



Acoustics Bulletin

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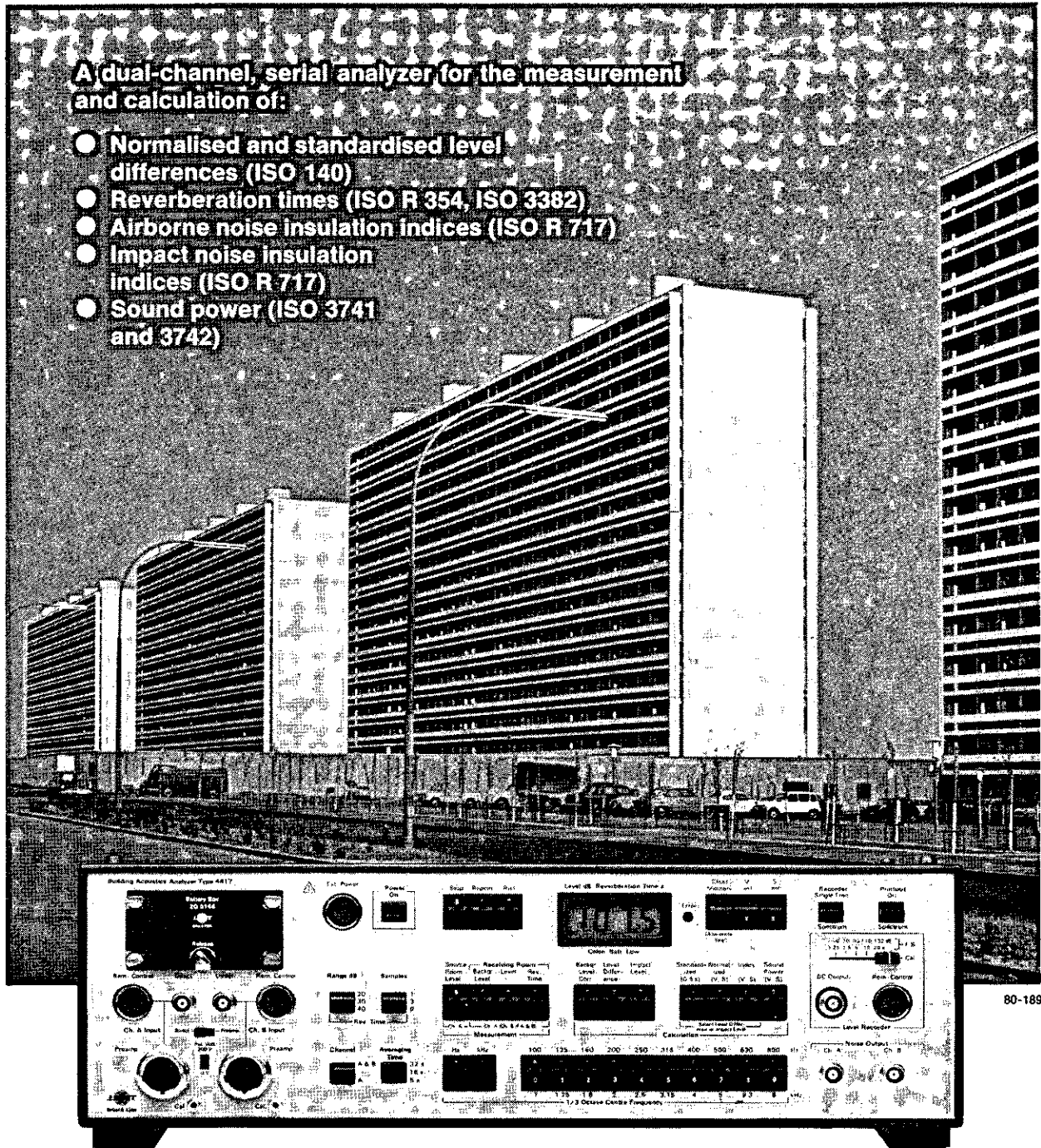
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Editor:
F A Hill

Associate Editors:
S J Flockton J W Sargent
A J Pretlove R W B Stephens

Advertising enquiries to:
H A Collins Ltd
37 Ruskin Road
Carshalton
Surrey SM5 3BQ
Telephone: 01-647 1393

Contributions and letters to:
Editor, IOA Bulletin
25 Elm Drive
St Albans
Herts AL4 0EJ

Books for review to:
S J Flockton
Physics Department
Chelsea College
Pulton Place
London SW6

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October 1981

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The Institute of Acoustics was formed in 1974 by the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is now the largest organisation in the United Kingdom concerned with acoustics. The present membership is in excess of one thousand and since the beginning of 1977 it is a fully professional Institute.

The Institute has representation in practically all the major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental acoustics, architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration.

Membership of the Institute of Acoustics

Membership of the Institute is generally open to all individuals concerned with the study or application of acoustics. There are two main categories of membership, Corporate and Non-corporate. Corporate Membership (Honorary Fellow, Fellow, Member) confers the right to attend and vote at all Institute General Meetings and to stand for election to Council; it also confers recognition of high professional standing. A brief outline of the various membership grades is given below.

Honorary Fellow (HonFIOA)

Honorary Fellowship of the Institute is conferred by Council on distinguished persons intimately connected with acoustics whom it specially desires to honour.

Fellow (FIOA)

Candidates for election to Fellow shall normally have attained the age of 35 years, have had at least seven years of responsible work in acoustics or its application, and have made a significant contribution to the science or profession of acoustics.

Member (MIOA)

Candidates for election to Member shall normally have attained the age of 25 years, must either (a) have obtained a degree or diploma acceptable to Council and have had experience of at least three years of responsible work in acoustics, or (b) possess an equivalent knowledge of

acoustics and cognate subjects, have had experience for not less than seven years of responsible work in acoustics or its application, and must have been a Non-corporate member of the Institute in the class of Associate for not less than three years.

Associate

Candidates for election to the class of Associate shall have attained the age of 18 years and (a) be a graduate in acoustics or a discipline approved by Council, or (b) be a technician in a branch of acoustics approved by Council, or (c) be engaged or interested in acoustics or a related discipline.

Student

Candidates for election to the class of Student shall have attained the age of 16 years and at the time of application be a bona-fide student in acoustics or in a related subject to which acoustics forms an integral part. Normally a student shall cease to be a Student at the end of the year in which he attains the age of 25 years or after five years in the class of Student, whichever is the earlier.

Full details and membership application form are available from: The Secretary,
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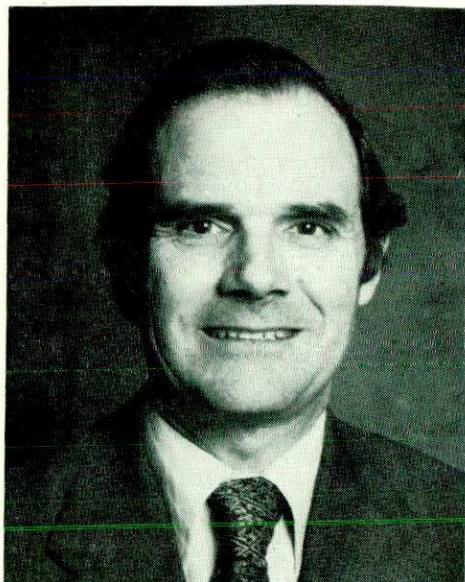
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President's Letter

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Dear Member,

In the middle of the holiday period there is little in the way of new activities for me to bring to your attention. As an economy measure, the usual June Council meeting has been cancelled and the business held over to the normal October meeting. In the meantime consultations are going on between our Sub-Committee and Branches and Groups on the proposals for developing the Branch activities. It is the long-term aim of Council to have an active and lively Branch within easy reach of every member of the Institute. It will obviously take several years to build up to this level of local activity but Council would like to hear from bands of enthusiasts in the regions who are prepared to help in this evangelisation.

Unfortunately there will be no autumn meeting in the Lake District this year but I hope that there will be enough support to reinstate this popular event next year. This break in general meetings will give you all time to prepare your contributions to the Spring Conference to be held in Guildford at the end of March next year!

In this Bulletin you will read of the request for nominations for the 1982 Medals of the Institute. Please send any suggestions to me in confidence for consideration by the committee of Council which is responsible for preparing recommendations.

By the time that you receive this Bulletin I hope that you have had an enjoyable holiday and that you have now returned to work with new enthusiasm to see the activities of the Institute develop.

B. L. Clarkson

Letters to the Editor

Dear Madam,

Agreed conclusions as to the degree of nuisance aroused by an intruding noise are always hard to produce, but used with care and understanding BS 4142 provides guidance and a nuisance scale that long experience in its use has shown to be in very good agreement with unbiased subjective opinion. Like all scales developed to provide a numerical score for a human judgement there is a median band in which the result is indeterminate but so, I would suggest, is the unbiased opinion of an independent observer in the same situation.

In spite of the irreplaceable guidance it provides, we find BS 4142 increasingly ignored in coming to a decision about the degree of nuisance due to an intruding noise. The Control of Pollution Act is invoked as justification for deciding that a particular noise is a nuisance, though in fact the Act provides no guidance except in a designated noise control zone. Why therefore abandon BS 4142 in favour of the 'This noise is a nuisance because I think that it is a nuisance' approach?

The result of basing decisions on the Act rather than on the Standard is just what might be expected. In one area a noise 10 dB(A) above the ambient is considered to define the nuisance boundary, whereas in another area a noise 9 dB(A) below the ambient is held to be a nuisance. Even more stringent are those areas where a noise is claimed to constitute a nuisance if it can be heard in any circumstances. A politically advantageous standard to adopt though it should be realised that the cost of adopting such a stringent standard must ultimately come out of industry.

Should we not be refining the British Standard to improve the agreement between decisions based on the Standard and those based on unbiased study when dealing with those situations where the Standard is known to be weak? Intermittent noises, particularly of the impact variety, require more study as do broad-band noises that include pure tones. L_{90} is a good description of the ambient noise level, but L_{10} has some limitations as a measure of the maximum effective intensity level. Is L_{eq} over five or fifteen minutes a better descriptor? How does the duration of a noise affect the subjectively assessed degree of nuisance? No doubt

there are other aspects that would benefit from discussion. Though the preface notes that the Standard is not intended to apply to noise generated inside a house I find that it provides very reasonable decisions in these situations.

I would suggest that *Strengthening BS 4142* would be a good subject for a day's discussion.

Yours sincerely,
James Moir

Readers will see from the list of IOA Meetings inside the back cover that the Meetings Committee has already taken up Mr Moir's suggestion of a day's discussion of BS 4142 — Ed.

Dear Madam,

I wonder if any of your readers might be able to give me some advice.

I am a sculptor. I'm making a walk in Exeter Forest, on the theme of the process of creation — as it actually happens, with all its vagaries, mistakes and muddles. It starts with a maze; goes on to problem identification (a garden of Eden gone wrong); takes risks (a terrifyingly delicate suspension bridge) and so on.

Now, I want to make a place which reflects the times when you're working on pure intuition. The best way to describe it seems to be that you're getting resonances and echoes back from the idea you're considering. So round about the middle of the walk I want to build an 'echo garden'—where any sound you make resonates deeper and clearer as you stroll through it.

I'd seen the whispering circles at Dartington Hall gardens, the amphitheatre at Epidauros, and the whispering gallery at St Paul's, so I took to the library to see what I could find as starting points for something slightly smaller—only to find that all the textbooks treated these effects as the villains of the piece, and told you only how to get rid of them.

So I'm hoping to meet someone who has a soft spot for the acoustic oddities that must be scattered round the country, who could give me a few pointers.

Ideally, the solution would: (a) Use as little sound-reflecting surface as possible (the materials which fit naturally

in the forest, and are easily available, are knapped flint and timber; but everything has to be carried by hand at least half a mile off the road). (b) Give a steadily increasing progression of resonance/echo as you walk through the garden. (c) Leave you very uncertain as to exactly where the echo was coming from. Architectural ventriloquy, anyone?

I suppose we could reinforce the acoustics with a little electronic amplification and delay, but I'd rather stick to honest acoustics where at all possible.

So if there's anyone out there who's ever pipe-dreamed an acoustical adventure playground, I'd very much like to hear from you.

Yours faithfully,
Jamie McCullough

Pipe-dreamers are invited to contact the Editor, who will put them in touch with Mr McCullough.

Dear Madam,

I would be interested to know if any of your readers can provide an explanation for the following observations.

We have a 128 Hz tuning fork (Downs Surgical Ltd) which is used for medical purposes. This fork radiates airborne sound principally at 128 Hz but there is a moderately strong component at 256 Hz. When struck violently, overtones at 815 and 2267 Hz are clearly evident. The vibration of the stem, measured with an artificial mastoid is, however, strongest at 256 Hz with a very weak component at 128 Hz. The frequency doubling of the stem vibration is not the result of distortion in the measuring apparatus. It is clearly audible and moreover it can be used to excite a fork tuned to 256 Hz by bringing the stems of the two forks into contact.

According to the standard texts a tuning fork can be regarded as two fixed-free bars, each of length L (A B Wood) having overtones at frequencies f_1 , $6.27f_1$, $17.55f_1$, etc, or as a single free-free bar of length $2L$ (Kinsler and Frey) having overtones $\frac{1}{4}$ (f_1 , $2.76f_1$, $5.40f_1$, etc). The former description accounts reasonably well for the overtones at 815 and 2267 Hz but neither description explains the frequency doubling nor can it be explained as a transition from a fixed-free to a free-free vibration.

Yours faithfully,
P M Houghton.

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Calls for Papers

The Meetings Committee of the Institute of Acoustics is always pleased to receive offers of contributions to any of its meetings. Contributions are particularly sought for the following:

BS 4142 Reviewed and Criticised

London, 8 February 1982

Meeting Organiser: James Moir

James Moir & Associates, 16 Wayside, Chipperfield, Herts WD4 9JJ

(200 word abstracts as soon as possible)

Design and the Consultant — Everyday Acoustic Details

Portsmouth Polytechnic, 26 February 1982

Meeting Organiser: Dr J A Powell

Portsmouth Polytechnic, School of Architecture, King Henry I Street,
Portsmouth PO1 2DY

(200 word abstracts as soon as possible)

International Conference on Spectral Analysis and its Use in Underwater Acoustics

Imperial College, London, 29 - 30 April 1982

Conference Organiser: Dr T S Durrani

Department of Electronic Science and Telecommunications,
University of Strathclyde, Royal College,
204 George Street, Glasgow G1 1XW

(300 word abstracts by 15 November)

Noise Control in Factory Buildings

Department of Architecture, University of Cambridge, 26 May 1982

Meeting Organiser: Dr R J Orlowski

Department of Architecture, University of Cambridge,
1 Scroope Terrace, Cambridge CB2 1PX

(200 word abstracts by 31 January)

Design and Use of Acoustic Test Rooms

London, June 1982

Conference Organiser: Dr G M Jackson

Atkins Research and Development,
Woodcote Grove, Ashley Road, Epsom, Surrey

(200 word abstracts by 31 January)

Auditorium Acoustics

Edinburgh, 8 - 10 September 1982

Conference Organiser: Dr R K Mackenzie

Heriot-Watt University, 25 Chambers Street, Edinburgh EH1 1HU

(200 word abstracts by 31 March)

Health and Safety at Work etc Act 1974

Proposed new Regulations and Approved Code of Practice on protection of hearing at work

A consultative document and associated papers have now been prepared containing Health and Safety Commission proposals for regulations and an approved code of practice dealing with the protection of hearing at work.

In compliance with its duty to consult appropriate bodies before submitting proposals for the making of regulations or the approval of codes of practice to the Secretary of State, the Commission has invited the views of the IOA on the consultative document. Comments should be sent to Mr C O Leite at the Health & Safety Executive, Hazardous Substances Division D3, 25 Chapel Street, London NW1 5DT, by 30 April 1982. The document is held at the IOA Secretariat in Edinburgh. □

Scientific Collaboration with Australasia

Officers of the Royal Society in concert with the Science and Engineering Research Council have for some time been discussing ideas for establishing new schemes to enhance scientific collaboration between the United Kingdom and Australia and New Zealand. Council of the Royal Society has accordingly decided to establish a Royal Society fellowship scheme with particular intent to improve access to major 'facilities'—such as specialised laboratories. The scheme includes applied science and engineering as well as fundamental aspects.

Applications are now invited from United Kingdom postdoctoral scientists who wish to visit Australasia to undertake research or learn new techniques or both in the laboratory or in the field. Support where given will be in the form of fellowships normally of three to twelve months duration. Alternatively, where especially fruitful collaboration can be expected from a visit by an Australian or New Zealand scientist to the United Kingdom, a potential host may submit an application on behalf of the visitor. Further details are available from the Royal Society. □

Spacecraft Structural Acoustics at the European Space Agency

High frequency mechanical vibrations are induced in spacecraft and their equipment during launch due to the effects of the launch vehicle rocket motor noise and aerodynamic noise transmitted into the payload bay. Acoustic fatigue in the primary spacecraft structure is unlikely even in the case of multi-mission spacecraft of the sort that could be envisaged for use with the Space Shuttle but the induced vibrations can create problems in service and payload equipment. The acoustic energy accepted by large spacecraft surfaces such as antennae and solar arrays can augment these levels of vibration. The research into structural acoustics being conducted for ESTEC (mainly by British Aerospace Aircraft Group, Bristol, in conjunction with the Institute of Sound and Vibration Research at Southampton University) as part of ESA's Technological Research Programme is aimed at a better understanding of the structural behaviour of spacecraft when subjected to the noise and high frequency vibrations of the launch environment.

THE MEANS for predicting the vibration levels to which spacecraft will be subjected during launch, at an early stage in the design process and for defining subsystem vibration test levels and test requirements, have yet to be fully developed into a readily available design aid.

Zoning of the spacecraft into regions in which vibration levels are likely to be similar is a technique that has already been used in aerospace investigations. Acoustic-fatigue investigations such as those conducted for the Concorde programme have demonstrated that it is possible to confine oneself to structural segments rather than the complete structure when conducting experimental investigations or making theoretical predictions.

In the current ESA spacecraft research activities these concepts are being further investigated. The ultimate goals are to provide a better understanding of response behaviour, to reduce the complexity of the theoretical models and test configurations and to evolve improved structural configurations for housing payloads and equipment from the high frequency vibration viewpoint. This should also lead to more realistic test levels when mechanical vibration tests are used to simulate acoustic-environment effects in the qualification of spacecraft structures and spacecraft equipment.

Typical noise levels encountered in the Ariane launcher payload bay are presented in Figure 1, while Figure 2 shows examples of typical vibrations induced in spacecraft panels during acoustic qualification testing.

Spacecraft Zoning

To explore experimentally the feasi-

bility of zoning a spacecraft, a simplified satellite configuration has been evolved which can be readily broken down into its constituent parts or partial assemblies constructed (Figures 3 and 4). The complete assembly or subassemblies can be examined under acoustic excitation to study the contributions of individual components and their structural-acoustic couplings. The dynamic behaviour of such components can also be investigated. Corresponding theoretical estimations are being made in order to assess the scope and accuracy of the prediction methods currently available.

A reverberant sound field is assumed in both the acoustic testing and theoretical predictions. However, the near-field sound characteristics within a shroud can modify the local structural response and this effect is the subject of additional studies using a simulated shroud enclosure containing the satellite structures.

Statistical Energy Analysis

Earlier investigations of high frequency vibration predictions, particularly structural resonances at specific frequencies, have used normal-mode vibration analyses or similar techniques. However, over much of the frequency range of interest the number of such modes becomes too high for the use of these classical techniques.

This led to the formulation by R H Lyon and others of a method known as statistical energy analysis (SEA), which can provide information on average vibration levels for structural subsystems.

