No. 1 pp. 28-30). In these guidelines the following additional requirement is added. "Applicants must show that they have been actively engaged in the science or practice of acoustics at a professional level for not less than five years".

Applicants under the most used Membership gate MA are required to have a recognised educational qualification which is a degree or diploma comprising the equivalent of at least three years fulltime study (usually more), and to have been actively engaged in the science or practice of acoustics at a professional level for not less than two years. Even if the Member's degree is in the field of Acoustics it has taken him or her at least five years (i.e. two years after graduation) to satisfy gate MA. If the qualification is not in the field of Acoustics it will take longer to complete satisfactory experience at a professional level. Hence, the requirement of five years under gate MD is not unreasonable.

As a person's experience in Acoustics under all gates is discounted for time spent on work of a non-acoustical nature, a long period of work may be required to accumulate the required experience. If only 50 per cent of an applicant's time is spent working in Acoustics at a professional level, then it would take ten years to qualify under the "Grandfather" gate MD (Clause 16(d)). Thus, on this account alone, it becomes quite difficult to satisfy the requirements of gate MD.

The Council Standing Committee on Membership (CSCM) had existed for many years under a variety of names as a one man advisory committee to Council. In December 1982, the Council confirmed that the correct name was CSCM and appointed a chairman and two members. It empowered the CSCM "to act for and make decisions regarding grading of applications for membership on behalf of the Council". The purpose of the CSCM is to consider applications for membership grading following the recommendation by the forwarding division. Any differences of opinion between CSCM and the division are resolved before a final decision is made by CSCM.

Fergus Frickle (AA Vol. 13 No. 2 p. 80) claims "that since the Annual General Meeting at Cowes in 1981 the Council of the Society has been resisting attempts to bring in new members using Clause 16(d)". The CSCM does not believe that this is the case. Indeed, while consulting the Council Minutes for December 1982 concerning the reorganisation of CSCM it was noted that two Members were elected under Clause 16(d).

The CSCM welcomes debate in this very difficult area. If members of the society are unhappy with the current admission policies they should suggest changes to the wording of the "Guidelines for admission and grading of members" and, if necessary, the Articles of Association of the Society.

Ken Cook
Chairman,
on behalf of the Council Standing Committee on Membership.
10 January, 1986

* * *

Noise: Problems and Remedies

In his article "Noise: Problems and Remedies" Ac. Aust. Vol. 13, p. 99, December 1985) Kenneth H. Gifford scrupulously ascribes many of his "legal aspects" to relevant cases; the references are there in complete detail so that anybody can conveniently look them up. Yet, curiously, he also makes two unsubstantiated statements.

I refer to the first: "Noise, as doctors have proved, plays a substantial part in causing fatigue". Proved?

The second needs even closer scrutiny: "A leading ear specialist has said that by the time the average teenager of today reaches the age of 21, ten per cent of their hearing capacity has been lost because of the noise to which they have been subjected". Ten per cent?

It would be helpful if he would bring to our notice the studies on which these opinions are based.

Volney Bulteau, D.L.O., F.R.A.C.S.
R.P.A.H. Medical Centre,
Newtown.
9 December, 1985

Author's reply

Thank you for your comment that the references I made to legal decisions "are there in complete detail so that anybody can conveniently look them up". I agree with you that it is important that all references should be available; and, in all my publications, whether "The Town Planning and Local Government Guide", the two series of law reports which I edit (Local Government Reports of Australia and Australian Planning Appeals Decisions) or the various textbooks I have written, I have always given complete references.

The two medical aspects to which you advert were based on statements made by doctors. The first ("Noise, as doctors have proved, plays a substantial part in causing fatigue") refers to statements made to me by various doctors in workers' compensation and noise nuisance cases; but, as my practice at the bar extended over a period of almost forty years, I cannot now recall the names of those doctors. "Proved" was used in the legal sense since, as I recall, evidence of noise-induced fatigue was given and accepted.

The second statement ("A leading ear specialist has said that by the time the average teenager of today reaches the age of 21, ten per cent of their hearing capacity has been lost because of the noise to which they have been subjected") is exactly what it says it is: a statement made by a leading ear specialist. It is an observation based upon his own experience as a leading specialist over many years.

Kenneth H. Gifford, Q.C.
Editor, the Town Planning and Local Government Guide. 22 January, 1986

* * *

Cordless telephones cause of hearing loss in U.S.

A New York specialist has reported 28 cases of permanent hearing loss due to cordless telephones.

The ear damage was caused in most cases by the telephone's loud bell which rings directly into the user's ear when the flip switch is not manually moved from the standby to talk position.

In all cordless telephones except one model the sound device for signalling incoming calls and the intercom or page, is located in the ear piece.

Another reported cause of permanent hearing loss was a loud cracking noise like a gun shot which is believed to have been caused by some kind of radio interference.

Australian Safety News October, 1984.

PEOPLE —

Marshall Smither is acting Director at NAL while **Ray Piesse** has been seconded to explore the possibilities of alternative arrangements for the procurement of hearing aids by NAL.

A users group committee of seven members from both Industry and Government sectors has been established to co-ordinate the usage of the facilities at NAL. **Fergus Fricke** is the leader of this group and their first meeting will be late March.

* * *

Dick Godson has left BMI and joined Richard Heggie & Assoc. in January 1986.

* * *

Anita Lawrence who has been involved with many of the SAA committees has recently been elected to the Executive Board of SAA.

* * *

From 11th February 1986, the NSW **SPCC Noise Branch** has moved location from the 7th to the 5th floor of the Union Carbide Building (157 Liverpool Street). This downward move has an upward aspect as they are now closer to the Executive Suite!

* * *

Greg Lee-Manwan is now ensconced in Townsville running the recently opened office of the Queensland Noise Abatement Authority.

* * *

Professor Graeme Clarke who has spent 20 years developing what has become known as the bionic ear has again been honoured by his receipt on Australia Day of the Advance Australia award.

Andy Hede has moved from his position of Chief Noise Control Officer at the Environment Protection Authority of Victoria, to the Victorian Public Service Board. He has advised me that "he intends to maintain his interest in acoustics, and will be on the lookout for research opportunities in the future".

With Andy Hede's move from Victoria's EPA, much speculation has been ecntred on his replacement. We now know that **Norm Parris** has been appointed to the position. Norm has been with the EPA Noise Control Branch virtually since its inception and was, prior to his new appointment, a principal noise control officer in the branch.

* * *

Maurie Nelms has retired from his position at the N.S.W. Public Works Department. Rumours about his successor abound.

* * *

Graeme Moss. It is with deep regret that I advise that one of the nicest gentlemen in acoustics died suddenly in Box Hill Hospital on February 28. Graeme's death is a significant loss to Watson Moss Growcott Acoustics Pty Ltd where he has been a principal acoustical consultant through the successive changes of that company's name and organisation since he left the CSIRO to join them some fifteen or more years ago. The funeral was attended by nearly every acoustical consultant in Melbourne; all told about 20 members of the Victoria Division paid tribute to Graeme.

Andrew Middlin has recently returned to Queensland after three years working with Vipac in Melbourne. Andrew whose special area of interest is the effects of low frequency vibration on humans joins Vipac's Brisbane office.

* * *

Ian Sheppard, of quiet lawnmower fame, spent six months last year at Stanford University where he examined the stability of natural gas diffusion flames. He worked with **Professor Brian Cantwell** who plans to continue the collaboration with CSIRO Division of Engineering Technology and Ian Sheppard during a six month visit to Melbourne supported by the University of Melbourne.

* * *

John Shearer, formerly of Shearer and Gardiner in Adelaide is still moving around the world. After some time in the U.K. where he worked on acoustic problems of oil rigs in the North Sea, he has now joined Wilson, Ihrig and Assoc. in the USA.

* * *

Don Gibson, head of the Division of Engineering Technology also spent time overseas last year, including attending a ten week course at M.I.T. on "Management of Research and Development and Technology based Inovation". The course was run by the Sloan School of Management for practising R & D managers. Of the 71 participants, 60 were from private R & D organisations! Don says the course "showed graphically where Don Gibson did wrong".

Graeme Harding

Industry and Govts resist lower noise levels

A leading hearing researcher with the National Acoustic Laboratories, Sydney says State Governments and industry have failed to reduce noise limits as recommended by the National Health and Medical Research Council. In an article in the June 1985 "Hearing Technology Review," **Dick Waugh** says the maximum level of exposure, 90 dB(A) per eight hours, has been adopted by most states in legislation, but they have failed to progressively reduce levels as called for by the NH & MRC.

The council said in 1973 in its model regulations that the exposure level should be reduced to 85 dB(A) per eight hours in all new premises and progressively over a period of five years in all workplaces. The article points out that compliance with state noise regulations is "far from perfect" and in many small industries is almost non-existent.

Waugh also points out the difficulties caused by the variations between the states and the fact that regulations are limited by the Act under which they were introduced. "For example, in Queensland the regulations fall under the Factories and Shops Act, thus many noise-exposed workers in the agricultural, fisheries and entertainment industries are excluded," he says.

The ACTU has consistently argued for an *immediate reduction in noise levels to 85 dB(A) and for 80 dB(A) within three years.* This call has been supported by the NH & MRC hearing committee which said: "The estimated risks associated with exposure to noise levels of 85 dB(A) and 90 dB(A) over a working lifetime lead to an incidence of hearing loss in the working community which is unacceptable on medical grounds in the long term."

In his article, Waugh calls for a more clearly defined method of measuring impulse noise, more determined enforcement of regulations, a review of current regulations, better education, more attractive, comfortable and reliable personal hearing protectors and a national hearing strategy. Industrial deafness is Australia's most widespread but easily preventable occupational health hazard. A co-ordinated national strategy will be one of the early tasks for the National Occupational Health and Safety Commission.

Occupational Health Newsletter 24 June, 1985.

* * *

Conference Proceedings

INTER-NOISE 85, the 1985 International Conference on Noise Control Engineering was held in Munich, Federal Republic of Germany on 18-20 September, 1985. There were 351 technical papers presented at the meeting covering all areas of noise control engineering, including aircraft noise, road traffic noise, machinery noise reduction, sound intensity measurement techniques, modern instrumentation for noise control and noise regulations. The Proceedings of INTER-NOISE are now available as a two-volume set for $80 (U.S.) There is an additional $30 for overseas air mail postage.

The *Second International Congress on Acoustic Intensity* was held at the French Technique des Industries Mechaniques (CETIM) in Senlis, France on 23-26 September, 1985. Among the subjects covered were instrumentation, vector acoustics, sound radiation, intensity in the presence of flow, intensity flow in structures, techniques for determination of sound power, noise source localisation, impedance measurements, absorption measurements and sound transmission measurements. The technical papers presented at this conference have been collected and published in a bound volume which contains 570 pages of technical papers; 58 are in English and 20 are in French with English abstracts and figure captions. The cost for this volume is $80 (U.S.) with an additional $27 for overseas air mail postage.

Payment for either of these Proceedings must be made in U.S. funds through a U.S. bank (or bank which has correspondent relationship in U.S.).

Orders to . . .

Noise Control Foundation, P.O. Box 3469, Arlington Beach, Poughkeepsie, NY 12603, U.S.A.

Computers in Acoustics

Manfred R. Schroeder
Drittes Physikalisches Institut
Universitaet Goettingen, F.R. Germany
AT&T Bell Laboratories
Murray Hill, NJ 07974

ABSTRACT: A number of applications of computers to acoustics are described ranging from early simulation studies to recent work on speech and speaker recognition. Among topics discussed are problems encountered with the Philharmonic Hall in New York: the "clouds" leading to destructive wave interference at low frequencies and further low frequency attenuation caused by the "seat effect". Extensive work performed at the University of Goettingen, relating the physical parameters of concert halls and their subjective quality, enabled listeners to make instantaneous comparisons between different halls, the results being evaluated by a "preference test". Interaural dissimilarity was found to be the most important parameter governing subjective preference. Other topics discussed include experiments with lateral sound, the design of reflection phase gratings to control ceiling and wall diffusion, the acoustic camera, the use of on-line computers and computer music.

INTRODUCTION

Computers arose very early in acoustics. Already in 1958, crucial problems in both speech coding and room acoustics were being successfully attacked by computer simulation.

The main hurdle in compressing speech signals for more efficient storage and transmission was the complexity of the circuits required for the necessary operations. There were no dearth of new ideas, but their implementation far exceeded the capabilities of soldering iron and wire spool. It was primarily M.V. Mathews who pointed out at the time that signal processing was — of course! — described by mathematical expressions and that such expressions could — again, of course — be executed on digital computers. These two "of course" were the beginning of digital simulation that grew and grew, until it became nearly unthinkable in many fields — not just acoustics — to proceed without it. (See [1] for early references up to 1968.)

