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INSTITUTE OF ACOUSTICS

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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.

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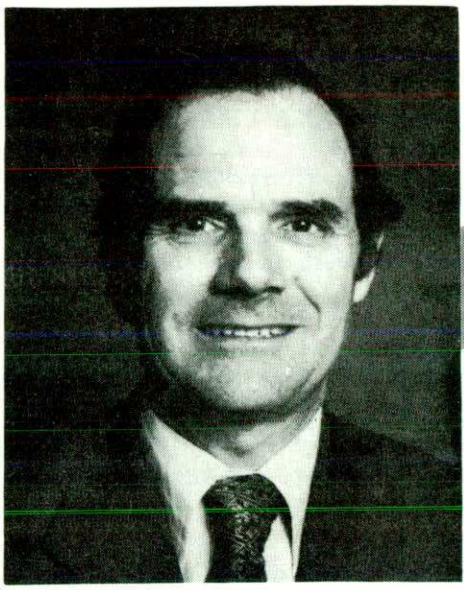


President's Letter

Dear Member,

I look forward to meeting many members of the Institute at the Spring Conference in Newcastle. You will know from the programme that a wide range of contributions and associated activities are in store for us. The Conference will be enhanced by the presentation of the Rayleigh Medal to Prof Uno Ingard, the very well known physical acoustician from MIT. We shall also be acknowledging the great contribution which Prof Ingerslev has made to international acoustics by the award to him of Honorary Fellowship of the Institute. The Tyndall Medal Lecture to be given by Robin Mackenzie will also be included. The packed technical programme and the many other events should make this a worthwhile and memorable conference.

The major item of business at the December meeting of Council was the discussion of the report by the Working Party on Groups and Branches. More information on the policy to be adopted will be given at the AGM but I am pleased to say that Council has accepted the main recommendation that every effort should be made to encourage Group and Branch activities. The long-term aim is for there to be an active Branch within easy reach of every member. This cannot be organised from the centre but depends on the encouragement of local initiatives. To emphasise the importance attached to this new venture, Council has appointed Trevor Smith a Vice-President with special responsibilities for the encouragement of Branches. We hope to have a lively discussion on this topic at the AGM and following that I hope that we shall be able to identify one or two more areas where there is sufficient interest and keenness for new Branches to be created.

B. L. Clarkson

NPL and Acoustical Standardization

Dr D W Robinson

At a recent IOA meeting on Acoustical Standards held at the National Physical Laboratory, Dr Robinson, head of the Acoustics Unit there, spoke on national and international standardization and the role played by NPL. His paper gives a welcome insight into the processes of preparing and updating Standards at all levels and is given here for the benefit of the many users of Standards for whom their background remains a mystery.

What is a Standard?

English dictionaries give twenty or more meanings of this remarkable word. Leaving out some of the more recondite and the botanical, here are a few which come within hailing distance of today's proceedings:

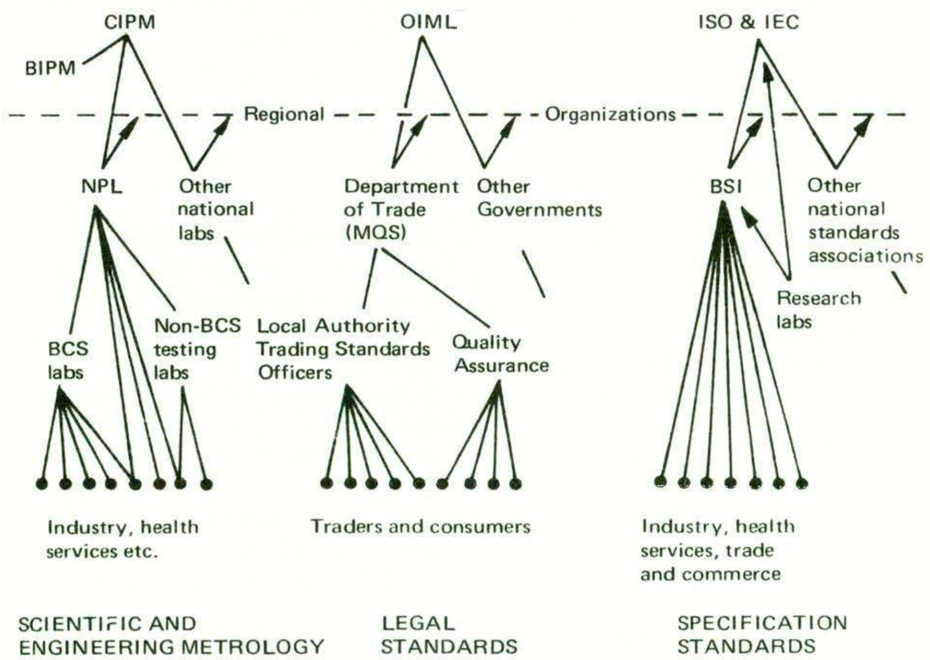
- a flag or banner
- a class
- a level of excellence required, aimed at, or possible
- a criterion
- an established or accepted model
- a basis of measurement
- an exemplar or substance chosen to be, or afford, a unit.

No single one of these fits all ten occurrences of the word 'standard' in the programme of this meeting. In USA there are two well-known institutions named for standards, the National Bureau of Standards (NBS) and the American National Standards Institute (ANSI), which nicely exemplify the conceptual distinction between the two sorts of standards—metrological and specification—which principally concern us. These two types are complementary although they lead to different sorts of activity.

Broadly, standardization in metrology means the realization of physical units and quantities, and the system whereby these material representations are propagated down a traceability chain from a unique exemplar of great accuracy at the apex, through successively lower levels with ever-increasing replicas and correspondingly decreasing accuracy (or increasing uncertainty as we are nowadays encouraged to say). At the international level, the Comité International des Poids et Mesures (CIPM) with its laboratory at Sèvres (BIPM) is at the head of this chain; national standardizing laboratories, of which NPL is one, stand at the apex of the respective national pyramids, and below them various forms of dissemination and calibration service operate to provide standards of measurement for the end users in manufacturing industry, health services, environmental protection and so on. This pyramid shown greatly simplified in Figure 1 (left) operates, at the top, in a purely scientific climate whilst technological and engineering emphasis dominates at the base. The recommendations of the 18 members of the CIPM on SI units, such as the value of the metre and ampere, are generally accepted by states which are signatories of the Metre Convention of 1875; the pyramid operates on the basis of mutual acceptance without important political or economic distortions but in a financial straightjacket.

Paralleling this is the other metrological pyramid shown at centre, in which the driving force is not science or engineering but legislation on weights and measures for trade and consumer protection. The International Organization for Legal Metrology (OIML) at the apex is composed of the representatives of member Governments and the standards it produces are usually in the form of model laws. OIML has a long history, but its activities have, as yet, barely touched on acoustics so we can conveniently leave OIML aside.

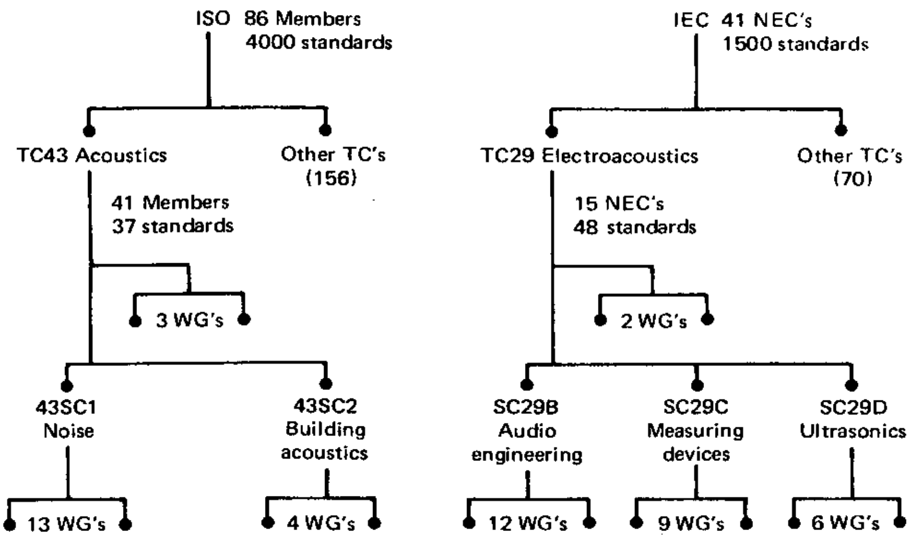
In contrast to these metrological activities, the pyramid for specification standards (Figure 1, right) exists primarily to prevent barriers to trade, and also to establish voluntary norms where proliferation would be in nobody's interest, in the fields of applied science and technology. Specification standards at the international level are produced



Key:

CIPM	**– Comité International des Poids et Mesures**
BIPM	**– Bureau International des Poids et Mesures**
OIML	**– Organisation Internationale de Métrologie Légale**
ISO	**– International Organization for Standardization**
IEC	**– International Electrotechnical Commission**
NPL	**– National Physical Laboratory**
MQS	**– Metrology, Quality Assurance, Safety and Standards Division (Department of Trade)**
BSI	**– British Standards Institution**
BCS	**– British Calibration Service**

Figure 1. Three branches of Standards activity, simplified.



Key:
NEC —National Electrotechnical Committee
TC —Technical Committee
SC —Sub-committee
WG —Working Group

Figure 2. Structure of international acoustical standardizing organisations.

mainly by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) through a vast network of technical committees. Although the two bodies are separate they share a common address in Geneva, and IEC works in practice as the electrical division of ISO. The members of ISO are the national standardizing institutions, and of IEC the National Electrotechnical Committees. In UK, the British Standards Institution (BSI) fills both roles but this unity is not the case everywhere. ISO and IEC standards are voluntary although member bodies who vote in favour of them are pledged to adopt them. If there is a conflict with national requirements they are not supposed to vote in favour. Obviously this provides opportunities, in an imperfect world, for pre-emption, backsliding, using the standards as instruments of national commercial policy, and other scientifically 'impure' acts. This is most marked in the case of instrument specifications, where the commercial interests are greatest, and also for some standards dealing with methods of measurement of products, but happily almost absent in the case of applied scientific data. Despite the limitations a great deal has been accomplished (over 5,000 standards, 80-odd in the acoustical sphere) which must gratify any but a perfectionist. It is worth adding that these standards sometimes permit, within them, different standards (using the word in the sense of 'levels') of measurement accuracy, manufacturing tolerances etc. What they expressly do not do is to incorporate standards (using the word in yet another sense, to mean 'criteria') which imply or assert limit values; this would undermine the system fatally.

As mentioned, Figure 1 is greatly simplified. There are cross-links at various levels, for example between NPL and its sister institutions abroad. There are a number of regional organizations (EEC, NATO etc) that operate supranationally but not fully internationally. There are fully international organizations that produce specification standards in particular technologies, for example ICAO in civil aviation and CCITT in telecommunications, including acoustical aspects of these fields. Furthermore there is no sharp dividing line between the fields of metrological standards (ètalons) and specification standards (normes); an example is the realization of the sound pressure unit. This is clearly metrology but it happens to be done through the medium of a series of IEC specification standards detailing the calibration of condenser microphones by reciprocity.

Acoustical Standards

The important physical quantities in acoustics are sound pressure and, to a lesser extent, sound power. The respective units, pascal and watt, are derived units in the SI system and, although their realizations in the frequency range of acoustics differ in form from those of the pascal as a static pressure and of the watt in its electrical manifestation, it might be supposed that they would feature in the work programme of BIPM. This, however, is not the case, probably due to resource limitations and competing demands on the Sèvres laboratory. Furthermore, the UK traceability chain for acoustical measurement standards is less organized than the diagram suggests. The British Calibration Service (BCS), for example, does not cover any part of the acoustical field (vibration excepted); potential test laboratories have apparently judged the profitability insufficient in relation to the costs of BCS approval. Pressure from the ultimate customer for guaranteed acoustical performance of products (eg noise emission) has not built up to the extent that it has in other countries, notably USA and West Germany, or in other technologies such as radiological protection. NPL therefore has to provide acoustical calibration services through non-BCS channels or direct to users. There is also some leakage due to the large fraction of imported acoustical instruments in UK, calibration traceability of which sometimes by-passes the orthodox UK chain. We at NPL cannot regard this situation as satisfactory from a national viewpoint.

In contrast to the above, specification standards both nationally and internationally present a lively picture with a long and active history of UK participation. The rest of this paper will be devoted to an outline of this activity.