SEA considers the vibratory energy flow that occurs between subsystems, such as the random noise field inside a rocket payload shroud and the vibrating spacecraft structure and between the various components of the structure (such as sidewalls and a platform). It is possible to consider a 'power balance' between different sub-

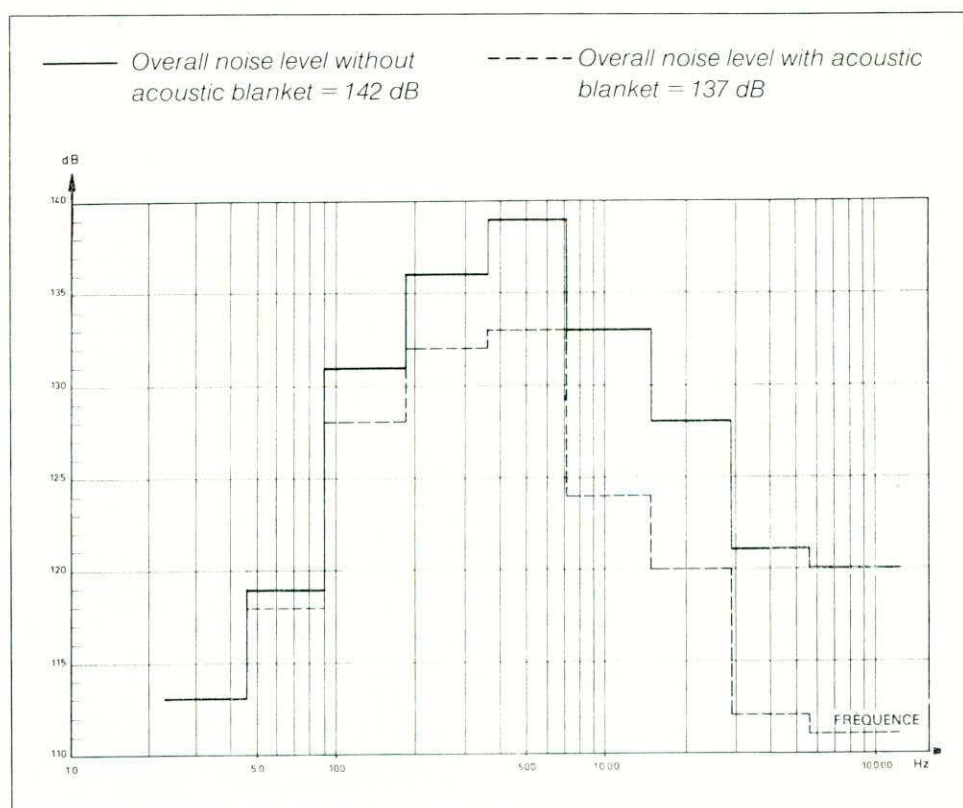


Figure 1 Ariane payload-bay internal noise levels during flight

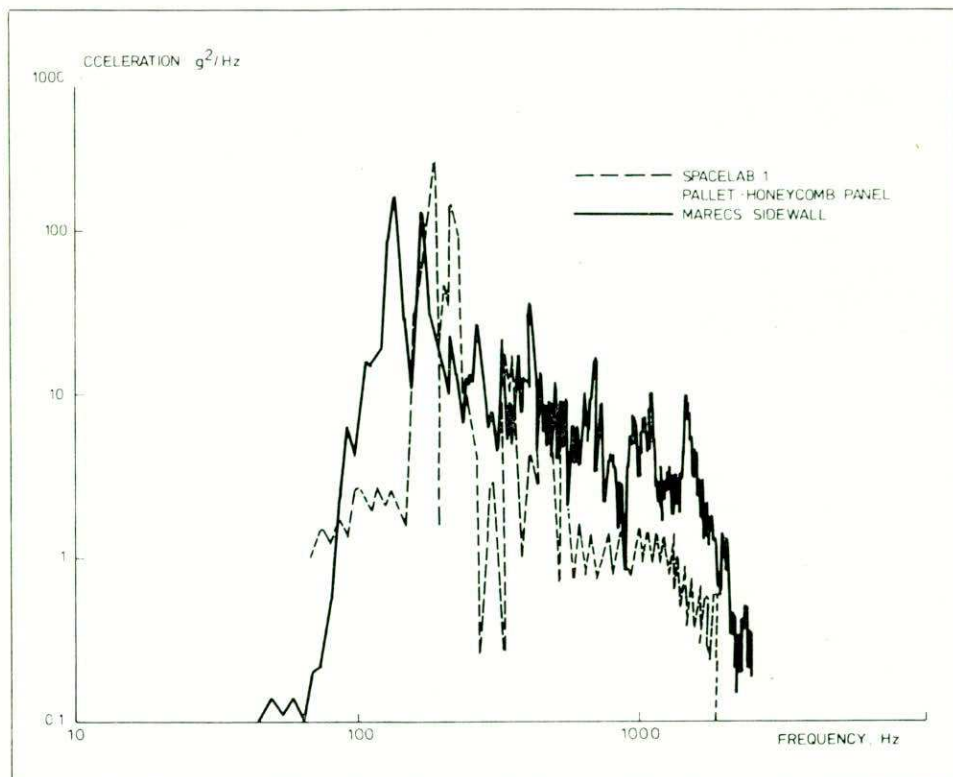


Figure 2 Typical structural vibrations induced in panels during acoustic qualification testing (narrowband spectral analyses)

systems. The energy received by one subsystem from the others will be equal to the energy given to the other subsystems plus that dissipated within itself. From such analyses it is possible to obtain a statistical assessment of the typical average response behaviours of the various subsystems.

Initial investigations for ESA, conducted by British Aerospace Dynamics Group (Stevenage), explored the potential of the SEA approach, while the Office National d'Etudes et de Recherches Aérospatiales explored a related statistical approach. It became clear that the analysis could be formalised, and as a result British Aerospace (Aircraft Group, Bristol) have developed a suite of computer programs called GENSTEP which allows the SEA technique to be applied to a wide range of spacecraft structural components, including such items as plain and stiffened thin-walled cylinders, plain and stiffened flat and curved panels, honeycomb panels, beams, and hoops subjected to acoustic excitation.

The GENSTEP Computer Programs

The programs have been developed on a modular basis, which facilitates trouble shooting and the introduction of new features. In a first step, the basic properties of the noise field and the structure are introduced. This information is then checked and some

basic subsystem properties are calculated. In subsequent steps matrices of modal density, loss factor and coupling loss factor for the subsystems are constructed. Further steps permit the assessment of the energy distribution discussed above and calculation of the energies in the individual subsystems.

The final steps allow the responses and sound-transmission characteristics of the various units to be calculated.

The GENSTEP suite of programs is

capable of handling twenty linked subsystems.

Work in Progress

Much of the current effort is devoted to producing a data bank of information for use with the GENSTEP programs, such as damping values (loss factors) and modal density characteristics, because during the related initial experimental work carried out at ESTEC difficulties were experienced in establishing such parameters.

Means of establishing both the loss factor and modal density indirectly have been developed as a result of theoretical and experimental studies conducted at Southampton University's Institute of Sound and Vibration Research. Using SEA power-flow concepts, it is possible to demonstrate that both parameters can be derived by measuring the input forces generated by point excitations and considering spatial average response velocity characteristics (Figure 5). In most of the work, a fast sine sweep (transient excitation) has been used. Similar results can be obtained using stationary random point excitation, though more sophisticated data-reduction techniques are then called for.

Interim Findings

It has been found that over most of the important high frequency range it may well be possible to test spacecraft-platform-mounted equipment using a representation of the platform alone. This could simplify development testing and provide more representative conditions than are presently realised in mechanical vibration testing.

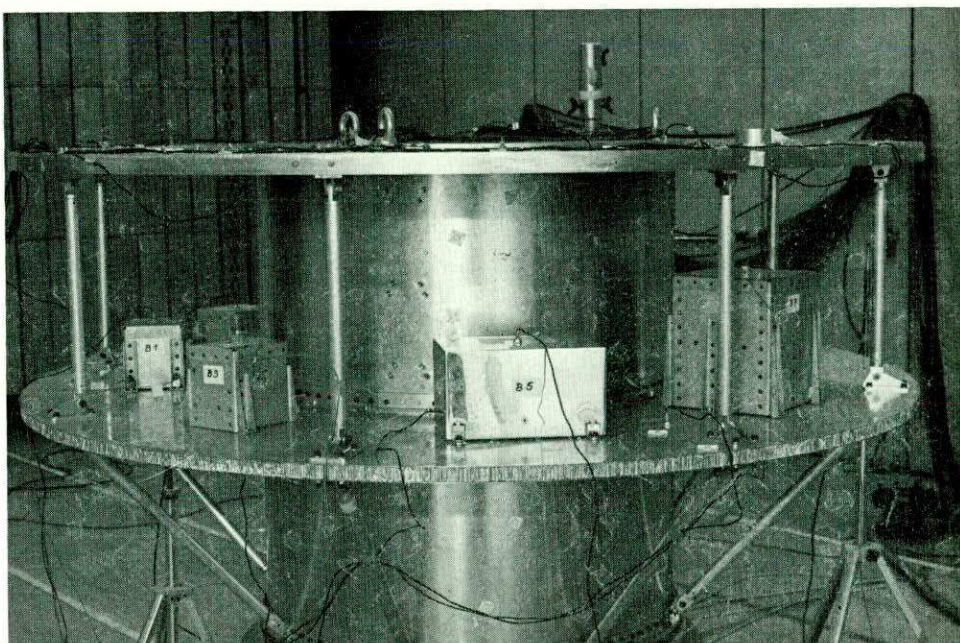


Figure 3 Simplified satellite structure with equipment boxes

The presence of a large central mass on the spacecraft, which could be an apogee boost motor or fuel tank, has been shown to have little effect on the response levels of the satellite structure. Struts in the structure only noticeably modify the responses of adjacent structures in the frequency bands where fundamental flexural strut resonances occur. Cable harnesses have some effect on local frequency response characteristics but little on average behaviour.

The method of mounting the simplified satellite specimen in the acoustic chamber, whether with a low frequency sling or by supporting it at its base, has little effect on its high frequency response characteristics.

Comparison of the effects of the shroud enclosure configuration with the results of basic reverberant room tests indicate that platform responses may be enhanced at frequencies greater than 1 kHz, but that the central cylinder levels are reduced in the lower frequency regime. The responses of spacecraft appendages that lie relatively close to the shroud wall are, of course, likely to be significantly increased.

An example of a check on the accuracy of the indirectly measured modal density compared with the theoretical value is shown in Figure 6. A similar standard of correlation has been found for a cylinder except that a greater deviation occurs in the vicinity of its ring frequency.

An example of measured and SEA-

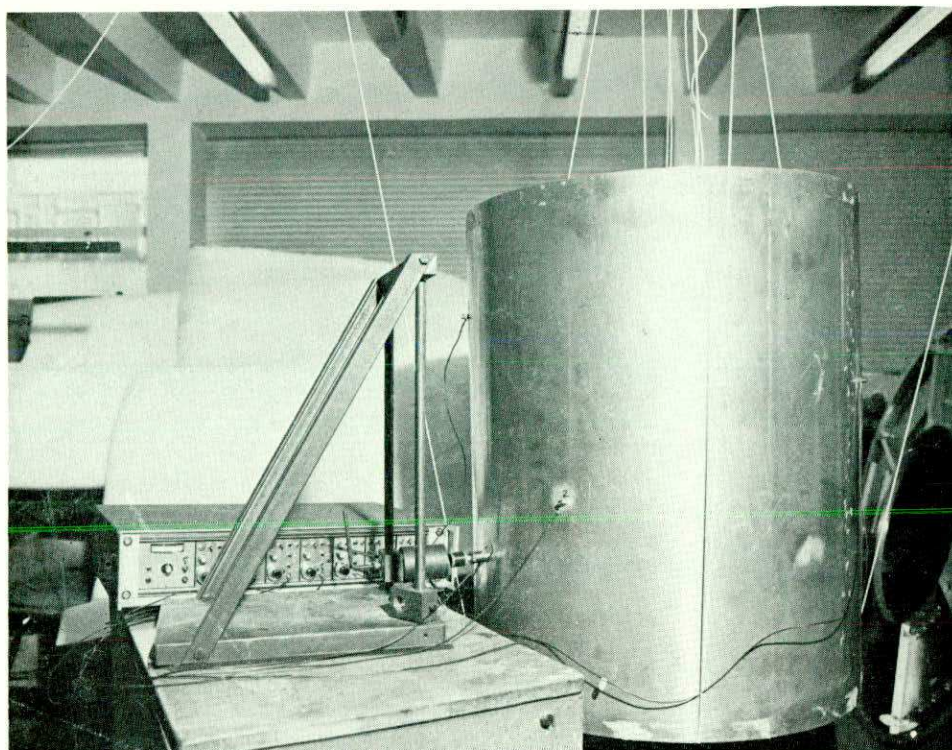


Figure 5 Proximity exciter and accelerometers located for spatial average assessments (modal-density determination for a cylinder), at Southampton University

predicted response values for a skin-stiffened platform attached to the stiffened central cylinder of a simplified satellite specimen is shown in Figure 7. The correlation is generally very good, the greatest error occurring mainly below about 200 Hz, probably due to the low modal densities in this region. Large errors are also incurred at the cylinder ring frequency and at the critical coincidence frequency, discrepancies that are always observed and have yet to be fully explained.

Some difficulties have been encountered in the past in predicting responses for honeycomb structures, and on occasions for certain classes of honeycomb structure it has been necessary to resort to a simplified normal mode analysis to establish low frequency response with sufficient accuracy. A better understanding of the structural parameters that are important in the response behaviour is now leading to improved assessments.

Other work being undertaken using the test structures and simulated spacecraft experiments, appendages and equipment is examining the effects of mechanically induced high frequency vibrations at the base of the spacecraft structure.

As a result of the directional nature of such vibrations and their localised input, substantially different response behaviours in different structural zones are observed when compared with those set up by the loadings induced by a diffuse acoustic field. This serves to demonstrate that it is often impractical to simulate acoustic excitation by mechanical testing, at least for complex configurations. Mechanical testing is suitable for many classes of equipment when it can be demonstrated that the vibratory energy is mainly transmitted by the local structure, but this is not the case if large flexible equipment surfaces likely to

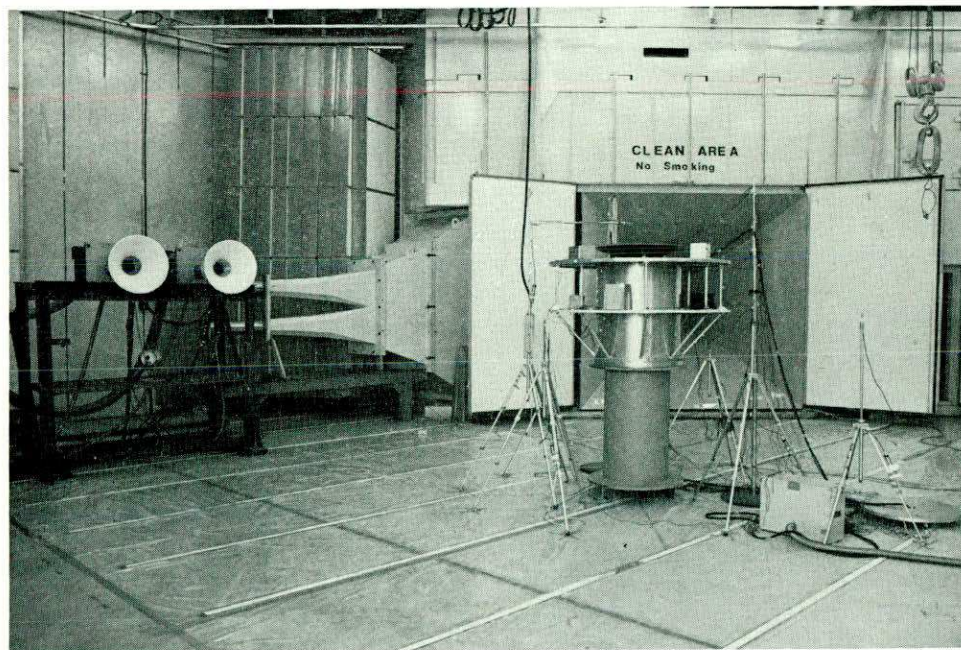


Figure 4 Selected spacecraft subsystems assembled for acoustic tests at IABG (Munich)

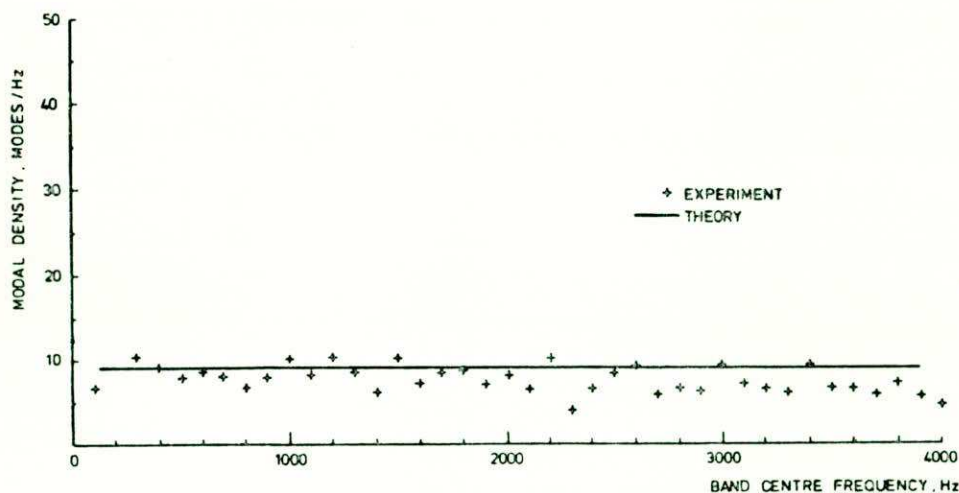


Figure 6 Modal-density of a flat plate (average value from three-point impedance measurements)

accept acoustic energy are involved. Current activities will culminate in the first issue of a 'Structural Acoustics Design Guide' later this year, containing:

- 1 A guide to modelling techniques and how they should be used.
- 2 Guidance on the choice of SEA parameters.
- 3 A glossary of loss factors.

4 Recommended test methods, including guidance on the simulation of structure vibrations in equipment testing.

5 Recommendations on means of scaling past test data for use in confirming vibration levels.

6 General observations from surveys of various acoustic and high frequency mechanical vibration tests.

7 Examples of applications of prediction and scaling methods.

Future Work

Future work will consider the application of SEA to mechanically induced vibrations and explore the practical boundaries of such techniques. The establishment of greater understanding of response behaviours should lead to improved scaling laws, which in turn should permit the extrapolation of test data to a wide range of launch configurations.

Further work is required in order to design against high frequency vibration problems and the use of artificial damping treatments to reduce vibration levels is but one aspect of such work. Further studies of coupling loss factor have also to be undertaken and the modal densities of advanced materials such as carbon-fibre light alloy honeycomb platforms have yet to be properly investigated. □

D C G Eaton

This article is an abridged version of one originally appearing in the ESA Bulletin for May 1981.

$$f_{\text{CRITICAL}} \approx \frac{C^2}{2\pi} \sqrt{\frac{m}{B}}$$

$$f_{\text{RING}} = \left(2\pi R / C_b\right)^{-1}$$

m = MASS/UNIT AREA OF STRUCTURE SUBSYSTEM

B = BENDING STIFFNESS OF STRUCTURE SUBSYSTEM

C = SPEED OF SOUND IN AIR

R = CYLINDER RADIUS

C_b = PLATE BENDING WAVE VELOCITY

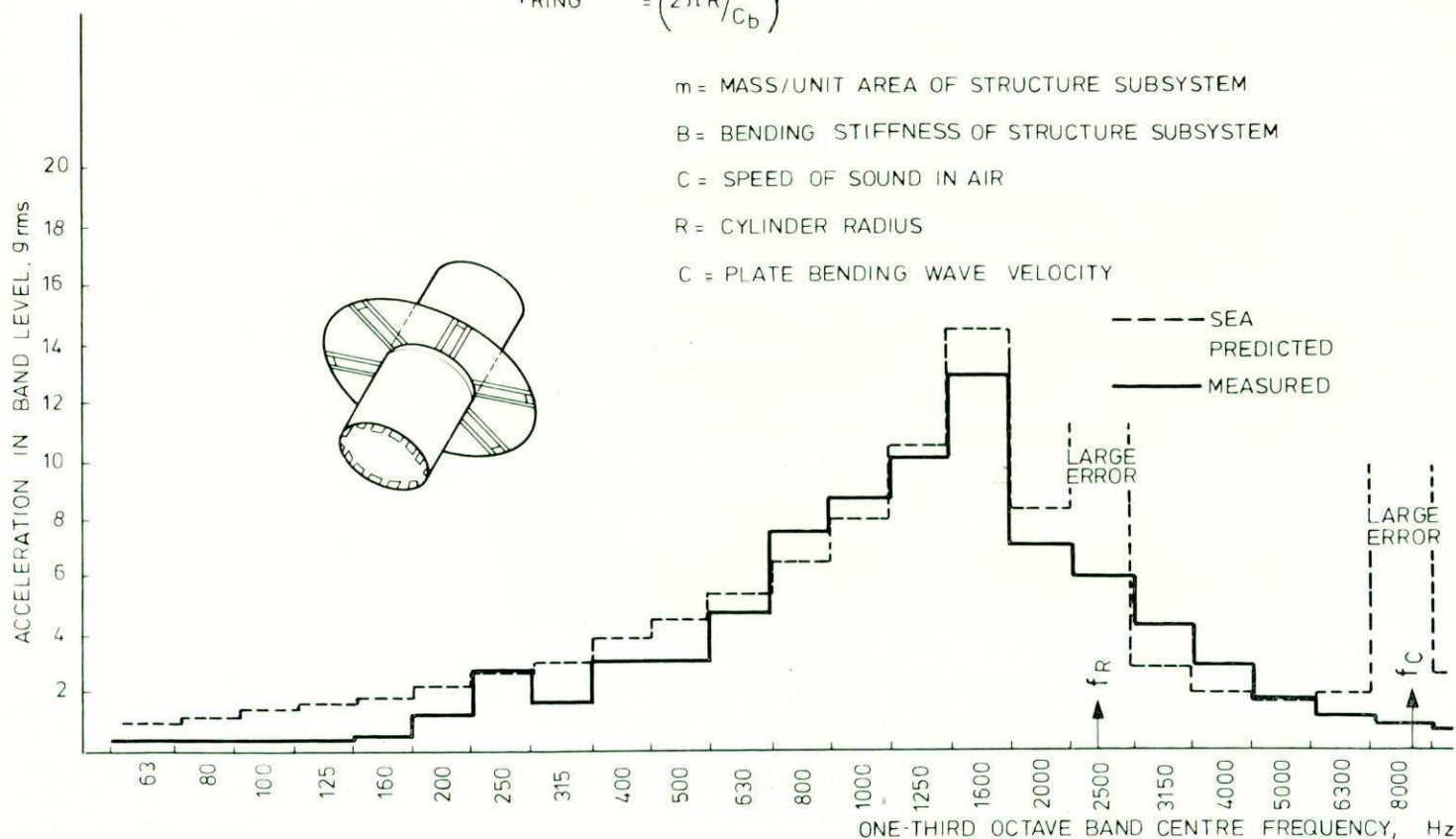


Figure 7 Average response of stiffened cylinder coupled to stiffened plate platform

SPEECH RESEARCH

Although acoustics is at its heart, speech research is essentially a multidisciplinary activity. The following five papers review the broad scope of this work.