DIGITAL SIMULATION

In the early dawn of computer simulation, a single sentence of speech meant a trunkful of computer cards, hand-delivered from Bell Laboratories to IBM headquarters in New York City. (No magnetic tape input/output then; and even the largest machine at Bell Labs was inadequate for our jobs.)

One of the main benefits of digital simulation, besides the rapid progress it engendered was — curiously — rather unexpected. While before digital simulation many unworkable ideas were never exposed for what they were — inadequate implementation was much easier to blame — proper digital simulation left little room for cheap excuses. One of the main advantages was indeed the very fact that it allowed people to free themselves from their pet projects ("if my idea could only be implemented the way I conceived it!") in order to focus on the *workable* [2].

* Manfred Schroeder is the Director of the Drittes Physikalisches Institut at the University of Goettingen, Germany and also continues his research association with the AT&T Bell Laboratories in New Jersey. This article was specially written for our current series on the use of computers in acoustics.

ARTIFICIAL REVERBERATION

Not long after the first simulation in speech, the author saw a resounding opportunity for digital simulation in room acoustics. He had just heard about the awful spectral distortions that some artificial ("spring") reverberators were then (ca. 1958) producing and it occurred to him that artificial reverberation should be produced by electronic all-pass networks. And what was more natural than to simulate the "natural-sounding" artificial reverberation on the computer. (I still remember the expressions of astonishment and disbelief on the part of our computer colleagues when symphonic music — reverberated on their numerical machines — emerged from the digital-to-analog converters [3].)

CONCERT HALL ACOUSTICS

Another opportunity for the use of computers in acoustics arose in September 1962 when Philharmonic Hall, the initial instalment of New York City's Lincoln Center for the Performing Arts, first bowed before the world of music under the baton of its first chief tenant (Leonard Bernstein), in the presence of the First Lady of the Republic (Jacqueline Kennedy). Acoustical expectations were soaring. But the elegant new hall on Upper Broadway, carefully designed by its acoustical consultants on the basis of encompassing data, meticulously collected by L. Beranek [4] in concert halls around the globe, left something to be desired. The high hopes held for the hall were soon dashed.

In nontechnical terms, there was a lack of "warmth" and "intimacy". There were also audible echoes — not from some mythical past of perfect musical balance, but of a harsher origin: the rear of the hall. The musicians, too, did not remain silent: they could not always hear each other well enough, thus making ensemble playing difficult.

George Szell, the most vociferous of the leading conductors, called for more "microdiffusion" and derided the overhead acoustic panels (untranslatably) as "schwangere Froesche mit beleuchtetem Bauchnabel".

In this cacophony of complaints, Lincoln Center sought technical help from a resourceful neighbour on Lower Broadway, the American Telephone and Telegraph Company. AT&T in turn asked Bell Laboratories, who appointed the author to join a committee of four "experts" chaired by the eminent physicist and former Chancellor of the University of California at Los Angeles, Vern Knudsen, to see what could be done (without building a new hall).

PRECISION MEASUREMENTS

Bell Laboratories charter in this rescue mission was to ascertain — by acoustic measurements — the physical facts and their potential subjective significance. As a first step, new measurement methods, based on computer-generated test tones and digital filtering, were developed, aiming for high precision in both temporal and spectral aspects of the hall's acoustic response [5]. These measurements revealed a strong attenuation of musically important low frequency components in the reflection from the overhead panels or "clouds" [6]. This effect was also found in model experiments performed by E. Meyer and H. Kuttruff at the University of Goettingen [7].

The clouds were introduced into Philharmonic Hall by the original consultants for the express purpose of interpolating "early" reflections between the direct sound and late-arriving energy. But the cloud size and shape was inadequate to diffuse low frequencies and, to compound the insufficiency, the regular, crystal-lattice-like array in which they were arranged along the ceiling led to destructive wave interference at adjacent low frequencies.

This lack of low frequencies in the first overhead reflection revealed another low-frequency deficiency discovered by G.M. Sessler and J.E. West: a progressive attenuation of low frequencies in the *direct* sound as it grazes across the rows of seats [8]. (This "seat effect" must exist in many other halls in which the main floor is insufficiently raked; but it is usually masked by the presence of low-frequency components in the early overhead reflections.)

As a result of these various attenuating circumstances, the low notes in the range from 100 to 250 Hz, compared to the higher frequencies, were depressed by as much as 15 dB in much of the main seating area.

However, there was at least one excellent seat: "A 15" on the Second Terrace (old style, the number system has since been changed several times). Before the measurements were begun, the ushers (students of the Juilliard School of Music) had pointed out this seat as optimum in their opinion. And, lo and listen, in the measurements, too, "A 15" emerged as best by far: the gap of 15 dB between low notes and high notes was narrowed to less than 2 dB.

SUBJECTIVE EFFECTS

I think it is no exaggeration to say that only the precision of digital signal generation and processing made these results as accurate and reliable as they were. But there was another, less predictable, effect of the overhead panels: what reflections they interpolated arrived at a listener's two ears almost simultaneously. The subjective consequence of this lack of *lateral* reflections is a sensation of "detachment" from the sound generated on the stage, rather than a desirable feeling of *envelopment* by the music [9].

In order to elucidate some of the fundamental problems in concert hall acoustics the author in 1969 petitioned the German Science Foundation (DFG) to support basic research on the interplay between the physical parameters of a concert hall and its subjective quality. The work was performed at the Drittes Physikalisches Institut of the University of Goettingen with the collaboration of D. Gottlob, K.F. Siebrasse, U. Eysholdt and Y. Ando from the University of Kobe, Japan, who joined the Goettingen group as a Humboldt Foundation Fellow.

Reliable subjective evaluations of the acoustic quality of different halls had become possible because of a new method, invented by B.S. Atal and the author and further refined by P. Damaske, B. Wagener and V. Mellert, that allowed the faithful reproduction, in a suitable anechoic chamber, of music played in different halls [10]. For this purpose, two-channel *Kunstkopf* ("dummy-head") recordings were made at "strategic" locations throughout the audience area in each hall to be evaluated. The musical "input" for these tests was a recording in an anechoic environment of Mozart's Jupiter Symphony, kindly provided by the BBC Orchestra [11]. Similar tests were also performed with *live* (but of course not completely reproducible) music by G. Plenge, H. Wilkens, P. Lehmann and R. Wettschureck from L. Cremer's Institut fur Technische Akustik at the Technical University of Berlin.

The recordings, made in some 20 different halls, were played back over two loudspeakers, after having been processed electronically in such a way that the original dummy-head ear signals are reproduced at a listener's ears when he was seated in a given position in front of the speakers. Listeners were thus able to make repeated *instantaneous* comparisons between different halls. In this manner, such pronounced differences as exist between the Vienna Musikvereinssaal and the Royal Festival Hall, London, become overpowering. But even very subtle acoustic distinctions are easily perceived in these direct comparisons. The wide spatial separation between different halls has finally been overcome; they are all brought together for a grand rendezvous in the same test chamber!

To avoid biasing the subjective results by misleading semantics, the use of ill-defined adjectives was religiously eschewed. This was achieved by reducing the evaluation for each pair of seats (in the same or different halls) to a simple *preference test*. Rather than describing their subjective impressions by such nebulous terms as "sweet", "cold", "warm", "rich", "narrow", "clear", "intimate" or the like, listeners had to state solely whether they preferred condition A or B. Many hundred such preference judgments were combined by a multidimensional scaling technique (invented by J. Douglas Carroll at Bell Laboratories [12]) and used to construct, on a digital computer, a three-dimensional *preference space*. The two main dimensions of this spatial representation of the data could be identified as "consensus preference" and "individual differences in preference", respectively. (The third dimension was essentially "noise"). This space then represents listeners' acoustic preferences without semantic bias, while giving full weight to their different musical tastes [13].

INTERAURAL DISSIMILARITY

Cross-correlation of the preference data with the *physical* parameters of the different halls revealed that, besides reverberation time and other well-known effects, *interaural dissimilarity* was the most important parameter governing subjective preference. The greater the dissimilarity between the two ear signals (as would obtain in old-style narrow halls with high ceilings) the greater the consensus preference, *independent of individual tastes* [13].

Most modern wide halls showed up with a low preference ranking, confirming the above interpretation that narrow halls are good because they provide earlier arriving, and therefore more intense, lateral sound. The importance of early lateral reflections was also stressed by A.H. Marshall and M. Barron in earlier, independent investigations [14]. The preponderance of lateral sound leads to a greater (preferred!) interaural dissimilarity, which in turn results in a feeling of being "enveloped" by, rather than separated from, the music [15].

MORE LATERAL SOUND

This then was the main result of the subjective tests conducted over several years at Goettingen. They were supplemented by numerous other experiments involving sound fields created by both analog techniques and digital modification of existing concert halls. In the latter method, the impulse responses of wide halls, deficient in lateral sound, are modified on the computer by the addition of simulated lateral reflections. These modified responses are then convolved with music and subjectively evaluated. In this manner, the connection between early lateral reflections and preference was settled beyond reasonable doubt. In fact, in these tests *everything* remained unaltered, except for the addition of lateral reflections [16].

NUMBER THEORY!

The remaining nontrivial question, now that the causes of prior failings have been identified, is how to avoid costly mistakes in the future. Wide halls with relatively low ceilings are, unfortunately, here to stay: high building costs as well as larger (and wider) audiences will see to that. Of course, detrimental ceiling reflections could be eliminated by sound absorption in the upper reaches of the hall. But, especially in a large modern hall whose volume has to be filled by a single instrument or voice, every "phonon" counts; there is no surplus acoustic energy available to be wasted.

The solution to this dilemma came in the 1970s: surface structures for ceiling and walls that diffuse the sound as widely as possible over the entire frequency range of interest. The design principles for such "reflection phase gratings" (as the physicist would call such structures that diffuse sound, but do not absorb it) came from the unlikely mathematical field of *number theory* [17].

Thus, a symbiosis of methods from a wide spectrum of scholarly disciplines — digital measurement methods, sound field reproduction and computer simulation, multidimensional scaling on the computer, and number theory — has finally elevated the art of concert hall acoustics to the level of a reliable science [18].

In the meantime number-theoretic sound diffusors (based on "quadratic residues" or "primitive roots") have been installed in several new halls (and numerous sound studios) with, apparently, great success [19]. In fact, this is what one should expect, given that such diffusors break up solid specular reflections (that can also give rise to unpleasant echoes) into broad lateral patterns of *mini*-reflections that arrive at a listener's ears *laterally* rather than from straight above.

Perhaps the ultimate use of computers is the simulation of concert halls while they are still in the planning stage. The programming of a computer on the basis of architectural plans is of course far from easy, but considering the financial (and other) stakes involved, no effort should be spared to promote progress in this direction [20].

RANDOM WAVE INTERFERENCE

One of the early uses of digital computers in room acoustics was the author's simulation of randomly interfering waves and their effects on (sound) transmission responses. In this manner his theoretic prediction based on complex Gaussian statistics above a critical "large-room frequency" could be validated by "computer experiments" [21]. In the last decade this theory has taken on a new importance in the interpretation of laser speckle statistics.

REVERBERATION TIME

Given the fact that reverberation time formulas can only give an approximate idea of the reverberation process, one has to rely on solving the appropriate integral equations unless something can be done by digital calculation. Some progress in this direction has recently been made [22].

ACOUSTIC CAMERA

Another noteworthy use of computers in acoustics is the realisation of an "acoustic camera". In the acoustic camera the sound field diffracted by some unknown object is recorded at a number of sampling points that are accessible to microphones. By solving the so-called "inverse diffraction problem" on a digital computer, the soundfield in the immediate neighbourhood of the unknown object can be reconstructed [23]. This calculated soundfield, in turn, defines the shape of the diffracting object and its surface impedance (hard, soft, etc). The application of this method in nondestructive materials testing and especially medical diagnostics, is obvious. Again the digital computer was crucial, because the kind of precision that is required in solving inverse diffraction problems could not be realised with analog methods.

ARTICULATORY STUDIES

A related application of digital computers is the derivation of vocal tract shapes (tongue positions, etc) from the measured sound pressure or acoustic impedance at the lips [24]. This method of monitoring the motions of the articulatory organs in the human vocal tract avoids the dangers of excessive x-ray exposure that goes with the previously used cine-radiographic methods.

ON-LINE COMPUTERS

One of the most important uses of computers occurs as on-line computers for research in speech and hearing [25]. In contemporary psycho-acoustic work, test stimuli are prepared by computer and presented to listeners, whose responses are also evaluated by the computer. Furthermore, the computer can select subsequent stimuli "on the run" based on the subject's current responses.