Process of International Standardization

The forerunner of ISO, a body called the International Federation of the National Standardizing Associations (ISA for short), convened the first acoustical standards convention in June 1937 in Paris. This meeting did accomplish, among other things, the definition of the *phon* substantially as it is today, but the committee (TC43) had hardly got off the ground before the outbreak of war. Acoustical activity resumed in 1953 with the re-establishment of Technical Committee 43 (Acoustics) under auspices of the newly-formed ISO, and of Technical Committee 29 (Electroacoustics) of IEC. Their first meetings were held in 1953 in London and The Hague respectively. The founding fathers were sharply divided over the wisdom of having two technical committees (TC) instead of one, but the constitutions of ISO and IEC made it logical and the arrangement was endorsed by the ISO General Council and the IEC Committee of Action.

Progress was assured by the pragmatic solutions of a joint Steering Committee and coordinated meeting schedules. Save for a temporary and unsuccessful break in the latter, now repaired, both arrangements have survived. The respective domains of interest, though theoretically split along non-electrical versus electrotechnical lines, in practice divide neatly along a related axis: ISO TC43 deals with acoustical data, principles and measurement procedures, IEC with instruments. There are few exceptions to this.

The time scale of production of standards is often criticized by the technical public and sometimes, with greater justification, by those directly involved. It must be remembered that standards cannot be imposed but can only represent a consensus reached after rounds of draft-writing, commenting and voting. Furthermore, it is rarely possible to plunge straight into the writing phase. If a project is started at a stage of technical development early enough to forestall proliferation, it often has to begin with 2 or 3 years of co-ordinated research work, exchange measurements or evaluation of prototype devices by members of the appointed Working Group (WG) (Figure 2); on the other hand if it is initiated too late, time is lost at the later stages in compromises and unscrambling national standards which diverge and harden in the meantime. At best, the course of events follows the plan in Figure 3.

A new project may either be started on the initiative of a member body (provided it receives majority support under the ISO or IEC balloting directives) or on request of another ISO or IEC technical committee or of an international body in official liaison. The latter is well illustrated by ICAO's request to ISO to standardize a method of measuring and describing aircraft noise heard on the ground. To do this TC43 in turn requested IEC TC29 to prepare a standard specification for the relevant instrumentation. The usual (dare I say 'standard'?) procedure is to set up a Working Group of experts drawn from the principal interested countries. They serve in a personal capacity, not as national delegates, nor as emissaries of the member bodies. They have to keep in mind, of course, that the fruits of their labours must pass the test of acceptance by the member bodies, including their own, BSI in our case.

The secretariat of a TC circulates a WG proposal as soon as it judges—or is advised—that a sufficient technical consensus exists. The proposal is circulated to all member bodies for comment (or, under accelerated procedure, for voting as well but this is appropriate only in cases where agreement is thought highly likely). ISO has two types of member body: 'P' (participating) who can vote and 'O' (observing) who can comment but not vote. TC43 has 26 'P' - and 15 'O' - members. IEC does not have this distinction; there are 15 national electrotechnical committees in TC29. The comment document is called a Draft Proposal (DP) in ISO parlance, a Secretariat document in IEC. Assisted by the WG, the secretariat next prepares a revised version which is usually placed on the agenda of the next plenary meeting of the TC. With luck the meeting will approve the document with only minor changes and it then goes to the ISO Central Secretariat (or IEC Central Office) for issue as a draft standard for

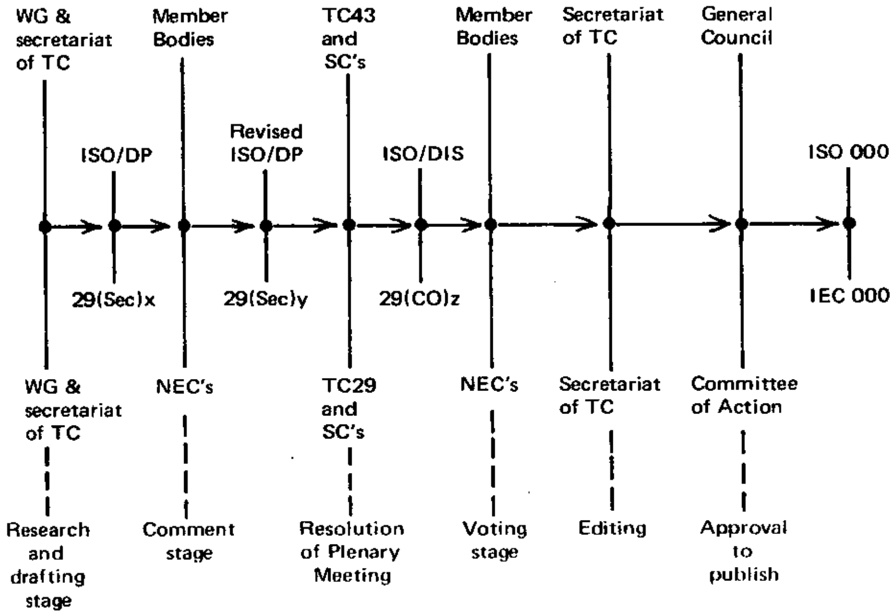


Figure 3. Stages in preparation of an International Standard (upper and lower parts correspond to ISO and IEC terminology respectively).

voting. At this stage it is called a DIS (Draft International Standard) or a Central Office 'Six Months' Rule' document in ISO and IEC parlance respectively. The time limit for voting is six months and in principle this is a yes/no ballot with opportunity for editorial but not technical comments. If the requisite number of votes is favourable the document goes to a permanent editing committee and thence to the ISO General Council or IEC Committee of Action for approval to publish. More often than not, a document has to be recycled at one stage or another due to objections from one or more member bodies. Not infrequently, such delays snowball because the technical state of the art does not stand still.

Once the standard is published it is expected that national standards should be issued, or old ones amended, in line with it. By a recent change of ISO rules, their standards come up for automatic review every five years—a ridiculously short time for some types of document, eg the data standards of psychoacoustics. This has greatly increased the already substantial volume of second-generation work, which in any case brings new dimensions of difficulty into the proceedings. First-generation standards will have been followed by contingent national standards and sometimes legislation which tend, in their nature, to be resistant to amendment. This is why, for example, the first ISO document on motor vehicle noise emission measurement (R362) was completed from start to finish in the period 1959 to 1964, whereas its revision begun in 1971 is still at the voting stage in 1980 with dubious prospects of agreement.

Another feature causing problems in the second generation work is awareness that specifications of measurement uncertainty are wanting or deficient in many of the earlier productions. Whilst certainly necessary on good metrological principles, these features prove quite difficult to implement in a consistent (standard!) manner.

Acoustical Specification Standards

In 1953, TC43 had a single project, namely musical pitch, as important as it is simple to state: A = 440 Hz. Between then and 1967 (the next cardinal date) this was followed by 14 more standards on topics as diverse as threshold of hearing, loudness, sound insulation and absorption, motor vehicle and aircraft noise, preferred measuring frequencies etc. During the same period, IEC produced standards on hearing aid performance, sound level meters, audiometers, band-pass filters, and the testing and calibration of therapeutic ultrasonic generators. A sub-committee (SC 29A) also issued several standards in the commercially important field of sound recording; in the mid-sixties SC 29A was 'promoted' to become an independent TC (TC60).

TC43 and TC29 were reconstructed in 1967, due to increasing specialization of the work, and sub-committees were added. The bulk of TC43 work was delegated to SC1 (Noise), this being by far the larger share, and to SC2 (Building Acoustics). The parent committee retained responsibility for audiometry, thresholds of hearing etc. Since 1967, the noise work of 43 SC1 has proliferated, with 20 standards published and 35 more in the pipeline. They range from the general to the particular and cover all sorts of machines; there are also standards on hearing protector tests, noise as a hearing damage risk and as an environmental pollutant, sonic boom measurements etc. Due to a 1972 resolution of the ISO General Council, TC43 is responsible for all noise emission standards whether originating within TC43 or other ISO committees, which contributes heavily to its work load. IEC TC29 continued, after the reconstruction, with the residual functions of hearing aid and vocabulary standards but delegated the bulk of its programme to three subcommittees. SC 29B (Audio engineering) operates in the rapidly-changing fields of sound systems and hi-fi and holds the record for output measured in pages of print. SC 29C (Measuring devices) has issued 12 standards in as many years on things as diverse as audiometers, artificial ears and mastoids, sound level meters, pressure and free-field calibration of condenser microphones (referred to earlier), and equipment for measuring aircraft noise; in the pipeline are, among other things, important documents on personal sound exposure meters and integrating sound level meters. SC 29D (Ultrasonics) is smaller than the others but likely to develop; it has produced a specification for a standard hydrophone (up to 100 kHz) and the calibration of hydrophones (1 Hz to 1 MHz); in the pipeline are standards for ultrasonic cleaning and medical diagnostic equipment, surgical and dental apparatus, underwater echo-sounding devices, and hydrophone calibration up to 15 MHz.

NPL Participation in International Standardizing Activity

The technical work of ISO and IEC depends in large measure on the voluntary input of research data from laboratories in the participating countries. A complete listing of the contributions of NPL to the acoustics work would not be appropriate here, but mention of some examples of standards which owe their existence wholly or largely to this work carried out at NPL in the last three decades may be of interest.

An early example was ISO R226—the equal-loudness contours—standardized exactly as published by Dadson and the author in 1956. Research on the relation between the *phon* and *sone* scales of loudness, and on the loudness of diffuse sound fields went into the making of ISO 131 and ISO 454. We also participated in the 'round robin' comparisons that produced respectively the method of measuring reverberation absorption coefficient of materials (R354), and the normal threshold of hearing (or audiometric zero) in ISO 389. With the Motor Industry Research Association we did the original experiments that decided the scale of noise measurement for motor vehicles (R362).

Later we became involved in occupational hearing loss and the associated measure of noise exposure (A-weighted daily noise immission) which is found in ISO 1999; also with the measurement of sonic boom given in ISO 2249, and with other aspects of aircraft noise measurement (atmospheric attenuation, the scale of effective perceived noise level, characteristics of microphones and analysers etc) which have been incorporated in the evolving series of ISO and IEC documents (R507, R1761, ISO 3891, IEC 537, IEC 561) on this subject.

Considerable effort has been devoted in the last few years to the standards (already mentioned) which in effect comprise a realization of the unit of sound pressure. This work, which mainly involved other national standardizing laboratories besides NPL, was co-ordinated in a WG of SC29C and some continuations of it are still proceeding. Also, at this time, we are acting as the lead laboratory in microphone calibration exchanges at regional level, in this case under the applied metrology programme of the EEC.

In the audiological sphere, both the artificial ear and the artificial mastoid specified in IEC standards 318 and 373 originated here with the prototype instruments developed by Delany, Whittle and the author in the '60s; and coming up to recent times we have provided major input to current ISO work on the threshold of hearing by bone conduction and on the age effect in hearing. Finally it is topical to mention the imminent publication of ISO 4869 describing the real-ear method for determining the acoustical attenuation of ear protectors on lines similar to those devised at NPL.

Bearing in mind that the NPL Acoustics Unit is just one among many of the research groups—albeit one with a long record—which contribute to the work of international standardization, the sum total of knowledge and expertise available to the committees can be seen to be wide in scope and large in volume. □

Courses at ISVR

Machinery Design and Installation for Noise and Vibration Control
29 June to 2 July 1981

This Course is intended to bring engineers, mathematicians, physicists, acousticians and designers up to date with recent advances in both theory and practice of noise control in machines and vehicles. The Course, led by Professor E J Richards, covers the latest methods for reducing noise for impact machines, pumps, saws, diesel engines and other machines and systems commonplace in factories, ships and vehicles.

Tenth Advanced Noise and Vibration Course
14 to 18 September 1981

This Course is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. The Course, which is designed to refresh and cover the latest theories and techniques, initially deals with fundamentals and common ground; then offers a choice of specialist topics.

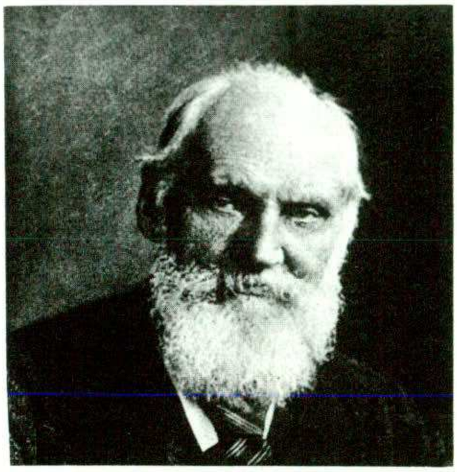
Other short courses are presented regularly at ISVR and further information may be obtained from the ISVR Conference Secretary, The University, Southampton SO9 5NH. Tel: 0703 559122, Ext. 2310 (Mrs Hyde) or 752 (Dr J G Walker, ISVR Short Course Organiser).