The generation of speech is discussed by Celia Scully. She shows how the articulatory mechanisms operate in various ways to produce acoustic waves which are characteristic of speech. In particular she is concerned how these processes can be modelled so that a better understanding may be obtained. These mechanisms sometimes malfunction, leading to speech disorders. This is the topic of the paper by Ronald Beresford.

Although speech production may be studied in isolation, it is more profitable to include it in the larger topic of speech communication. Normally we speak not only to be heard, but also to be understood. The other side of the coin is thus speech perception. This topic is reviewed by Chris Darwin.

In order to carry out experiments in this field it is useful to be able to have precise control over the acoustic stimuli, and this is best achieved by speech synthesis. John Holmes discusses the techniques which have been employed, and also introduces one of the main applications of speech research: enabling machines to communicate with human beings by voice. As this has now become feasible, it is natural to study the reverse process. Roger Moore traces the development of automatic speech recognition by machine. This work is providing systems which are useful not only in certain applications, but also in suggesting new theories of speech perception.

Thus all the strands of speech research are interlinked, with each providing assistance and criticism for the others.

*W A Ainsworth
Chairman, IOA Speech Group*

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Applied Acoustics and Speech Disorders

RONALD BERESFORD

Sub-Department of Speech, University of Newcastle upon Tyne

The acoustics of speech is a part of phonetics, the science of vocal communication, and is the study of the physical medium of spoken language. Such a study would be of the acoustic output of the initiation and regulation of the airstream in the vocal tract, manifest in utterance as voice (including intonation), fluency, and the sequenced sounds of speech. Speech disorders may be regarded as dysfunction, inherited or acquired, related to speech production; recognised by deviation in such vocal features. The disorders outlined below are particularly of voice and nasalisation (dysphonia and hyper-nasality) where acoustics has made a greater impact than in its applications to the study of dysfluency, articulatory disorders and the evaluation of clinical methods of speech assessment.

Applications to the study of voice disorders

By *voice* is meant the regulation of the pulmonic airstream by the vocal folds in the larynx to produce the glottal sound source (the principal auditory basis of speech) which is further modified by the supraglottal vocal tract.

This vocal fold regulation may vary in at least five ways within one vibratory cycle:

- a absence of closure of the glottis
- b absence of movement of one fold
- c movement of the two folds being of different speeds
- d movement of the two folds being at different amplitudes
- e dissimilar movement, along the folds, between the two folds.

The vocal folds, in health, are assumed to be identical, thus vocal fold movement is constant from cycle to cycle; but if not healthy, then the folds are often not identical and their movement is inconsistent from cycle to cycle.

Techniques for voice analysis can be divided into those whose source is *direct*: radiated sound pressure and throat contact signals; and those whose source is *indirect*: glottal signals derived using inverse filtering. Either source may be analysed to determine mean fundamental frequency or energy distribution.

Direct techniques of using the radiated pressure waveform seem the most readily available but where such techniques do not appear to hinder a glottal sound source* analysis it must be remembered that such resonance characteristics are affected by the

supraglottal structure there; hence if the glottal sound source originates from a pathological condition of the folds then such resonances could be masked by the effects of the healthy supraglottal structure. Contact microphones might avoid such effects but there are further problems because of the low-pass filtering action of the intervening tissues and the placement of the microphone.

Indirect techniques assume that any voiced sound can be modelled as a sound pressure waveform resulting from periodic source excitation (the vibration of the vocal folds) of an acoustic tube (the vocal tract); then by inverse filtering, the effects of such a tube can be removed and the resulting signal is an approximation of the source. Such filtered measures are not affected by the supraglottal structure. There are two inverse filtering methods: the glottal and the residual. The former uses the inverse of the lip radiation and vocal tract spectral energy to estimate the glottal volume velocity waveform as a function of time. Such a method is theoretically indebted to linear voiced speech production models (Fant, 1960; Flanagan, 1972). The latter is based on a linear model of speech production (Markel and Gray, 1976). Davis (1976) substantiated earlier claims (Koike and Markel, 1975) that more acoustic information relevant to pathology is conveyed by the indirect method than directly from the speech signal. Further, the residue signal is easier to obtain than the glottal signal (but see Fourcin, 1974).

Cine-photography has shown that in pathological conditions of the folds

there are frequently irregular vibratory patterns. Measures of these perturbations (pitch or amplitude) can be made (Crystal and Jackson, 1970; Davis, 1976; Hecker and Kreul, 1971; Lieberman, 1961; Takahashi and Koike, 1975). Such perturbation seems to correlate closely with subjective judgements of degree of 'roughness'.

Sound spectrographic study shows attenuation of higher frequency harmonics from a pathologically affected glottal sound source. The folds in such dysphonic conditions often fail to produce complete closure or vibrate irregularly, which results in noise components being distributed over the spectrum, the extent depending upon the severity of the disease (Gray and Markel, 1974; Yanagihara, 1967).

The presence of such noise correlates with subjective judgements of hoarseness. A more significant correlation is between subjective assessment of voice quality and the relative energy of the harmonics, although if the harmonics carry a high proportion of the total energy of the speech wave (>80%) this correlation begins to break down.†

Applications to the study of Hypernasality

Such excessive nasality is referred to in the speech of cleft-palate speakers. Acoustically, nasalisation is the change in transfer function of the vocal tract (the introduction of anti-resonances) made by the coupling of the pharyngo-oral cavities with the nasal cavities, such coupling being effected by lowering the velum (Fant, 1960). However, a complication is that, not only are there two transmission channels (the mouth and the nose), but the manner in which the energy is divided between these channels is related both to the extent of the velo-pharyngeal opening and to the articulatory configuration of the tongue, jaw and lips. In other words, the division of energy will be inversely proportional to the impedance and will vary with frequency. The effects of such coupling will be to increase the damping of the system (the nasal cavities having a large surface area of spongy membrane in proportion to their volume). The spectral effect of this is to increase the band-

* despite the basic problem of separating the fundamental excitation frequency from the vocal tract response components of the speech waveform (see Noll, 1967).

† Does this have an implication for those speech synthesis models which assume that speech energy in voiced sounds is 100% carried by the harmonic structure?

width of formants with a flattening of their peaks and an overall reduction of the energy level. Thus the cleft-palate speaker has a vocal tract system that absorbs much more energy than that of a normal speaker, so by way of compensation he must drive the system harder with an increased expiratory pressure from the lungs and often with a higher rate of airflow. Acoustic examination of nasalisation in the past has been made principally by sound spectrography but more recently synthesis analogues have been used, although they are of limited clinical availability. The variability of acoustic characteristics of nasality from person to person (Dickson, 1962) and the lack of correlation between manometric data and spectrographic analysis is still

a problem in clinical assessment (Bjork, 1961). Nevertheless, as an initial approach in the clinic, sound spectrography can still be useful, as it can also be useful in examining the speech of the dysarthric and in the evaluation of the efficacy of vocal-fold teflon injection.

As a coda to all the foregoing, it can be said that despite many insights gained there are still many basic problems in acoustic phonetics, not least that sounds articulated differently may nevertheless be similar acoustically—a problem in the investigation of supraglottal regulation of an airstream (articulation) which must be investigated aerodynamically as well as acoustically and include articulatory

timing as well as articulatory position. This problem of articulatory-acoustic relations (a specific domain of phonetics) still remains despite the considerable achievement of an account of such relations by Gunnar Fant (1960). Even in models of one speaker there are discrepancies between the observed and the generated formant frequencies (Mermelstein, 1973; Rice, 1976). Such variability suggests that speakers do only what is necessary to produce an appropriate acoustic output, which augurs ill for theories of the quantal nature of speech production and perception (Lindau, 1975). □

A list of references is available from the author on request.

Automatic Speech Recognition

R K MOORE

RSRE Malvern

In these days of ever advancing technology there is an increasing need for effective and efficient means by which man can communicate with machines. Push buttons and indicator lamps are being replaced by keyboards and visual displays. As a consequence, man is having to learn new skills and adapt his behaviour in order to control his machines. However, there is one mode of communication which has so far had little application in man's dealings with machines, a mode in which man has a natural and highly developed skill, a mode which is man's primary method of communicating with his fellow man: speech.

IN THE world at large, man uses his voice to great effect. It is therefore not unreasonable to expect that, in his search for improved communication with machines, man will want to be able to issue spoken instructions into a microphone rather than spend time at a computer terminal. Not only would such a facility be more natural but, in general, communication by voice has a number of advantages over other modes, and these advantages would also apply to vocal communication between man and machine.

For example, spoken communication can be very efficient since speech has a potentially high data transfer rate. It is possible to speak at rates of up to 200 words per minute (wpm). Whereas a skilled typist may achieve 120 wpm, a relatively untrained computer operator may only manage 20 wpm.

Another advantage is that vocal communication between man and machine would provide a supplementary channel for information transfer or control. This means that a person could execute more complex control tasks since he could use his hands and his voice simultaneously.

A further advantage is that speech communication with machines would place few physical constraints upon the user. Obviously he is required to wear a microphone, but he can be completely mobile and he does not have to sit at a keyboard or stand by a control panel.

With these advantages in mind, research began some 29 years ago with a view to making man-machine communication by voice a practical reality. The field became known as Automatic Speech Recognition (ASR). Currently,

ASR is enjoying a boom in terms of commercial interest. Both in the UK and abroad there is a feeling that research has reached a stage where techniques can be taken out of the laboratory and put into real applications.

One view of the reasons behind this sudden interest is that recent research innovations have led to significant improvements in recogniser performance. The field has taken an identifiable step forwards and has crossed the threshold of usability.

However, there is an opposing view which is that these recent research developments are, in fact, a step backwards or, at best, a step in the wrong direction. Improvements in performance are fortuitous, will only lead to short-term exploitation, and will ultimately cultivate dissatisfaction with the ASR field.

In order to explain these contrasting views, the field has to be put into historical perspective. But before that, it is necessary to discuss the four main problem areas facing ASR research: continuity, variability, ambiguity and complexity.

Firstly, contrary to what one might feel from introspection, individual words are not separated from each other by short pauses. It sounds as if they are, but, within a phrase, spoken words flow smoothly one into another. In fact there are no acoustic cues at all to signal the beginnings and ends of words. The acoustic signal is a continuously changing pattern of sounds, and the brain is able to segment an utterance into its constituent words

from its *a priori* knowledge of what words are like. The problem is thus how to build a recogniser which can find words in an utterance without knowing in advance where they begin and end.

This leads on to one of the many problems of variability. Because words flow smoothly, the acoustic realisation of a word spoken in isolation is not the same as its realisation when spoken within a sentence. The beginnings and ends of words modify each other. For example, 'bread and butter' often becomes 'brem butter' in normal running speech.

Other problems of variability arise due to the various characteristics of different people's voices. Apart from differences due to sex, accent, age and state of health, even under strictly controlled conditions no word is ever produced in exactly the same way on different occasions. A spoken word does not have an absolute acoustical identity. Consequently a recogniser must treat speech as a complex of patterns and not as a signal to be decoded.

Another source of variability is interference. Words are seldom spoken in a quiet environment. There will be background noise, maybe doors banging or people talking, or the speech might be distorted by coming down a telephone line.

These problems of variability can be characterised by effects which cause speech patterns to be different when they should be similar. In contrast, problems of ambiguity can be characterised by effects which cause speech patterns to be similar when they should be different. For example, the words 'two', 'too' and 'to' cannot be disambiguated acoustically. Similarly, it is possible to make a difference between 'grey tape' and 'great ape', but normally it would be impossible to distinguish between the two from acoustic information alone.

Finally, a major problem is the sheer overwhelming sophistication and complexity of human speech communication. The human is able to use his knowledge of grammar, or the topic of conversation or familiarity with the voice of the speaker in ways which have yet to be modelled or understood. There is more to speech communication than recognising words. Often the message being communicated is implied rather than spoken. For example,

the phrase 'lovely day' can have quite the opposite meaning when spoken with an appropriate intonation.

Returning to the historical development of the ASR field, the very first recogniser was published in 1952. This device set the scene for about twenty years. It overcame the continuity problem by forcing the speaker to put pauses between his words, so that the task became one of trying to recognise isolated words, in this case digits.

The machine worked on the now well-known principle of dividing the speech spectrum into two frequency bands. This was done because some speech sounds can be characterised by the two major resonances of the mouth cavity. These resonances are known as formants. The two frequency bands were chosen such that each would contain the energy due to one formant and from this information estimates of the frequencies of the two formants could be obtained. As a word is spoken so the frequencies of the two formants vary and hence two-dimensional plots were obtained for each digit and stored in the machine. An unknown word was then able to be recognised by obtaining a two-dimensional plot of its formants, and then correlating this with the stored versions. The identity of the unknown word is then determined by whichever stored digit gives rise to the highest correlation. The machine required extensive tuning to each speaker but, when that had been done, the accuracy of recognition was between 97 and 99 per cent.

The 1952 recogniser thus avoided the continuity problem by dealing only with isolated words, and it avoided some of the variability problems by allowing only one speaker to use it at a time. Similarly, it avoided ambiguity and complexity problems by simply using a very small vocabulary.

Automatic recognition of isolated digits has continued right up to the present day as one of the main subjects of interest in ASR research. This fact alone might give the layman some insight into the extent of the progress that has been made over the last 29 years.

In the 1950s and 60s researchers began to look at both the time and the frequency structure of isolated words and they found that durational differences were a major source of variability and hence misrecognition. To overcome this, a technique known as linear time normalisation was introduced. This

simply meant that the time scales of individual words were linearly distorted such that unknown and reference words all had the same duration.

It is difficult to summarise quantitatively the success or otherwise of the 50s and 60s. In general it seemed that recognition accuracies in the 95 - 99% region could be obtained using a small vocabulary of isolated words spoken by a single speaker. With larger vocabularies or more speakers, performance deteriorated dramatically. In terms of finding solutions to the fundamental problems of ASR, so many had been avoided that very little had been learnt. This view was expounded at the time in a resounding letter to the Journal of the Acoustical Society of America by J R Pierce and entitled *Whither Speech Recognition*. Pierce accused researchers not only of avoiding the real problems, but also of completely ignoring them and treating the whole speech communication system as if it could be explained by a simple pattern recognition process. In fact he went so far as to liken these meagre attempts at ASR to attempts to turn water into gold!

It is often assumed that Pierce's letter caused a slump in the field but, judging from the numbers of papers published in the 1969 to '72 period, the effect was minimal. Also, at least one group of researchers felt that their machine was good enough to be exploited commercially. Threshold Technology Inc was set up in 1970 to market the VIP-100 isolated word recogniser, and its descendants are still available today.

What can be seen during this period is a definite change of emphasis away from the engineering/acoustics approach. Researchers got the idea that there simply was not enough information present in the acoustic signal to enable a machine to recognise words. There had to be access to higher level information such as grammatical rules or semantic processes, especially in the continuous speech situation. This view was in marked contrast to the 1950s and 60s idea that the speech signal contained too much information and the problem was to find ways of reducing the redundancy to get at the supposed underlying invariant features of speech sounds.

Thus in the period 1970 to '72 interest in isolated word recognisers began to decline and ideas for continuous speech recognisers began to emerge. The basic premise of most of these

machines was that speech had to be segmented into units smaller than words, possibly phonemes. This proved to be singularly difficult.

The most significant development at this time was the appearance of a report produced by a study group set up by the US Advanced Research Projects Agency. In their report, the study group outlined a proposal for a new type of speech recogniser called a Speech Understanding System (SUS). The basic idea was that the recognition process was divided up into separate processing levels each containing independent sources of speech knowledge. These might be acoustics, phonetics, syntax and semantics, for example. The knowledge sources would then interact co-operatively such that the system would perform an appropriate action in response to a spoken request. The emphasis was thus on understanding an utterance rather than correctly recognising each word.

As a result of the report, ARPA set up a multi-million dollar five-year research programme encompassing the work at a number of major US speech research laboratories. The project ran from 1971 to 1976 and in 1977 a review paper pointed out that, in terms of meeting the specifications set out in the original proposal, only one system had come up to the mark. To make matters worse, this system was not one of the multi-million dollar projects, but the result of a one man-year PhD thesis. The system in question was called HARPY.

HARPY had quite a different structure from the interacting knowledge source approach employed in the ARPA systems. Basically it consists of two entirely separate procedures. Prior to any attempt at recognition, HARPY compiles all its grammatical, lexical and phonetic knowledge into a single huge network. The network contains a representation of all possible utterances within its limited task domain. The compilation procedure is a one-off process; once created the network remains fixed. To recognise an unknown utterance, it is simply matched against the entire network in order to find the path through the network that best explains the unknown utterance data. The location of the path determines the identity of the utterance and hence the identity of the words within it.

At first sight HARPY seemed a very shallow approach to the speech recognition problem. It recognises whole

sentences as if they were just long words. However, it has several redeeming factors. Firstly, it achieved every single one of the twelve ARPA project specifications. HARPY could accept continuous speech from three male and two female speakers in a document retrieval task which had a vocabulary of over 1000 words, and with an utterance recognition rate of 95%. Secondly, HARPY represented an attempt to find real solutions to some of the fundamental problems of ASR. The continuity problem was overcome by recognising speech at the phrase level. The presence of individual words is implied in the network structure but recognition proceeds without explicit concern as to where word boundaries might be. Problems of variability, in particular word juncture effects and durational variations, were overcome by applying a few rules to the construction of the network at word boundaries, and by allowing the matching process to be flexible, such that small timing differences could be absorbed. Problems of ambiguity and complexity were avoided by specifying a fixed language with a predefined grammar; HARPY could not recognise any sentences not specified by those rules.

Despite its controversial structure HARPY stimulated a great deal of thought and interest in finding out exactly why it performed so well. One hypothesis was that the technique used to find the best path through the network allowing for time scale variations was very powerful, and that it alone accounted for the high recognition scores. This technique, known as Dynamic Programming (DP), is simply a mathematical method of sequential decision making which could search all of the very large number of possible paths through a network in an efficient and optimal way.

The failure of the ARPA sponsored systems led to a backlash of opinion which pointed out that they had been too top-heavy. Great effort had been put into sophisticated grammatical and inference procedures whilst the acoustic front ends had tended to be rather crude. The feeling in 1977 was that the speech signal was not as devoid of information as had been thought. What was needed was more research into acoustic-phonetics in order to understand how the information is organised.

These views caused ASR researchers to look once again at isolated word recognition. In particular, it was real-

ised that the old technique of linear time normalisation was a quite unsuitable way of accounting for durational differences between words. Although the beginnings and ends of words could be aligned in this way, the patterned infrastructure was still in disagreement. Thus it was felt that what was really needed was non-linear time scale normalisation. Of course there is a very large number of possible ways that a word's time scale can be distorted non-linearly, hence DP was used to find the best. Suddenly, isolated word recognisers were capable of 99%+ recognition accuracy on small vocabularies, and so the technique of non-linear time warp matching by DP became a major subject of research. From 1978 up to today, DP dominates the ASR field.