In on-line speech research the vocal tract model cannot only be displayed on a video monitor but the model's acoustic output can also be made immediately audible for subjective evaluation by the experimenter — who is then free to change his model parameters until a satisfactory speech quality is obtained.

COMPUTER MUSIC

M.V. Mathews, who introduced digital simulation to acoustics signal processing, also pioneered the use of computers in music [26]. From simulating traditional instruments to composing and synthesising new sounds, both off-line and in real time, from conducting an "orchestra" of computer voices, to the testing of new musical scales, the place of the computer in the future of music is firmly established [27].

SPEECH AND SPEAKER RECOGNITION

Automatic speech recognition and speaker verification are among the most challenging problems of modern man-machine interaction. Among their numerous useful applications are a future "chequeless" society in which all financial transactions are executed over the telephone and "signed" by voice. Access to confidential data can be made secure by speaker certification. Other applications include voice information and reservation systems covering a wide spectrum of human activities from travel and study to purchasing and partner matching. In these applications, spoken requests (over the telephone, say) are understood by machines and answered by synthesised voice. Voice control of computers and spacecraft (and machines in general whose operators have limited use of their hands) is an aspiration of long standing. Activation by voice could be particularly beneficial for the severely handicapped who have lost one or several limbs.

The surgeon, in the middle of a difficult operation, needing the latest medical information, is another instance where only the acoustic channels are still fully available both for requesting and receiving the urgently required advice. And finally, the editing of "manuscripts" by *voice* may supplement much present paper-and-pencil pushing or mouse play at the graphics terminal. (See [28] for a recent "snapshot" of the state of the art and further references.)

CONCLUSION

In the last 30 years, digital computers, both large central installations and small "dedicated" on-line processors, have proven powerful research and design tools in many human endeavours — including acoustics, from which digital simulation received strong early impulses. Yet with optical and massive parallel computing rising on the horizon, the past will prove only a beginning.

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TECHNICAL NOTES —

Early diagnosis of deafness

A new compact portable instrument that will enable **deafness due to malfunction of the cochlea** (part of the inner ear) to be detected at an early stage has been developed by the Peters Audiometric and Acoustic Equipment division of Medi-tech International, under licence from the British Technology Group. The **AP200 Otoacoustic Emission Processor** has been developed from work done on 'cochlear echoes' by **Dr. David Kemp** at the Institute of Laryngology and Otology (based at the Royal National Throat, Nose and Ear Hospital, London).

The AP200 records, analyses and interprets cochlear echoes. The cochlea is the spirally coiled part of the inner ear that translates mechanical vibrations (i.e. sound waves) into nerve impulses that are processed and interpreted by the brain. *When a healthy ear receives a sound, it has been found that the cochlea, as well as absorbing the sound, sends a weak echo of it back to the ear canal.* This results in an otoacoustic emission and, for this to be produced, a near normal degree of cochlear activity is needed. If the cochlear function is impaired sufficiently to cause a hearing loss of as little as 20 dB, the power of these emissions is greatly reduced at the frequency of the hearing loss.

With an earpiece containing a small loudspeaker to produce repeated 'clicks', the AP200 picks up and records the associated cochlear echoes using a miniature microphone also mounted in the earpiece. Signal processing electronics separates the cochlear response from noise and middle ear reactions. The echo is then broken down into frequency components.

Because no two persons' echo responses are the same the cochlear echo response forms a unique 'ear print' which under normal conditions remains unchanged for years. The AP200 can thus be used for the regular monitoring of cochlear function of people at risk of progressive deafness due to prolonged exposure to high noise levels.

Analysis of otological emissions with the AP200 is painless, noninvasive and does not rely on the co-operation of the patient or subjective responses. It is, therefore, particularly useful as part of paediatric hearing testing or in cases of suspected false hearing loss claims.

Physics Bulletin
12 December, 1985.

Lasers and Guitars

Sydney scientists and musical instrument-makers have joined forces in an unusual high-technology research project aimed at building a **better guitar.**

Although the instrument's musical pedigree can be traced back 5000 years, no-one knows for sure — apart from an expert ear — just what construction features distinguish a good guitar from a bad one.

But the research project, **details of which will soon be published in the ANZAAS journal "Search",** shows that with a little help from laser holography and sophisticated computer models, some of the secrets can be unlocked.

Holographic images of guitar soundboards (the upper wooden figure-eight portion of the guitar) have been made by **Dr Bob Oreb at the CSIRO division of applied physics, at Lindfield.**

They show the distinctive vibration patterns set up in the soundboard at various frequencies.

"It's the interaction of the air inside the guitar and the vibrations of the soundboard that produce the note. The strings are just a means of exciting a sound from the body of the instrument," Dr. Oreb said.

By comparing the way the soundboards vibrate, Dr. Oreb and Sydney guitar-maker **Mr. Simon Marty, a PhD student at Sydney University,** are trying to establish the best characteristics for a guitar.

The results have been surprising in some cases: a $4500 Spanish guitar, for example, vibrates in a distorted and irregular pattern, while cheaper guitars show a pleasing symmetry.

Dr. Oreb says it may be that the better guitar has a more complex vibration pattern, giving it a richer, more complex sound.

It is hoped that the scientific approach can be applied as well to the making of other acoustic instruments, including violins, for which a potentially large export market exists.

Bob Beale
Sydney Morning Herald
13 December, 1985.

Computer Control of the Acoustic Impedance Tube

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The acoustic absorptivity of many materials may be conveniently measured using the acoustic impedance tube. This comprises a long heavy-walled tube in which acoustic plane waves are induced by a loudspeaker placed at one end or in a suitably designed side-branch. A test sample of the material under investigation is fitted into a heavy end cap attached to the end of the tube. The sound waves propagating down the tube impinge on the sample and are partially reflected by it. Measurements of the acoustic pressure in the sound field in front of the sample will yield values for the reflectivity of the sample and hence its specific acoustic impedance.

In the conventional apparatus — as described in Australian Standard AS 1935 (1976) or the Bruel and Kjaer Tube Apparatus 4006 — the sound field in front of the sample is explored using a travelling microphone or microphone probe placed directly in the field. At each frequency of measurement the microphone is moved through the field and the magnitudes and positions of the pressure maxima and minima determined. These measurements are then related to complex reflectivity, R, of the sample viz

$$R = |R| \exp(j\phi),$$
$$|R| = (SWR - 1)/(SWR + 1)$$
$$\phi = [x_1/(x_2 - x_1) - 1]\,\pi$$

where SWR is the standing wave ratio or the ratio of the pressure maximum to minimum and x_1 and x_2 are the distances of the 1st and 2nd pressure minima from the sample face.

This technique is time consuming and not readily automated (Dunlop 1976) because of the mechanical complexity of the operation. An alternative technique is that explored by Seybert and Ross (1977) which makes use of two fixed microphones placed in the reflection sound field in front of the sample. The reflectivity of the sample may be determined from measurements of the pressure ratio P_{12} and phase difference ϕ_{12} between these two positions viz

$$R = (P_{12} \exp(-jkx_2) - \exp(-jkx_1))/$$
$$(\exp(jkx_1) - P_{12} \exp(jkx_2))$$

where x_1 and x_2 are the distances of the microphones from the sample face and k the wave number of the sound waves. This technique is more suited to computer control, the arrangement shown in Fig. 1 having been operated successfully for some years in the Acoustics Laboratory, School of Physics, UNSW.

As shown in Fig. 1, the impedance tube is acoustically excited using the band limited noise output from a spectrum analyser (Hewlett Packard type 3582A). The signals detected at x_1 and x_2 are then passed through this analyser to give values of P_{12} and ϕ_{12} at

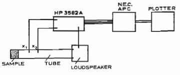

Fig. 1. Schematic of acoustic impedance tube arrangement.

each of 128 discrete frequencies within the pass band used. The analysis is repeated and averaged over a number of scans (32 being a convenient number). The spectrum analyser is controlled by a computer (Apple II or N.E.C.) through an I.E.E.E. interface card and the 256 data points (128 each of P_{12} and ϕ_{12}) resulting from the averaging are transferred to the computer for computation and plotting of absorptivity or other acoustic property. A typical result of the specific acoustic impedance of a sample consisting of 150 mm of open cell flexible polystyrene foam is shown in Fig. 2.

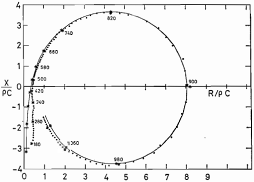

Fig. 2. Plots on the complex impedance plane of the specific acoustic impedance of 150 mm of open cell polystyrene foam with rigid backing (solid curve calculated points; dots, measured points; *frequency markers in Hertz).

The specific acoustic impedance, Z, of a length, *l*, of absorbing material placed on a rigid backing may be described by the equation (Zwikker and Kosten 1949)

$$Z = W \coth \gamma l$$

where W and γ are the characteristic acoustic impedance and propagation constant of the material being related as

$$W = \varrho C(1 - j\delta/2)$$

and $\gamma = j2\pi f/C(1 - j\delta/2)$

where C and ϱ are the sound speed and acoustic density in the material and δ is the lag between the phase of the pressure and condensation waves indicating dissipation of energy. This formula may then be fitted to the experimental points, stored in the computer, using a curve fitting algorithm (e.g. IBM Share Program EID-NLIN No. 3094.01) and the acoustic parameters ϱ, C and δ obtained. Such a curve fitting has been applied to the results shown in Fig. 2.

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Experimental Studies of Acoustic Resonant Phenomena in Turbomachinery

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ABSTRACT: An experimental investigation of flow-induced acoustic resonances in an axial flow compressor (conducted at the University College Swansea) is described and discussed. A further experimental investigation of tandem plates in a wind tunnel, as a model of the turbomachinery blade rolls (conducted at CSIRO, Melbourne, Australia) is presented. This is done both in terms of a new phenomenon which has been identified and also in terms of the correlation between the experimental data gathered in the turbomachine and the wind tunnel.

INTRODUCTION

Acoustic resonances in turbomachinery have been known and studied for a number of years [1]. Latterly, in collaboration with Rolls-Royce, Parker and Stoneman have been investigating the nature of acoustic resonances in a single stage, axial flow compressor test rig to identify the parameters which are a major influence on the generation of circumferentially propagating acoustic waves. The collaboration arose from the identification by Rolls-Royce of unacceptably high rotor blade stresses in a research compressor for the RB-211 aero engine.

This article briefly re-states the main conclusions of the above work [2 to 5] and reports the results of wind tunnel experiments conducted at the Division of Energy Technology, CSIRO, Melbourne, to investigate the acoustic properties of tandem plate configurations, of varying axial spacing, which was intended to model the Inlet Guide Vane (IGV) and rotor blade geometry of the turbomachine.

TURBOMACHINERY TEST RIG AND RESULTS, University College Swansea

Figure 1 is a half-sectional elevation of the single stage axial flow compressor test rig at the Department of Mechanical Engineering, University College Swansea.

Figure 2 is a partially assembled view of the test rig showing the major components.

Figure 3 shows the blade geometries for the two main phases of the work, i.e. vortex shedding from (a) 33 zero stagger, slab-sided, rounded trailing edged IGVs and (b) 33 and 66 zero stagger, airfoil sectioned IGVs subjected to incident flow produced by an upstream row of pre-swirl vanes. The results from the slab-sided test were representative of all the results obtained and the following is therefore limited to a description and discussion of this geometry.

Figure 4 shows the frequency/flow velocity relationship for a stationary microphone at mid-chord and between two IGVs. These results are for an IGV/rotor axial spacing of 33 mm which, non-dimensionalised in terms of the thickness of the vortex shedding IGVs (5 mm), is a space to thickness ratio of 6.6. It can be seen that the resonances manifest themselves as a series of locally approximately constant frequency lines over small ranges of velocity, with the mode number varying from 7 to 16, propagating sometimes with and sometimes against the rotor direction of rotation (indicated and positive and negative respectively). The range of Strouhal numbers over which the resonances were generated being 0.229 to 0.292.

Figure 5 shows the relationship for a space to thickness ratio of 1.04 where the long series of resonances has been replaced by just two resonances, modes 15 and 16 which are frequency locked over a very large velocity range, corresponding to a range of Strouhal numbers from 0.252 to 0.335.