Pioneers of British Acoustics

Engineer-Scientists and Acoustics: Lord Kelvin and Michael Faraday

Although Lord Kelvin and Michael Faraday regarded themselves as scientists in many ways their greatest contributions were more in the electrical engineering field. The advent of electronic developments in the last two or three decades has involved electrical engineers in acoustical activity at both microwave and audio frequencies. In the nineteenth century their contributions to acoustics were less evident but in this article two examples of such participation to the advancement of the subject will be given, which came about in two different ways.

William Thomson (1824-1907), probably better known as Lord Kelvin, was born in Belfast, the second son of James Thomson LlD, a mathematics teacher in the Royal Academical Institute, who later became Professor of Mathematics at the University of Glasgow. William entered Cambridge in 1845 and won the first Smith's Prize for Mathematics. Owing to the scarcity of experimental study facilities at that time in the UK, he worked for a year in Regnault's laboratory in Paris and in the following year he accepted the chair of natural philosophy in the University of Glasgow, which he occupied for 53 years.



Lord Kelvin

Lord Kelvin published more than 300 original papers covering nearly every branch of physical science. He saw science in all its aspects as a single enterprise and with this objective in mind he developed a 'vortex-atom' theory in which he envisaged atoms as little vortices in an all-pervading aether. These 'smoke-rings' were supposed to operate in the manner of an atom, *viz:* have an independent existence, collide and rebound with each other, combine and vibrate. Although Kelvin's atomic conception was a failure it was utilised as a vehicle of explanation by many physicists in several areas of chemistry and physics and moreover provided a stimulus for the rapid growth of fluid dynamics in the late nineteenth century. So in this roundabout way basic acoustics derived much benefit. Kelvin's direct contribution to acoustic instrumentation was his development in 1872 of the first harmonic synthesiser, although its purpose was for tide prediction. This invention was followed four years later by his harmonic analyser which is now exhibited in the Science Museum, London.

With all his achievements, Lord Kelvin showed extreme modesty, which he combined with the utmost kindness and he obtained great pleasure in the encouragement of the efforts of students and others who came into contact with him.

Michael Faraday, often referred to as a chemist and a physicist, was largely self-educated. At the age of fourteen he was apprenticed to a bookseller, a trade in which he worked for the next six or seven years. His interest then turned to science and he attended Sir Humphrey Davy's lectures on Chemistry at the Royal Institution. It was the result of his careful write-up of these lectures and their subsequent transmission to Davy with a request to be considered for a laboratory post as his assistant that led to Faraday's real entry into scientific work. His earlier investigations were naturally towards chemistry but gradually he became more concerned with electrical phenomena, leading to his crowning triumph of the discovery of the induction of electrical currents in 1824.

Faraday had a great reputation as a lecturer but was not much concerned with the publication of his lectures. It was his excellence and fondness for lecturing that led to his contribution to the dissemination of acoustical knowledge to a wider audience. The work he described in a number of acoustical lectures in the period 1828-1831 on such topics as the nature of Musical Sound, on the nodal figures of vibrating surfaces, on the transmission of musical sounds through solid conductors etc, was compiled from notes supplied by Charles Wheatstone. The latter avoided lecturing (see earlier reference to this fact in the April 1977 issue of the Bulletin) whenever possible and Faraday was in this way instrumental in publicising the pioneer experiments of Wheatstone. □

A B Wood Medal 1981

Council has accepted the recommendation of the Acoustical Society of America that the 1981 A B Wood Medal and Prize should be awarded to Dr Robert Charles Spindel of the Oceanographic Institute. The presentation will be made at a meeting of the Underwater Acoustics Group later in the year. □

NEW ELECTIONS

At its recent meetings Council approved the following elections:

Fellow

J C Dering	W Powell
C E Gough	G C C Smith
M P Haggard	R M Taylor
D E O'Connor	W Tempest
R J Peters	M C P Underwood

Member

R P Atherton	K-M Lo
J D Athey	K J Marsh
M R Bailey	L S Moye
W A Baines	R B Parker
W J Best	R A Pettitt
A J Brookes	Y Shen
P S Court	M W Simons
R J M Craik	R T Stoker
M Crisp	N P Walker
J A Dinsdale	P A Walker
J W Edwards	P A Wilkins
J F Hinton	W-K G Wu
W-F S Ho	

Associate

R S Bleach	W J Laurie
P R Blewden	H R Leadbeater
A Bolandi	A Marshall
C J Bourne	P Neville
D C Cook	A K Pratt
G M Coward	P R Russell
P J Crank	H E Thomas
I K Cross	I D Travers
P G George	R N Wade
P Guest	H G Warren
A R Jones	S J Willis
E K-K Lau	

Student

M C Dyson	R F Harrison

Proceedings of The Institute of Acoustics - Abstracts
Spring Conference - Acoustics '81
22-24 April at Castle Leazes, Newcastle University

Plenary Session

Rayleigh Medal Lecture: Acoustics in Physics and Engineering
Professor K Uno Ingard
Massachusetts Institute of Technology

Tyndall Medal Lecture: Sound Insulation in Buildings – a Review
Dr R K Mackenzie
Heriot-Watt University

Specialist Lecture: Acoustics and the Performance of Music
Dr Ing Jürgen Meyer
Braunschweig University

When musicians talk about acoustics, they nearly always think only about room acoustics. Of course energy storage effects and time structure do have an influence on the listener's impression of the sound; the conductor has to adjust the dynamics of the orchestra to the hall and consider how many players to use, and the players have to adapt their playing to the environment. But there are further connections between acoustics and practical music making. The physics of the musical instruments gives detailed information to the player about how to influence the frequency, the timbre and the sound power by different playing technique parameters, for example the speed and pressure of the bow and its position on the string for stringed instruments, or the air pressure, lip pressure and lip position for wind instruments. The directivity of the instruments must also be considered in connection with seating positions of the players on the stage so that the best sound can be received by the audience. Last, but by no means least, it is very important for the musicians to be able to hear each other as well as possible. This problem may be solved by knowing not only the details of the acoustical properties of the instruments and of the room acoustics, but also by an understanding of the directional dependence of the masking introduced by the player's own instrument.

Presidential Address: A Structural Dynamicist looks at Statistical Energy Analysis
Professor B L Clarkson
ISVR, Southampton

The Statistical Energy Analysis method is explained to a general audience. The development of the method from ideas in room acoustics is traced and coupled oscillator theory introduced. The application of the method to structural vibration problems is outlined and the limitations described. Recent work to study the individual parameters such as modal density and loss factor of typical structural components is described. Finally examples are given of application of the method to the problem of estimating the vibration levels in satellite structures during launch.

Specialist Lecture: Vibration and Noise Relationships. Some Simple Rules for the Machinery Engineer
Professor E J Richards
ISVR, Southampton

In a world in which the expert is king, countries become very small and communication between them becomes very difficult. This is so in the world of acoustics; symposia are divided into specialist sections, and experts only want to hear from greater experts than themselves.

Unfortunately new technologies develop across such separations, and from time to time it is necessary to try to bridge the gaps in a manner which is simple enough to persuade each group to interest itself more widely. Such a technology is that of trying to design industrial machinery which, while increasing productivity, reduces its noise and minimises deafness.

Machinery noise emanates from heavy impacts between parts. Vibration arises from these impacts, some of which flows into parts which can radiate energy efficiently; the noise radiated depends upon the magnitude and the wave form of this vibration, upon its frequency and upon the balance between the rate of radiation and the rate of absorption in the machine as heat. The seriousness of the noise, and the methods of reduction must depend upon the form of the units by which it is measured. This paper goes back to first principles in trying to provide the basic physical insights which will permit an approach to machinery noise which can both be used by the design engineer looking for simple design rules, while also tempting the expert acoustician, vibration engineer and psychoacoustician to extend his interests into what must surely become a new branch of acoustic technology.

Structural Dynamics 1

A1. Some Aspects of the Parametric and Nonlinear Vibration of Structures
A D S Barr
Department of Mechanical Engineering University of Dundee

Virtually all structures at some level of modelling are nonlinear or have coefficients which are explicitly time dependent. Such nonlinearities and parametric terms even when they are relatively small can have a significant influence on the dynamics of the system.

The paper describes some aspects of the internal resonance of structures in which its modes through the nonlinearities interact on each other and are involved in energy interchanges. In addition some recent results on the dynamic stability of simple systems under multi-frequency parametric excitation are outlined. The frequencies involved are close together and the results are related to those for random parametric excitation.

A2. Nonlinear Interactions in Coupled Beam Systems
J W Roberts and L Bux
Edinburgh University

Systems involving pairs of beams coupled at right angles in an 'L' configuration have been found to display complex patterns of response to forced vibration, in which for example excitation in the neighbourhood of the second bending mode causes response in the first bending mode. The motions have been explained on the basis of small quadratic nonlinear coupling terms which lead to a four mode interaction involving two in-plane bending modes, together with the first out of plane bending and torsion modes of the secondary beam. These interactions are shown to become significant when two internal resonance conditions are satisfied simultaneously. The paper describes the analysis and experimental work carried out on this problem.

A3. Dynamic Plastic Buckling of Stiffened Cylindrical Shells
Norman Jones
University of Liverpool

The dynamic buckling of stringer-stiffened cylindrical shells subjected to axial impact is examined in this manuscript. The impact load is sufficiently severe to cause buckling in the plastic range and the material is idealised as rigid-plastic with linear strain hardening.

Theoretical results are obtained using a perturbation method of analysis which shows the influence of inside and outside stiffeners, initial geometrical imperfections, stiffener eccentricity and material properties on the dynamic plastic buckling characteristics. It transpires that it is more efficient to place stiffeners with rectangular cross-sections on the outer surface on a cylindrical shell impacted axially than on the inside.

A4. Parameter Sensitivity Calculations in Dynamic Design
D Taylor
Cornell University

Abstract not available.

A5. Frequency Response Testing a Non-Linear Structure in a Noisy Environment with a Distorting Shaker
H G D Goyder
AERE Harwell

Abstract not available.

A6. On the Influence of Stiffness and Location of Shear Centre in the Dynamics of a Container Ship
R E D Bishop, W G Price and P Temarel
University College, London

By representing a containership as a non-uniform free-free Timoshenko beam, lateral bending moment and twisting responses are evaluated from a unified dynamical theory. Results are presented for various values of the flexible hull generalised stiffness properties and shear distances. It is shown that the dry

B8. Application of Statistical Energy Analysis to High Frequency Ship Vibration

G T Willshare, D Catley and A Crexis

This paper is based on a study of the application of Statistical Energy Analysis (SEA) to high frequency ship vibration. The advantages implicit in the use of SEA methods to determine the distribution of vibration energy in an extended structure have been described in published literature over a number of years. Although the methods appear particularly attractive in considering ship vibration, because of the broad-band vibration excitation from main engines and propeller and the importance of limiting the consequent noise radiated from vibrating panels in areas of the ship which are remote from these sources, their application to this aspect of ship design has not yet been established. The objective of this study, therefore, was to assess the use and limitations of the technique.

The study included both calculation and experimental work. The theoretical work investigated energy flows and resulting vibration levels for typical local areas of a ship's structure and the paper reports a procedure for reducing the relatively heavy and complicated stiffened panel, commonly used in ship structures, to a corresponding simple subsystem.

Measurements of vibration and sound pressure taken on a full scale mock-up of part of a ship's accommodation are presented. The results suggest that relatively simple calculations might be applied successfully to more extended structures which are of similar, relatively light, uniform scantlings.

B9. A Two-Wave Type Model for Estimating the Dynamical Response of Frame Structures

L A Walker
University of Leeds

Travelling waves of both flexural and dilatational type are allowed simultaneously in a model study of the response of plane and space framed structures to harmonic forcing. Some experimental confirmation of the theory is presented.

B11. Optimum Absorber Parameters for Minimising Vibration Response

G B Warburton
University of Nottingham

The author extends his recent work where he has shown that optimum parameters for absorbers attached to one degree-of-freedom systems, for which simple expressions exist, can be used to predict parameters for absorbers attached to more complex systems, provided that the natural frequencies of the latter are well separated. He derives optimum absorber parameters for equivalent one degree-of-freedom systems for harmonic and white noise random excitations with force and frame acceleration as input and minimisation of various response parameters. The effect of damping in the main system, which must exist in practice but is neglected in classical theory, on optimum absorber parameters is investigated also.

B12. Frictional Damping in Structures – Some Aspects of Measurement and Modelling

SWE Earles, Kings College, London
L J Wilkins, The City University

The work reported concerns a possible linear model of interface frictional damping in a vibrating structure.

Two experimental programmes are summarised:

(i) Measurement of the dynamic response of an octagonal ring force transducer and the use of that response to establish an acceptable mathematical model.

(ii) Measurement of the damping present in a composite structure which utilises two such transducers and incorporates two clamped interfaces. The logarithmic amplitude plots and polar diagrams of the mobility/impedance responses lead to an assessment of damping using a normal mode approach based on a complex stiffness model for interface slip damping.