The DP approach to ASR is as controversial now as HARPY was in 1976. It certainly has raised the performance of isolated word recognisers to the level where they might be useful in some limited applications. Also, like HARPY, it can be used to overcome the continuity problem as demonstrated by the appearance in 1979 of the first commercial connected word recogniser: the DP100. On the other hand, the DP approach only attempts to explain durational differences between words, it does not address the vast array of other variability problems discussed earlier. Neither does it provide answers to the problems of ambiguity or complexity. If it does constitute a step forward, then it is certainly a small one when put alongside the ultimate objectives of ASR.

However, putting aside the specific use of DP in time scale normalisation, the general concept of a non-linear pattern matching methodology is particularly exciting. It does seem that, for perhaps the first time in the ASR field, there is a possibility of developing a powerful research tool. What is required now is a dedicated effort to characterise the effects of variability using this tool. DP is just an optimal search technique, but non-linear pattern matching applied to the different dimensions of the speech pattern complex will enable a corpus of knowledge to be built up, thus turning ASR research away from the world of heuristic ideas towards a truly scientific endeavour. That way lie true progress and realistic opportunities for man-machine communication by voice. □

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Machines that Speak

J N HOLMES

Joint Speech Research Unit

The development of modern technology, including the information management and processing power of computers, has made communication between humans and machines of great importance. In many cases speech is the most convenient medium for this purpose. An important part of recent research and technological development of speech signal processing has therefore been directed to the problems of providing machine voice output.

FOR THIS article machine voice output is assumed to include all cases where a machine-controlled speech is structured automatically to suit the particular circumstances required, but it does not include mere replaying of complete recordings, such as in the telephone weather forecast service. The applications are many and varied. At one extreme they involve simple announcements, with no control by the listener over what is heard. At the other extreme are machines for reading books to the blind. At intermediate levels various types of highly structured simple man-machine dialogue can be made using voice output, with either automatic speech recognition or key pressing for the man-to-machine direction of communication.

Although the rather limited requirements of a speaking clock have been successfully met by an operational system since 1936, more general applications of voice output did not arise until digital computers began to come into widespread use in the 1960s. During this period IBM offered a computer peripheral voice response system using analogue storage of speech waveforms on a magnetic drum. One serious disadvantage with this method is that the words can only start when the drum is in the right position, so messages need to be structured to use words at regular intervals if delays approaching the duration of one word are to be avoided. If the desired messages can be successfully made merely by replaying separately stored words in the desired order, the use of recorded natural speech means that the technical quality of the reproduction can be extremely high. It is apparent from the case of the speaking clock that there are applications where this method works extremely well.

The development of large cheap computer memories has made it reasonable to store speech signals in digitally coded form for use with computer-controlled replay, and, provided sufficiently fast memory-access is avail-

able, this arrangement overcomes the timing problems of analogue waveform storage. Digitally coded waveforms of speech signals of adequate quality for announcing machines require digit rates of 16-32 kbits per second of message stored, so quite a large memory is needed if many different elements are required to make up the messages. There are now many computer voice response systems commercially available that work on the principle of stored digitally coded speech message elements. They can work well when the messages are in the form of a list, such as a simple digit sequence, or where each message unit always occurs in the same place in a sentence, so that it is comparatively easy to ensure that it is spoken with a suitable timing and pitch pattern.

In spite of its success for quite advanced applications, such as the latest 'VOLMET' system of automatic airport weather reports that has recently gone into service in the UK, there are a number of disadvantages with using stored speech waveforms for voice output. The main one is that they are not suitable for messages of arbitrary structure. For purposes such as reading machines for the blind any word in the required language might be needed, and for each one there should be variations in pronunciation, pitch and timing dependent on its function in the sentence. If these factors are not taken into account, and only one version of each word is stored, it is not possible to construct fluent sentences. Another problem is merely the size of memory to store a large vocabulary, although the current trend in memory costs is making this disadvantage less serious. In addition there is an insuperable limitation with all systems using stored human speech in words or larger units: every utterance component must have been previously spoken by a human talker. It is thus not possible to add even a single new word without making a new recording. This process requires a suitable acoustic environ-

ment and either finding the original talker to say the new material or re-recording and editing the entire vocabulary with a new talker. This restriction prevents waveform storage from giving good results in cases where it is necessary to add new items locally to a system already in service.

The large amount of digital storage needed for speech waveforms can be greatly reduced by using some low-bit-rate coding method for the message elements. Use of some type of 'vocoder' (a vocoder analyses a speech signal, and subsequently resynthesises it from a low-data-rate specification of its main features) can reduce the digit rate of the stored utterances to 2400 or even 1200 bit/s, albeit with some reduction in speech quality compared with the stored waveform approach. A good example of the use of vocoder methods to reduce the memory requirements is in the mass-produced 'Speak and Spell' device of Texas Instruments. Texas and many other manufacturers are now also offering speech synthesis products for more general voice output applications, based on vocoder storage.

Besides memory size reduction there is another great potential advantage with vocoder storage of message elements: the pitch and timing of messages (usually known as the 'prosodic' structure) can easily be changed without disturbing the other features of the stored words. It is thus possible in principle to modify the prosody automatically to suit a word's function in a sentence, without storing alternative versions. There are, of course, difficulties in choosing suitable timing and intonation patterns, and there are still problems at word boundaries because speech properties will in general not match where words join, but the results can be noticeably more fluent than concatenated stored waveforms.

Given that vocoder storage of naturally spoken speech segments is to be used, the logical next step is to make the units much shorter. A popular current method, being extensively investigated at Bell Laboratories, is to use 'dyads', which are sections of signal between the middle of one speech sound and the middle of the next. A full set of elements of this type to make up all possible messages in a language is only of the order of a few hundreds, and each corresponds to only perhaps 0.2 seconds of speech. There is thus a fairly small storage

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Generation, Measurement and Effects of High Intensity Sound

22 September 1981 at the University of Birmingham

High Intensity Acoustic Testing to Determine Structural Fatigue Life and to Improve Reliability in Nuclear Reactor and Aerospace Structures

L Yeh
GEC Power Engineering Limited, Whetstone

In this paper we review some of the techniques in which high intensity acoustic testing is used in engineering practice. These are as follows.

a. In the nuclear engineering field we describe the simulation of reactor noise due to the CO₂ circulator and the use of strain gauges to obtain a response spectrum in order to predict the fatigue life of gas-cooled nuclear reactor structures where a 30-year lifespan is of paramount importance. It will be realised that, once the reactor becomes critical, the radiation hazard in the vessel will prevent any repairs from being carried out inside the reactor. Therefore it is important to ascertain the

structural life before introducing the structure into a reactor. The method described here is generally used for advanced gas-cooled nuclear reactors in Britain.

b. In the satellite field we discuss the simulation of the high intensity noise due to the launching rocket motors and the testing of the integrity of the satellite structure and the behaviour of the electronic control system when affected by high intensity acoustic excitation. The use of acoustic testing to improve the reliability before the launching of the satellite is also considered.

c. In the aircraft and rocket field the generation of high intensity noise to simulate boundary layer pressure fluctuation or turbulence of a flying object or aircraft at various speeds is considered. This is to improve the reliability before manned flight is carried out and to eliminate premature malfunction and failures.

Response of Nuclear Reactor Gas Circuit Structural Components to Circulator Generated Noise

B H Bickers
National Nuclear Corporation Limited, Sutton, Surrey

The circulators used in gas-cooled nuclear reactors to circulate the high pressure primary coolant can generate a considerable amount of energy at acoustic frequencies which can cause vibration and, in extreme cases, fatigue failure of structural components. To ensure the integrity of the structure over the reactor life, it is necessary to be able to evaluate the response of the structure to the noise field.

The interaction between the noise and the structure is extremely complex and not amenable to analysis by classical methods. However, the Statistical Energy Method which describes the interaction in terms of the statistical properties of the acoustic

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Generation Measurement and Effects of High Intensity Sound

field and the structure is available and has been described in detail in the literature. The paper to be presented discusses the circumstances in which the method may be used to obtain estimates of structural response and investigates its limitations. It is shown that the method is particularly useful in identifying problem areas for acoustically-induced response. In many such cases, the information required for a detailed and accurate estimate of response is not available and recourse must be made to testing structures in acoustic chambers.

The low frequency response of small components presents particular problems in that, although the Statistical Energy Method may be used, some of the assumptions inherent in the method are extremely pessimistic owing to cancellation effects where noise wavelengths are large compared with structural dimensions.

High Intensity Acoustic Testing at British Aerospace, Weybridge

A Failey
British Aerospace, Weybridge

This paper discusses experience at Weybridge in the field of high intensity acoustic testing. A general description of the test facility is given and an account of measures taken to counteract practical problems is included.

Generation of High Intensity Noise in High Pressure Gas

A C Rapier and M W Parkin
United Kingdom Atomic Energy Authority
Windscale Nuclear Laboratory

The components of the coolant circuits of gas-cooled reactors are subjected to very high intensity noise. It is necessary, therefore, to test specimen components, in particular insulation, to ensure that they are not damaged and do not have a lower performance under simulated reactor

acoustic conditions. An electro-pneumatic transducer capable of producing the required acoustic power in air at atmospheric pressure was commercially available. Its performance with high pressure gas was predicted theoretically and confirmed by experiment. On the basis of these results, a high pressure acoustic test chamber was designed.

A CEGB High Intensity Acoustic Noise Facility at Gravesend

E J Smeaton
CEGB SE Region Scientific Services,
Gravesend

This paper gives a basic description of the CEGB test facility at Gravesend and discusses problems, and the solutions applied to them, involving noise generation and measurement arising during operation.

Some Aspects of the Nature of Acoustically-Induced Strains in Isotropic and Composite Plates

R G White
ISVR, Southampton

Panel-type structures may be subjected to high intensity acoustic excitation in service and simple methods have been used in the past for the prediction of dynamic response. The use of fundamental mode approximations for estimating induced strain levels under the action of random acoustic excitation rely on the assumption of linear behaviour and have been well validated for metallic structures. The use of new structural materials, such as carbon fibre reinforced plastics, necessitates some re-appraisal of the 'Engineering' approach to dynamic response prediction.

This paper concerns a study of the response of plates to acoustic excitation. A comparison is made between the spectral and statistical properties of acoustically-induced strains in aluminium alloy and

CFRP structures which includes discussion of nonlinear effects. The behaviour of plates under the action of combined acoustic excitation and static, in-plane compression is also examined and effects of damage, in the form of edge cracks, on the stability and dynamic characteristics of composite panels are presented.

Acoustic Vibration Techniques for Testing Guided Weapons

D Sims

An air-to-air missile can spend many hours of its life carried on a high performance aircraft and in this condition is subjected to acoustic excitation from its own boundary layer or that of the aircraft. All missiles in flight experience boundary layer excitation and additional vibration can be acoustically induced from the internal propulsion system. This paper describes the available methods for simulating this vibration environment and details one method that has been developed to the stage where it is now in use as a routine method of vibration testing on weapon systems. A particular problem of simulating the high frequency energy produced by a supersonic weapon having a ram-jet engine is examined. The method of generating the high frequency spectrum is described and typical applications of the equipment discussed.

Some Aspects of Sound Absorption in a High Pressure Gas

I H G Hopkins
National Nuclear Corporation Ltd, Risley

This paper describes absorption measurements made on test specimens of thermal insulation that line the walls of some gas-cooled nuclear reactors. One test involved normal incidence absorption measurements made at several gas pressures in a standing wave tube. A second test involved measurements made in a pressurised reverberation chamber.

Outdoor Sound Propagation

14 December 1981 at the Open University

Sound Propagation Over Surfaces Consisting of Hard and Soft Areas

S Simpson and D C Hothersall
University of Bradford

Sound propagation near a surface can be investigated theoretically by solving the wave equation in the space above the surface with suitable boundary conditions. Solutions have been restricted to plane surfaces of infinite extent with uniform characteristic acoustic impedance. When these results are applied to propagation over the ground in environmental acoustics one problem commonly encountered is that various types of ground cover can occur at different places below the sound path. Practical suggestions making allowance for these conditions have been crude and empirical. In this paper an attempt is made to describe sound propagation by a method which provides resolution over the area of the surface and allows changes in surface

height and characteristic acoustic impedance to be considered. The analysis is based on the Kirchhoff-Fresnel diffraction theory and the solution is obtained numerically. A number of results will be discussed in which the effects of combinations of soft and hard ground cover are considered and these will be compared with experiment.

Scale Modelling of Sound Propagation over Flat Unobstructed Absorbing Terrain

N W Heap
The Open University, Milton Keynes

Acoustic scale modelling has been used extensively to investigate outdoor sound propagation, particularly from road traffic, in view of the considerable difficulties of relevant theoretical analyses and of outdoor experiments. Use of scaling factors as low as 1 to 60 will be described with reference to choice of source, detectors, model impedance surfaces and anechoic character-

istics. Results obtained from small-scale modelling of propagation over unobstructed absorbing terrain will be compared with theoretical predictions based upon supposed locally-reacting and externally-reacting characteristics of the model ground cover.

In situ and Laboratory Measurements of Ground Impedance

L A M van der Heijden
Catholic University, Nijmegen,
The Netherlands

In order to investigate the influences of vegetation on the sound absorbing qualities of soils, a number of non-invasive methods of measuring ground impedance *in situ* and in the laboratory have been investigated. These techniques include the inclined track method *in situ* and Fast Fourier Transform of pink noise and gated sine pulses reflected by natural soils and semi-natural soil

samples in an anechoic room. Results on five different soils show a relationship between surface impedance, porosity and moisture content.

Lateral Noise Attenuation

R F Lambert and P Evans
Engineering Sciences Data Unit Ltd, London

Analysis of air-to-ground aircraft noise data to predict lateral noise attenuation is described. Experimental evidence suggests that sound propagating in the vicinity of the ground is attenuated more than can be predicted from considerations of spherical divergence, ground reflection and atmospheric attenuation. The work described is intended to lead to an empirical procedure for the estimation of this extra ground attenuation.

The first stage is the development of a procedure for the correction of measured noise spectra for the effects of ground reflection. Then the free-field spectrum measured under the flight path and the free-field sideline spectrum, at the same range as the under-the-flightpath spectrum, are compared to evaluate lateral noise attenuation. These values of lateral attenuation are correlated to derive empirical relationships. One-third octave band spectra are used in the analysis and a range of noise propagation angles is investigated to expose possible airframe shielding effects.

Investigations into Low Frequency Blast Noise Propagation

G Kerry and C Waites
University of Salford

As part of a research programme the Acoustics Department at the University of Salford has been involved in the measurement of blasting noise at a large limestone

quarry. Measurements of peak sound pressure level over a period of two years have shown a large degree of variability that cannot be adequately explained in terms of variation in charge weight or distance from the source.

It is well known that the propagation of low frequency blast noise is affected by wind and temperature gradients in the lower atmosphere. Working in conjunction with the Meteorological Office at the Royal School of Artillery, Larkhill, a technique for predicting sound intensity using on-site meteorological data has been developed. This technique has been evolved in an attempt to account for the variability in measured levels and to produce a reliable method for predicting noise levels around the quarry. Furthermore, effects of using synoptic meteorological data are being investigated so that the prediction technique may be applied where detailed on-site weather data is not available.

It is hoped to provide sensible guidelines that will protect residents in the locality of quarries without unduly restricting blasting.

Propagation of Noise from Petrochemical Works

P Sutton
Esso Petroleum Company Limited,
Southampton

Oil refinery and petrochemical plant is generally installed out of doors. The attenuation of noise during propagation is therefore an important factor in the control of neighbourhood noise from such works. There are no generally accepted comprehensive mathematical models for this attenuation.

The oil companies' European conservation group CONCAWE commissioned an investigation by Acoustic Technology Ltd of

the propagation of noise from petrochemical works. This paper summarises the method of investigation, which consisted of a literature survey and a major programme of field measurement. The conclusions are presented and compared with the earlier simple OCMA model and the draft VDI Code No 2714.

Sound Propagation in Forests

M J M Martens
Catholic University, Nijmegen,
The Netherlands

A review of factors that influence the acoustic climate of plant communities and belts of trees will be presented. Particular attention will be paid to the vibrations induced in leaves. A method of observing and measuring these vibrations by laser scanning will be described. New results concerning the influence on the sound field in vegetations caused by the changing meteorological conditions during the night will be analysed.

Long-Range Propagation of Airport Ground Noise

I H Flindell and J G Walker
ISVR, Southampton

Airport ground activity generates noise which may be intrusive in nearby communities but the noise levels are subject to considerable variability. Many researchers have studied the theoretical aspects of long-range noise propagation but practical experience in this area is limited. This is due to the difficulties in obtaining suitable high intensity noise sources for tests. This report presents data obtained from a number of controlled tests using real aircraft engine run-ups and remote noise monitoring teams. The authors' current philosophy with respect to airport ground noise prediction will be discussed.

ISVR Courses

The following courses are being organised in ISVR in 1981/2.

1981

Series of courses on Vibration Theory and Practice:

27 - 29 October Vibration theory and applications to design
24 - 26 November Computer techniques for dynamic structural design

1982

16 - 18 February Vibration testing and signal analysis
16 - 18 March Shock and vibration control
29 March - 2 April Clinical audiology
29 March - 2 April Noise and vibration control for environmental health officers
28 - 30 June Clinical vestibular function

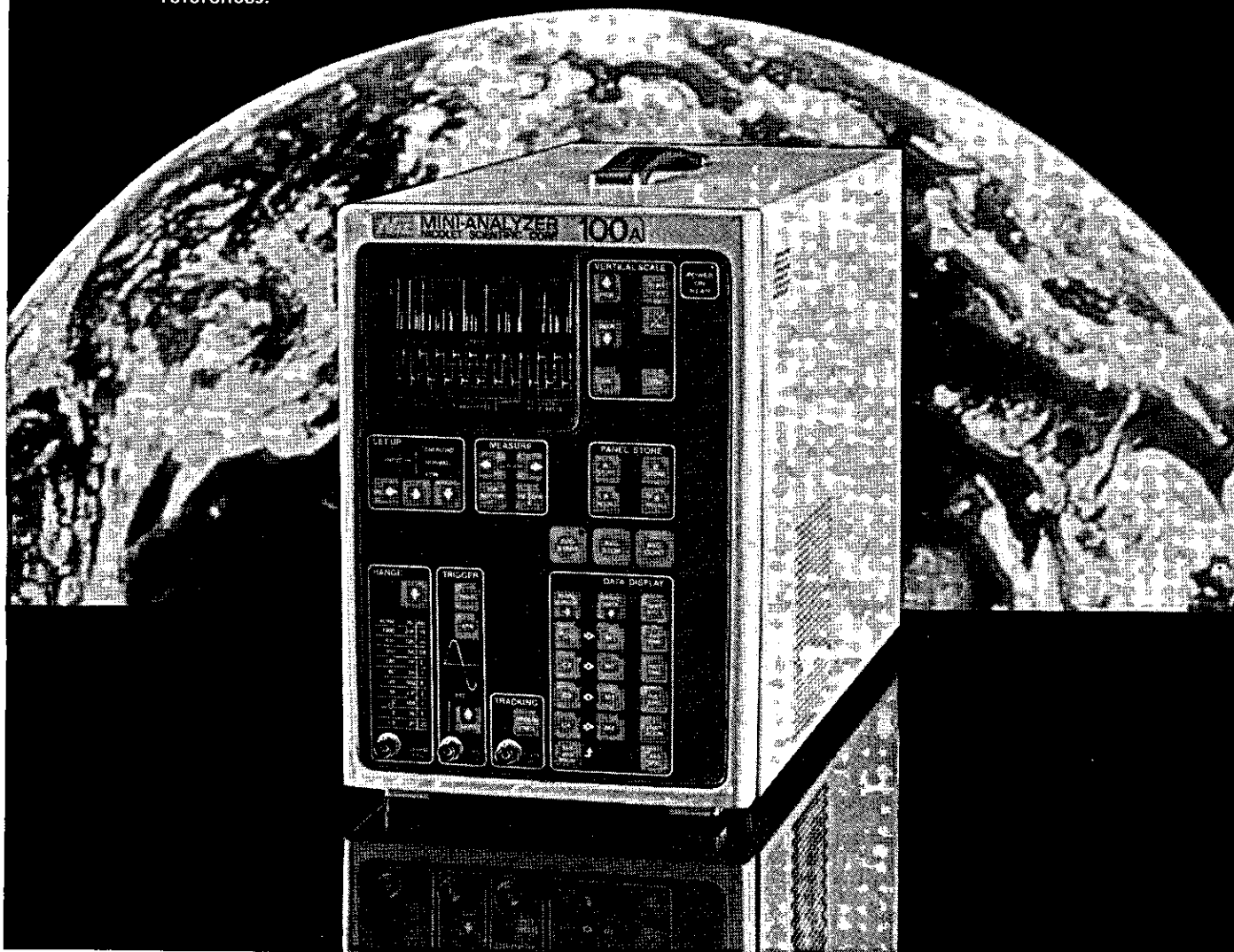
Other courses are planned on Instrumentation and measurement techniques for noise and vibration control; Machinery noise and vibration control; Building acoustics and noise control for architects and building engineers. Dates for these courses are yet to be finalised. Further details of all courses are available from John Walker or Grace Hyde at ISVR. Telephone: 0703 559122, ext 752/2310/742. □