When the space to thickness ratio was an intermediate value of 2.68 (Figure 6) two series of resonances were generated. As the flow velocity was decreased the modes changed in a series of steps from 16 to 12 whereupon the mode number jumped to 16 again (at approximately 42 metres per second), decreasing to mode 8 with decreasing flow velocity. The Strouhal number ranges corresponding to this series of resonances were 0.212 to 0.260 for the high velocity series and 0.316 to 0.363 for the low velocity series. It was to provide an explanation of the means by which two very different resonances can be excited at similar flow velocities as a result of changing the axial blade spacing that an experimental programme was undertaken in collaboration with CSIRO.

TANDEM PLATES IN A WIND TUNNEL, CSIRO

To simulate the geometry of a vortex shedding IGV positioned upstream of a rotor row, two plates were mounted on the axial centre line of a wind tunnel in a tandem configuration (Figure 7) such that the axial spacing between the two plates could be varied from 0 to 20 mm (space to thickness ratios of 0 to 25). The vortex shedding and the acoustic field were monitored by a probe microphone located in the wake region of the upstream plate and a 3582A Hewlett-Packard Spectrum Analyser.

Figure 8 shows the now familiar result for a single plate in a wind tunnel where over a limited speed range the vortex shedding excites the duct acoustic resonance which in turn

* The material in this article includes work conducted initially by Dr Stoneman in the U.K. and work conducted jointly while on leave with CSIRO. A paper on this research was presented at the 2nd Wind Engineering and Industrial Aerodynamics Workshop held at CSIRO Division of Energy Technology, Melbourne in August 1985.

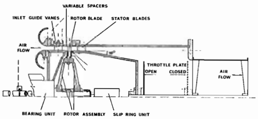

Figure 1: Half sectional elevation of axial flow compressor test rig

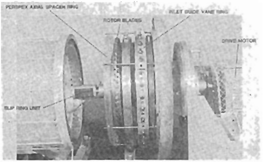

Figure 2: Partially assembled view of test rig

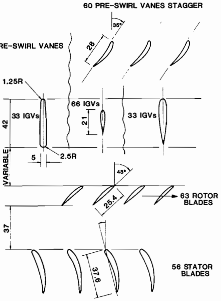

Figure 3: Blade profiles and configuration

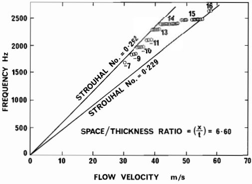

Figure 4: Frqeuency/velocity relationship x/t = 6.6

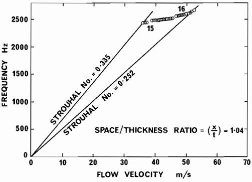

Figure 5: Frequency/velocity relationship x/t = 1.04

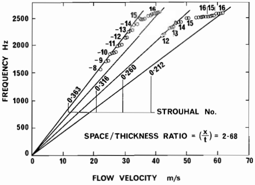

Figure 6: Frequency/velocity relationship x/t = 2.68

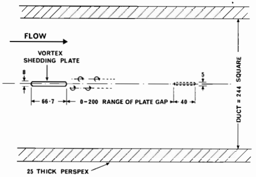

Figure 7: Variable spacing tandem plates in wind tunnel

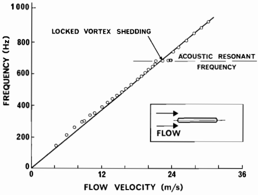

Figure 8: Frequency/velocity relationship—single plate

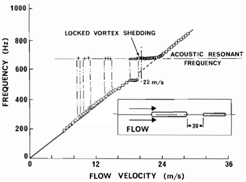

Figure 9: Frequency/velocity relationship—tandem plates

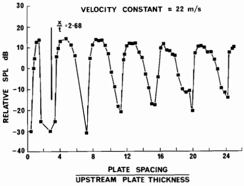

Figure 10: Variation of peak SPL with plate axial spacing at constant flow velocity

becomes locked to the acoustic resonant frequency. Figure 9 shows the results obtained with a second plate installed 30 mm downstream of the first plate (space to thickness ratio 3.75) where it can be seen that when the vortex shedding frequency is near to the acoustic resonant frequency, the vortex shedding is locked to it, as with a single plate. Over and above this, there were a number of other flow velocities at which an acoustic resonance was excited which were found to occur when the vortex shedding frequency was an integer submultiple of the acoustic resonant frequency, e.g. 9:8, 7:5, 5:2 and 2:1. The particular value of the integer submultiple was a function of the axial spacing between the plates. Work is in hand at CSIRO to mathematically model the transfer of energy from integer submultiple vortex shedding to an acoustic field and initial results indicate that the essential character of the phenomenon can be predicted.

When the flow velocity was set at a constant 22 metres per second (such that in the absence of the second plate a strong acoustic resonance would have been generated) then varying the plate spacing from 0 to 200 mm caused the peak sound pressure level to vary as shown in Figure 10. The peak sound pressure levels obtained corresponded approximately to those found in the absence of the second plate. However, at the intermediate positions the acoustic resonances were effectively destroyed being some 30 to 50 decibels lower than the peaks.

DISCUSSION

It is not known at this time whether the low velocity series of resonances in the compressor (Figure 6) was integer submultiple vortex shedding. The frequency step from mode 12 to mode 16 is an integer ratio of 5 to 6 but no evidence has yet been found to indicate that the IGV vortex shedding is not locked to the acoustic field. However, this may not be necessary since in the turbomachine there is a greater number of sound sources generating much higher sound pressure levels which may lock the vortex shedding once acoustic resonance is established.

An explanation of the variation of sound pressure level with plate spacing is that energy can be transferred from the flow to the acoustic field when there is a net positive imbalance in the summation of the individual values of the vector triple product of the Howe Integral associated with each vortex as it traverses the acoustic field [6, 7]. The position of the second plate influences the total number of generating vortices in relation to the total number of absorbing vortices, since when a vortex traverses the second plate the net effect it has on the acoustic field must be zero due to the convection and acoustic velocities (as terms in the vector triple product) being parallel.

The IGV/rotor spacings from which the turbomachinery results were obtained are indicated in Figure 10 and it is significant that the spacing at which the double series of resonances was obtained (Figure 6) corresponds to one of the spacings of which the tandem plate resonance was effectively destroyed. This may indicate that the phase relationship of the vortex arrival at the rotor favoured the excitation of the sub-multiple resonances at the lower flow velocities over those at the higher flow velocities.

CONCLUSIONS

1 The results of turbomachinery experiments and those from tandem plates in a wind tunnel show encouraging simularities suggesting that modelling the acoustic properties of turbo-machines with stationary plates in a wind tunnel has a contribution to make in expediting investigations.
2 Two plates in tandem in a wind tunnel can excite an acoustic resonance when the vortex shedding frequency is an integer submultiple of the acoustic resonant frequency.
3 The presence of a second plate in tandem with a vortex shedding plate in a wind tunnel can destroy the presence of the acoustic resonance normally associated with vortex shedding at the acoustic resonant frequency.

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Paul Dubout

Interview by John Davy

Paul Dubout was born in Melbourne where he spent all his childhood. He obtained a Bachelor of Science in Physics and Electronics from Melbourne University and joined the CSIRO Division of Building Research in 1951. The acoustical research had been under way for about two years in the Acoustical and Thermal Investigations Section led by Roy Muncey together with two other acoustics researchers: Arthur Nickson and Werner Lippert. Werner worked on sound transmission in ducts, the rest of the team on auditorium acoustics.

Work began on *subjective acoustics* when Paul arrived. The first item of interest was the perception of echos. Haas, in Germany, had worked with speech and a single artificial echo. The work at DBR extended this to music and ultimately showed that similar underlying parameters applied to all sounds. A paper describing this work is referenced by Kuttruff in his book on room acoustics.

In 1953 DBR was asked if it was possible to use the Exhibition Hall for the Melbourne Film Festival. The building volume was about 100 000 m^3 with a throw from the screen to the rear seats of about 80 m, and it was proposed to seat 1800 people. Shortly before this St Paul's Cathedral in London had been equipped with a *speech reinforcement* system using loudspeaker columns and time delays for the more distant columns, and DBR said that it could also be done in the Exhibition Building. An EMI tape recorder using a tape speed of 30 in/s was modified to run a continuous loop. This provided the delay for loudspeakers half way down the hall.

"The evening on which we conducted our main comparative tests on four variations of our system, with full audience opinion poll, was a disaster. Of the two main films on that night, one turned out to be a silent film and the other was an Irish film which was supposed to have a sound track but it was defective and completely unintelligible. You can imagine the remarks we got back on our 1800 questionnaires." However, the other sessions were all successful and soon afterwards similar equipment was used in the same building for the Royal Ball during the Queen's visit and for a Melbourne High School anniversary pageant. These applications both involved even longer throws, and multiple delays, which were provided from the 60 in/s tape loop equipment built at DBR for the echo-perception investigations.

The work on subjective auditorium acoustics was wound up in 1959. About this time Paul spent some time working on measurement of thermal conductivity and developing an air-change-rate measuring apparatus which was used by colleagues. This apparatus used 0.1% nitrous oxide as a tracer but there was an even more dangerous apparatus which used 1% hydrogen. "Thankfully, we never blew up any buildings, but on one occasion a colleague accidentally released excess N_2O, with laughable results."

Paul then worked on community noise and transmission acoustics. Arthur Nickson and Paul both became interested in the *noise of rain* on steel roofs, which was pressed on them by a "flood" of public dissatisfaction with the new steel trough roofing. Arthur developed a miniature tapping machine for roofs using "Meccano" 5/32 in. rods, but it did not correlate very well with rain noise. Meanwhile Paul set up a shed on which real rain noise was measured. Paul also

worked with Keith Martin on evaluating two different rain noise damping treatments for steel roofs.

By this time Paul was project officer for the construction of the DBR acoustical chambers, and the services of Roy, Arthur and Werner were soon to be lost to the acoustics group. Meanwhile, some other earlier staff changes should be mentioned. Paul met his future wife, Val, at Melbourne University, where she was studying physics and mathematics. Val was already working in the concrete laboratory at DBR when Paul joined the Division. Later, in 1951, there was a budgetary crisis. There was even talk of a merger with EBS! Instead, there was an internal reshuffle and Val was transferred to Roy Muncey's group where she worked on acoustic and thermal investigations before leaving in 1954 to raise a family of four.

In 1955 Anita Greenslade (Lawrence) came at first as a guest worker doing a Master of Science with the University of New South Wales, and then for a while as a temporary staff member. "That was quite a memorable period. We did subjective and objective appraisals of the *acoustics of Victorian concert halls* while tagging along with tours by a symphony orchestra and a light opera company. We all squeezed into an FJ Holden. The measuring equipment, up on a roof rack, came through the floods in the Murray Valley unscathed, but we (and our luggage in the boot) all got wetted."

Bill Davern joined the group in 1957. Roy Muncey left DBR in January 1966 and Werner Lippert became group leader in acoustics. Unfortunately he took ill a year later in January 1967 and never fully recovered. Arthur Nickson took ill during 1967 and died in January 1968. "So within a period of two years the leading lights went out." These losses occurred during the construction of DBR's acoustic chambers. A lot of qualification work was performed on the acoustic chambers at this time. Diffusers were installed in the DBR reverberation chambers to improve their performance. "John Irvine of CSR was pressing for an improvement in reproducibility of sound absorption coefficient measurements, so DBR decided to conduct an Australian and New Zealand "round robin" in this area of measurement. The last paper analyzing these results was only published in 1985. How's that for spinning out a project?"

After three years of pleading that if they could not have the lost staff replaced they needed automatic measuring equipment, the acoustics group obtained a $30 000 grant in 1971 to purchase a real time analyzer and minicomputer system which was delivered in June 1972. The system was used initially with machine language programming and the reverberation time

Continued on page 23

Microphone Sensitivity Calibration at NML

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ABSTRACT: A figure for the ratio of "voltage-out" to "sound-pressure-in" is the fundamental piece of information required for any measurement microphone. With the completion of development work at the high frequency end of the audio spectrum, NML can now determine the response of microphones at frequencies in the range 31.5 Hz to 20 kHz. The range 31.5 Hz to 1 kHz is conveniently covered by coupler techniques, and from 200 Hz to 20 kHz by substitution in free-field.

1. INTRODUCTION

Instruments for measuring sound pressure invariably begin with a microphone to convert the sound pressure signal into an electrical voltage signal, and for quantitative results it is necessary to have numerical values specifying the relationship between these two quantities. Nowadays, it is customary to express these numbers in the units Volts per Pascal, though one still comes across relics of the past such as pressures given in dynes per square centimetre.

The practical user may, of course, choose to set up his system with respect to the output from a sound calibrator, without any explicit knowledge of microphone sensitivity, but this merely postpones the need for such knowledge, since the calibrator itself must have been calibrated by reference to a calibrated microphone. There are, moreover, serious difficulties in using the sound calibrator technique at frequencies above a few kilohertz.