B13. Measurement of Loss Factor in Floors

M F White and K H Liasjo
Electronics Research Laboratory
Trondheim

Loss factor was measured for some common types of industrial floor and in a newly constructed, unfurnished office building. A vertically applied excitation force was applied and damping was estimated either from resonance peaks in the mobility diagrams, or with the help of decay time measurements. Results were obtained in a frequency range from 5 to 1600 Hz and the loss factor lay typically in the region of 0.01 – 0.6 depending on floor construction and frequency.

B14. Measurements of the Longitudinal Wave Propagation Properties of Reinforced Flexible Hose

D K Longmore, C W Stammers and B Tuc

Resonances of fluid columns in hydraulic circuits can be excited by pressure fluctuations from pumps, and such resonances influence airborne noise emitted from pipework, panels and other surfaces. Calculation of dynamic pressures in circuits requires a knowledge of the relevant properties of pumps, lines and other components. The paper describes a convenient method of measuring the wave properties of a fluid filled hose using an axial resonance test. The properties so obtained are shown to give accurate predictions of pressures in circuits and so would allow optimum tuning.

B15. The Increase of Structural Damping by Controlled Slip in Joints

C F Beards
Imperial College of Science and Technology, London

The most significant source of inherent damping in a structure is that damping which occurs in the structural joints, and thus particular emphasis should be put on controlling and increasing joint damping.

Of the damping mechanisms which may occur in a joint, the slip mechanisms yield the greatest damping. Fretting corrosion occurring in a slipping joint can be reduced by joint interface preparations such as cyanide hardening or EDM machining.

It is shown that an optimum clamping force exists for maximum energy dissipation due to slip, and that the resonance frequencies of structures can be controlled to some extent by adjusting the clamping, and hence the slip in joints. The application of joint damping to beam-like structures, plates and frameworks is considered, and its effect on the vibration of these structures discussed. Good qualitative agreement between theory and experiment has been obtained by using a linearised analysis.

It is concluded that the inherent damping in most structures can be significantly increased by controlling joint clamping forces more carefully than is current practice.

B16. Vibration Response to Wind of Two In-Line Circular Cylinders for Various Wind Approach Angles and Speeds

D J Johns and R H Masters
Loughborough University of Technology

The results of experiments are presented giving the cross-wind response of a pair of identical cylinders at various spacings (2D to 10D) and flow approach angles (0, 10°, 20°). The reduced velocities were chosen in the range 11 to 28 so that vortex shedding effects in the range about 5 were not observed.

The maximum response of both cylinders occurred with a spacing of 3-5 diameters and at incidence angles between 10° and 20°. The response spectra obtained, particularly for the downstream cylinder, showed significant peaks corresponding to integer multiples of the natural frequency.

B17. Structural Dynamics of Wind Turbines

A J Pretlove
University of Reading

The scale of development activity in high technology electrical power generation using wind turbines is increasing rapidly in the UK. Until recently structural design was regarded as routine and containing few hidden difficulties. A number of structural failures, both here and abroad, have provoked a change in thinking. In the last year a programme of structures and materials research has started which contains several elements of interest to the structural dynamicist. This paper briefly reviews some of these problems and the work which is currently going on to resolve them.

B18. Sound Radiation from Walls and Windows

Y Shen and D J Oldham
University of Sheffield

A theoretical model is developed for predicting the directivity of building elements such as walls and windows. These elements are treated as homogenous plates of constant thickness and their vibrational response to a reverberant field is calculated for a number of different frequencies using the Galerkin method. The sound pressure level at a distant point is calculated by applying Rayleigh's formula. The predicted directivity is then checked by means of acoustic scale models.

B19. Sound Radiation Prediction by Models

R Pompoli
Bologna University, Italy

Abstract not available.

B20. New Means of Reducing Propeller Induced Cabin Noise

Mrs E H Waterman
Fokker BV, Schiphol, The Netherlands

The noise levels in current propeller driven aeroplanes are substantially above those experienced in aeroplanes powered by jet engines. In order to obtain an acceptable environment in Fokker F27 propeller driven aeroplanes a noise reduction of at least 6 dB(A) was required in the passenger cabin. A completely new interior was designed and thoroughly flight-tested. The basic concept consists of 2 parts, viz (a) flexibly mounted interior panels and (b) the application of vibration neutralisers on these panels.

The flexible mounting isolates the interior panels from most of the propeller-tip induced structural vibrations. That part of the vibrations still reaching the interior panels through the air-gap between panels and outer skin is reduced by the use of the vibration neutralisers.

The vibration neutralisers had to be tuned carefully at the propeller blade passing frequency and its most dominating harmonics. A total noise reduction of 7 dB(A) was achieved at the cruise condition.

Industrial Noise

C1. Measurement by Vendors: Ferragos, Fallacies and Facts

S G Tame and D A Richardson
Davy McKee (Oil & Chemicals) Ltd, London

In order to make any prediction of 'on plant' sound levels, it is necessary to obtain and use data on the individual items of machinery on the plant.

It is common practice to ask the supplier (Vendor) of equipment to provide the data necessary in the form of estimates of sound emission from each machine. Each selected Vendor is then obliged to offer his completed machine for inspection at his works in order to prove that his estimate was correct, or nearly correct.

This process of acquiring data is not foolproof at present. The Vendors generally do not appreciate what is required of them or why it is required. They are further confused by the current multiplicity of standards and guidance notes available on the subject of sound measurement. Vendor response to requests for data thus varies from the provision of data from similar equipment correctly measured to estimates based on standard formulae.

The Vendor's acoustic inspection area may be a correctly calibrated semi-reverberant chamber, or a corner of a noisy workshop. The running conditions of the equipment for this test may or may not bear any relationship to the conditions in service.

This paper gives case histories of tests at Vendors' works, shows the potentially confusing requirements for the testing of equipment, and shows what can be done with limited resources to produce a test chamber which might give reasonable results for a small investment. The object is to avoid the pitfall of doing nothing because it would cost too much to do the job properly.

C2. Acoustic Design of Large Process Plants

J B Erskine
ICI, Billingham

A large process plant poses noise problems from both environmental nuisance and hazard to hearing points of view, which requires that acoustic design is part of the whole engineering design process. Initially, one needs to define the internal (nuisance and hazard) and external (nuisance) requirements which depend on layout and location, together with existing noise levels at local housing areas. This is an inevitable part of the process of producing a proper noise specification.

In the second phase, one uses the process flow sheet to pin-point major potential problems which need early identification because they require work by and with equipment vendors to minimise design delays. As part of the process, one allocates sound power outputs initially to various major sections of the plant and then one breaks this down in turn to items of equipment. This process will be illustrated using a fictional flow sheet.

The solution of major potential problems will be discussed by considering in some depth:

a) Noise from cooling systems (both conventional water cooling towers and fan driven air cooling systems)
b) Control of noise from compression plant by use of acoustic hoods and buildings, as well as with considered layout.
c) Large controlled vent systems.

Finally, the paper will illustrate the results obtained by employing these principles for a recent large project and will discuss two unforeseen problems which were revealed and solved in commissioning.

C3. Noise Analysis of Impact Hammer — Full Size and Working Scaled Model Comparison

G J McNulty
Sheffield City Polytechnic
N Dean
W H Davis & Sons Ltd

This paper compares the initial results of some frequencies, mode shapes and noise radiation of full size and working scaled model forging hammers. Extensive vibration measurements were taken together with the noise radiation measurements using a specially constructed and calibrated directional tube. Certain advancements from the work already reported (1-3) are presented in that two different working scaled models are compared with two full size hammers: firstly a 10 cwt Ross type Steam Hammer and secondly a Davy Bros Arch type Forging Hammer. Both hammers have accelerated tups. It appears that in both cases consistency with high noise radiation locations is established despite the two machines having different geometrical configurations.

In order to establish the viability of scaling it is important that the geometry, frequency and accelerations are scaled and that the damping is the same. Work is in progress to establish all the above parameters and so far, for the results obtained, the scaling property is consistent for frequency.

References

1. G J McNulty and J Charman (1978). An Investigation into Steam Hammer Noise using Scaled Models and On Line Computer Facilities. Journal of Noise Control, Sept 1978 pp 285-291.
2. N Dean (1980). Noise and Vibration Analysis of a Machine Structure. I. Mech E. Graduates Evening, Presentation 3rd December.
3. G J McNulty et al (1978). Use of a Small Scaled Model to Predict Steam Hammer Noise. J S V 58 (4) 587-591.

C4. Research into Drop Hammer Noise

M E Westcott
ISVR, Southampton

Of all industrial noise sources, that of the drop hammer presents one of the most serious hazards, and the possibility of legislation regarding noise exposure limits has led to the need for a detailed investigation into the noise generation mechanisms of such machines.

An analysis of energy radiated using vibration measurements has shown that a large fraction (46%) of the total is radiated from the impact area, ie the dies and dieholders, but at frequencies too low to be accounted for by the natural flexural and longitudinal vibration of these components alone. This area must therefore receive priority in any noise reduction programme (in this case, reduction at source) and has been considered in some detail. Several mechanisms have been suggested to account for this and it seems that stress concentrations arising from the die location methods act as springs on which the dies and dieholders vibrate as solid masses. A one-third scale drop hammer has recently been built on which various methods of noise reduction can conveniently be assessed. On completion of this a modified model will be built incorporating these design changes with a view to the construction of a similar full size machine. Progress will be discussed.

C5. Noise Reduction During Rock Drilling

G Stimpson and E J Richards
ISVR, Southampton

The very high levels of noise which exist in mines throughout the world are currently an area of considerable concern and subject to much pending and increasingly enforced legislation. Some of the highest noise levels to which miners are continually exposed are those produced during percussive rock drilling used extensively for tunnelling and ore removal. Although hydraulics are starting to move into this field still the most commonly used tool is the pneumatic hammer drill. These are used either handheld on an air leg or mounted on the fixed frame or mobile boom. Pneumatic rock drills typically produce noise levels in excess of 115 dB(A) at 1m, the primary source being the exhaust air. Other major noise sources are radiation from the vibrating drill rod, $\sim$ 110 dB(A) at 1m, and mechanical impacts within the body of the drill $\simeq$ 95 – 105dB(A).

A review of silencing treatments for the drilling string is presented with emphasis on reducing noise radiation from the drill steel. The paper includes work carried out by the Institute aimed at reducing drill rod radiated noise to below 100 dB(A) at 1 m to meet proposed legislation for German mines.

C6. Resonance Spectroscopy — a New Method of Quality Control in Mass Production

E Roeder
Kletek GmbH, West Germany

Resonance Spectroscopy has been developed as a high speed non-destructive test method for the detection of faults in metal and ceramic components. Excitation of the component by a wide range swept frequency signal and measurement of the structure's response can produce immediate diagnosis of the presence of faults. The paper discusses specific applications on metal forgings both before and after assembly of the completed component into machinery.

C7. Digital Noise Correction as a Means of Reducing Inherent Noise Levels in Community Noise Analysis

H W Hardenbergh, Digital Acoustics Inc. Marshall Long, Marshall Long Acoustics, and David Marsh, General Acoustics Limited

The inherent noise level of instrumentation has long been a fundamental problem in the monitoring of countryside noise levels. Outdoor microphone systems of the best quality available today provide measurement capabilities down to 20-26 dB(A) but a recent technique enables a further downward extension of the order of 10 dB(A). The technique and background theory are presented.

C8. Noise Hazard Assessment — Do we have it Right?

R M Howie
Institute of Occupational Medicine
Edinburgh

Abstract not available.

C9. Noise Dosimetry — Advanced Concepts and Instrumentation

J Earshen
Metronics Incorporated, New York, USA

Micro-processor based new instruments now provide the capability to compute noise dose for a work shift extrapolated from a brief explanatory measurement. Additionally, the time profile and statistical distribution of incremental dose accumulation can be measured and stored over a work shift. This paper discusses the concepts and describes new instruments for implementing them.

C10. A Method to Predict Sound Pressure Levels Radiated by Machines at their Design Stage

R K Jeyapalan and N A Halliwell
ISVR, Southampton

To date there are essentially two methods available for predicting sound pressure levels around a machine having first obtained vibration information. One method involves the use of acoustic finite element techniques (ie solving the Helmholtz integral equation) whilst the other uses linear system theories to establish transfer functions between vibration data and sound pressure by experiment. The first method has always been found to be very difficult even in the case of simple sound sources and the second involves a great deal of computation and can only be used to evaluate the effect of changing the design of existing machines. In order to *predict* sound levels at the design stage we must have a simple *theoretical* means of converting vibrational data to sound pressure at a point. This paper shows how acoustic modelling can be used to approximate the transfer functions in the second method and thus avoid the need for long computation and experiment. Results obtained by the new method are compared with measured data from a full scale drop hammer. Sound pressure in the operator's position can be predicted to within ± 1 dB. The technique is applicable to any machine which could be recognised as a collection of separate identifiable sound sources.