BRE Publications

The BRE Information Directory 1981 and the Research Programme 1981/82 are both now available, free of charge, from the Distribution Unit, Building Research Establishment, Garston, Watford WD2 7JR. Also recently published is BRE News for Summer 1981, which celebrates the Diamond Jubilee of the BRS, the oldest building research organisation in the world. Sir Frederick Lea's book Science and Building gave a detailed history of the Station up to 1965, and the celebration of the Golden Jubilee and the accompanying Congress and Open Days were reported in issues 16, 17 and 18 of the magazine. BRE News therefore devotes its 8-page feature, highlighting a selection of the major research projects, to the last ten years, to bring the existing records up to date. □

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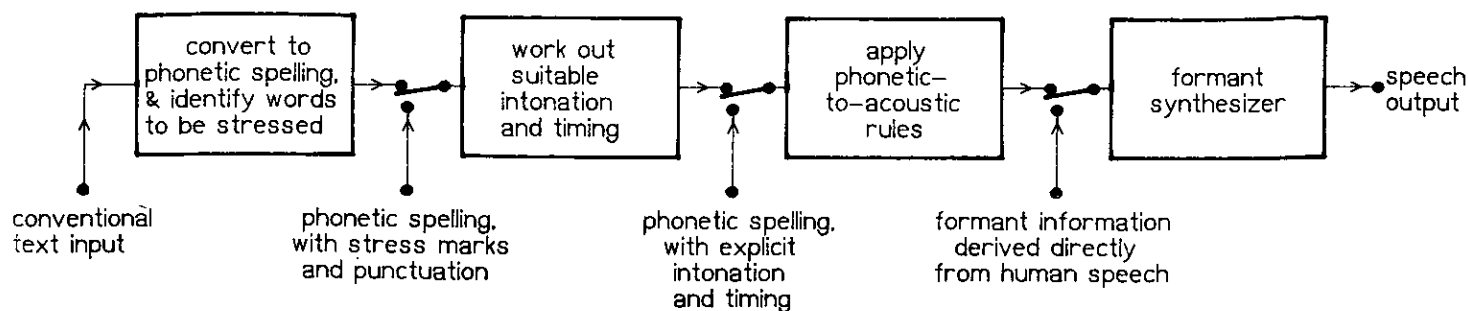


Figure 1 Speech synthesis system, illustrating various ways of providing input

requirement. The rules of operation of the system mainly concern the method for converting the message into a specification of the sequence of elements with appropriate prosodic features. This method can produce highly intelligible speech, although it is difficult to make the dyads join up well in all circumstances.

A completely different approach is not to use any form of stored natural utterances to provide the raw material of the messages, but instead to generate the entire messages 'by rule' from a specification of the phonetic sequence and the pitch and timing. The speech generation with this process normally uses a 'formant' synthesiser, which fairly directly models the resonances (formants) of the human vocal tract. If the rules are sufficiently carefully constructed, synthesis by rule is in principle capable of simulating the interaction of each speech sound on its neighbours in a very realistic way, and overcomes many of the problems of synthesis using dyads or related methods. However, although formant synthesisers, when suitably controlled, have been shown to be capable of producing very high quality copies of natural utterances, the synthesis by rule demonstrations so far have been nothing like so natural-sounding, because much more research on the rules is needed.

All of the methods which use smaller units than words for message construction require a method to generate a specification of the phonetic content and prosodic structure of the required messages. If the message format is very restricted or the range of possible messages is small these specifications can be worked out laboriously for each element of the message, possibly by modelling some example natural utterances. More generally, a system for specifying messages in terms of phonetic spelling and the pattern of stressed words and punctuation could be used. A trained operator should find it fairly easy to specify new messages for addition in this way, but the system would

require a good set of rules for working out the timing and intonation from this information. At the highest level of technical difficulty, conversion from conventional orthography with punctuation is necessary for reading machines for the blind, and would also be very convenient for other message generation applications. In this case it is necessary for the system to choose the appropriate pronunciation for each word, and to analyse the syntactic structure of each sentence sufficiently to choose a suitable prosodic pattern. The most advanced system of this type, developed under the supervision of Jonathan Allen at MIT, has been extremely successful with American English. Other less ambitious schemes have been much less successful at producing high intelligibility, but have produced marketable products that are already being used by blind people.

What of the future? At present stored

waveforms can give very good quality speech for limited applications. Synthesis from coded dyads or by rule from a formant synthesiser is more versatile, but with somewhat poorer speech quality. Of these latter methods, I believe there is much more potential for improvement in the rule approach. Formant synthesis by rule also gives the possibility of varying the voice quality (or presumed sex) of the speaker merely by changing preset synthesiser parameters. As technology evolves to produce good formant synthesis using only one or two integrated circuit chips I believe that this type of voice output will eventually prove the most versatile and economical for almost all applications. The most obvious possible exceptions are in machines made in very large numbers but only needing a small range of fixed messages, for which coded storage of human speech might be more appropriate. □

Speech Production Modelling

CELIA SCULLY

Department of Linguistics and Phonetics, University of Leeds

Sound waves of speech have special properties because they are generated and received by human beings. It would be useful to know more about these two constraints and their relative weights. Studies of the processes of normal speech encoding may help towards a greater understanding of the human nervous system and may shed some light on speech malfunction. There may be benefits eventually for adaptable low-bit-rate transmission, automatic speech recognition and the provision of natural-sounding synthetic voices. Listeners have learnt, by years of experience, the kinds of combinations of sound patterns to expect from different types of speaker, short or tall, for example; with different accents, speaking in different surroundings and in different physical and emotional states, out of breath, for example. The extrication of the strands of speaker information and coded linguistic message from the speech signal is a task to which modelling of speech production should be able to contribute.

DYNAMICALLY controlled artificial speech was made by von Kempelen in the late eighteenth century, with bellows for the lungs, a reed for the voice and cupped hands for the resonators. Hardware models have immediacy of response, but computer-based simulations are generally

preferred for their versatility and precision of dynamic control. Modern synthetic speech takes two forms. In a terminal-analog synthesiser a speaker's acoustic output is matched directly by sources and filters. This gives good artificial speech from synthesis-by-rule and is also a valuable tool for discover-

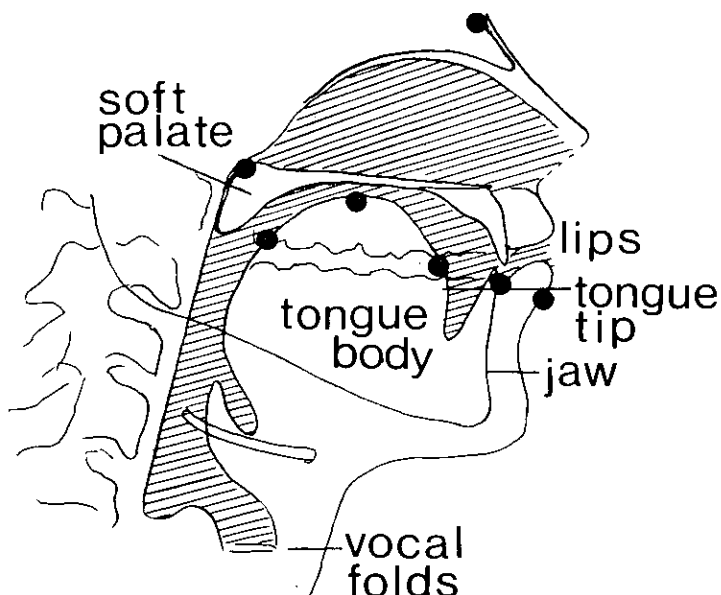


Figure 1 Cross section of the vocal tract

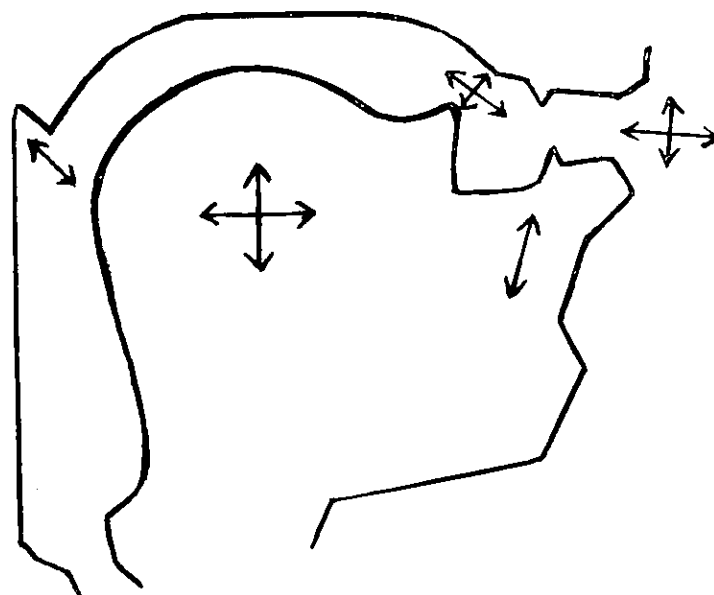


Figure 2 Dynamic model of vocal tract

ing how listeners process the sounds. Articulatory or line-analog synthesizers represent more directly the physics of a speech-producing system. They should give insight into how the acoustic ends are achieved. Interactions within the system should be generated automatically by a model of this kind.

The chain of events constituting speech production is partly under the speaker's control and partly governed by the physical laws of mechanics, aerodynamics and acoustics. Neural signals carry instructions to perhaps seventy muscles. Mechanical structures are moved: the lungs deflate in a controlled way, two lip-like structures in the larynx, the vocal folds, move together or apart and are co-ordinated with other articulators, most of which are labelled in Figure 1. Air flows from the lungs and, unlike normal breathing, encounters several obstructions where air pressure rises (by up to 1% of atmospheric pressure) and the linear velocity of the airstream increases, according to the Bernoulli equation of fluid flow. At these orifices the energy of the airstream is partially converted into the audio frequency range. The mechanisms involved are not at all well understood, but three types of sound source are identified: voice, turbulence noise and pulse (or transient). These contain significant energy up to about 5 or 6 kHz in the case of voice and at least twice that for the turbulence and transient sources. The acoustic system is described as a number of sources modified by filtering. The spectral peaks in the output associated with resonances are called formants. Volume velocity

output at the lips and/or nostrils converts to sound pressure some distance away by a spectral boost of 6 dB per octave.

Figure 1 is a side view of the vocal tract, based on a tracing from an X-ray film. Hatching indicates the acoustic air-filled tubes of interest in the throat, mouth and nose. The total shape of the tubes, the area function, is controlled by articulator movements and determines the resonances and anti-resonances. Modelling must not only achieve appropriate vocal tract target shapes but must also match the dynamics of real speech. Data on this are difficult to obtain. Direct observation by X-ray film has attendant problems of radiation dosage, poor definition of soft tissues and laborious frame-by-frame analysis. New xero-radiographic and computer-controlled microbeam techniques, with radio-opaque markers to follow articulator dynamics (as shown in Figure 1), are giving improved definition and reduced dosage. The slowest articulator, the tongue body, requires about 0.2

seconds to complete a transition, yet the transmission rate for speech is about 20 sounds (phonemes) per second. This remarkable disparity is achieved through simultaneous control of several independent articulators, which must move at different times. Modelling allows the possibility of generating 'wrong' sound patterns by combining articulatory components in unsuitable ways, and then asking why these are wrong.

Models of the dynamics generally take the forms shown in Figures 2 and 3, with Figure 2 most often favoured. Arrows in Figure 3 show points each of which represents a portion of the vocal tract dynamics by means of changing orifice cross-section area. Both approaches concentrate the finest control at the front of the mouth. The third dimension across the vocal tract is not usually considered in detail. One model, however, represents the tongue as a three-dimensional uniform, isotropic and incompressible medium, using the finite element method.

The aerodynamic system consists of

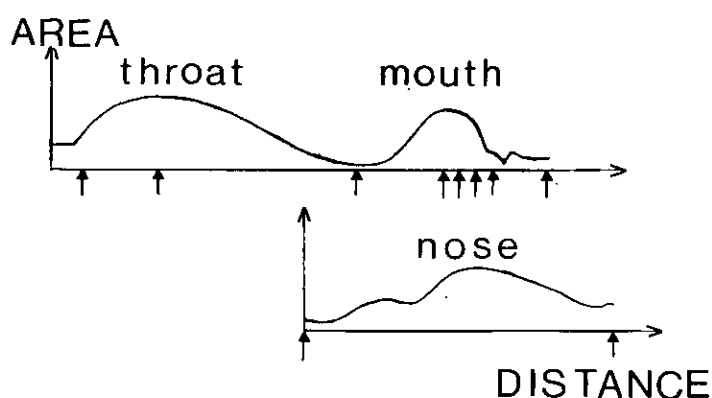


Figure 3 Model of the vocal and nasal tract

about five major cavities with compliant walls, linked by orifices with turbulent (flow-dependent) as well as viscous resistance to flow. Volume flow rate may be above 1000 cm³/s during *h* sounds. In the modelling of Figure 3 noise sources are introduced only at those points included in the aerodynamic system. Other models permit noise sources at any point along the vocal tract (see P_N and R_N in Figure 5 (b)).

The voice source is a quasi-periodic airflow waveform associated with the separation and closure of the vocal

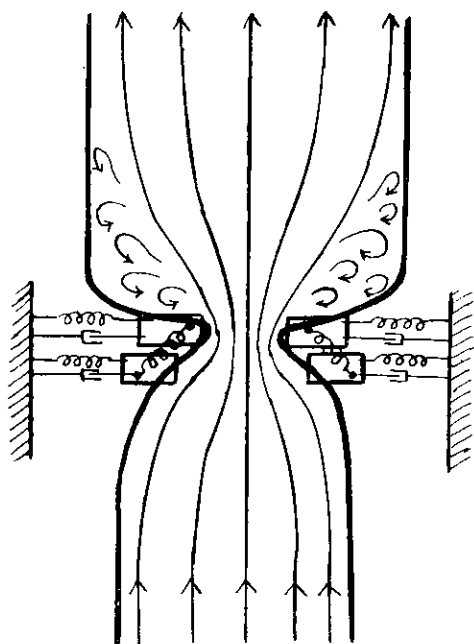


Figure 4 One method of modelling the voice generating system

folds at rates between about 50 and 500 Hz, under the combined influence of aerodynamic and elastic forces. Many modes of vibration are possible. Figure 4 sketches the voice generating system and one way of modelling it. The two vocal folds running horizontally from front to back are seen in vertical section. Air flows upwards from the trachea (windpipe) through a tapered entry into the orifice (the glottis) formed by the vocal folds. At the abrupt exit, separation of the streamlines from the boundaries takes place and energy is dissipated by turbulent mixing between a central jet and more stagnant regions near the throat walls. Here each vocal fold is represented by two masses with springs and viscous damping. The number of masses has been increased to eight and in current research each fold is modelled as a visco-elastic continuous

medium by the finite element method. Three distinct tissue layers and the non-isotropic nature of the fibres are included. Even this sophisticated model does not yet represent the non-linear stress-strain curves of the real tissues and does not yet capture some aerodynamic-acoustic interactions clearly seen in real speech.

Data for turbulence noise sources in speech are lacking and little basic research is being done on their modelling. The yielding tube walls are highly likely to interact with the turbulence to give a significant contribution to the noise source. Yielding walls would be expected to modify the velocity of sound propagation also, but effects would vary along the vocal tract and modelling has not been attempted.

The transmission characteristics are usually derived by one of the two methods shown in Figure 5. The acoustic tube is quantised into abutting cylindrical sections, generally 0.5 cm in length. The curved shape of the tubes is ignored, but current research is assisting in the derivation of an effective midline for the vocal tract. In the pressure wave reflection method of Figure 5 (a) amplitudes for reflected waves at alternate section boundaries at one time sample become incident waves at the intermediate boundaries at the next sample. An undesirably high sampling frequency, determined by propagation velocity, must be used in the computation. For a tube of cross-section area A and length l (density of air ρ , velocity of sound c) elements of an electrical transmission-

line analog are $L = \frac{\rho l}{A}$ and $C = \frac{A l}{\rho c^2}$.

Each section, shown in Figure 5 (b), represents heat conduction losses by G , viscous friction losses by R , the resistance and reactance of the wall by

Z_W and radiation impedance of the wall by Z_{RW} . The expressions for R and G are frequency-dependent, but for time-domain modelling fixed values must be assumed.

An adult woman's vocal tract is about 14 cm long and a man's about 3 cm longer. This is comparable to the wavelength for frequencies above about 150 Hz so that a Helmholtz resonator model is not appropriate.

The maximum cross-dimensions are about 6 cm for men and probably less for women. Wave propagation may therefore be considered one-dimensional up to about 3 kHz for men and a little higher for women. This is not as severe a limitation on modelling as might appear from the much greater bandwidth of the acoustic sources, because the first three or four formants, which are the major information-bearing portions of the spectrum, all lie below about 4 kHz for men and 5 kHz for women. (Sections 0.5 cm long permit modelling up to about 8 kHz.) Hardware modelling has recently shown that the removal of the assumption of one-dimensional wave propagation introduces additional formants above 2.8 kHz, but these have been shown to be auditorily unimportant. Thus, some simplifications made in current models of speech production are justified by the limitations of the human auditory system.

Failures to match real speech are instructive. Through modelling, mainly by trial and error with auditory monitoring, the problems to be solved by human speakers and the options available to them become clearer. □

References to the research described here are available from the author on request.

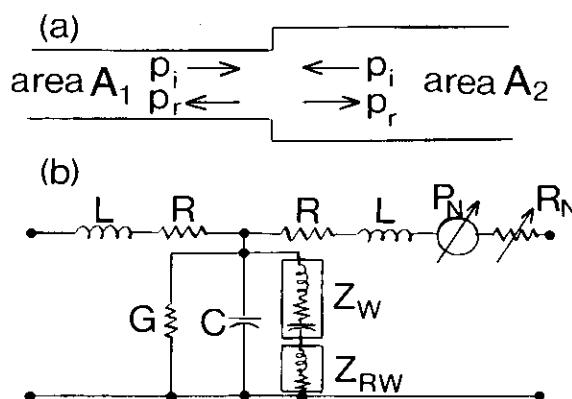


Figure 5 (a) Acoustic tube model (b) Equivalent electrical circuit

Some Current Issues in Speech Perception

C J DARWIN

Laboratory of Experimental Psychology, University of Sussex

This is a challenging time for those who profess an expertise in speech perception. For many years phoneticians, experimental psychologists and engineers interested in the perception of speech have plied their trade, chipping away at the monumental task of understanding what is surely one of man's most complex skills. Then suddenly, the chips are down and Speech Recognition has arrived. An expensive box of tricks from Japan's NEC will recognise enough speech to have numerous commercially exploitable applications; a program (HARPY) that violates almost every known psychological principle wins first prize from the US Advanced Research Projects Agency for recognising sentences; and to add to the insult its principles are then proposed as a psychological model on the grounds that 'it works'. What is happening? Where does perceptual research stand and what can it contribute?

Perception and Recognition

PERCEPTUAL research has largely concentrated on the complex relationship between sound and the phonemized units that carry the minimal linguistic distinctions in language — what are the acoustic cues to /k/ as in cat, ox and skunk? The current generation of speech recognition devices avoids this level completely, matching spectral cross-sections of the signal to a network of similar cross-sections that represent either words (in the NEC machine) or entire sentences (in HARPY). The strength and the weakness of this iconoclastic step is the explicit representation of all the variations that occur. Little attempt is made to represent the underlying reasons for the variability as rules. The recognition process has the insight of a shopping list.