As custodian of the national system of units for physical measurement, NML has developed facilities for the determination of microphone sensitivity in the frequency range 31.5 Hz to 20 kHz. The highest accuracy is realised at low audio frequencies, 250 Hz to 1 kHz where, for one inch microphones equivalent in design to the Western Electric 640 AA that can be compared directly with the primary standards, the uncertainty is believed to be less than 0.05 dB. For other microphones and frequencies, the uncertainty is estimated to be 0.1 dB plus 0.02 dB times the frequency in kilohertz, i.e. 0.1 dB up to 1 kHz, 0.2 dB at 5 kHz and 0.5 dB at 20 kHz. These estimates are meant to be conservative, 99% confidence values.

2. CALIBRATION TECHNIQUES

2.1 Coupler Reciprocity

The frequency response of a respectable measurement microphone characteristically begins with an extensive more or less flat region at low frequencies, growing more irregular as the frequency rises and ending ultimately in a steep descent into oblivion. The sensitivity in the flat portion is the number usually quoted as the microphone sensitivity and there is universal agreement that the best way to determine it is by the reciprocity method in a closed coupler. The method has been hallowed by the issue of an IEC standard, Publication 327 [1], and one can buy an apparatus for carrying it out. Various standardising laboratories have described their own versions, NML amongst them [2, 3, 4].

The reciprocity method owes its success to the circumstance that a mechanically suitable microphone will act not only in the forward direction as a transducer of sound pressure to voltage with sensitivity M, but also in reverse as a transducer of electric current to volume velocity, and that the transduction coefficient in the second case is the same as in the first. Accordingly, one couples two microphones of sensitivities M_1 and M_2 by a known acoustic impedance — which at low frequencies is a dignified way of saying by a hole of known volume — and passes an electric current into the first. A sound pressure proportional to M_1 is generated in the coupling impedance and a voltage proportional to M_2M_1 is generated by the second microphone. Having obtained a measurement of M_2M_1, the remaining trick is to carry out the operation three times on a group of three microphones taken in pairs and, by taking the product of two results and dividing by the third, to obtain sensitivity values for the three microphones individually.

The sketchy account of reciprocity calibration given above has of course glossed over a number of subtleties. Anyone interested in going further should consult Delany and Basley [5]. NML's contribution, apart from the relative sophistication of its electrical measurement technique, lies in the idea of making the acoustic coupling impedance more complex than the simple hole to minimise the physical manipulation required in measuring three microphones two at a time.

The NML 3-aperture coupler is shown in Figure 1. Because the microphones can no longer face each other co-axially, the

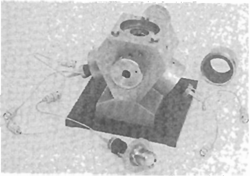

Figure 1: The NML 3-aperture reciprocity coupler, shown with one microphone removed.

useful high-frequency range for precise calibration is limited to 1 kHz, but this merely means that the problems arising in all coupler methods when the wavelength becomes comparable with the coupler dimensions, and the inevitable changeover to acoustic field methods, must be faced at a lower frequency. In compensation, the 3-aperture coupler permits the calibration by substitution, with reciprocity accuracy, of a range of types of microphone for which the method is not ordinarily available. After the standard group of three has been calibrated, the unknown is substituted for one of them, leaving the remaining pair to monitor, by their change in apparent sensitivity, any change in the measurement parameters caued by the introduction of the unknown.

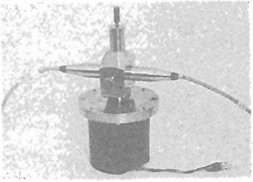

Figure 2: Comparison coupler showing two 1-inch microphones installed.

2.2 The Comparison Coupler

The device illustrated in Figure 2 is a comparison coupler for comparing microphones over a range of frequencies up to about 2 kHz or more dubiously, to 4 kHz. The loudspeaker in the lower section introduces sound into the periphery of a coupler of the same dimensions as the 3 ml IEC design, whilst the two microphones to be compared are introduced axially from either side. Levels up to 124 dB are possible to 1 kHz and 114 dB to 4 kHz. Measurements of the relative sensitivity of, for example, a standard microphone and an unknown can be made with a precision of 0.01 dB by the technique of including a precise gain control in the output line from one microphone and adjusting it to achieve equality with the output from the second when the two are compared alternately. By this means it becomes unnecessary to know anything about the measuring amplifier or the sound source provided they are stable over the short period it takes to switch between outputs, and a digital voltmeter can be used to expand the resolution available in a measuring amplifier meter scale. For the most precise work, the two microphones are compared by substitution on the same side of the coupler, a fixed microphone on the other side being used simply to monitor the transfer.

The coupler may also be used as what is, in effect, a monitored sound calibrator, for establishing and maintaining sound pressures of arbitrary frequency and level. The constancy of level is monitored by a microphone on one side of the coupler, whilst the other side is available for the introduction of the microphone of a sound level meter or other instrument. The calibration of a portable sound calibrator can then be checked by comparing the response of an instrument to it and to the known sound pressure in the comparison coupler.

2.3 Reciprocity in Free-field

Apart from the assumption of reciprocal behaviour in the microphones themselves, one of the basic requirements for coupler reciprocity is that the dimensions of the coupler should be small compared with the wavelength so that the driver and driven microphones can be assumed to experience the same sound pressure without serious error. At 20 Hz, where the wavelength in air is about 17 metres, there is no difficulty in satisfying this condition, but it is clear that, if any sort of precision is required, trouble will be experienced long before a frequency of 20 kHz is reached. In a coupler of simple shape one can derive a theory to try to take into account these so-called "wavemotion" corrections, or one can fill the cavity with hydrogen rather than air and take advantage of the high velocity of sound to achieve a greater wavelength for a given frequency, but all these expedients are merely palliatives, and sooner or later one must abandon coupler measurement for measurement in a real acoustic field. Quantification of the response of the microphone to some type of acoustic field is, after all, what the calibration exercise is all about. At NML we have chosen to make the change sooner rather than later and have had thereby to confront a unique set of problems.

There is no fundamental difficulty with reciprocity theory in free-field [6]. Given a high-quality anechoic space, one sets up a pair of microphones in some such arrangement as Figure 3 and proceeds as before to measure the voltage output from one when the other is excited by an electric current input [7]. One endeavours to keep the space anechoic by excluding reflecting supporting structures, relying for alignment on a system of cords.

The anechoic chamber illustrated here is of brick and concrete, lined on all surfaces to a depth of 600 mm with 25 mm thick layers of absorbent material in four graduations of density. The deeper 300 mm consists of 12 layers of Wawn's "Innerbond" which is made from bonded acetate fibres, whilst the front 300 mm consists of 3 grades of bonded acrylic fibre from the same supplier. The least dense layers (nearest the surface) are of a grade of material normally intended for garment padding; the two deeper grades were manufactured especially. The recipe for the number of layers of each density was adjusted by measuring the absorption of a 600 mm plug of the composite material, 100 mm in diameter, in an impedance tube. The

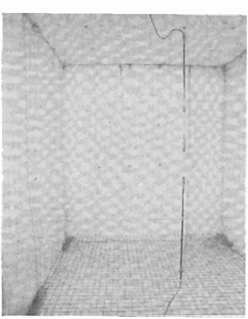

Figure 3: Reciprocity calibration in free-field of 1-inch standards.

material is supported by a system of wires and fishing net, the trickiest surface being the ceiling where the denser material above must not be allowed to crush the flimsier material below it.

The capacitor microphone has many virtues as a transducer, but high sound output for any feasible current input is not among them, so that the achievement of an adequate signal is always a problem in free-field reciprocity. The combination of the high impedance of the small electrical capacitance and the nature of the coupling between microphones in free-field results in a ratio of voltage-out to current-in that varies with the frequency squared, and the signal to noise ratio is at least 100 times worse at 1 kHz than at 10 kHz. The NML measurements aimed to extend the free-field results as far down into the coupler reciprocity frequency range as possible to minimise the magnitude and uncertainty of the difference between pressure and free-field calibration, and it proved possible to get down to 315 Hz before the difficulties became prohibitive. The coupler results from 31.5 Hz to 1 kHz could then be combined with the free-field results from 315 Hz to 20 kHz to give a very satisfactory wide-band calibration for the three B&K microphones type 4145 designated as the NML Primary Free-Field Group [8].

Since reciprocity calibration in free-field is an excessively arduous undertaking, small drifts in sensitivity with time are monitored by means of the electrostatic actuator, and in the three years since their reciprocity calibrations were completed, the free-field standards have been found to have drifted by amounts of the order of 0.02 dB at low frequencies to 0.1 dB at high. Note that we are only making small corrections to a reciprocity calibration by actuator measurements, not deriving the free-field response by adding a very large diffraction correction to actuator results, which is a very different proposition. Electrostatic actuator measurements to the required order of resolution can be achieved by the use of the same sort of precision gain-control technique as was described for the comparison coupler.

2.4 Substitution in Free-field

Given a set of calibrated reference microphones, unknowns may be calibrated by substitution in an arrangement such as that depicted in Figure 4. The loudspeaker is caused to emit a series of tones covering the required frequency range at approximately constant level, and the outputs from the first microphone are noted. Another microphone is substituted and the sequence repeated, and so on. If required, an instrument such as a sound level meter may replace the microphone. Providing one is content with a fairly low sound pressure level (e.g. 74 dB) one can cover the range 200 Hz to 20 kHz with a single loudspeaker that is not impossibly directional at the high end, and avoid the nuisance of changing the source in mid-range. In the figure, the loudspeaker is of 76 mm nominal diameter mounted in a rigid aluminium sphere which acts as an infinite baffle. Measurements have shown that if the substituted microphone replaces the standard with a positional uncertainty not greater than 5 mm, the uncertainty in sensitivity will be less than 0.1 dB over the whole frequency range, and it is not difficult to achieve this.

3. CONFIDENCE IN THE RESULTS

It is of some interest to try and gauge the accuracy achieved in the measurement of any physical quantity, though metrologists are notoriously optimistic in this regard. The evidence that the uncertainty in NML's primary coupler calibrations is not more than 0.05 dB has a number of sources: (1) It turns out that the most likely source of error in coupler reciprocity is the measurement and reproducibility of the coupler volume itself. Assuming dimensions can be relied on to ± 0.01 mm, the uncertainty in sensitivity is of the order of 0.01 dB. With the addition of a number of small uncertainties, a figure of 0.02 dB looks realistic, and determinations of sensitivity of the same microphones in different couplers have shown a range of this

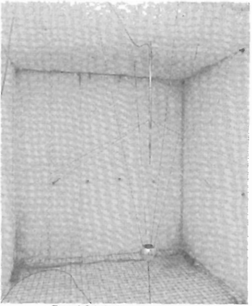

Figure 4: Substitution calibration of ¼-inch microphone in free-field.

order; (2) A determination of microphone sensitivity by Taylor [9] via the totally dissimilar route of the Laser-Doppler measurement of particle velocity agreed with the reciprocity results to this order also, as did an intercomparison with Corney at the Physics and Engineering Laboratory, New Zealand. NML hopes to take part in an International Intercomparison at present being organised in which standaradising laboratories in Japan, USA, Canada, Europe etc will submit calibrated microphones to the National Physical Laboratory, England. If all goes according to plan, the various national laboratories should at least get from their peers an opinion on the soundness of their respective guesses at their own systematic errors.

As an indication of the consistency of our coupler results, the most stable 4144 from our primary group has maintained its calibration within ± 0.01 dB since March 1979 when the corrections applied in calibration assumed their definitive values.

The uncertainty of free-field calibration is more difficult to assess, though likely to be worse than coupler calibration at low frequencies and to become progressively worse as the frequency increases. The figure of 0.5 dB at 20 kHz is based on the observation that differences of the order of 0.2 dB are observed when the same microphone is calibrated with the loudspeaker or with a second microphone as the source. The reproducibility of a given calibration is better than the latter figure by a factor of at least 2.

As an example of the results obtained for a quality modern microphone, the frequency response curve for a B&K high-sensitivity half-inch microphone type 4165 is shown in Figure 5 with the NML calibration superimposed upon an enlarged plot derived from the makers' chart. It will be seen that with the exception of the extreme high-frequency end, the on-axis sensitivity stays within 0.5 dB of flatness, and that the NML calibration generally says that the microphone is actually better than the manufacturer claims. Results for this particular microphone type are consistently good. Results for the older half-inch type show discrepancies of 0.5 to 1.0 dB above 5 kHz but since our specimens are 5 to 10 years old, it is possible that the current frequency response is no longer adequately represented by the calibration at manufacture.