C11. Measurement of the Sound Absorption Coefficient of a Factory Roof at Various Angles of Incidence

R J Orlowski
University of Cambridge

An impulse technique has been used to measure the sound absorption coefficient of a factory roof *in situ*. An impulsive signal was fed to a highly directional column loudspeaker which could be adjusted to provide various angles of incidence with the roof. The reflected pulse was received by an omnidirectional microphone and the signal was subsequently gated, squared and integrated to give a measure of the energy in the pulse. A separate experiment was performed to measure the energy in a pulse coming directly from the loudspeaker and the two values enabled the absorption coefficient to be evaluated.

The results of this experiment enable an accurate physical model to be constructed of the factory roof which, in turn, permits further work to be undertaken on the behaviour of sound fields in industrial spaces using scale model techniques.

C12. A Method of Predicting Sound Level as a Function of Distance from an Incoherent Rectangular Plane Source

Rupert Taylor
Consultant, Salisbury

Standard textbooks offer no satisfactory method of predicting the sound level at a distance from a large rectangular source such as the side of an industrial building. The inverse-square law is quite inappropriate in these cases and while it is well known that the source characteristics change from plane source to line source to point source depending on the distance relative to the length of each side, no satisfactory prediction formula is established.

The paper derives an expression for the sound level as a function of distance and angle from a rectangular incoherent sound source, which is an infinite series. It is shown that, for distances greater than the longest source dimension, all but the first term of the series may be ignored to give a simple expression for sound level relative to that in the near field of the source or to the sound power level.

C13. The Prediction of Noise Sources in Forging Machines

D C Hodgson and M M Sadek
University of Birmingham

There are four principal sources of noise in impact forming machines; billet expansion, tup deceleration, ringing of the structure and air ejection. The various mathematical techniques available for the prediction of these sources are described and the most appropriate techniques for any particular problem are indicated.

Theoretical predictions for real forging machines are made which are found to compare well with experimental.

C14. Sound Propagation in Factories

M Hodgson
University of Cambridge

To predict the sound field in a factory it is necessary to know how sound propagates from a source in the space. In this paper the factors influencing the propagation of sound in factories are discussed and the effects shown using theory as well as real and scale model-factory measured results. Image methods are used to show the effect of room dimensions and an angularly varying roof absorption coefficient. The theory of Jovicic, based on Kuttruff's work on sound propagation through regions with scattering objects, predicts sound propagation in flat factories with uniformly distributed scattering objects. This theory is presented and used to show the influence of scatterers. The theory can be extended to predict propagation in most 'uniform' factories - comparisons between theory and prediction are presented. Finally the paper discusses sound propagation and its prediction in 'real' non-uniform factories.

C15. Recent Laboratory Measurements on Thermal/Acoustic Lagging

B Berger, J M Rea, N E I Parsons and R A Iredale
CEGB

A lagging system consists essentially of an insulating material and an outer protective sheath. It is well known that such thermal lagging systems, used widely in industry for insulating pipes, machine casings and vessels, can reduce the high frequency noise radiation from these items. This has led to the use of lagging systems purely for acoustic purposes, with however disappointing results in many practical situations.

A laboratory study carried out by two of the authors in collaboration with Trevor Smith of the British Gas Corporation has shown that thermal/acoustic lagging is indeed intrinsically capable of a high insertion loss, but that its performance can be degraded by flanking paths, such as exposed flanges or by coupling the outer sheath to the pipe. Such coupling can usually not be avoided in practice since it provides the mechanical anchor and support for the lagging.

In the paper the authors present recent laboratory measurements on lagging systems, including data on systems in which an attempt has been made to reduce flanking due to vibration.

C16. Mammoth Acoustic Enclosures Contain 'Rolling Road' Noise at Leyland Vehicles Limited — Truck and Bus Works Preston

D F Percy
IAC Ltd, Staines

When Leyland Vehicles Ltd, Division of British Leyland, decided to incorporate vehicle test dynamometers in their new Truck and Bus Assembly Plant at Preston they were very concerned at the anticipated 105 dB(A) noise level that this type of plant would produce. Hoffmann Prueftechnik, who provided the roller test dynamometers, commissioned the services of Industrial Acoustics Company to undertake the provision of the sophisticated noise control measures and other associated equipment required on this project on a 'turn-key' basis.

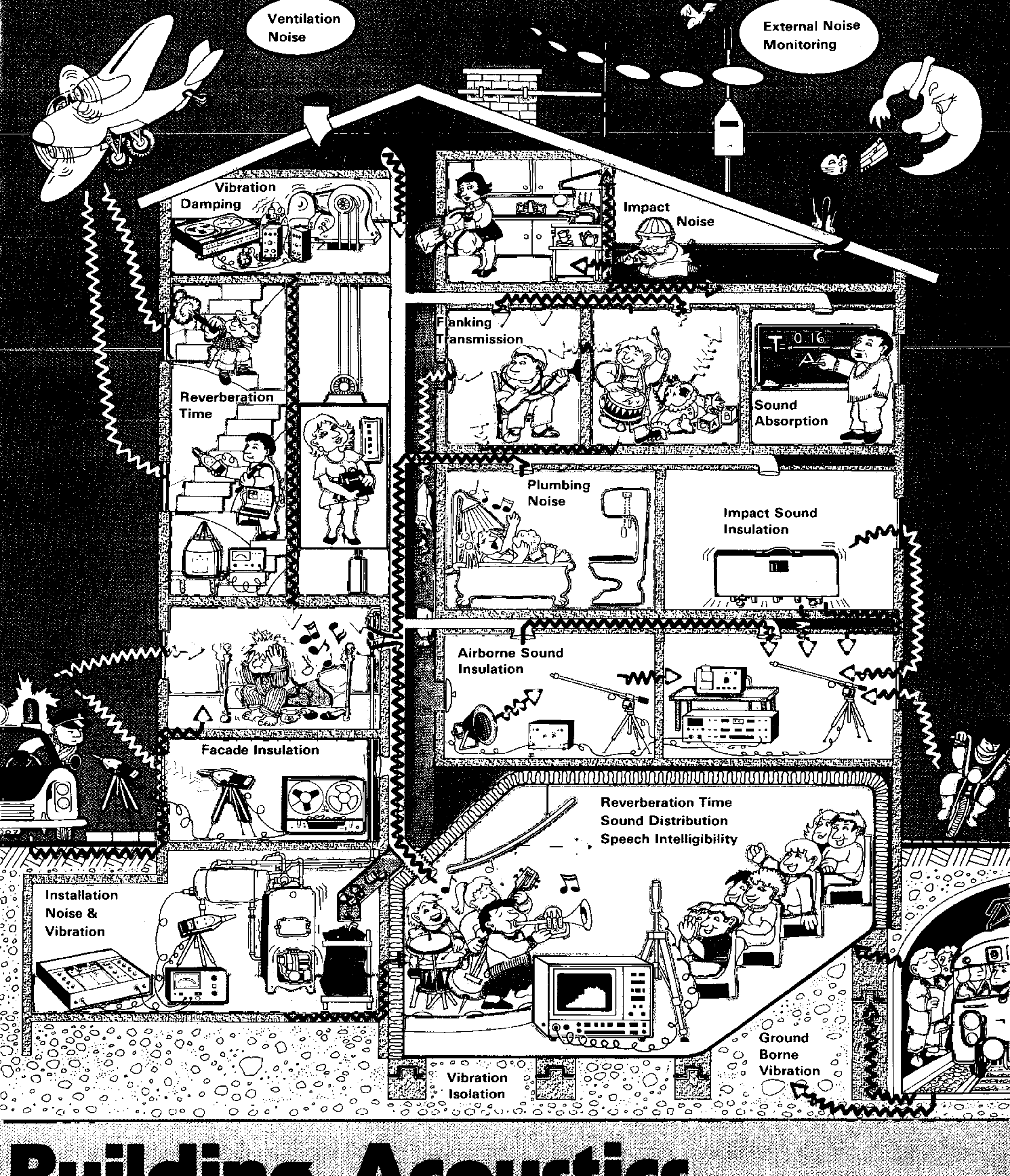
The basic noise control equipment consists of three giant sized acoustic enclosures grouped together and one separate enclosure, each capable of reducing the external level created by the test methods to 75 dB(A). Each enclosed area is approximately 8.5 metres wide x 17 metres long and 5.5 metres high, big enough to allow a bus to be driven in onto the roller test set-up.

The enclosures were designed using the IAC Moduline Noishield system. Apart from containing the noise it was essential that the noise build-up inside the enclosures by reverberation was kept to a minimum. Each enclosure has a silenced ventilation system capable of providing 40, 80 or 120 air changes per hour. The IAC supply also included electrically operated roller shutter doors, acoustic personnel access doors, fire protection, cranes, stainless steel hoses for exhaust extract etc.

C17. Attenuation of High Amplitude Acoustic Waves in Perforated Structures

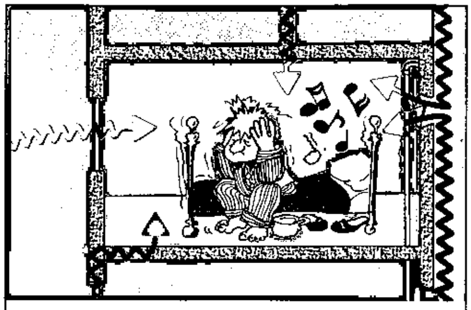
Alan Cummings
University of Missouri — Rolla, Missouri, USA

It has been known for some time that perforated structures exhibit nonlinear acoustic

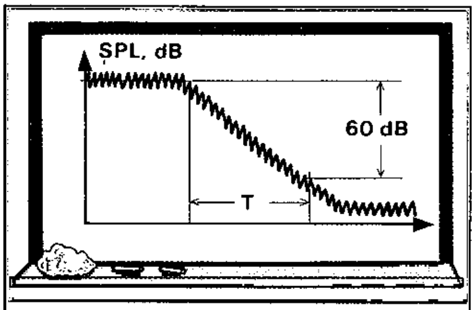


Building Acoustics Measurements

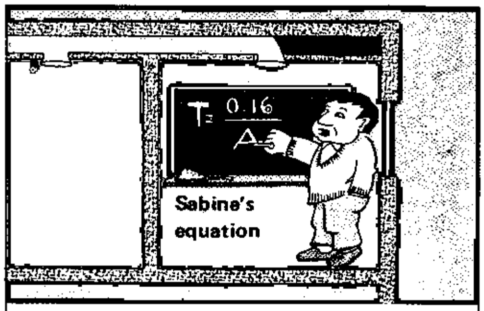
Brüel & Kjær



In our crowded cities a reasonable level of acoustic comfort is a necessity to prevent noise from intruding on our private lives and disrupting our leisure. Many countries have introduced law-enforceable specifications for the acoustic comfort in houses, schools and places of work. Acoustic comfort depends on such quantities as airborne and impact insulation, reverberation time, vibration isolation and a host of others. To determine whether a building complies or can be made to comply with the regulations, these quantities must be measured.

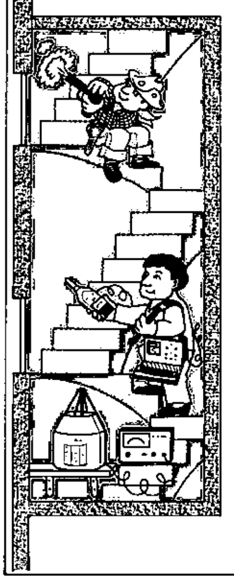


One of the most important quantities in building acoustics is the reverberation time, RT. This is the time required for a known sound pressure level to decrease by 60 dB from the moment the sound source ceases. This "lingering on" of sound is particularly pronounced in, for example, stair wells, churches and lightly furnished rooms. Too long an RT renders speech less intelligible and music cacophonic, and produces higher background noise levels. Too short an RT muffles speech, makes music sound "thin" and staccato and deadens background noise.

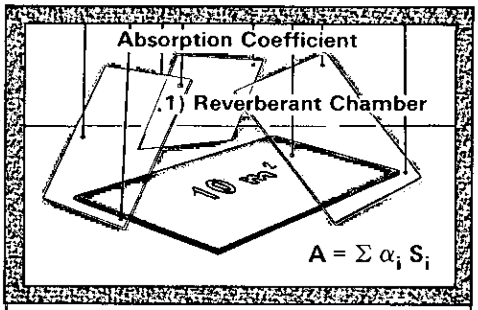


RT is frequency dependent and therefore for a particular room the RT should be stated in each octave or third octave band over a frequency range not narrower than 125 Hz to 4000 Hz. The RT is related to the volume, V, of the room and the total acoustic absorption present, A. The best-known relationship between these quantities is Sabine's equation. Altering A or V or both enables the RT to be tailored to suit the particular function of the room. The RT can be prolonged by electroacoustical means; a method often used in large multipurpose halls.