The approach works as well as it does thanks to efficient algorithms (based on dynamic programming) for time-warping a template against an input. It fails as a general solution to speech recognition because it lacks generality. As they stand neither of these methods can generalise across speakers or to new utterances without retraining. New words that consist of different orderings of sounds found in currently recognisable words, or sentences that are new permutations of words already existing in the network, cannot be recognised without recompiling. The cost of such lack of generality is a rapid growth in the amount of storage required to hold the enlarging vocabulary of speaker (and sentence) specific words. Once the cost of storage or search time becomes prohibitive, the technique becomes unworkable.

Other approaches, which presently are less successful, do attempt some phonetic transcription of the input. But a major problem is that speakers are lazy. They rely on listeners complementing poor articulation with knowledge about what is being said, such as what are possible words, syntactic structures and semantic relationships. One simple and psychologically attractive way to represent the words of the language is as a network that branches out from the first phoneme of a word. Words that have the first three phonemes in common share a common path until the fourth. The recognition choice at any point is then constrained to precisely those words which are possible in the language. Problems with this scheme (which was introduced by engineers at BBN and which has been explored as a psychological model by Marslen-Wilson) are that it does not permit (as it stands) identification of neologisms, and, more seriously, it relies heavily on correct choices being made early on in the word, if computationally expensive back-tracking is to be avoided. Thus the dual fact that we can hear 'shigarette' as a mispronunciation of 'cigarette' is not readily explained. Nevertheless, such models are computationally viable and do capture in a plausible way generalities about the language.

Perceptual principles can be applied to improve even the most psychologically implausible recognition schemes, for instance by exploiting psycho-acoustic knowledge about the low-level mental representation of sounds. The basic tenet here is that those features which are most perceptible to the ear are

likely to be the most reliable in speech perception. Since speech has, presumably, evolved to give maximum intelligibility with the minimum of articulatory effort, the tenet is at least half true.

There are proven advantages in word recognition and in speech analysis and resynthesis schemes (particularly at low data rates) in using a frequency scale that is warped to model the frequency selectivity of the ear. Figure 1 compares spectrograms of the word 'frequency' made on a conventional linear scale (with a bandwidth of 300 Hz) and made on a Bark scale (with a bandwidth of 1 Bark). A Bark is a critical bandwidth—a psycho-acoustic measure of the ear's bandwidth at a particular frequency. The effect of the Bark scale is to improve resolution in the region below about 1500 Hz at the expense of higher frequencies. Formants above the third are not clearly separated and even the second and third formants of [i] begin to merge. Three-formant [i] vowels can in fact be matched perceptually by a two-formant vowel whose second formant is a compromise between the original higher two formants.

It is possible that similar improvements can also be made by attempting to extract from such frequency-warped spectrograms complex acoustic features, rather than using as recognition elements simple spectral cross-sections. The attraction of doing this is to make recognition less vulnerable to extraneous factors such as the particular recording conditions, background noise and speakers, changes in spectral balance and intensity and so on.

It is currently fashionable in speech perception to attempt to explain the constellation of cues that make up a phonetic category in terms of invariant patterns to which the mammalian auditory system is particularly sensitive. Impetus to this reductionist tendency was given by the demonstration that a sub-human species (the chinchilla) and a proto-human species (the 2-month old child) both perceived a particular phonetic continuum (that separating voiced [ba] from voiceless aspirated [p^ha]) in a way that uncannily mirrored that of adult English speakers. Subsequent work has reassuringly pointed to complexities in the adult perception that cannot be explained away on purely psycho-acoustic grounds, but there is doubtless much to be gained by representing speech sounds in terms of psychologically plausible complex features. The

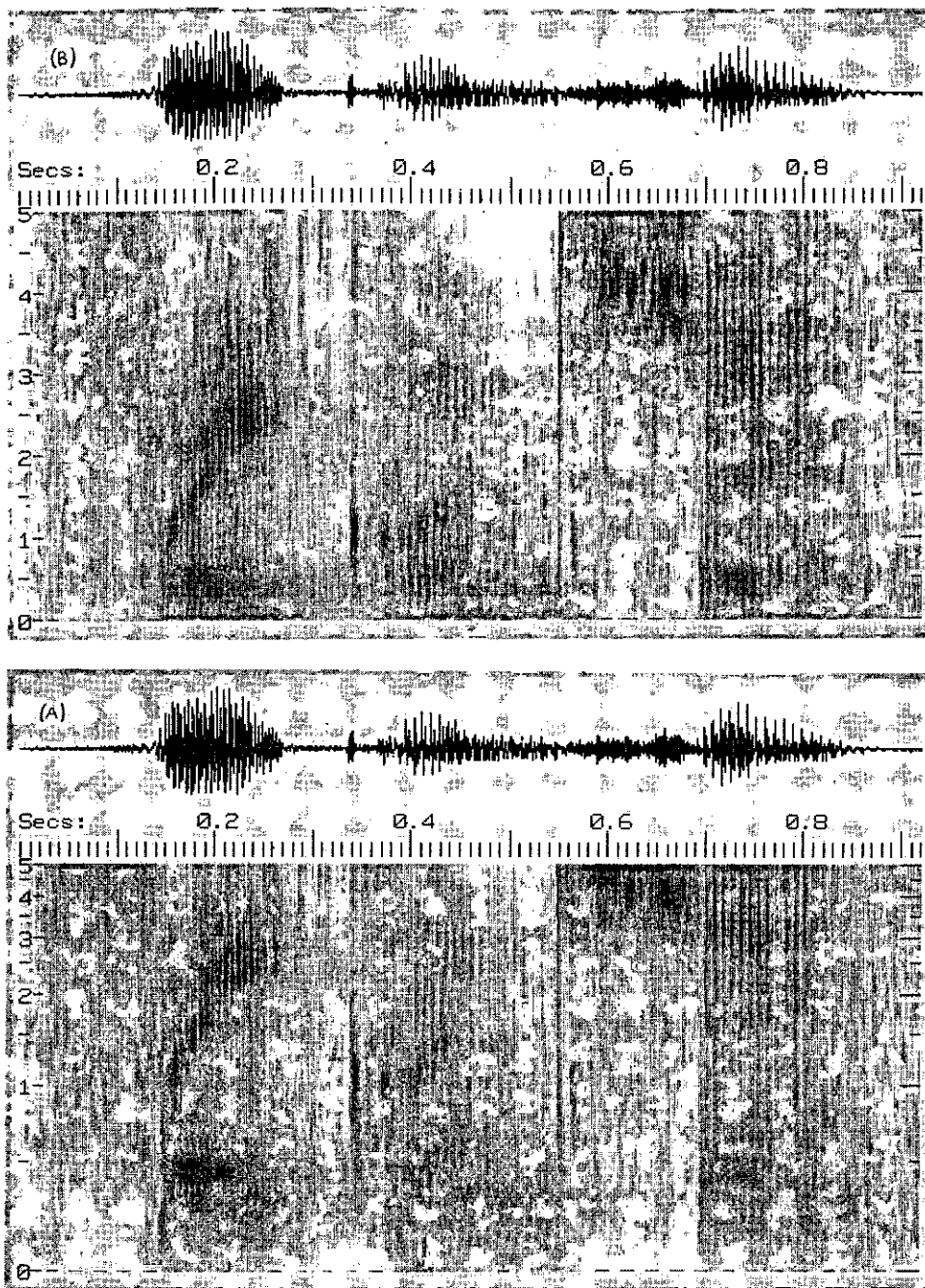


Figure 1 These two spectrograms of the word 'frequency' differ in their frequency scale and filter bandwidths. Above is a conventional wide-band spectrogram on a linear frequency scale with a constant bandwidth of 300 Hz. The lower one has been produced by a series of filters of critical bandwidth and plotted on a frequency axis that spaces critical bandwidths equally. The frequency markings on both spectrograms are in kHz and both spectrograms have been pre-emphasised at about 6 dB per octave.

problem, though, is that we have no very clear indication from either psycho-physics or neuro-physiology what such features are. We know that there are units that respond to frequency modulation in various specific ways and it is likely that there are units that respond to a pattern of frequency movement over a wider range than a particular formant. But there are not many more clues; audition lags behind vision in this respect.

The computational prowess that has made possible the first generation of

commercially viable speech recognisers has presented perceptual research with a complement to its traditional tool of speech synthesis. Theories of how phonetic distinctions are perceived can now be tested algorithmically on large bodies of natural speech. In addition, attempts to write such algorithms unearth new problems for the perception researcher to tackle.

Speech Perception and the Deaf

A continuing challenge to the speech scientist is to exploit phonetic knowledge for the benefit of the deaf. Apart

from the substantial effort being made to match more effectively the characteristics of hearing aids to auditory properties important for speech, there is a renewed interest in this country in finding new ways to complement the auditory signal with information from other senses.

Most people think that they cannot lip-read, yet even the completely untrained are subject to a very powerful and striking illusion discovered serendipitously by Dr Harry McGurk of Surrey University. If a video recording of someone saying 'ba' is carefully dubbed with the sound of 'ga', subjects who watch and hear the dubbed recording perceive quite clearly 'da'. Trained phoneticians are subject to the illusion even when they know what is going on. The perceived syllable changes dramatically as you open and close your eyes. Eyes open—'da'; eyes closed—'ga'. A generalisation that goes some way to covering the available data on this intriguing illusion is that the perceived syllable is the one that is compatible with what is seen and involves the smallest acoustic change in the sound. Even in speech perception vision seems to dominate hearing. It is an intriguing possibility that some stylisation of facial movements can be found that when transmitted over a narrow-band channel will improve speech intelligibility for the hard of hearing. Research towards this goal is under way at the Institute for Hearing Research in Nottingham.

Although lip-reading gives good information about the place of articulation of many speech sounds it gives little or nothing about the activity of the larynx. The larynx carries the important segmental distinction between voiced and unvoiced sounds as well as those pitch and intensity movements that transmit such dimensions as stress and numerous semantic and pragmatic nuances. A number of different prostheses for supplementing lip-reading are being explored. An implanted electrode in the cochlea is capable of conveying at least some pitch information, and experiments carried out at University College London have shown that when normal listeners are given only as much pitch information as the best of the implanted 'deaf' patients are thought to be receiving, the intelligibility of lip-read speech improves markedly. Whether all implantees will show this improvement, considering the variability in their pitch discrimination ability and their previous training in lip-reading, remains to be seen. □

Seventh International Conference on Internal Friction and Ultrasonic Attenuation in Solids

This conference was held in the new buildings of the Swiss Federal Institute of Technology at Ecublens near Lausanne. It is an entirely new campus which is under development and the buildings are most impressive as regards spaciousness, laboratory equipment and layout. The meeting attracted about 200 participants and 20 countries were represented.

The meeting was of particular interest as it departed from the conventional procedure whereby all contributors read their papers. The subjects of the submitted papers were divided into nine themes and for each was chosen a specialist (in the case of a large section, two) in the particular field, who was allocated a period of forty-five minutes to give an up-to-date review of his topic. This was followed by a similar time period for one, or two, referees to express their opinions on the papers submitted on the particular theme. After a coffee interval there was a similar procedure of review and

refereeing for a second theme. Following a liberal lunch time of two hours, which permitted the authors of the papers in the first two themes to assemble their displays, a period of one and a half hours was available for 'viewing' these. The remaining one and a half hours of the day's programme were devoted to open discussion of the papers under the guidance of one or two chairmen. The foregoing pattern was followed for the other full days of the meeting.

As a personal viewpoint, I have always favoured the need for a good review paper as the prelude for the ensuing session on the particular theme; in this meeting those of Seeger (*Dislocations*) and Elbaum (*Diffusion Assisted Phase Transformations*) were outstanding. The refereeing of the contributed papers I consider was of a mixed value and in any case is very demanding of the referee as he will require to spend a great deal of time in co-ordinating his individual comments to avoid the

'cataloguing effect'. The arrangements for the poster sessions were the best I have experienced: the rooms were uniformly equipped with display boards and situated close to the lecture theatre.

It would be impracticable to select even a limited number of papers for comment from the 170 or so submitted. As a guide however to those who might be interested in obtaining a copy of the Proceedings, it might be of value to state that slightly more than one third of the contributions were concerned with some aspects of dislocations. The rest of the papers were approximately evenly divided between the themes of amorphous materials, magnetic, electronic and dielectric properties, point defects, diffusion-assisted phase transformations and diffusionless phase transformations. The remaining theme on technical developments contained such items as an automatic system for micro-mechanical properties analysis, the effects of ultrasonic vibration on the metallurgical properties of steel, and the study of hydrogen entry into metals using ultrasonic surface waves. □

RWBS

International Symposium on Underwater Acoustics

This underwater acoustics meeting was held in Israel on 15 to 18 June 1981, the main venue being the Dan Hotel in Tel Aviv, although some parts of the programme took place in the School of Engineering at Tel Aviv University, which was responsible for the Symposium, and some at Haifa.

The registration figure was a very respectable 114 participants. Naturally there were many from Israel, but it is interesting that no less than 49 of the remainder were from the USA — and 12 from the UK.

There were four special or review lectures in order to set the tone, and the writer considers they did this very effectively. Alan Berman spoke on the attenuation of low frequency acoustic energy in sea water, concentrating on the boron relaxation process and its history. Ira Dyer's talk was on basin acoustics, contrasting the Arctic and the Mediterranean. Probing the ocean

with sound was the subject chosen by Stan Flatté, including the fluctuations due to inhomogeneities and the recent ideas on acoustic tomography. Bob Urick covered fluctuations of sound in the sea and their effects on sonar detection. The emphasis on fluctuations in the last two of these talks was very obviously carried through in the rest of the symposium.

The schedule of contributed papers extended to a nominal 61, with very few 'no-shows'. Israel is obviously a place with many and varied attractions, but these numbers demonstrate the hard work in the programme. The work reference here is not only to the organising but to the taking part — and the listening. Virtually all aspects of underwater acoustics were represented, but propagation occupied nearly half the time.

Specialising still further, there was a very great deal on fluctuations due to

internal waves in the deep ocean, as already indicated above. Workers from several different schools reported various theoretical attacks on this problem, using for example the second moment equation for the coherence function and the fourth moment equation for the intensity fluctuations. The interest is initially to explain observation; but of course fluctuations enter into virtually every measurement and system application in underwater acoustics.

The social aspects involved almost as much hard work, filling up much of the spare time and in fact leaving surprisingly little chance to look around on one's own. This could of course be remedied before or after the symposium.

There were too many on the various committees to list here. But many people will keep the memory of Gideon Maidanik's red shirt lighting the way to conference and cocktail room, to remind them of a useful and enjoyable meeting. □

D E Weston

Pioneers of British Acoustics

Mathematicians and Acoustics:

Robert Smith

There have been a number of instances of mathematicians being strongly interested in musical acoustics and Robert Smith FRS (1689 - 1768) was such an example. Born near Gainsborough, the son of a clergyman, Smith has been described as a mathematician, astronomer and 'experimental philosopher'.

He was associated throughout his working life with Trinity College Cambridge, succeeding his cousin, Roger Cotes, as professor of astronomy in 1716. He held this post until 1760 but meanwhile in 1742 he became Master of Trinity College and also served as Vice-Chancellor of the University.

Smith was the author of a well-known treatise on optics known as *A Compleat System of Opticks* and published in 1738 as two volumes, parts of which were translated into French and German. His interest in musical acoustics was shown, apart from his playing of the cello, in his fascinating and prophetic book entitled *Harmonics or the Philosophy of Musical Sounds*. Although this work, first published in 1749, had three editions in fourteen years, its contents did not have any great impact on his immediate contemporaries. His presentation was rather for scholars interested in music than for actual musicians and he assumed a knowledge of advanced mathematics but in contrast defined the simplest of musical terms.

In his treatise Smith attempted to obtain a solution for the practical problems of temperament and tuning, which were of considerable concern for performers of the eighteenth century. He postulated a mean-time temperament which was founded on his own quite original system of 'equal harmony'.

In a 1966 reprint Da Capo edition of *Harmonics*, J Murray Barbour writes a very informative introduction. He points out that a number of musical terms used by Smith have a different meaning today; for example his imperfect consonances are the tempered intervals of today. His expert knowledge of optics, it should be noted, led him to use optics to illustrate analogous acoustical phenomena and tempered intervals provide an example of this. He employed logarithms to represent intervals, which was later to lead to the introduction of cents by Ellis. Smith had a deep understanding of

acoustic principles and discussed beats at great length, referring to the fact that tempered intervals always 'beat'. Smith's main objective was to improve the mean-tone temperament by finding a system 'in which as many concords as possible are as harmonious as possible'.

Barbour's summation of Smith's work was in praise of his mathematics but concluded that the practical application of his theory was weak. It was over 100 years later that his theories were experimentally confirmed by Helmholtz and Ellis. In the Additions at the end of *Harmonics* Smith gives some practical hints on the tuning of different types of organ-pipes — metal, wood and reed. □

RWBS

NEW ELECTIONS

The following elections have been approved by Council.

Fellow

D C G Eaton J Meyer

Member

N Basu	J C Goodwin
D R Bower	M Klein
R V Ceen	T M Pamplin
A Y-K Chung	J H B Poole
M J Davies	P S Watkinson
K Eghtesadi	K Willson
A J Fenwick	

Associate

B R Barr	S G Lindsey
P Berriman	M E Luckett
K-A Chan	J J Melville
W-T Cheung	P F O'Halloran
G P Frost	N C Rotheroe
J E Gibbs	S K Sharma
M J Green	J M Southwell
I R Hebblethwaite	W J Strang
T Jones	J R Tanswell
Y K Kam	K E Thomas
P D Latimer	P S Twigg

Student

J R Howes

Non-Institute Meetings

1981

13 November BSA Meeting on Ototoxicity London

4 - 5 November 7^{ème} Colloque d'Acoustique Lyon, France
Aérodynamique

1982

12 - 14 January Euromech Colloquium on The Creation and Behaviour of Short Fatigue Cracks Sheffield

2 - 5 March 71st Audio Engineering Convention Montreux, Switzerland

3 - 5 May IEEE International Conference on Acoustics, Speech and Signal Processing Paris, France

16 - 19 May Inter-Noise '82 San Francisco, USA

21 - 24 June Symposium on Fisheries Acoustics Bergen, Norway

September Noise Control Conference Warsaw, Poland

13 - 17 September 3rd FASE Conference, jointly with DAGA '82 Gottingen, Federal Republic of Germany

October 21st Acoustical Conference on Noise and Environment High Tatra, Czechoslovakia

BRANCH AND GROUP NEWS

Underwater Acoustics Group Visit to the Institute of Oceanographic Sciences 8 April 1981

The Underwater Acoustics Group organised a visit to the Institute of Oceanographic Sciences (Wormley) where various members of staff gave informal talks about some of the current work involving underwater acoustics. The members of staff were available afterwards for further discussion and guests were also able to view the establishment.

The fifteen visitors were welcomed by the head of the acoustics section, Mr M Somers, who then started the technical talks with an explanation of the digital techniques used on GLORIA II. Other topics covered in the morning were Doppler Sonar, Transducers and Remote Control and Monitoring Systems. After lunch talks were opened with an overview of Neutrally Buoyant Floats followed by

Shear Wave Measurements in sediments and finally the problems arising from the Digitising of Echo Soundings.

The speakers provided brief written handouts of their talks and copies of these may be obtained from Mr N Millard, Institute of Oceanographic Sciences, Brook Road, Wormley, Godalming, Surrey.

North Eastern Branch

After the major activity of the 1980/81 session which included hosting the Spring Conference at Newcastle, the Branch is now looking forward to a more normal level of activity in 1981/82. Support for local meetings has been quite good during the last year, although it is worth noting that this is often derived from non-IOA visitors and especially Environmental Health Officers. At the Annual General Meeting Trevor Smith and the

Committee were re-elected, with Neil Richardson and Peter Buttress as extra members. Chris Norris and Brian Oakes will continue as Honorary Secretary and Honorary Treasurer respectively. Ian Diggory will be generally responsible for the programme. Trevor Smith will continue to represent the Branch's views to Council.

The programme for 1981/82 is almost finalised and the membership will be informed of the details shortly. The first meeting will be held at Newcastle Polytechnic in October (the exact time and date to be announced). This will be a new type of meeting for the Branch and will take the form of two or three short presentations of the final year Diploma projects by students of the Polytechnic. A prize of a book token will be awarded to the best student project.

The November meeting will be held at the University of Newcastle on the topic of Medical Physics — further details to be announced soon. The December meeting will be a social

THE INSTITUTE OF ACOUSTICS

STANDING COMMITTEES

The President, Honorary Secretary and Honorary Treasurer are ex-officio members of each Standing Committee, except Medals and Awards.