4. CONCLUSION

By a suitable selection of techniques, microphones can be calibrated at NML over the frequency range 31.5 Hz to 20 kHz with a precision sufficient to verify the tolerances for a type O instrument as specified in AS1259 — 1982. Because of the range of wavelengths involved, the complete frequency span must be calibrated in two parts, but the free-field measurements extend down to frequencies low enough for overlap between the parts of the range not to be a problem.

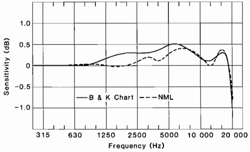

Figure 5: Comparison of NML and maker's calibration of B&K microphone 4165/1159169.

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(Received 17 September 1985)

A 5-year strategy for CSIRO

A new focus for CSIRO's research with special emphasis on high-technology industries and work more closely attuned to commercial benefit are key planks of a 5-year plan to strengthen the organisation's position as an effective, dynamic and flexible research institution.

The plan was issued in the form of a booklet entitled "Shaping the Future — a Strategy for CSIRO 1985-1990" on 29th September, 1985.

The strategy, which was formulated from the recommendations of five executive working parties, has the following objectives:

- to develop more systematic procedures for identifying growth areas and assessing the balance of research across economic sectors;
- to concentrate CSIRO's research effort into fewer programmes focussed on fewer national objectives;
- to introduce more systematic evaluation of research;
- to improve the two-way communication of results and information between the organisation and its user groups; and
- to develop better management practices and more flexible staffing policies.

Of the current top five priority growth areas, the four which have particular relevance to manufacturing industry are as follows:

- developing and encouraging the application of computer-based information technologies in all sectors of industry and the community;
- developing technologies that are widely applicable in manufacturing industry;
- encouraging the development of an Australian space industry; and
- developing and applying biotechnological techniques to improve Australian agriculture and create new manufacturing opportunities.

Criteria for recognising growth areas and for assessing sectoral balance include factors such as the potential of an industry to generate wealth and employment and to be export oriented.

The strategy notes the importance of strengthening CSIRO's interactions with industry, government and the community.

It calls for close contact with potential customers in the setting of research objectives and in evaluating the results of research. Also more day-to-day contact between staff and potential customers, more secondments between CSIRO and industry, and more user-oriented seminars and courses will be encouraged.

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(Continued from page 18)

measuring program developed by Ian Dunn, who had joined the group in 1969, was the first published in the world. In 1974 John Davy joined the acoustics group and soon began making the significant contributions to acoustical theory on the statistics of reverberant sound fields which have continued to the present day.

Paul has been very active in the *standards* area. His involvement started about 1966 when he was invited to join AK/2. Then Paul inherited the role as DBR representative on AK/4 and AK/1. "This was a very badly chosen time to join that committee. It was being driven, and I mean driven, by Ken Connor at that time, and I was appalled at my first meeting there. It went all day and at six o'clock I thought, well it must be going to wind up soon. I foolishly said that I had a document or a reference in my office which would clear up a certain point. Ken said, 'Could you bring it along please?' I said, 'Certainly, I will bring it to the next meeting.' He said, 'No, would you mind getting it now?' My office being at Highett and the meeting at Clayton, I thought he was joking, but he was not because the meeting went on until eleven that night. There was no worry about my disappearing for an hour or so while I went to get the document."

Paul is also on the main AK/- acoustics standards committee. The 1977 standard on aircraft noise is the most memorable standard for Paul because of the really effective team work that took place on the committee. It was also an original document rather than a rework of an ISO standard. "Of course, it had a few warts but some of these have been fixed up in the 1985 revision."

A significant proportion of Paul's time is spent commenting on draft standards, particularly international ones. Paul has been told that Standards Association keeps sending drafts to him because he is the only person who ever writes back. "Perhaps they say that to all their contributors?"

Paul has been an *assessor for NATA* since about 1970. "The first assessment that I did was quite a test for me too, because I had to fail the applicant. Looking back I think that I may have been a bit too tough." Paul also served five years on NATA's Acoustics and Vibration Registration Advisory Committee.

Bill Davern and Paul also handled most of the acoustics enquiries to DBR. In the 1960s these totalled about 300 per year which grew to about 600 before the DBR enquiry service was severely restricted in the early 1980s. "In the early days there was only one acoustical consultant in Australia with whom we could be said to compete. We used to do quite substantial field measurements and investigations for government and semi-government bodies. I think it is a good thing for people in a research laboratory to keep up some practice in applied acoustics."

Paul was a *foundation member* of the Victoria Division of the Acoustical Society. The first meeting of interested people in Victoria was held in November 1964. Ron Barden was the chairman and Ken Connor was the treasurer/secretary. The other members were Paul, Arthur Nickson, Ron Carr, John Heinie, Gerald Riley and Vivian Taylor. Paul was the secretary of this committee in 1966. This committee ran the acoustical society in Victoria for six years until the Federal society was incorporated in 1970, and the Victoria Division was formally recognized. Paul has served as the society's archivist for many years. He was also a one-man federal membership grading sub-committee until 1982.

"I don't think there was much real growth in the acoustics profession after the mid-1970s, but the Acoustical Society continued to grow for another few years. It still has an important role to fulfil in the community."

THE PHYSICS OF THE VIOLIN

Lothar Cremer
(translated by J. S. Allen)

MIT Press, Cambridge Mass. and London 1984; 450 pp. Review copy from Book & Film Services, PO Box 226, Artarmon, NSW 2064. Price $82.50 (Aust.)

The violin, more than any other musical instrument, has attracted the homage of musicians and the respectful attention of distinguished scientists.

Professor Cremer, as Director of the Institute for Acoustical Engineering at the Technical University of Berlin, devoted much of his later working life — he is now 80 — to the study of the physics of bowed-string instruments, and this book, first published in German in 1981, is a careful and scholarly survey of our present state of understanding. Much of the basic work, it is true, was done by Helmholtz and Raman, and this is given a clear exposition, but the book concentrates on more recent advances, many of them made by Cremer and his co-workers and hitherto available only in widely scattered parts of the scientific literature.

This is a book about physical phenomena much more than it is a book about the violin as a musical instrument or as a piece of technology. 200 of the 450 pages are devoted to a careful consideration of the way in which the bow sets the string into vibration and determines the details of its motion, 150 deal with the vibrations of the instrument body excited by the strings, and the final 100 or so discuss the radiation of sound from the instrument into the room. The approach throughout is careful and detailed, with an adequate amount of mathematics, but there is nothing more demanding than an occasional differential equation, and those who prefer to skip the detail will still be rewarded by a very considerable insight into the subtleties underlying the basic mechanisms. Indeed, since Professor Cremer is careful to go back to fundamentals in each section, the reader will also be rewarded by a rich and perhaps unusual set of insights into many aspects of acoustical and mechanical vibration theory.

While the book is primarily analytical, it does discuss many elegant experimental techniques and their application to the violin, ranging from Helmholtz's vibration microscope to modern holographic photography, and there is also a detailed account of computer simulation of the whole nonlinear bowing process.

This book is a must for anyone seriously interested in the physics of bowed string instruments. Its scope is, I think, at least in the English language, unique, and it complements admirably the few available works on the construction, history and playing technique of instruments of the violin family. It will be many years before the slow advance of our understanding requires any significant extension or revision of what is bound to become a standard work.

NEVILLE FLETCHER

ACOUSTIC AND VIBRATIONAL COMMUNICATION IN INSECTS

K. Kalmring and N. Elsner (Editors)

Paul Parey, Berlin and Hamburg 1985; 230 pp. Review Copy from D.A. Book (Aust.) Pty Ltd, 11-13 Station Street, Mitcham, Vic 3132. Price $55.00 (Aust.) (soft covers)

This book records the proceedings of two symposia presented at the XVII International Congress of Entomology, held in Hamburg in August 1984. This provenance immediately defines the sort of book it is — a collection of 26 short papers aimed at research biologists working in the field, and generally reporting particular experimental results. The book is divided into two broad sections — acoustic communication and vibrational communication respectively — and each section begins with one or two rather more general papers before plunging into detail. Even these general papers are written, naturally enough, for the initiated.

Nearly all the papers deal with crickets or their close relatives, with just one contribution on discrimination of surface-wave signals by the fishing spider. Presumably this concentration reflects the current emphasis in the subject, those animals being preferred because of their convenient size and anatomy and their active singing behaviour.

The emphasis in most of the papers is neurophysiological rather than acoustic, as is indeed to be expected, and comments on acoustic matters in some papers are somewhat naive — the introductory paper by Axel Michelsen properly makes this point. But equally one cannot but be impressed by the virtuosity of some of the neuraphysical techniques now regarded as standard.

In short, then, this is a publication for biologists working in the field of the symposia who need to read the published proceedings and are prepared to pay the rather high price. Biological libraries should have a copy, but I cannot recommend it for the general acoustically literate reader interested in a survey of the field.

NEVILLE FLETCHER

* * *

ENVIRONMENTAL NOISE CONTROL MANUAL

NSW State Pollution Control Commission

SPCC, 157 Liverpool Street, Sydney, 1985. Price $30 (Aust).

1985 saw the culmination of an ambitious project with the issue by the New South Wales State Pollution Control Commission of its Environmental Noise Control Manual. In the statement of the Minister for Planning and Environment announcing the release of the manual, the comprehensive document purports to be a breakthrough for N.S.W. which "will prove an invaluable resource for all involved in solving neighbourhood noise problems." It was being issued, so the statement continued, to authorised officers of local councils, police, and the Maritime Services Board. Although there was a qualification here that it would also be of interest to acoustic consultants, engineers, and environmental groups, the intent would seem to be primarily as a set of guidelines for those vested with the responsibility for the implementation of the N.S.W. Noise Control Act, and secondarily to those planning compliance with the Act.

To achieve its aims the manual is subdivided into as many major parts as there are half the number of letters in the alphabet with each of these parts further subdivided into chapters. Each major part has its individual contents page, and the overall presentation would seem to fulfil with high efficiency its obvious objective of enabling quick reference to whatever may be sought, be it a personal, council, police, or an authority responsibility for noise from musical motor horns, ultra-light aircraft, licensed premises, or any of a wide variety of sources. The likelihood of a changing scene is recognised by the manual being produced in loose-leaf form with a section to record amendments to ensure hopefully that it will always be kept up-to-date and continue as a useful reference.

It is always possible to be critical with most texts and this one is no exception. For instance, one could take issue with the early section of the manual that seeks to set out the environmental noise quality objectives. It launches off into speech interference, description of the hearing process, with complex diagrams of the ear, audiograms, and types of deafness. Inevitably, dB, dB(A), and Hz enter into all this although it is not until a later chapter in the section that explanations of decibels and A-weighted sound level appear. It is these latter that are almost exclusively the only ones of which use is made in the discussion of quality objectives which is the stated purpose of the section. Granted, there is need to note such precautions as apply to the hearing ability of noise enforcement shift, but the danger exists that such information may be overlooked in the feast of material not immediately required and which it would seem may be more logically incorporated in the reference sections appended to the manual.

Part G, entitled "Assessment Procedures", devotes Chapter 80 almost exclusively to sound level meters which is to be expected in view of those for whom the manual is mainly intended. Several vital precautions are rightly included such as the need for regular calibration, for calibration checks before and after use, and for care for this type of instrument. However, there are many other important aspects such as the errors that can arise from uninformed use of extensions, the effect of the presence of the observer and others in proximity to the meter, and from making measurements in even moderate wind conditions. At the least, reference might have been expected to SAA Publication MP 44 (yes, it is listed in Chap-

Continued on page 25

ter 302 of general reference material) but better still would seem to be a summarised version of points to watch. Some of the sources of error in the use of the meters are, of course, called up in Chapters 82 and 84 in regard to measurement for control purposes.

Observations such as those above can be continued, but by so doing there is the danger of appearing to deprecate an admirable effort on the part of the Commission. This would be unfortunate and particularly so in view of the attitude expressed in the manual that it is not intended to stand unassailed and unchanged for all time. To quote from the introduction . . . . "Thus the manual is designed to be dynamic, to be revised and added to as circumstances require. To assist in this, the Commission will always welcome constructive criticism of the content or suggestions for additions to it." The loose leaf format referred earlier is indicative that this is a firm commitment. Clearly readers and users should take up this offer and return to the Commission such suggestions as they believe would improve the presentation. To them, perhaps rather than the Commission, should it be said to bear in mind how best to satisfy the needs of those intended to be its main users. Authorised officers in the broadest sense frequently have a wider range of duties than those concerned with noise alone and it is important to avoid obfuscation of the essentials. For them, concise presentation of vital requirements may be more valuable than impeccable theoretical expositions. Consultants and their ilk might find most value in the manual in the guidelines which the Commission has set out to be followed in its efforts to provide the community with the desirable environment it would like.