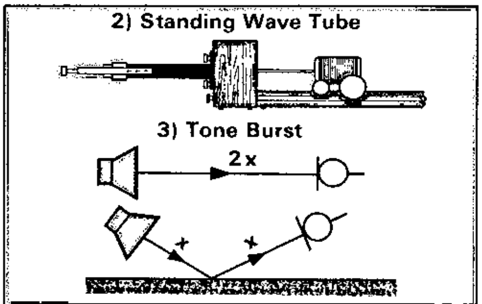
Reverberation Time



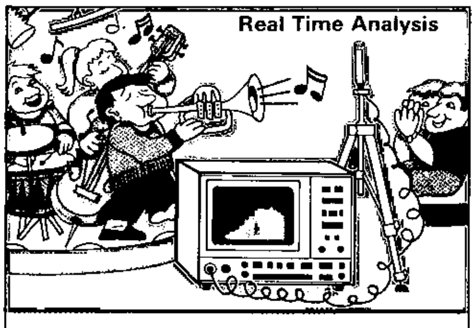
Here are 2 portable systems for measuring RT. A pistol shot as a sound source is adequate for a rapid survey but has two serious drawbacks: an insufficient frequency content and irreproducibility. It is better to use a source yielding bands of random noise. For both methods the decay of the sound pressure level is monitored by a sound level meter with a built-in octave filter-set and the decay curve(s) for each octave band is traced out by a level recorder.



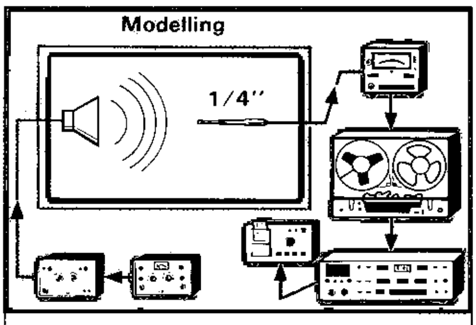
The total acoustic absorption, A, is the sum of the products of the various surfaces, S_i, within the room and their respective absorption coefficients, α_i. The coefficient α for a surface is the ratio of the absorbed to the incident sound energy on that surface. A perfect absorber has an α of 1 and a perfect reflector an α of 0. Tables listing α at various frequencies for commonly used building materials can be used together with Sabine's equation to obtain a crude estimate for the RT of a room. However if α needs to be known then it is best to measure it.



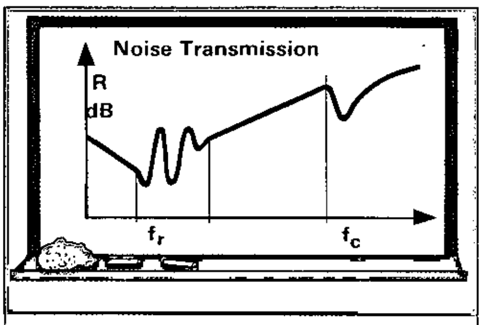
Values of α depend on the measurement method and the angle of incidence of the sound. The usual methods are:
1) *Reverberant Chamber (diffuse sound field assumed. α found from the change in RT after the introduction of the sample. For large samples.)*
2) *Standing Wave Tube (normal incidence; small samples)*
3) *Tone Burst (various angles of incidence; simulated free field; large plane samples)*



A correct RT is not necessarily synonymous with good acoustics. In a hall for example one must have good speech intelligibility and an even sound distribution i. e. no "dead spots". Sound distribution in a hall is best investigated using a real time analyser, which displays on a screen a bar graph of level vs. frequency. Sound distribution can be improved by correctly positioned diffusers or by an electroacoustic reinforcement system. The use of tone burst and gating techniques enables undesirable phenomena (e.g. echoes, flutter effect) to be detected and remedied.

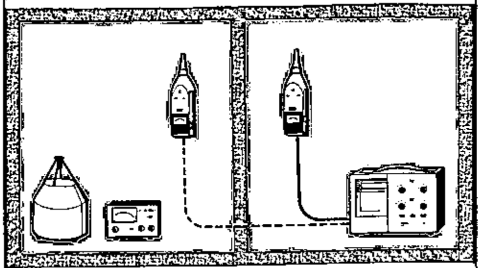


It will often pay to experiment on scale models. In the model the frequencies used will have to be higher than at full scale. A tape recorder is used to produce the required frequency transformation, after which usual analysis techniques can be used. Materials used in the model must be chosen with care as their acoustic properties must also be scaled down. At high frequencies the size of the microphone is comparable to the wavelength being used. A small microphone is essential so that the sound field within the model is disturbed as little as possible.



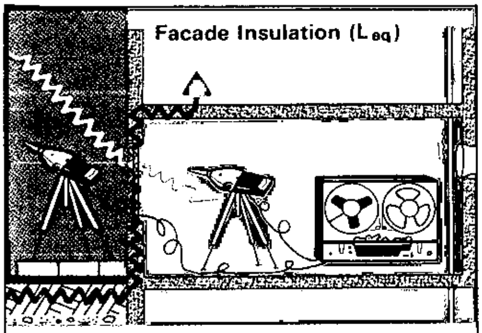
Sound does not remain in the room where it is produced but propagates throughout the building and intrudes into other rooms as unwanted noise. The amount of sound energy transmitted through a solid wall depends primarily on the wall's superficial weight and the frequency content of the sound. Theoretically, the Mass Law predicts that a doubling of either the frequency or the superficial mass of a wall will yield a 6 dB better sound insulation. However, resonance and coincidence effects produce large deviations from the predicted values.

Airborne Sound Insulation



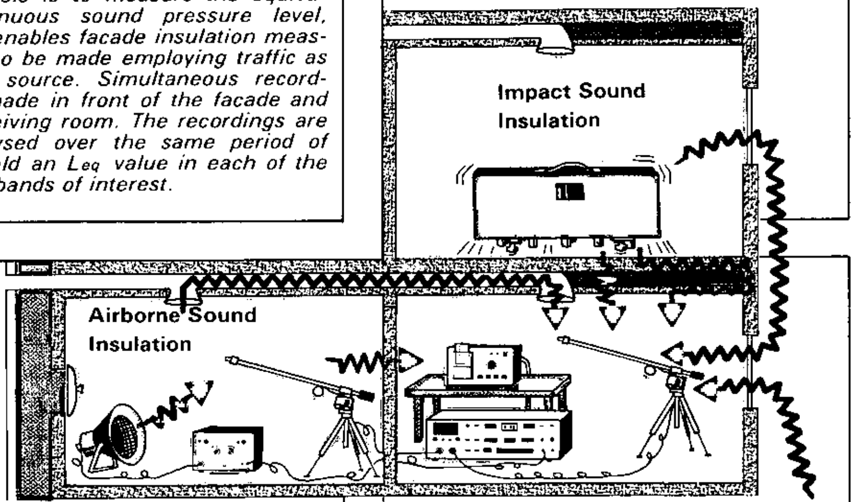
The sound insulation afforded by a wall is measured by placing a sound source on one side of the wall and measuring the sound pressure levels produced in the source and the receiving room over a range of frequencies. Many indices for expressing sound insulation have been defined in various international standards. Most indices differ from the measured level differences by a correction obtained from the RT or the absorption of the receiving room.

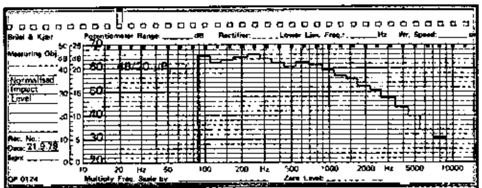
Facade Insulation (L_{eq})



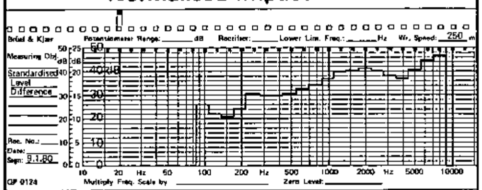
Environmental noise fluctuates greatly in level. The best way to average rapidly fluctuating levels is to measure the equivalent continuous sound pressure level, L_{eq}. This enables facade insulation measurements to be made employing traffic as the noise source. Simultaneous recordings are made in front of the facade and in the receiving room. The recordings are then analysed over the same period of time to yield an L_{eq} value in each of the frequency bands of interest.

Footsteps and the moving of furniture are examples of energy being directly transmitted to the building's structure. This energy is readily transmitted though the structure and especially through homogeneous walls with low loss factors. To measure the impact noise insulation a standard tapping machine is used to excite the structure while the sound pressure levels are measured in the receiving room. Impact noise can be considerably reduced by installing a floating floor, i.e. a floor separated from the main structure of the building by a resilient layer.

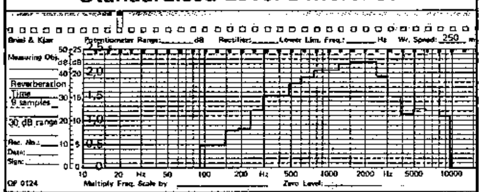




Normalised Impact Level



Standardised Level Difference



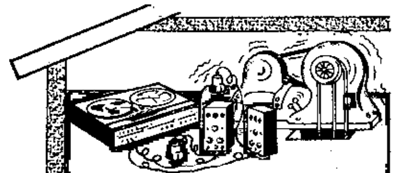
Reverberation Time

During a measurement, one must ensure an adequate spatial average of the SPL in the room. The main methods are:
1) a single microphone moved from place to place
2) an array of microphones
3) a rotating microphone boom.
Measurements can be automated by employing the Building Acoustics Analyzer. This instrument generates third octave band random noise in the range 100 Hz to 8 kHz and measures and memorises the source room level, the receiving room level, the impact level and the RT.

From these results and the preset values of the room's volume and the area of the dividing wall (or, if required, the total area of the surfaces of receiving room) the Building Acoustics Analyzer will calculate any or all of 7 commonly used indices, namely:
Standardised Level Difference
Normalised Level Difference
Airborne Sound Insulation Index, I_a
Standardised Impact Level
Normalised Impact Level
Impact Sound Index, I_i
Sound Power Level

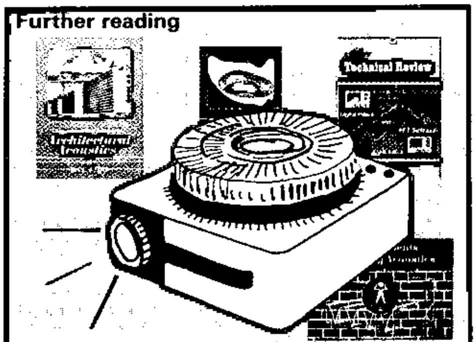
There can be an enormous difference between the laboratory and the in situ measured values for sound insulation. In a laboratory transmission suite the source and the receiving rooms are structurally independent so that energy transfer between rooms can only occur through the building element under test. In practice, flanking transmission occurs via the flanking walls, the plumbing and the ventilation system and through gaps around doors and windows giving rise to a disappointingly low sound insulation.

Installation Noise & Vibration
Shock Measurements
Vibration Damping



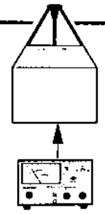
Installations such as lifts, washing machines and ventilation systems produce both noise and vibration. Vibration measurements must therefore complement the noise measurements. Sources of vibration can be traced using accelerometers attached to the structure. The accelerometer signal is amplified and displayed by a vibration meter or a sound level meter fitted with a suitable adaptor. Vibration isolation can be investigated by recording the vibration levels of both the machine's mounting and the building's structure on a tape recorder for later analysis.

Further reading



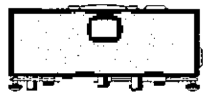
Brüel & Kjær can offer a wide range of literature dealing with building acoustics and related subjects. Books, application notes, slide shows and complete courses are available. A selection of Brüel & Kjær's instruments for building acoustics measurements is illustrated and briefly described on the rear page. The full range of B & K instruments is covered in our Short Form Catalogue. If you have a specific problem please do not hesitate to contact your local B & K representative.

SOUND SOURCES

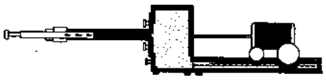


Reference Sound Sources for Rev. Time and Sound Insulation meas.
4205: Battery op. 7 octave bands + Wide band noise.

4204: Mains op. Wide band noise.

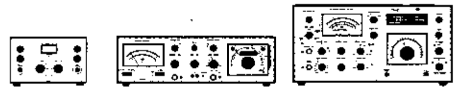


3204: Tapping Machine for Impact Sound measurements to ISO 140.



4002: Standing Wave Apparatus for Absorption Coef. meas. of small samples.