Meetings

Dr H G Leventhall (Chairman)
Mrs C M Mackenzie (Secretary)
Dr J M Bowsher
Dr R C Chivers
Mr B C Grover
Mr J N Holmes
Mr B Oakes
Dr A Pratt
Mr N Spring

Membership

Prof D J Johns (Chairman)
Mrs C M Mackenzie (Secretary)
Dr W A Allen
Mr J Bickerdike
Dr J M Bowsher
Dr R W G Haslett
Mr J H Kuehn
Dr R K Mackenzie

Publications

Dr D E Weston (Chairman)
Dr S J Flockton (Secretary)
Dr M E Delany
Mrs F A Hill
Mrs C M Mackenzie
Dr R W B Stephens

Medals and Awards

Prof B Clarkson (Chairman)
Mrs C M Mackenzie (Secretary)
Prof D J Johns
Dr H G Leventhall
Prof P Lord
Mr T Smith
Dr D E Weston

Diploma Advisory Board

Dr B J Smith (Chairman)
Mrs C Farrow (Secretary)
Mr P H Allaway
Mr J Bickerdike
Mr A Dove
Mr J Hay
Dr J J Knight
Dr R W B Stephens
Mrs S Stern
Mr D Turner
Mr H Willis

Diploma Board of Examiners

Dr R W B Stephens (Chief Examiner)
Mrs C Farrow (Secretary)
Mr J Bickerdike
Dr F J Fahy
Dr J J Knight
Dr R Lawrence
Dr H G Leventhall
Dr B J Smith
Mr H Willis

evening and will include a demonstration of bell ringing and a buffet supper.

A full day meeting is planned for 24 March and will be held in Newcastle. The theme of the meeting will be Flow Induced Vibration. Anyone interested in presenting a lecture should contact Ian Diggory at British Gas for further information as soon as possible.

C Norris

South Western Branch

On 11 June a joint meeting was held with the SW Centre of the Institute of Environmental Health Officers, the title of which was *Health and Noise '81*. It proved to be a very interesting meeting and covered, by a series of papers, Noise Control, Medical risk, Protection, Litigation towards compensation and the placement of the hearing damaged back into the working situation.

The next meeting of this Branch will be on 27 November 1981 at Plymouth Polytechnic, School of Architecture, with the controversial title *Noise the Architects' Fault?* This should prove to be a highly entertaining, as well as educational, meeting. The format of the meeting will be that of a formal debate.

Further details can be obtained from Michael J Squires, 1 Feebers Cottage, Westwood, Broadclyst, Exeter, Devon. Telephone: work — Exeter 77888 ext 2476; home — Whimple 822118. □

Advanced Problems of Vibration Control

A three-day course in English is to be held in Paris from 17 to 19 November 1981 on Advanced Problems of Vibration Control. The course will be given by Dr Eric Ungar of Bolt Beranek and Newman and Dr Denys J Mead of the University of Southampton. One of the aims of the course is to encourage discussion between delegates and speakers, and delegates will be invited to raise with the speakers questions relating to vibration problems—however complex—which they are involved in treating.

Details are available from Mlle Jacquemin, commins-bbm, 51 route de Chartres, F-91440 Bures-sur-Yvette, Chartres. □

International Conference on Acoustic Emission and Photo-Acoustic Spectroscopy

Chelsea College, 21 - 23 July 1981

The fourth International Conference on Acoustic Emission, held at Chelsea College this year, was jointly sponsored by the IOA and the UK Working Group on Acoustic Emission and was enlarged to encompass the growing field of Photo-Acoustic Spectroscopy. This was the first scientific meeting on the subject in the UK and attracted eighteen contributions of which more than half were from overseas, six different countries being represented.

The first section was devoted to reviews of the subject and the opening address by Dr C K N Patel, Director of Physical Research at the Bell Laboratories, USA, was an excellent survey of photo-acoustic spectroscopy development and had particular reference in its application to solids. In the second lecture T Hunter (University of East Anglia) spoke on the recent advances in gas-phase measurements, an area in which the initial academic experiments had been made in the 1950s, in the UK at Edinburgh and at Imperial College, London. Hunter spoke with particular emphasis on very weak transition phenomena.

Three sessions were devoted to general applications, with emphasis on the chemical and biological. The remaining topic, Imaging, was introduced with an interesting talk by Busse (Federal Republic of Germany) on optoacoustic and photothermal imaging, the difference in techniques being associated with the way the temperature modulation is detected. The latter technique depends on the correlation of the modulated thermal emission with the temperature modulation and

has the advantage of remote detection. The holding of this section of the meeting was fully justified by the response from prominent overseas workers and by the high standard of their presentations. It also served to give a 'window' for the presently small number of UK workers in the field.

The acoustic emission section of the meeting was also well-supported by overseas workers. Two sessions were devoted to sources, calibration and analysis and included an interesting contribution from Yoon of Rensselaer Polytechnic, New York, on the non-invasive and non-traumatic diagnosis of bone abnormalities. The objective of giving prominence to non-metal applications was fairly well achieved since about forty per cent of the lectures were in this area, ranging from polymer systems under load to concrete and reinforced plastics. An interesting extension of the domains of application of acoustic emission was evident in the two contributions under Machine Diagnostics. That by Roeder of Germany was on the Diagnosis of engine faults; the other, by Mike Arrington (UK), was concerned with the Application of A E evaluation to machine health and process monitoring.

As in previous meetings the exhibitors of apparatus were given the opportunity to give a short talk on their products, and there was a small display of books and literature on the subjects of the meeting. The number of registrations was about 70. □

RWBS

Noise : its measurement, analysis, rating and control

A two-day post-experience course on noise is to be held on 5 and 6 January 1982 at the City University. The course should be helpful to those who are not specialists in noise, but are required as part of their jobs to measure sound, interpret noise measurements or give preliminary advice on noise control. It is expected that participants will be professional workers such as building services and plant engineers, mechanical design engineers, municipal engineers, factory safety officers, environmental health officers, etc.

Topics covered will include: elementary theory of acoustics and wave propagation; sound measurement; subjective aspects and standards; hearing loss criteria and protection; analysis of noise; room acoustics; machinery noise and noise legislation.

For further information and application forms contact: Dr J S Anderson, The City University, Department of Mechanical Engineering, Northampton Square, London EC1V 0BH. Telephone: 01-253 4399 ext 601. □

Recent British Standards

BS 3045: 1981 Method of expression of physical and subjective magnitudes of sound or noise in air. (Supersedes BS 3045: 1958.)

BS 4196: Sound power levels of noise sources.

4196: Part 0: 1981 Guide for the use of basic standards and for the preparation of noise test codes (ISO 3740).

4196: Part 1: 1981 Precision methods for determination of sound power levels for broad-band sources in reverberation rooms (ISO 3741).

4196: Part 2: 1981 Precision methods for determination of sound power levels for discrete-frequency and narrow-band sources in reverberation rooms (ISO 3742).

4196: Part 3: 1981 Engineering methods for determination of sound power levels for sources in special reverberation test rooms (ISO 3743).

4196: Part 5: 1981 Precision methods for determination of sound power levels in anechoic and semi-anechoic rooms (ISO 3745).

4196: Part 6: 1981 Survey method for determination of sound power levels of noise sources.

(Parts 0, 1, 2, 3 and 5 supersede BS 4196: 1967.)

BS 5428: Methods for specifying and measuring the characteristics of sound system equipment.

5428: Part 5: Section 5.1: 1981 Dimensional characteristics of single moving-coil (dynamic) loudspeakers (IEC 268-14). (Supersedes BS 1927: 1953.)

5428: Part 5: Section 5.2: 1981 Circular connectors for the interconnection of sound system components (IEC 268-14A).

5428: Part 5: Section 5.3: 1981 Circular connectors for broadcast and similar use (IEC 268-12).

5428: Part 11: Supplement 1: 1980 Noise signals for loudspeaker units and loudspeaker systems (IEC 268-5A).

BS 5817: Specification for audio-visual, video and television equipment and systems.

5817: Part 8: 1981 Symbols and identification (IEC 574-8).

BS 5942: High fidelity audio equipment and systems: minimum performance requirements.

5942: Part 4: 1981 Specification for magnetic recording and reproducing equipment (IEC 581-4).

BS 5969: 1981 Specification for sound level meters (IEC 651). Will eventually supersede BS 3489 and BS 4197 which will however be retained for at least two years, to accommodate the large number of sound level meters in current use and allow manufacturers time to meet the new international aspects of BS 5969.

BS 6055: 1981 Methods for measurement of whole-body vibration of the operators of agricultural wheeled tractors and machinery (ISO 5008).

BS 6083: Hearing aids.

6083: Part 1: 1981 Method of measurement of characteristics of hearing aids with induction pick-up coil input (IEC 118-1).

6083: Part 2: 1981 Methods of measurement of electro-acoustical characteristics of hearing aids with automatic gain control circuits (IEC 118-2).

6083: Part 3: 1981 Methods of measurement of electro-acoustical characteristics of hearing aid equipment not entirely worn on the listener. (The background to and development of this standard are described by Mr M C Martin, the Chairman of the sub-committee responsible, in BSI News, May 1981.)

New Work Started

Code of practice for noise control on open sites. (Will revise BS 5228 converting it into a code.)

Recent International Standards

IEC 565: Calibration of hydrophones.

IEC 565A: 1980 First supplement to IEC 565: 1980. To be implemented as Amendment No 1 to BS 5652.

International New Work Started

Safety of ultra-sonic therapy equipment.

Will prepare a draft standard specification based on the general requirements of IEC 601-1: 1977 and will provide the particular requirements for the safety of the equipment. Will eventually be published as a section of Part 2 of BS 5724. □

American National Standards

In the January 1979 issue of Acoustics Bulletin we gave a listing of American National Standards. New Standards issued since then are given below.

S1 — Acoustics

S1.31-1980 Precision Methods for the Determination of Sound Power Levels of Broad-Band Noise Sources in Reverberation Rooms. (Agrees with ISO 3741-1975.)

S1.32-1980 Precision Methods for the Determination of Sound Power Levels of Discrete-Frequency and Narrow-Band Noise Sources in Reverberation Rooms. (Agrees with ISO 3742-1975.)

S1.34-1980 Engineering Methods for the Determination of Sound Power Levels of Noise Sources for Essentially Free-Field Conditions over a Reflecting Plane.

S1.36-1979 Survey Methods for the Determination of Sound Power Levels of Noise Sources.

S2 — Mechanical Shock and Vibration

S2.17-1980 Techniques of Machinery Vibration Measurement.

S2.31-1979 Method for the Experimental Determination of Mechanical Mobility. Part 1: Basic Definitions and Transducers.

S3 — Bioacoustics

S3.4-1980 Procedure for the Computation of Loudness of Noise.

S3.18-1979 Guide for the Evaluation of Human Exposure to Whole-Body Vibration. (Agrees with ISO 2631-1974.)

S3.23-1980 Sound Level Descriptors for Determination of Compatible Land Use.

S3.25-1979 Standard for an Occluded Ear Simulator.

All the above Standards are available from: Back Numbers Department, American Institute of Physics, 335 East 45th Street, New York 10017. □

Book Reviews

Physical Principles of Audiology

P M Haughton

Adam Hilger Ltd 1980

183 pp £12.95

Audiology, the study of hearing, is a rapidly expanding area of science. This book provides a good introduction to the related physics of the subject.

There are seven chapters, an appendix listing relevant international standards, a bibliography and a reasonable index.

The first two chapters give an overview of audiological acoustics and the anatomy and physiology of the human ear. The transformer function of the middle ear and the transducer function of the inner ear receive more detailed attention. The third chapter, on the nature of hearing, is covered at a basic level but with clear descriptions of the psycho-physics involved.

Electro-physiological tests of hearing are assuming greater importance and Chapter 4 gives a good grounding in the relevant responses and their significance. It would have been useful to include more information on electrode selection and siting in this chapter.

Chapters 5 and 6 describe, simply, the disorders of hearing and their measurement. These chapters devote most of their attention to the physical principles underlying the diagnostic tests of hearing. There is a good description of impedance tests of middle ear function, often a difficult subject to con-

vey. The final chapter on hearing aids is less detailed than it could be. However, the problems associated with hearing aid design and use are clearly described.

Overall, the book favours readers with a background in the physical rather than the biological or psychological sciences. It is an honest book which does not attempt to cover the whole of audiology. As its title suggests, it provides a useful and much needed introduction to the physical principles of audiology.

A L Corcoran

Guide to Acoustic Practice

Prepared by K A Rose

BBC Engineering: Architectural & Civil Engineering Department
95 pp £10.00

For the benefit of the growing number of newcomers to the field of architectural acoustics generally and studio design particularly, to whom my name and those of the others mentioned herein will mean nothing, I should perhaps declare my background before proceeding with this review. I was for eighteen years an acoustic engineer in the BBC Engineering Research Department before joining the present consultancy. I am sure no better background has existed for studying and practising the art of studio design. It was during this period that continuing research and measurement in studios indicated the importance of the atten-

tion to detail which is the background of this most useful book.

It is a book that had to be written — many people have agreed on this; some half-hearted attempts have been made to start it but until now it had been no more than an idea.

Sandy Brown himself—that master of the spoken or written word—would have been proud of the efforts of his one-time assistant, now the Acoustic Architect of the BBC in his own right, in setting down the requirements for success when stringent standards of acoustic control are necessary. The principles are indicated, but this book is much more about the details and, in architectural acoustics particularly, it is lack of attention to detail that spells disaster—or, if not disaster, at least in large part a waste of the effort that has gone into the design. Most public bodies, and a lot of cash-conscious private companies too, will feel constrained to accept the lowest tender for a project without always requiring pre-qualification of the tenderers. It should come as no surprise that the 'successful' tenderer is the one who has no experience of the complexity of the design.

It is important that this complexity and the essential attention to detail should be clearly spelled out in the drawings and in the specification of the works. The final stage, however, is to ensure that the work is actually carried out as designed. An enormous responsibility here rests on the Supervising Officer or his representative on site, the Clerk of Works, and, indeed, anyone else who visits and examines the works. Faults will be shown up by the final acoustic tests even though the Contractor has covered up his sins of omission or commission; however, the remedies at that stage can be expensive, time consuming or occasionally impossible.

It is refreshing to find an architect who appreciates the value of the written word; it is not true that 'if it can't be shown on a drawing, it doesn't exist'! Many useful drawings and standard details are shown in a separate section at the end of the book but its main value, I feel, lies in the description of the important aspects of each component part of a design.

The guide is not a design handbook; it gives little indication as to how much of each component is necessary for a given project. Don't get me wrong, I'm not complaining; it would be a poor outlook for the acoustics consultant if

LEM: Communication in a high noise environment

The November London Evening Meeting is being held by kind permission of Air Commodore Peter Howard, Commandant of the Royal Air Force Institute of Aviation Medicine. Within the Institute are medical doctors who are also operational test pilots. One important aspect of their work is communication — not only for the pilot's safety but also for our safety on the ground.

The speakers will be Squadron Leader Brian Lisher and Doctor Richard Pratt. They will be demonstrating with the aid of visual and audio effects the situation that daily faces modern aircrew.

It is hoped that there will be a good attendance of IOA members as well as others to join with the organisers in extending their thanks to the RAF for their co-operation in mounting this event. Please come along for an entertaining and informative evening at County Hall, London, at 6.00 pm on 26 November. □

J Fegan

it was all contained in a DIY handbook.

However, the guide has a place on the bookshelves of specialist designers, specifiers, Clerks of Works and others involved in the creation of buildings requiring stringent acoustic standards. The sum of £10 for this book could prove to be a very worthwhile investment.

Alex Burd

ACOUSTICS

An introduction to its physical principles and applications

A D Pierce

McGraw-Hill 1981

642 pp £20.25

The author is Regents' Professor in Mechanical Engineering at the Georgia Institute of Technology and has been engaged in teaching acoustics to engineers for many years. This book is a product of that teaching and is intended for graduate students. No holds are barred nor punches pulled in the presentation of material — 'The text is intended to be at a level of mathematical sophistication and intellectual challenge comparable to distinguished graduate texts in the basic engineering sciences . . . ; a deep understanding of acoustical principles is not acquired by superficial efforts'.

The presentation is indeed very thorough, encyclopaedic at times, with numerous references to original work throughout the text. Judged in terms of style and content, it falls somewhere between the easy-to-read classic by Kinsler and Frey and the mathematical approach of Morse and Ingard. In some respects it is more complete than either of those in that the author has chosen his material in the light of current trends and applications.

Chapters 1 and 2 present the wave theory of sound and quantitative measures of sound while Chapter 3 deals with the reflection, transmission and excitation of plane waves at boundaries and interfaces. Chapters 4 and 5 are concerned with radiation from vibrating bodies and radiation from sources near and on solid surfaces. Chapter 6 gives the standard theories for room acoustics and Chapter 7 deals with low-frequency models of sound transmission, which means the transmission of sound in ducts with reference to filters, side branches and horns. Chapter 8 presents an extensive treatment of ray acoustics in inhomogeneous, stratified and moving media

Titles of Diploma Project Reports submitted for 1981 Exam

Colchester Institute

An examination of the correlation between predicted and measured road traffic noise levels
An investigation into the noise emitted from an internal combustion engine laboratory test rig and noise recommendations for control of that noise to within acceptable limits

Planning and noise control

Some aspects of cooling tower noise

Planning and noise

Complaint of noise from a swimming pool plant room — A case history

The control of noise in a wood-working machine shop

Noise from late night parties — a local authority approach

An investigation into the problem of noise from condensing units at Clacton-on-Sea

telephone exchange; recommendations for its reduction and use to validate BS 4142 criteria

An introduction to aircraft noise and some effects in a rural environment containing two military airbases

Newcastle Polytechnic

An assessment of the airborne sound insulation achieved by the party wall structure of newly constructed dwellings

Methods of control available to LA's for noise from construction and demolition sites

An acoustic analysis of the 'Playhouse', Whitley Bay

An assessment of noise problems in a computer room

An investigation into the acoustic properties of the exhauster and exhauster house at Lambton Coking Works

An acoustic assessment of the existing anechoic chamber at Newcastle-upon-Tyne Polytechnic and design parameters for a replacement facility

An investigation of the effectiveness of noise control measures at the Howard Opencast Coal Site, Netherton, Northumberland

A comparative study of the determination of L_{eq} for railway noise by prediction and direct measurement

Noise in the home

Leeds Polytechnic

Selby Codfield — A study of noise in the vicinity of level crossings

Compressor noise

Liverpool Polytechnic

An investigation into the absorption characteristics of a small area resonant absorber with perforated panel facing

A survey of noise pollution

An investigation into noise levels produced by electricity transformers

Investigation into noise produced in the domestic environment

An assessment of the airborne and impact sound insulation of an experimental floor between two flats

A comparison of the noise emitted by two electric lawnmowers

To assess the effects of railway noise on the residents of a small housing estate

The effectiveness of a dual-glazing system in a school classroom

Investigation of the effects of different spatial arrangements on the absorption coefficient of rockwool absorber

The evaluation of a dual-glazed window

An investigation into shortened measurement procedures for airborne sound insulation of party walls and floors

Propagation of traffic noise; in particular along side roads

An investigation into the reduction of noise produced by a spinning automatic washing machine

with obvious applications to atmospheric and ocean acoustics. Chapter 9 is entitled 'Scattering and diffraction' and includes sections on scattering from obstacles such as buildings or barriers. Chapter 10 is concerned with the effect of viscosity and other dissipative processes on sound waves, while the final chapter deals with the often neglected non-linear effects in sound propagation. Each chapter concludes with a large number of questions to provide homework assignments for the students. Unfortunately, no answers are provided and it seems probable

that the majority of students will never know whether their solutions are right or wrong.