Ted Weston

* * *

NOISE AND VIBRATION MEASUREMENT: PREDICTION AND MITIGATION

W. A. Redl (Editor)

American Society of Civil Engineers, New York, 1985. Review Copy from D.A. Book (Aust.) Pty Ltd, 11-13 Station Street, Mitcham, Vic 3132. Price $29.25 (Aust.) (soft covers).

This is a publication from the American Society of Civil Engineers and comprises 15 papers presented at a Symposium in May 1985. The papers can be loosely grouped into three main noise areas — construction, transportation and stationary sources.

In the first area there are four papers covering prediction of highway construction noise, blasting noise, cost assessment and vehicle sound power measurements using the acoustic intensity method.

The second area includes two papers on highway noise — one on the FHWA requirements and the other on the draft standard for measurement of effectiveness of barriers. The only paper specifically dealing with aircraft noise is a summary of the plans for noise mitigation at one U.S. airport. The noise characteristics of alternative transit systems for urban areas are discussed in another paper. The accomplishments of the Federal programme to control rail vibration and noise are summarised.

The remaining five papers deal generally with industrial noise, its measurement and control. Two of these papers deal with designs for minimising vibration.

As these are all contributed papers to a Symposium, areas are not covered completely as would be expected in a general reference book or handbook. Therefore, except for those who are working in one of the fields specifically covered by one of the papers, my recommendation is that this publication would be a useful addition to a library collection.

Marion Burgess

* * *

NOISE-CON 85 PROCEEDINGS

Computers for Noise Control

Noise Control Foundation, PO BOX 3469, Arlington Branch, Poughkeepsie, N.Y. 12603; $48 US (includes surface mail, extra $12.50 for air mail)

Noise-Con 85 was sponsored jointly by the Mechanical Engineering Dept of Ohio State University and the Institute of Noise Control Engineering. The proceedings contain 72 papers grouped into 12 general areas plus 3 papers in the "Distinguished Lecture Series". The 12 general areas are: Numerical Methods in Noise Control, Computer-Aided Testing, Office Equipment and Environment, Computer-Aided Design and Modal Analysis, Noise Control Solutions, Damping and Break Squeal, CAD Ducts and Muffers, Signal Processing and Diagnostics, Plant and Community Noise, Personal Computers and Spread Sheets, Intensity Measurements and Propellors/Fans/Cutters.

The majority of the papers are six to eight pages long and while most are on topics clearly within the area described by the theme others have a very tenuous link (in one case the link appeared to be that a computer was used to plot the results!). There are interesting papers in all aspects of Noise Control and one value of Conference Proceedings is that, usually, the findings which are presented relate to recent work. One can therefore get a better idea of the "state of the art" than from long delayed articles in journals.

The papers for the Distinguished Lectures are quite short (4 to 8 pages) and the topics are: Anti-Noise by J. E. Ffowcs Williams, Asymptotic Modal Analysis and Statistical Energy Analysis by E. H. Dowell and Y. Kubota and Machine Diagnostics and Noise Control by R. H. Lyon.

In summary, this volume would be a useful addition to reference libraries.

Marion Burgess.

THE EFFECTS OF NOISE ON MAN

Karl D. Kryter

Academic Press, London, 1985, 2nd Edition, pp. 688.

Review copy from Academic Press Australia, P.O. Box 300, Nth Ryde, N.S.W. 2113. Price A$79.60.

As stated in the preface, the material in this book was originally prepared for NASA with support from the U.S. D.O.T. and E.P.A. It consists of critical review and interpretations of original source material. Herein lie some of the book's strengths and weaknesses — one strength is the very large number of references (over 960) and one weakness, for an international audience, is its emphasis on methods of assessment of noise in the United States.

In Chapter 1 *noise and noise pollution* are briefly described and it is pointed out that the latter is as much a political problem as it is a scientific matter. The next chapter *"physical measures of sound and noise"* raises the question of the prospective readership of the book. Acousticians will be surprised at some of the definitions (of "impulsive sound" for example) whilst laymen will be bemused by the details of the method of calculating PNdB from 24, 1/3 octave band levels, complete with a table of noy values. It is to be hoped that non-acoustically versed legislators will not pick up such terms as the "A-weighted loudness level" or the "A-weighted perceived noise level"!

Considering the title of the book, the chapter dealing with the *physiological functioning of the ear and masking* is disappointing as it provides only a cursory description of the ear's physiology, accompanied by a very poor sketch. However, there is a good description of masking and many references are made to the early experimental work on critical bandwidth. Kryter also discusses the "critical summation time of the ear", sounds of shorter duration apparently not contributing to overall loudness. At threshold levels the time constant for detection of a change of loudness is about 1 sec. and at suprathreshold levels this reduces to about 300 msec. This seems to conflict somewhat with people's abilities to perceive short duration signals that occur in speech and music. The aural reflex is also well discussed.

Speech communication is the topic of a separate chapter, presumably because of the author's assertion that "the most common complaint about noise is that it interferes with or masks speech signals". Some very useful data is presented regarding typical speech levels in different environments and also speech spectra. The effects of intermittent noise on speech communication and methods of rating and combatting noise interference effects in cases where speech communication is important are fully discussed.

In Chapter 5, Kryter once again raises the issue of *loudness versus noisiness* — "loudness" he defines as the "subjective intensity of sound, independent of any meaning the sound might have"

Continued on page 26

and "noisiness" is "the subjective impression of the unwantedness of a not unexpected sound that does not provoke pain or fear" (definitions not quite in line with the SAA Glossary of Acoustic Terms!). As would be expected in a book by this author there is considerable discussion regarding the preferred methods of assessing the loudness/noisiness of complex sounds. Stevens and Zwicker phons, PNL and overall frequency-weighted SPL are all compared. Kryter concedes that for broadband noise, there is little difference between the D- or E- and the A-weighting although if there are significant high frequency narrow band components, or if the noise is impulsive, the D-weighting is superior. He considers that the general problem of corrections to overall levels for pure tones and narrow bands can only be resolved for steady-state situations. Sound such as sonic booms, artillery fire, etc. which cause building vibrations and rattles contribute an extra 5 dB to their "unwantedness". A proposed correction method to be applied for impulsive sounds is presented, although Kryter acknowledges the use of the C-weighting for this purpose.

The author next deals with *hearing loss in populations* — he postulates that it is a combination of "presbycusis" — resulting from aging, "sociocusis" — resulting from exposure to the sounds and noises of everyday living and "nosocusis" — resulting from common pathological conditions of the ear from other causes. He discusses many studies designed to determine "normal" hearing levels of populations.

Following this is a major chapter on *noise-induced hearing loss and its prediction*. Two questions are addressed — first the maximum level of daily noise exposure over a number of years that will *not* cause a measurable hearing loss (beyond that due to aging) in the undiseased ear typical of the general population and, secondly, what level of industrial noise exposure *will* cause measurable hearing loss in factory workers. One interesting statment is that industrial workers have greater sociocusis and nosocusis so that their hearing thresholds are elevated 10 dB or so above the general population, even without taking workplace noise exposure into account. Kryter proposes a new method of calculating Noise Induced Permanent Threshold Shift, but although this may well have greater validity than current methods, the input data required would be extremely difficult to obtain in the average workplace. Nearly 150 references accompany this chapter. A very brief note on hearing impairment and handicap follows.

A discussion on mental and psychomotor task performance in noise is somewhat inconclusive but the reader is offered 100 references for further information.

Another major chapter explores *non-auditory system response to noise* and effects on health. It covers topics such as autonomic response, sleep studies, health-related effects in workers, mental health in noise-affected communities and physiological stress induced by annoyance. Some 240 references are given as background to these topics!

A chapter on *community noise* breaks no new ground although Kryter persists in maintaining that people are less annoyed by road traffic noise than by aircraft noise at the same L_{dn} value. One explanation is that peoples' real exposure to traffic noise is less than that to aircraft because of shielding by buildings. He endorses the use of a 5 dB penalty for noise occurring between 1900 and 0700 hours rather than the 10 dB penalty between 2200 and 0700 hours used in L_{dn}.

Guidelines for assessment and control of noise are strongly related to the U.S. context and although Kryter is fairly critical of many of the systems in use in that country he finally supports an outdoor L_{dn} of 55 for residential areas, but with adjustments for climate and building attenuation.

The claim in the final chapter that "these findings and concepts allow for the specification of quantitative predictive relations between physical measures of exposure to noise and the known effects of noise on people" is perhaps a little ambitious.

To summarise — recommended as an excellent source book for those with good background knowledge in the field, *not* recommended as an introductory text book.

Anita Lawrence

NEW PRODUCTS —

BRADFORD INSULATION
THERMOFOIL (TM)

CSR Limited, through its Bradford Insulation Group, has acquired the Caroma reflective aluminium foil insulation business of GWA Limited.

Marketing under the brand name Thermofoil (TM), Bradford will manufacture and market a range of reflective aluminium foil for building, air conditioning and industrial applications and a range of specialist laminated aluminium foil products for packaging. Applications for foil include condensation control, sarking and facings for fibreglass and rockwool insulation.

BRUEL & KJAER
MOUTH SIMULATOR

The Bruel & Kjaer Mouth Simulator, Type 4227, is a development of the earlier Artificial Voice, Type 4219. Its sound field accurately simulates the sound field generated by the human mouth, making it an ideal device for testing telephone transmitters and close talking microphones. All significant characteristics have been improved. The 4227 offers a higher sound pressure level and better frequency response.

INDICATOR UNIT

The Type 2433 uses a light emitting diode (LED) thermometer-type display in an instrument only 34,5 mm wide. Overrange, underrange, or a signal with too high a crest factor are shown by a flashing indicator. The Indicator Unit has three full-scale outputs of 1; 0,3 and 0,1 V, matching the outputs of a number of B & K instruments, and uses a logarithmic RMS detector that can accommodate the high crest factors often found in mechanical vibration signals. Two selectable time-constants, of 1 s and 10 s, enable measurements to be made of either deterministic or random signals with frequency components as low as 1 Hz.

8-PEN GRAPHICS PLOTTER

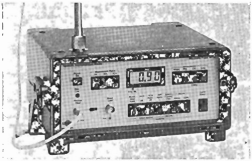
Bruel & Kjaer have introduced the Graphics Plotter Type 2319 to provide high quality multi-colour records of measurements made with the Dual Channel Signal Analyzer Type 2032. The 8-pen plotter accommodates metric A4 or US A-size plain paper or overhead-projection transparencies, and features IEEE-488 interfacing and an HP-GL compatible instruction set. The large, 7-kilobyte input buffer allows fast, efficient data transfer, quickly freeing the sending device and the interface bus for other duties. Using front-panel control or graphics language instructions, plots can be drawn any size and in any position within the plotting area.

The Type 2319 can be used with any instrument with an IEEE-488 interface and the capability to send HP-GL instructions. Single HP-GL commands allow, for instance, circles, arcs and sectors to be drawn either shaded or outlined. Alphanumeric characters can be selected from five sets of 96 characters each, and written onto the plot in any direction and with variable aspect and slant.

SPEECH TRANSMISSION METER

Using the RASTI (RApid Speech Transmission Index) method, the Type 3361 can measure a speech transmission index in less than 10 s. The RASTI method is currently being standardised by the IEC. Applications include the assessment of speech intelligibility in auditoria, lecture rooms, etc., with or without speech reinforcement systems. The speed of measurement of the Type 3361 permits a large number of measurements to be made from which intelligibility contours can be drawn.

To make a measurement the Transmitter is placed at the position normally occupied by the speaker and it sends out a special acoustic test signal from the built-in loudspeaker. The test signal consists of a pink noise carrier signal (octave bands centred at 500 Hz and 2 kHz) which is intensity modulated by a sum of low frequency sine waves. The Receiver is placed at the listening position and analyses the incoming signal, measuring the reduction in modulation depth for each of the modulation frequencies. This measured reduction in signal modulation is converted to an index of speech intelligibility.



NEW PUBLICATIONS —

PUBLICATIONS RECEIVED

The following publications have been received by the Society and are held, temporarily, in the Acoustics Laboratory, School of Physics, University of N.S.W. They are available for inspection by members or photocopies (not in contravention of copyright conditions) may be ordered by contacting Cronulla Secretarial Services (03) 527-3173. (Payment for photocopying and postage must be made).