GENERATORS & FILTERS

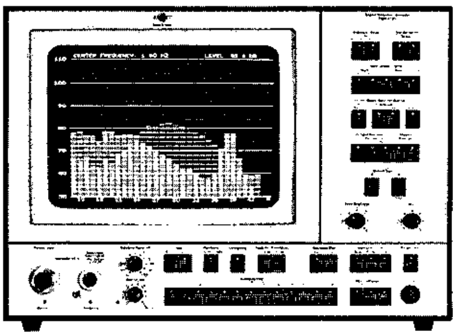


GENERATOR	1405	1023	1027
Output Signal	White & Pink Noise	Sine + Modulation (warble tone)	Sine Narrow band random White & Pink Noise
Freq. range	20 Hz — 50 kHz	10 Hz — 20 kHz	2 Hz — 200 kHz

1617/18: Band Pass Filters. Oct. & 1/3 oct. bands. Auto. Filter Shift.

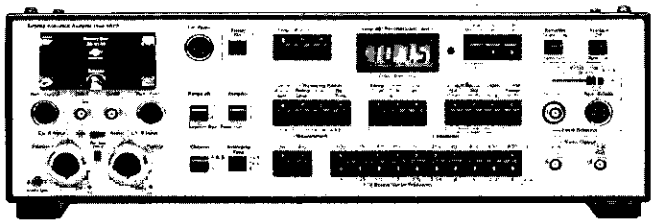
1613/16: Oct. Filter Set & 1/3 Oct. Filter Set for Sound Level Meters.

REAL TIME FREQUENCY ANALYZER



2131: Digital Frequency Analyzer for real time display of Oct. and 1/3 Oct. spectra of sound and vibration signals. For acoustical investigations in auditoria and studios (Rev. Time, Sound Distribution and Absorption). Sound and Vibration Insulation measurements in buildings. Combined with a desk calculator, three-dimensional plots. Memory for spectra comparison.

BUILDING ACOUSTICS ANALYZER

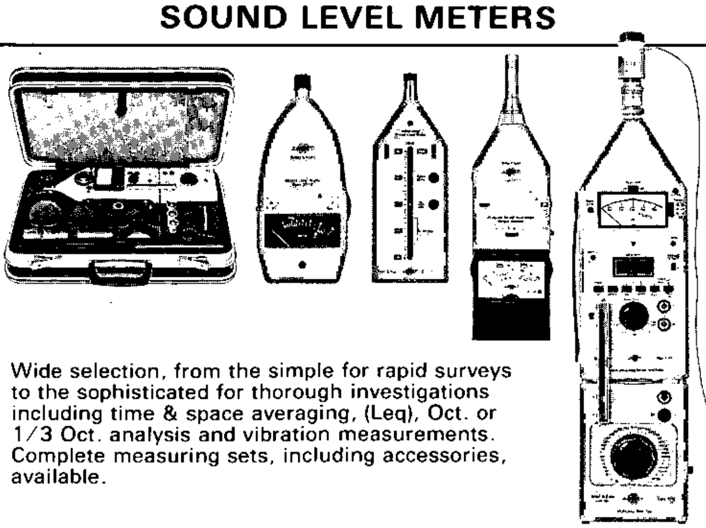


4417: Portable Building Acoustics Analyzer for Lab. and in situ measurements in 1/3 Oct. bands.

- Reverberation Time (ISO R 354 — ISO 3382)
- Airborne & Impact Sound Insulation (ISO 140)
- Airborne & Impact Sound Index (ISO R 717)
- Sound Power Measurements (ISO 3741/2)

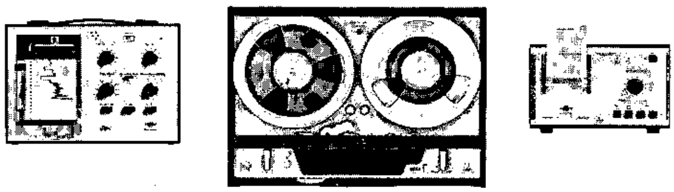
With Rotating Microphone Boom 3923 full automatic measurement sequence including background level correction and Time & Space Averaging.

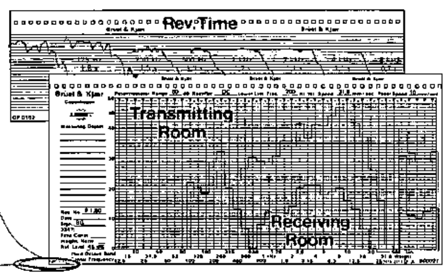
SOUND LEVEL METERS



Wide selection, from the simple for rapid surveys to the sophisticated for thorough investigations including time & space averaging, (Leq), Oct. or 1/3 Oct. analysis and vibration measurements. Complete measuring sets, including accessories, available.

RECORDERS





Level Recorders for plotting Rev. decays and frequency spectra. **Tape Recorders** for in situ recording of signals. **Digital Recorders** for print-out or storage of measured or calculated values.

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behaviour at high amplitudes, because of the conversion of acoustic energy into vortical energy. Power flow considerations have not previously been of interest in this context, but recent work on acoustic attenuation in shear layers has focussed attention upon this aspect of the problem. This paper presents experimental and theoretical data on the attenuation of high amplitude acoustic waves interacting with perforated structures in the absence of mean airflow. From these data, conclusions are drawn, concerning the practical usefulness of perforated materials in Noise Control applications.

C18. A Practical Approach to the Noise Suppression of High Pressure Vents

J F Brant
Burgess Industrial Silencing Ltd, South Shields

It is often necessary to release large volumes of air, steam or other compressible fluids from storage at high pressure to atmosphere.

The Petro-Chemical and Power Generation industries offer many examples of this 'venting' operation. Almost invariably such installations require some noise control measures to be taken to make them environmentally acceptable.

In order to determine the optimum treatment required for specific installations, it is necessary to know volume flow rate of the fluid, the intensity levels and frequency distribution of the noise generated and the associated radiation patterns of the various noise sources.

Methods of determining these factors and the effects of valve sizes and other parameters are discussed.

Some of the problems in selecting and specifying acceptable criteria are touched upon and types of commercially available noise control equipment are illustrated.

C19. A Portable Silencer for Temporary Venting Operations

T Smith
British Gas Corporation, Newcastle upon Tyne

Many routine maintenance operations involve work on small pressure vessels (up to 10 m^3); prior to being worked on these vessels must first be vented down and purged with an inert gas.

Where high pressures (up to 69 bar) are involved the venting operation can produce very high noise levels and result in complaints of noise nuisance in noise sensitive locations.

Noise control is therefore necessary at these sites; this can be achieved by careful control of the venting operation but this introduces other complications; the use of permanent silencers is not feasible due to the numbers required.

A portable silencer appears then to be the most practical solution; this paper describes the development of such a device.

By controlling the flow through the silencer it has been possible to keep the size relatively small (and hence portable). The diffuser is sized to be the controlling element in the system; by keeping a constant pressure of 5.1 bar at the diffuser a constant flow of 4400 m^3/h is obtained. A simple lined section after the diffuser then absorbs the noise produced by that source. An extension stack finally exhausts the gas to atmosphere, ensuring good gas dispersion without regenerative noise. Silencers to this design are now in regular use. A 10 m^3 vessel at 69 bar can be vented down to atmosphere in 10 minutes using this device; noise levels are about 80 dB(A) at 20 m, which is some 20 dB(A) below unsilenced vents doing comparable duty.

Speech and Hearing

D1. Speech for Hearing and Hearing for Speech

M Haggard
MRC Institute of Hearing Research, Nottingham

Abstract not available.

D2. Combining Frequency and Duration Information in Vowel Recognition

W A Ainsworth
University of Keele

Experiments have been performed with short vowels (50 msec duration) and long vowels (500 msec duration) in order to investigate the effects of duration on vowel recognition. Various models are proposed to account for the observed confusions. These models employ linear and euclidean distance measures. All of the models perform similarly, and each suggests that differences in duration of about 250 msec have about the same effect on vowel recognition as differences in formant frequency of about 100 Hz or one Bark.

D3. A Descriptive Approach to Computer Speech Understanding

P D Green and P J Grace
North Staffordshire Polytechnic

We hope to show that computer speech understanding can be viewed as the interpretation of a rich, symbolic description of an utterance, in contrast to the schemes employed by the ARPA projects (1), where interpretation followed some form of segmentation and labelling process.

A hierarchical description is derived from a parametric representation of the utterance (LPC, FFT and other information). Some elements of this data structure approximate the behaviour of individual parameters over short time intervals by straight lines (continuities), while other elements make the temporal relationships between these continuities explicit. This descriptive approach follows the work of Marr (2) with the 'primal sketch' in computer vision.

The process of understanding the utterances is that of matching patterns within the symbolic description with 'frames' (3). A frame is an elaborate data structure, compatible with the symbolic description, which when instantiated attempts to find a suitable match for each of its components. Frames may be constructed to correspond to some element of speech (eg a phoneme), and the interpretation of the utterance is the process of successfully matching a contiguous sequence of frames.

We hope to some extent to allow for natural speech effects such as coarticulation by making the instantiation of a frame dependent on neighbouring frame 'matches'.

References

(1) D H Klatt: Review of the ARPA Speech Understanding Project; JASA 62,6 (1977).

(2) D Marr: Early Processing of Visual Information: AI—M—340, The AI Lab, MIT (1975).

(3) M. Minsky: A Framework for Representing Knowledge: in P H Winston (ed) — Psychology of Computer Vision: McGraw Hill (1975).

D4. MYRTILLE II: A Unified Approach to Pseudo-natural Language Understanding

J-P Haton
Université de Nancy, France

MYRTILLE II is a system which is presently realised by our research group in order to understand a wide subset of spoken French. The syntax accepted is the one of basic French with some restrictions (eg pronominal references are not accepted). The application is concerned with meteorological inquiry and the vocabulary is about 400 words. This system was designed in an unified way at the various processing levels, with several key ideas:

- to design an experimental system in order to test several algorithms and strategies;
- to find the optimal data-structures adapted to the representation and use of the various knowledge sources;
- to adapt Artificial Intelligence techniques to the problem of speech understanding.

In this paper, we present the architecture of MYRTILLE II and we discuss the choices which were made at both levels of recognition and interpretation of a sentence. We also present several recognition examples which have already been obtained in the preliminary implementation of the system.

D5. Dynamic Programming Algorithm Variations in Automatic Speech Recognition

R K Moore
Royal Signals and Radar Establishment Malvern

Non-linear time warp pattern matching by dynamic programming has established itself as one of the most useful tools available for constructing an automatic speech recogniser. Using such techniques, present day recognisers achieve significantly better performance than their predecessors. This paper describes three basic dynamic programming algorithm variations; in the first, the cost of time compression/expansion is simply set to a constant value; in the second (the most commonly used algorithm), this cost is made a function of the relationship between the items being matched; and in the third, it is related to the rate at which the speech spectrum shape changes in time. The results of recognition experiments show that the first and third algorithmic variations substantially out-perform the second. In addition, two efficiency modifications are described. The first is shown to be capable of speeding up the matching process by a factor of 1.6 for all three algorithms, without loss of recognition accuracy. The second modification, based on a beam search technique, is shown to provide no speed up at all for the first algorithm but provides a speed up factor of 4 for the second. These experiments demonstrate that further improvements in recogniser performance may be obtained by optimising dynamic programming algorithms for speech data.

D6. Acoustical Transmission Losses in Telephone Connections

D L Richards and R W Whorwood
Aston University

To perform any calculation intended to predict such measures as 'intelligibility', it is necessary to know the transmission losses of certain paths terminating at acoustical interfaces (like mouths and ears). Unfortunately, it proves very difficult to determine the objective transmission losses required for such calculations when they are to be applied to practical telephone connections. Not only are the acoustical quantities concerned (sound pressure levels) rather troublesome to measure but what is to be measured is also difficult to define.

The paper is concerned with the use of a model implemented on a computer to represent the complex of acoustical (and other) paths concerned and used to analyse the results of certain series of experiments employing subjects. Results are available from two sets of experiments, one by Bell Laboratories and the other by the Hungarian Telephone Administration, and they are concerned with judgements of the relative interfering effects of circuit noise and room noise. The required information is obtained by varying certain parameters of the model to obtain agreement with certain results from the experiments.

It is concluded that subjects change the looseness of coupling between earphone and ear, and in consequence vary the amount of room noise reaching the ear, in a certain functional relationship to the ratio of speech to noise that they are experiencing. The experiments, and therefore the conclusions, cover a wide range of listening levels and room noise levels and certain variations in sidetone.