In summary, this book will find a place as a text for in-depth advanced courses on acoustics and as a reference book for acousticians with a mathematical turn of mind. I suspect, however, that the majority of practising engineers would prefer to see the material presented in a less sophisticated manner. □

R D Ford

An investigation of the sound field in an industrial semi-anechoic chamber
Noise nuisance from an industrial building in a housing area

NE Surrey College of Technology

The determination of single-event noise exposure levels for aircraft landings and take-offs
Field measurements of airborne sound transmission through party walls
Noise from general aviation aircraft
Attenuation measurements of ear defenders using miniature microphones
An investigation into the noise problems created by a domestic central heating and hot water system
The assessment of noise from a large photo-copier
Concorde: Noise and vibration. A comparison with subsonic aircraft using Heathrow Airport
The attenuation of noise by building facades
Estimation of machine sound power level by measurement of surface vibration on machine structure; compare the estimate with that derived from sound pressure level measurement
Project to investigate the properties of various silencer types in conjunction with a model internal combustion engine
Assessment of railway noise at housing site 375 Pinner Road, Northwood, Middlesex;
Measurement of impact sound transmission and airborne sound insulation at No 5 Carew Road, Northwood
The measurement of the noise characteristics of an electric lawnmower

Derby Lonsdale College of Higher Education

An examination of acoustics in a general purpose sports hall
Some aspects of a bottling and canning noise survey
Observed and predicted sound attenuation at a motor racing circuit
Acoustic screening of a scrap processing plant
Some recent experiences involving residential development close by a major railway line
Proposed hotel development, East Midlands Airport
The environmental impact of industry on dwellings — A case study
Design and evaluation of a loudspeaker enclosure
Control of noise from industry developed on green field sites

Tottenham College of Technology

An investigation of the impact of the Blackwall Tunnel Approach Road on adjacent buildings
An investigation into the environmental effect of Southend-on-Sea Airport at weekends
An investigation into the behaviour of sound in rooms
An investigation into acceptable (8-hr L_{eq}) levels in offices
An investigation into the problem of noise and vibration associated with living on a major heavy goods vehicle route
A study of one statistical method for the evaluation of noise measurement data
Field measurement insulation between floors in converted dwellings
A comparison of measured and predicted traffic noise levels, and An investigation into acceptable L_{eq} levels in offices

Heriot-Watt University

An examination of anomalies in accepted noise control criteria

Cornwall Technical College

Study into the external and internal noise levels surveyed at 10 Custom House Court, Penzance
Evaluation of the background noise level at Rosemangwas Quarry
An examination into the effect on acceleration levels of varying the down-forces as applied to a pneumatic road-breaker
A system for the measurement and analysis of low frequency impulsive noise
Commercial vehicle cab noise

Any enquiry concerning these reports should be addressed to The Secretary, Institute of Acoustics, 25 Chambers Street, Edinburgh, EH1 1HU.

The Teaching of Vibration and Noise

The Fourth British Conference on the Teaching of Vibration and Noise will be held at Sheffield City Polytechnic from 6 to 8 July 1982. The conference has been designed to give teachers and lecturers the opportunity to present their own novel ideas and experiences in the teaching of noise, vibration and acoustics. Papers are invited on a wide range of subjects; summaries of at least 500 words are requested by 19

October and papers, not exceeding 3000 words, will be required by 18 February 1982. An exhibition of vibration and noise equipment will be held parallel with the conference, and authors and delegates will also be given an opportunity to demonstrate their own ideas.

Details and application forms are available from Mr P B Round, Industrial Liaison Service, Sheffield City Polytechnic, Halfords House, 16 Fitzalan Square, Sheffield S1 2BG. Telephone: 0742 20911 ext 376. □

INSTITUTE MEDALS

Rayleigh Medal

The medal is awarded, without regard to age, to persons of undoubted acoustic renown for outstanding contributions to acoustics. The medal is normally awarded to a United Kingdom and to a foreign acoustician alternately. A suitable citation accompanies the presentation of the medal to the recipient. As a condition of the award, each recipient is required to give a presentation in a suitable form, to the Institute, of an acoustical topic of his interest.

Tyndall Medal

This medal is awarded biennially to a citizen of the United Kingdom, preferably under the age of 40, for achievement and services in the field of acoustics. A suitable citation accompanies the presentation of the medal to the recipient. As a condition of the award, each recipient is required to give a talk on an acoustical subject of his choice. The award is made in even-numbered years.

A B Wood Medal and Prize

This is an annual award made for distinguished contributions in the application of acoustics, preference being given to candidates whose work is associated with the sea. The award consists of a silver-gilt medal, a parchment scroll, and a cash prize. It is made alternately to a person domiciled in (i) the United Kingdom and (ii) in the USA or Canada. The recipient is preferably under 35 years of age in the year of award, which is normally made on a suitable occasion in the United Kingdom. Opportunity is given for the recipient to deliver a lecture at the time of the presentation.

Anyone wishing to put forward a name for consideration by the Medals and Awards Committee should write in strict confidence to the President, enclosing a brief outline of achievements, etc, before 15 November. The 1982 Medals will all be awarded to UK citizens. □

Material for the January issue of Acoustics Bulletin should reach Mrs F A Hill at 25 Elm Drive, St Albans, Herts AL4 0EJ, no later than 20 November.

New Products

Submissions for inclusion in this section should be sent direct to J W Sargent, Building Research Establishment, Garston, Watford WD2 7JR.

Tape Recorder B & K type 7005

The new B & K Portable Instrumentation Tape Recorder, type 7005, is a 4 channel attaché case sized instrument for recording analogue signals in the frequency range from DC to 60 kHz onto standard 7-inch spools of professional recording tape. It has self-contained rechargeable batteries and interchangeable plug-in units enabling up to 4 IRIG wide-band FM and intermediate band Direct record-reproduce channels to be obtained without head changes or adjustment. Supplementing the FM and Direct units is a plug-in 2-channel Comander unit providing an improved signal to noise ratio of 70 dB. The 7005 has tape speeds of 1.5 and 15 in/s.

Human Response Vibration Meter B & K type 2512

The Human Response Vibration Meter type 2512 is designed to make measurements in accordance with the latest ISO standards and recommendations which define limits for various periods of exposure to vibration and for various degrees of discomfort.

Three vibration categories are selectable: (1) Whole body vibration, (2) Hand-Arm vibration, (3) Motion Sickness; sub-categories involving specified discomfort levels within these ranges are also switch-selectable. The 2512 also incorporates the necessary circuitry to enable the resultant computation of the time, level, frequency and related variables to be indicated as one convenient figure on a 4-digit LED display. There is provision for three separate switchable vibration inputs.

A special Triaxial Seat Accelerometer has been designed for Whole Body and Motion Sickness measurements.

Microphone Pre-Amplifier B & K type 2633

Brüel & Kjær also announce a new microphone preamplifier, the 2633. This is for use with their $\frac{1}{4}$ -inch microphones.

Brüel & Kjær (UK) Ltd, Cross Lances Road, Hounslow, TW3 2AE. Tel: 01-570 7774.

1200 Signal Processor

The 1200 is a dual channel Spectrum Analyser from Solartron which provides all the normal features associated with a spectrum analyser such as signal generation and comprehensive analysis functions, plus Cepstrum analysis, log analysis and a multi-sine noise source which allows the examination of a small resonance close to a second large resonance. An IEEE 488 Interface, waterfall display and zoom are also included.

Further details from The Solartron Electronic Group Ltd, Victoria Road, Farnborough, Hampshire GU14 7PW. Tel: Farnborough (0252) 44433.

Dunlop Foams for Acoustic Dead Room

An acoustic dead room using foam

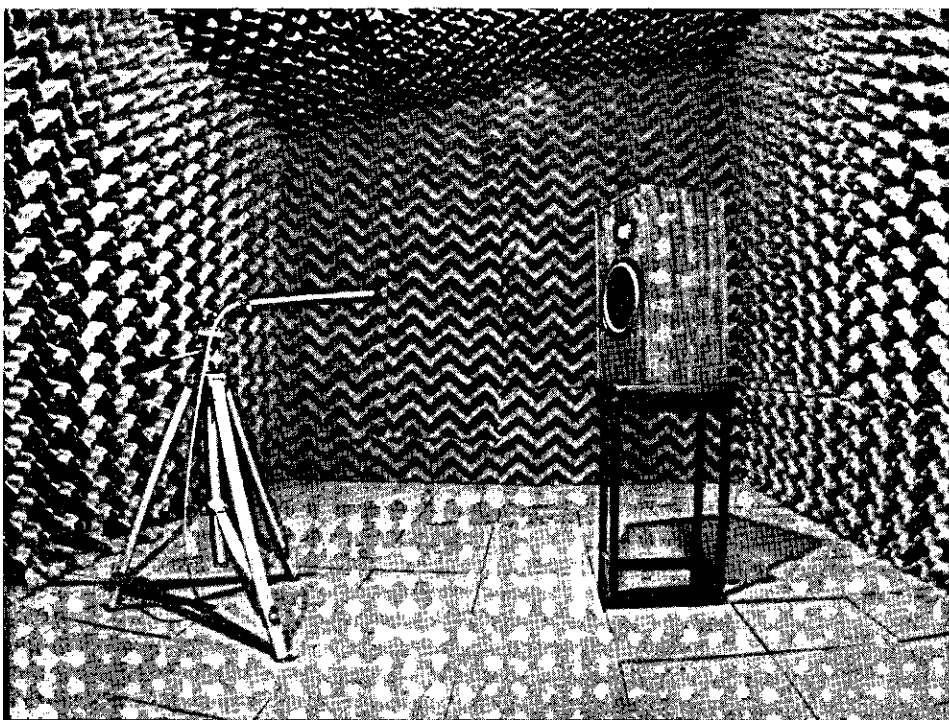
supplied by the Dunlopillo Division UK of Dunlop Limited has been installed at the Eastleigh, Hampshire, headquarters of Son Audax Limited. The company, who are manufacturers of loudspeakers, use the room for testing their own equipment and that of other manufacturers.

The Dunlop DF123 flexible polyurethane foam used for this contract has been specially formulated for acoustic use. This high quality foam has the mechanical properties and flow resistance that give excellent low frequency absorption and good energy dissipation. The walls of the room, which measure approximately 4.72 m $\times$ 2.9 m $\times$ 2.9 m, are covered first of all in 10 cm thick sheets of DF123, and these in turn are lined with deeply profiled foam with an overall thickness of 15 cm. The floor is covered in 15 cm thick slabs of foam.

Economical, and easy to cut and fit, the foam is light in weight and does not create dust. In its profiled form, it is an extremely effective sound absorber: above 150 Hz the reflection coefficient becomes better than 0.1.

Vibration Damping Compound

A new noise control compound has been produced by Swedac, which may be applied by trowel or by spray gun to



Profiled Dunlop foam in acoustic dead room

damp the vibration of panels. Acoustic performance of the compound at normal temperatures gives a loss factor of 0.08 when applied on steel panels at 1:1 weight ratio. With 1:2 weight ratio, the loss factor is 0.25. Further details from General Acoustics Ltd, PO Box 20, Scarborough, North Yorkshire YO11 1DE.

1995-9013 Four Channel, 1/3 Octave Integrating Real-Time Analyser

To meet a US Navy requirement, GenRad has developed a four channel version of the popular 1995 1/3 Octave Real-Time Analyser.

The standard model (the 1995-9008) has parallel 1/3 octave bands arranged internally as four sets of ten analogue filters. In the 1995-9013, the input to the four sets has been separated into four channels. The output is unchanged from the 1995-9008; therefore, signals from four different transducers can be analysed by separate sets of ten 1/3 octave filters. A variety of frequency ranges is available for each channel. The analysis results can then be output through the IEEE bus to a

calculator where the four channels of data may be separated, summed, or analysed as desired.

GenRad Limited, Norreys Drive, Maidenhead, Berkshire SL6 4BP. Telephone 0628 39181.

Pulsar Sound Level Meters

Pulsar announce their first precision grade sound level meter the Model 44. It is convertible between grades 1 and 3 by changing the microphone and has 'Impulse', 'Fast' and 'Slow' responses; price under £200 for the basic unit. Also new: the Pulsar 85E Industrial Sound Level Meter, scaled both in noise level and its allowable exposure time. Cost: £130.

Further details from Pulsar Instruments, 40-42 Westborough, Scarborough, North Yorks YO11 1UN

Sound Intensity Meter

Metravib have produced a sound intensity meter for industrial noise measurements. This instrument facili-

tates the localisation of the main noise sources irrespective of interfering noisy sources. Acoustic intensity flux is obtained from simultaneous measurements of pressure and particle velocity. Usable frequency range: 88 Hz to 5657 Hz. Octave filters: 125 Hz to 4 kHz. Accuracy: ± 1 dB. Dynamic range: Pressure 40-128 dB, Intensity 30-128 dB. Metravib, 24 bis, Chemin des Mouilles, 69130 Ecully.

Acoustical Doors

Clark Door Limited, specialists in power and manually operated sliding doors have produced new literature on their range of Sliding Acoustical Doors. The brochure outlines specifications up to SRI51 and includes a fully documented case history of an electrically operated sliding TV Studio door with a sound reduction index of 51 dB. Clark also manufacture hinged doors for locations where the sliding pattern is not practicable and will send literature on request.

Clark Door Limited, Willow Holme, Carlisle CA2 5RR. Telephone: 0228 22321. ☐

ACOUSTICS AND STRUCTURAL DYNAMICS

OVE ARUP PARTNERSHIP
13 Fitzroy Street, London W1P 6BQ.

Since its formation in May 1980 Arup Acoustics has attracted interesting work. Current commissions in the UK include a review of the acoustics of the Royal Festival Hall, speech reinforcement in Canterbury Cathedral, advice to the National Theatre Company, redevelopment at Alexandra Palace and at the Royal Exchange, IBM Offices Southbank, and a range of work relating to noise and vibration control in industry, civil engineering and building services. Overseas current projects include the new Hong Kong and Shanghai Bank Headquarters in Central Hong Kong, a stadium at Kano Nigeria, scientific research facilities in Kuwait and smaller projects in France, Germany and Eire.

The practice is small and now needs one or two more staff. Engineering Graduates with some practical experience — particularly anyone with experience of building vibration — are invited to write to Professor Peter Parkin, Arup Acoustics, quoting ref AAC81/2 and giving a brief account of their qualifications and experience.

Key appointments in noise and vibration research

Templecombe, Somerset

Plessey Marine has an international reputation as a forerunner in the research, design, development and manufacture of sophisticated sonar and anti-submarine equipment for the navies of the world.

At Templecombe, Somerset, our Research Department is looking at the future technology to be used in our next generation of equipment and the assessment of sonar performance generally, involving the isolation and control of sonar self and radiated noise on naval vessels.

We are currently looking for a number of people to increase the strength of the noise and vibration group in this challenging research area. Successful candidates will have every opportunity to make the most of their specialist background in fundamental vibration and acoustics, time series analysis or signal processing.

PROJECT LEADER You will manage a small team of mathematicians and experimental physicists involved in theoretical and experimental studies of noise transmission along fluid loaded structures.

You are likely to be a physicist/mechanical engineer, probably with a higher degree and five years' experience in a research environment involved with understanding soundstructure interactions, or the control of structure borne noise.

PRINCIPAL SCIENTIST An opportunity to occupy a key position within the noise and vibration group as a technical specialist, initiating and directing its signal processing and time series analysis activities.

You are likely to be a graduate physicist, applied mathematician or mechanical engineer with five years' experience in the use of Fourier analysis techniques in the solution of noise and vibration problems and should be fully conversant with the principles of time series analysis.

EXPERIMENTAL PHYSICISTS OR MECHANICAL ENGINEERS We are looking for experimental physicists or mechanical engineers to carry out experiments – both in the laboratory and on board naval vessels – concerned with increasing our understanding of noise generation, transmission and radiation.

Following your degree you will have gained experience in noise control in structures, machinery noise reduction, data collection and analysis. However, initiative, self-confidence and intrinsic scientific ability coupled with the ability to work under demanding conditions at sea could be of greater importance than direct experience in noise control.

Benefits are those you expect of a major organisation and include generous help with relocation to this attractive part of the West Country.

Please write, with brief career details, Robin Churchill,
Technical Recruitment Manager, Plessey Marine Research Unit,
Wilkinthorpe House, Templecombe, Somerset.



PLESSEY
electronic systems



Institute of Acoustics Meetings

1981

2 November	M	Noise Source Location	Birkbeck College, London
26 November	LEM	Communication in a High Noise Environment (relating to Aircraft)	County Hall, London
27 November	SWB	Noise the Architects' Fault?	Plymouth Polytechnic
14 December	M	Outdoor Sound Propagation	Open University, Milton Keynes

1982

28 January	LEM	Instrumentation for Environmental Noise Problems	County Hall, London
8 February	M(P)	BS 4142 Reviewed and Criticised	London
25 February	LEM	Attenuating High Velocity Systems	County Hall, London
26 February	SB	Design and the Consultant	Portsmouth Polytechnic
25 March	LEM		County Hall, London
29 March - 1 April	M	Spring Conference — Acoustics '82 Sessions on: Environmental, Transportation and Propulsion Noise; Physical Acoustics and Ultrasonics; Signal Processing in Acoustics; Subjective Auditory and Vibratory Effects; Poster Session	University of Surrey
29 April	LEM	Review of Acoustical Standards	
29 - 30 April	UW	Spectral Analysis and its use in Underwater Acoustics	Imperial College, London
26 May	M(P)	Noise Control in Factory Buildings	Cambridge
June	M	Design and Use of Acoustic Test Rooms	London
9 - 10 September	M	Auditorium Acoustics	Edinburgh

1983

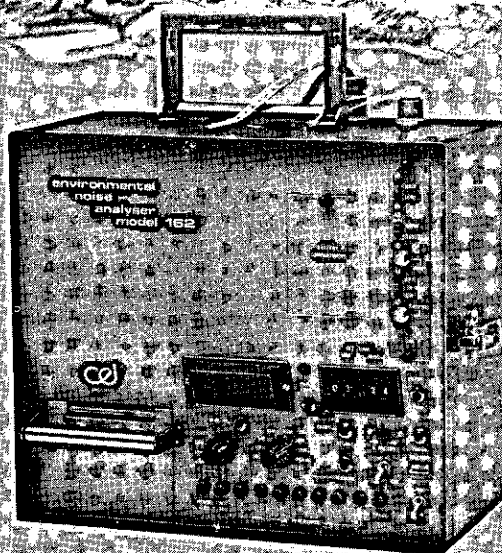
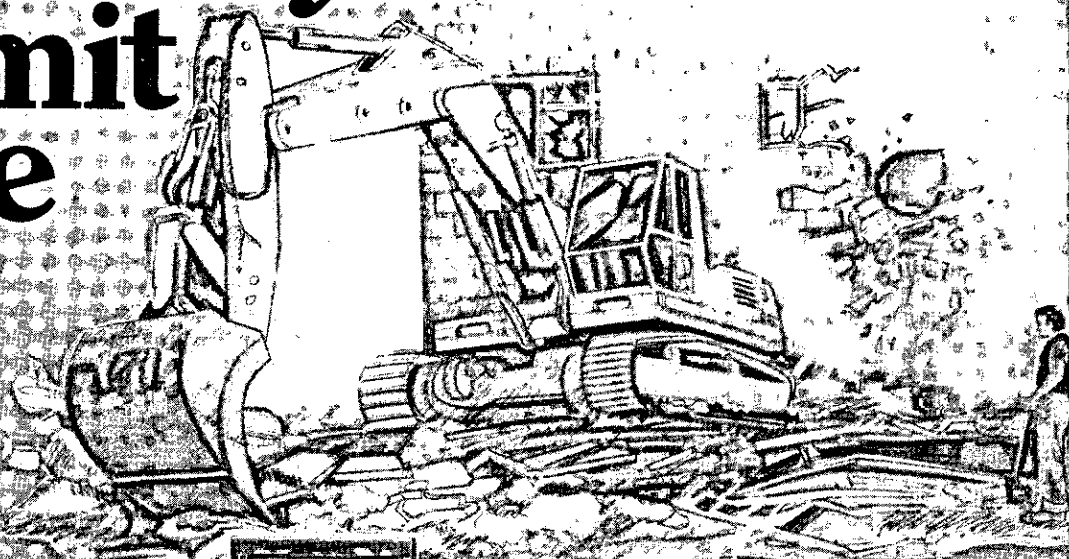
13 - 15 July	M	Inter-Noise '83	Edinburgh
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Key

M=Meetings Committee Programme
LEM=London Evening Meeting
SWB=South Western Branch
(P)=Provisional
SB=Southern Branch
UW=Underwater Acoustics Group

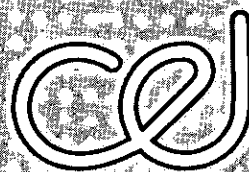
Further details from:
Institute of Acoustics
25 Chambers Street
Edinburgh EH1 1HU

It's so easy to limit noise



with the CEL-162

The CEL-162 Environmental Noise Analyser provides, within its fully weatherproof enclosure, a complete precision acoustic measuring, analysing and recording system. Capable of supplying all the information needed for a complete investigation into community noise problems, the CEL-162 can be left unattended for several days. The instrument incorporates a digital autoranging sound level meter and can provide both period and cumulative Leq values — by the true energy integration process — and up to seven simultaneous Ln values. Answers are calculated in real time and are recorded on the self-contained printer. In addition to the functions found in the standard instrument, the CEL-162LAX model includes a threshold detection arrangement that causes the time, duration, maximum and energy level of each event above the threshold to be separately printed. For full technical details of the CEL-162 and all its variants contact:



Computer Engineering Limited
14 Wallace Way, Hitchin, Herts, SG4 0SE
Tel: Hitchin (0462) 52731/3
Telex: 826615