REPORTS

Acoustically Compact Transient Sources for Underwater Measurement and Calibration, J. Nedwell, ISVR Technical Report No. 129, April 1985, pp. 42.
On the Prediction of Loss Factors Due to Squeeze Film Damping Mechanisms, L. C. Chow and R. J. Pinnington, ISVR Technical Report No. 130, October 1985, pp. 87.
Power Transmission of an Idealised Gearbox, R. C. N. Leung, ISVR Technical Report No. 131, November 1985, pp. 45.

JOURNALS

Archives of Acoustics (Polish Acoustical Society), Vol. 9, Nos. 3, 4.
Revue D'Acoustique (Groupement des Acousticiens de Langue Francaise, G.A.L.F.), Vol. 18, No. 74.
Applied Acoustics, Vol. 18, Nos. 5, 6; Vol. 19, No. 1.
Chinese Journal of Acoustics (Acoustical Society of China), Vol. 3, No. 4; Vol. 4, Nos. 1, 2, 3.
Anales Otorrinolaringologicos Ibero-Americanos, Vol. 12, Nos. 3, 5.
Acta Acoustica (Acoustical Society of China), Vol. 10, Nos. 3, 4, 5 and 6.
Aust. Journal Audiology (Audiological Society of Aust.), Vol. 7, No. 2.
Journal of Technical Physics (Polish Academy of Sciences), Vol. 15, Nos. 3, 4.
Canadian Acoustics, Vol. 13, Nos. 3, 4.
STL - QPSR (Royal Institute of Technology, Stockholm), 2-3 October, 1985.

ADVERTISER INDEX

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

FUTURE EVENTS —

● Indicates an Australian Conference

1986

April 7-10, SALFORD

SPRING CONFERENCE — ACOUSTICS '86
Noise Control, EEC Legislation, Underwater Acoustics, Physical Acoustics, Building Acoustics.

Details: Mrs. C. Mackenzie, I. of Acoustics, 25 Chalmers St., Edinburgh, EH1 1HU, Scotland.

April 8-11, TOKYO

INTERNATIONAL CONFERENCE ON ACOUSTICS SPEECH & SIGNAL PROCESSING

Details: Prof. H. Fujisaki, General Chairman of ICASSP 86, Dept. Electronic Eng., University of Tokyo, Bunkyo-ku, Tokyo, 113 Japan.

April 10-11, ROSTOCK, DDR

V. SYMPOSIUM ON MARINE ELECTRONICS
Includes hydro-acoustics.

Details: Prof. Dr. Schommartz, Wilhelm-Preck-Universitat Rostock, Sektion Technische Elektronik, Albert Einstein Strasse 2, DDR-2500 Rostock 1.

● April 14-18, ADELAIDE

1986 ENGINEERING CONFERENCE
Details: 1986 Conference Secretary, Institution of Engineers, 11 Bagot St., Nth. Adelaide, S.A. 5006.

April 16-18, CHINA

WORKSHOP ON ACOUSTICS, SPEECH & SIGNAL PROCESSING
Details: Inst. Acoustics of Academia, Sinica, Beijing, China.

May 12-16, CLEVELAND, U.S.A.

Meeting of the Acoustical Society of America.

Chairman: Arthur Benade, Case Western Reserve University, Physics Department. Cleveland, Ohio 44106.

26-31 May, GDANSK, POLAND

3rd International Spring School on Acoustoopics and Applications.

Details: from: Dr. A. Markiewicz, Uniwersytet Gdanski, Instytut fizyki Dosw. ul. Wita Stwosza 57, 80-952 Gdansk.

June 2-5, YUGOSLAVIA

XXX ETAN CONFERENCE
Joint meeting with Greece.

Details: Prof. P. Pravica, Electrotechnical Faculty, Bulevar Revolucije 73, Belgrade, Yugoslavia 11000.

June 3-6, SZEGED, HUNGARY

5th Hungarian Seminar and Exhibition on Noise Control.

Details: Optical, Acoustical and Film-technical Society Budapest, Anker koz 1. H—1061 Hungary.

June 3-7, CHINA

ACOUSTICS & SIGNAL '86
Large scale exhibition of equipment.

Details: P.O. Box 784, G.P.O. Hong Kong.

July 9-11, SEATTLE, USA

AIAA AEROACOUSTICS CONFERENCE
Details: Am. Inst. Aeronautics & Astronautics, 1633 Broadway, New York, NY 10019, U.S.A.

July 15-21, BRAZIL

4th BRAZILIAN ACOUSTICAL SYMPOSIUM

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

July 17-19, MASSACHUSETTS

INCE SEMINAR
Advanced Techniques for Noise Control Seminar Leader: Dr. Malcolm Crocker.

Details: INCE, P.O. Box 3206 Arlington Beach, Poughkeepsie, NY 12603, U.S.A.

July 21-23, MASSACHUSETTS

INTER-NOISE 86.

Progress in Noise Control.

Details: Inter-Noise 86 Secretariat, MIT Special Events Office, Room 7-111, Cambridge, Massachusetts, 02139, U.S.A.

July 16-18, HALIFAX

ICA SYMPOSIUM.

Underwater Acoustics.
Details: See 12th ICA.

July 21-22, MONTREAL

ICA SYMPOSIUM.

Units and their Representation in Speech Recognition.
Details: See 12th ICA.

July 24-August 1, TORONTO

12th ICA.
Details: 12th ICA Secretariat, Box 123, Station 'Q', Toronto, Canada M4T 2L7.

August 4-6, VANCOUVER

ICA SYMPOSIUM.
Acoustics and Theatre Planning for the Performing Arts.
Details: See 12th ICA.

August 6-8, NEW HAVEN, USA

1st IMACS SYMPOSIUM ON COMPUTATIONAL ACOUSTICS

Details: Dr. Ding Lee, Code 3332, Naval Underwater Systems Center, New London, CT 06320, U.S.A.

August 20-22, DENMARK

SCANDINAVIAN ACOUSTICAL MEETING
Details: NAM-86, Institute for Electronic Systems, Strandvejen 19, Aalborg, Denmark 9000.

August 24-28,

August 24-28, CZECHOSLOVAKIA

XVIII INTERNATIONAL CONGRESS ON AUDIOLOGY

Details: J. E. Purkyne, Vitezneha unora 31, 120 26 Prague 2.

September 2-6, HUNGARY

6th FASE SYMPOSIUM.
"Subjective evaluation of objective acoustical phenomena."
Details: 6 FASE-Opt. Akuszt. Filmt., Anker-koz 1, H—1061, Budapest.

September 19-28, LONDON

ULTRASOUND SYMPOSIUM

Details: M. J. Ullman, Medical Seminars Int. Inc., 22135 Roscoe Blvd., Suite 104, Canoga Park, CA 91304, U.S.A.

● October 1-3, TOOWOOMBA

CONFERENCE ON COMMUNITY NOISE.
Details: Ms Nola Eddington, Division of Noise Abatement, 64-70 May Street, BRISBANE, Q. 4000.

October 7-9, THE HAGUE

2nd INTERNATIONAL SYMPOSIUM ON SHIPBOARD ACOUSTICS

Details: J. Buiten, Institute of Applied Physics TNO, P.O. Box 155, 2600 AD Delft, The Netheralnds.

October 7-10, BASEL

XIV AICB CONGRESS
Traffic Noise and Urban Planning

Details: Dr. W. Aecherli, Hirschenplatz 7, Luzern, Switzerland 6004.

October 21-24, TOKYO

8th INTERNATIONAL ACOUSTIC EMISSION SYMPOSIUM.
Details: Prof. Dr. K. Yamaguchi, Institute of Industrial Science, University of Tokyo, 22.1 Roppongi-7, Minato-ku, TOKYO 106, JAPAN.

November 3-6, CZECHOSLOVAKIA

25th ACOUSTICAL CONFERENCE ON ULTRASOUND.
Details: House of Technology, Ing. Vani Skultetyho ul. 1 832 27 Bratislava.

November 17-19, WILLIAMSBURG, USA

ULTRASONICS SYMPOSIUM

Details: Inst. Elec. & Electronic Eng., Conference Cor-ordination, 345 E 47th St., New York, NY 10017, U.S.A.

December 8-12, CALIFORNIA

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

Continued on inside back cover

1987

January 26-30, NEW ZEALAND

56th ANZAAS
"Science in a Changing Society".

Details: 56th ANZAAS, P.O. Box 5158, Palmerston North, New Zealand.

March 24-26, AACHEN

DAGA '87

Details: H. Kutruff; Inst. Technische Akustik der RWTH, Templergraben 55, D-5100 Aachen.

May 11-15, INDIANAPOLIS

MEETING OF ACOUSTICAL SOCIETY OF AMERICA

Details: Mrs. B. Goodfriend, A.S.A., 335 East 45th St., New York, NY 10017, U.S.A.

May 19-21, POLAND

INTERNATIONAL CONFERENCE.
"How to teach Acoustics."

Details: Prof. Dr. A. Sliwinski, University of Gdansk, Institute of Experimental Physics, 80 952 Gdańsk, Wita Stwosza 57.

June 1-4, YUGOSLAVIA

XXXI ETAN CONFERENCE

Details: Prof. P. Pravica, Electrotechnical Faculty, Bulevar Revolucije 73, Belgrade, Yugoslavia 11000.

June 19, MADRID

ACOUSTICS AND OCEAN BOTTOM

Details: SEA - FASE 87, Calle Serrano, 144, Madrid 6, Spain.

June 23-25, LISBON

5th FASE CONGRESS

Details: SPA - FASE 87, Lab. Nac Engenharia Civil, Av. Brasil, 1799 Lisboa Codex, Portugal.

July, ANTWERP, BELGIUM

15-25, SUMMER SCHOOL ON INTERNAL FRICTION PROCESSES.

27-30, CONFERENCE ON INTERNAL FRICTION AND ULTRASONIC ATTENUATION IN SOLIDS.

Details: R. de Batist, S.C.K. — C.E.N., Boeretang 200, 2400 MOL, Belgium.

September 15-17, CHINA

INTER-NOISE 87
"Noise Control in Industry".

Details: Inter-Noise 87, 5 Zhonggvancun St., P.O. Box 2712, Beijing, China.

November 16-20, MIAMI

MEETING OF ACOUSTICAL SOCIETY OF AMERICA

Details: Mrs. B. Goodfrend, A.S.A., 335 East 45th St., New York, NY 10017, U.S.A.

1988

May 16-20, SEATTLE

MEETING OF ACOUSTICAL SOCIETY OF AMERICA

Details: Mrs. B. Goodfriend, A.S.A., 335 East 45th St., New York, NY 10017, U.S.A.

August 29 - September 1, EDINBURGH

7th FASE SYMPOSIUM ON SPEECH

Details: Mrs. C. Mackenzie, I.O. Acoustics, 25 Chambers St., Edinburgh, EH1 1HU, Scotland.

November 14-18, HONOLULU

2nd JOINT MEETING OF ACOUSTICAL SOCIETIES OF AMERICA AND JAPAN

Details: Mrs. B. Goodfriend, A.S.A., 335 East 45th St., New York, NY 10017, U.S.A.

1989

May 22-26, SYRACUSE

MEETING OF ACOUSTICAL SOCIETY OF AMERICA

Details: Mrs. B. Goodfriend, A.S.A., 335 East 45th St., New York, NY 10017, U.S.A.

November 6-10, ST LOUIS

MEETING OF ACOUSTICAL SOCIETY OF AMERICA

Details: Mrs. B. Goodfriend, A.S.A., 335 East 45th St., New York, NY 10017, U.S.A.

INDEX
Volume 13, 1985

Format: Author, issue, 1st page, title.

A. ARTICLES

B. REPORTS

C. AUTHOR INDEX

D. BOOK REVIEWS

E. INTERVIEW

F. LETTERS

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CONFERENCE ON COMMUNITY NOISE

Date:
1-3 October, 1986.

Venue:
Darling Downs Institute of Advanced Education, Toowoomba, Queensland.

Co-Sponsors:
The Queensland Division of Noise Abatement.
The Australian Acoustical Society.

Guest Speakers:
G. J. Walma van der Molen,
The Netherlands Planning for Noise Control.
Louis Sutherland, U.S.A.
Formulation and Application of Community Noise Assessment Procedures.

Theme:
Effective noise management through a multi-faceted approach. Participants will include planners, legislators, physiologists, psychologists, architects, occupational health and administrative personnel.

Technical Exhibition:
An exhibition of acoustical equipment, products and literature will be held conjointly with the Conference.

Further Information:
Mrs. N. Eddington
Secretary, Organising Committee
Division of Noise Abatement
64-70 Mary Street
Brisbane, Qld. 4000
Tel.: (07) 224 7698 or 224 4157

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