D7. Speech Dereverberation: Performance of Signal Processing Algorithms and their Effects on Intelligibility

P J Bloom
Polytechnic of Central London

Results of a previous evaluation of a two-input, signal processing dereverberation technique indicated that, *on average*, the intelligibility of isolated reverberated words was not significantly altered by processing, even though a decrease in measured and perceived reverberation time was observed. In this paper, we offer explanations for these earlier findings based on a detailed analysis of the following critical factors:

1. The effect of the room impulse response on the macrostructure of the speech waveform;
2. The problems associated with using the frequency-dependent interaural coherence estimate directly as a speech-filter gain modulator;
3. The influence of the expected direct-to-reflected energy ratio on the maximum expected interaural coherence; and
4. The effect that the 'noise' suppression (which takes place during processing) has on the perceptually important acoustic features of the speech waveform.

In consideration of the above factors, we have made experimental modifications to the original processing algorithm which are expected to improve its performance. Results will be presented which illustrate the effect of this modified process on relevant test signals and on word identification, and comparisons will be made with the original process. Lastly, it will be shown how many of the observations and operations associated with dereveberation processing are directly applicable to the more general problem of intelligibility enhancement in noisy environments.

D8. Video Speech Synthesis: A Flexible, Integrated System for Analysing and Synthesising Speech Production in the Visual Domain

N M Brooke
University of Lancaster

A modular, file-oriented system is being implemented to supersede an earlier graphics program which represented schematically the dynamic behaviour of the essential topography of the human face during short speech utterances. Facial features, shapes and modes of animation are specified as files of user-supplied descriptions, aiding the rapid production of a wide variety of facial schemata with the minimum of recomputation. The articulatory trajectory data which drive the animated display are obtained from high-resolution videotape recordings of a two-aspect view of speakers enunciating VCV utterances. Single frames from the videotape are replayed using a 'video-cursor' device linked to a microprocessor and the point co-ordinate data obtained are processed to eliminate projective errors and global head movements, producing a file of purely articulatory trajectories for user-selected features. The creation of the dynamic display as a quasi-cinematographic sequence of images proceeds via i) geometrical descriptions of the individual picture elements and ii) the generation of corresponding sets of vectors. Graphics device dependency arises only at the final, display phase. The visual display may be synchronised with an independently synthesised acoustic signal to generate bi-modal stimuli for use in analytical investigations of speech perception.

D9. Details of Formant Transitions in the Time Domain

G G R Green, University of Newcastle
R M C Gregson, University of Oxford

If the shape of the vocal tract changes during the production of a voiced sound, the attenuation and phase lags experienced by the components of the source waveform will also alter. These changes should be seen as amplitude and phase modulations of the harmonics of the voice and their characteristics will depend upon the rate and direction of the formant transition and on formant Q.
These modulations of the harmonics of voiced sounds are readily observed in speech as the large asymetrical spread of power around the harmonics in the frequency spectra of sounds containing rapid formant transitions.

Using simple statistical procedures it is possible to extract from the speech waveform the variation of amplitude and phase, with time, of each harmonic and this information can be used to provide estimates of how the formant Q's and formant frequencies have changed. These estimates agree well with other published results.

Two—alternative, forced choice presentation of computer generated stimuli showed that these formant transition derived phase and amplitude modulations are easily detected and are both well above threshold in normal speech.

The significance of these modulations and their use in the calculation of formant transitions will be discussed.

D10. Periodic Pitch Detection

W Millar and R Linggard
Queens University, Belfast

This paper describes a method of extracting the pitch frequency from a short-time frequency analysis of speech. The method used is the calculation of a harmonic histogram over an appropriate range of pitch values. In effect this is the summation of the amplitudes of each possible value of pitch and the amplitudes of the corresponding harmonics present in the short-time spectrum. In this way a maximum value is found in the histogram at the frequency corresponding to the pitch frequency.

The short-time frequency analysis is obtained from a digital filter bank. The design of the frequency scale of the filter bank in order to optimise the number of channels required, is presented. The effect of other parameters of the filter bank, ie the weighting of the filter outputs and the resolution of individual channels, is also discussed. It is then shown how this filter bank can be used to obtain estimates of pitch both in 'long' spectra (which contain the fundamental) and in 'short' spectra (corresponding to the telephone bandwidth). However, it is shown that in some cases the formant structure present in the frequency spectrum can distort the corresponding harmonic histogram and produce erroneous estimates of pitch. A method of removing the formant structure from the spectrum to produce an enhanced spectrum is given. This method is then used to produce pitch contours through segments of speech. Finally the performance of the pitch extraction system on an amplitude modulated test tone is discussed.

D11. Analytic Modelling of Speech Spectra

F Owens and R Linggard
Queens University, Belfast

This paper describes a speech resynthesis technique, in which the transfer function of a pole/zero model of the speech-production apparatus may be derived analytically from the smoothed short-time amplitude spectrum. The order of the pole/zero function is defined by twice the number of spectral maxima, and the fitting criteria are specified on a perceptual basis, rather than on the conventional least-squared error method. The technique provides exact matching at the spectral maxima and minima, and adequate matching at all other points.

The vocal tract frequency response is approximated by cepstrally-smoothing the output of a narrow-band digital filter bank, with the output of each channel being averaged over a period of 10 ms.
The time-varying nature of the vocal tract response is calculated by deriving a sequence of pole/zero locations every 10 ms. It is shown how the z-plane trajectories of these pole/zero sequences may be smoothed to render them suitable for speech resynthesis. For the real-time resynthesis of segments of speech a programmable, digital speech synthesiser is used and a comparison is made between serial and parallel digital filter realisations of the model.

D 12. Acoustic Measures in Voice Disorder

G G R Green, University of Newcastle
R M C Gregson, University of Oxford
E McGuirk, University Hospital, Nottingham

A measure of the spectral 'noise', the power at frequencies other than that of harmonics, in the voices of 68 dysphonic patients was shown to be significantly correlated with the perceived quality of the voice as measured by the mean score of 11 judges. Frequencies less than 1 kHz appeared to be the most important for this correlation, this range being the first formant region of the vowel used (/i:/). Significant correlations were also obtained when only the first two harmonics were included in the calculation of spectral noise.

Many other measures were investigated but no significant correlations with sound quality could be obtained.

Close examination of the spectra of these voices demonstrated that, in some cases, the spectral 'noise' was due to rapid modulations of the voice. When studied in terms of modulation rate it was found that rates between 1/8 and 3/8 of the fundamental frequency gave the strongest correlations with subjective quality.

It is suggested that in many, though not necessarily all, cases of 'roughness' of the voice there is rapid modulation of the voice source. The production and form of these modulations will be discussed.

D13. Incremental Model of the Basilar Membrane

R Linggard and P McCullagh
Queens University, Belfast

A software model which simulates the response of the basilar membrane to stimulation of the stapes has been derived. The model is based on the one dimensional longwave transmission line introduced by Person (1) and subsequently developed by Schroeder (2) and Hall (3). The basilar membrane is divided into a number of sections each of which is represented by a series connection of resistor, capacitor and inductor.

The values of the components, which are related to the mechanical properties of the cochlea, vary from section to section simulating the resonant properties of the membrane.

A typical section is analysed and expressions are obtained for node voltage (representing pressure difference across membrane) and capacitor voltage (proportional to displacement) in terms of nodal voltages of neighbouring sections. These are transformed into the z-domain using the backward difference approximation and an extra delay is incorporated to simulate the propagation time of the pressure wave from base to apex. An iterative procedure is used to obtain the response for the complete line for as many time increments as necessary.

Thus responses of membrane displacement or pressure, against section (ie along the membrane) or time can be obtained for a given input. The impulse response has been obtained and this clearly shows the frequency selectivity expected.

More complex inputs are being tested and it is hoped to explain psycho-acoustic phenomena such as two tone suppression and masking effects by altering model parameters subject to physiological criteria.

References

1. L C Person and B P Bogert, **A Dynamical Theory of the Cochlea** JASA Vol 22 (3) pp 369 – 381.
2. M R Schroeder, **An integrable model of the basilar membrane** JASA Vol 53 (2) pp 429 – 434.
3. J L Hall, **Spatial Differentiation as an auditory second filter: Assessment on a non-linear model of the basilar membrane.** JASA Vol 61 (2), pp 520 – 524.

D14. Articulation Testing of a Simulated Speech Coder — a 16 kbit/s Sub-band Coder

L S Moye
Standard Telecommunication Laboratories, Harlow

A 16 kbit/s sub-band coder has been developed as a potential replacement for existing 16 kbit/s CVSD systems in order to provide a system that will work satisfactorily in tandem with the channel vocoder. To evaluate the system and the tandem connections it was decided to use an articulation test with nonsense logatoms rather than the more common diagnostic rhyme test as this would provide a more sensitive test of a system of this quality and better diagnostic results.

In order to evaluate the system before building hardware, it has been necessary to do the articulation tests with a computer simulated system running in 340 times real-time. This poses some difficult problems in processing the required amount of speech material and has required that the logatoms be uttered in lists of 15 rather than each within its own carrier phrase.

The results of the articulation tests will be presented and the performance of the system will be discussed and demonstrated. Some of the problems encountered in the articulation tests and the way they have been solved will be explained.

Musical Acoustics

E1. Normal Modes of Church Bells

T Charnley and R Perrin
Loughborough University
J de Pont
Auckland

Frequencies and nodal patterns of a good quality modern English church bell have been measured as accurately as possible for the first hundred or so partials and the results compared with finite element calculations. This has enabled us to propose a much improved scheme for mode classification as well as shedding light on the mechanisms responsible for the production of the various partials. Some insight has been gained into the design of the bell.

E2. Analysis of Trombone Bell Vibrations

P Watkinson
ISVR, Southampton

Using Finite Element techniques, the effect of various properties of trombone bells on the natural modes of vibration may be investigated. Wall thickness, material properties, geometric shape, stay position and rim size are the parameters analysed. The set of 16 mode shapes extracted are typical for all cases, but the frequencies of these modes vary widely for different bells.

Generalised vibration methods are used to calculate the level of excitation of these modes under acoustic excitation. Some of these calculations may be compared with the experimental data of Kitchin (Study of Trombone Bell Vibrations using a Laser Doppler Velocimeter, Final Year Dissertation, University of Southampton, 1980), which show general agreement but discrepancies in detail.

E3. Material Vibration and its Influence on the Performance of Wind Instruments

R Smith
Boosey & Hawkes Ltd, Edgware, Middlesex

Abstract not available.

E4. Resonance Studies of the Guitar

B E Richardson and C A Taylor
University College, Cardiff

A series of measurements have been made on the top and back plates of a completed guitar, and on another guitar during various stages of construction. The principal techniques used were frequency response measurement and holographic interferometry.

The top plate of the second instrument has been examined (1) on its own, (2) when glued to the back and sides, (3) when the fingerboard is added, (4) when the bridge is added, (5) when the strings are on, (6) with the neck carved, and (7) when polished and complete. Major changes of mode frequencies and shapes occur at stages (2) and (4). This shows the bridge to be a major factor in selectively adjusting the frequency of certain modes in the completed instrument. The remaining stages in construction lead to very small changes only.

Variations in the important constructional parameters will be discussed and some comments will be made on their implications.

Some workers have attempted to apply the Hutchins violin plate-tuning criteria to guitars but our experience suggests that this is not desirable. Some tentative proposals about the most effective placement of resonances in a guitar will be made.

E5. Impulse Methods in Brass Instrument Measurement

J Goodwin
University of Surrey

The input impedance of a brass instrument has long been employed as a useful physical correlate of intonation and sound quality. This quantity can be measured directly, or calculated from the geometry of the instrument bore. While this is useful in the assessment of steady-state playing characteristics, it is known that the initial transient is of great importance in the perception of musical sounds.

Preliminary investigations indicate that French Horn players are able to distinguish the presence of early reflections in the impulse response of an instrument. These reflections are not readily found by inverse Fourier transforming input impedance data due to bandwidth limitations, so a direct approach must be adopted. An apparatus has been built to enable measurement of the impulse response directly, using a spark source and a miniature microphone positioned in the mouthpiece throat.

Results illustrate the effect of discontinuities in the bore. Comparisons between the measured input impedance and the Fourier transform of the impulse reponse show good agreement, especially if certain properties of the Hilbert transform are employed in the processing of experimental measurements.

E6. Vibrations of Piano Strings and Coupling to the Soundboard

A R Baxendell, I S Brown and C E Gough
University of Birmingham

Measurements of the transient and sinusoidally excited response of strings on the piano have been made in order to obtain information about the nature and strength of coupling between the strings and soundboard at the bridge. Measurements have been made over the full keyboard range on single strings and on the pairs and triplets of strings that comprise single notes over most of the range. For string triplets, it is possible to excite six independent vibrational modes of string vibration, at frequencies close to any given harmonic of the individual strings, making analysis rather complicated.

However, a single string, with all the others prevented from vibrating, supports only two modes. The damping and separation in frequency of these modes provides quantitative information on both the real and imaginary components of the complex mechanical admittance of the soundboard seen by the vibrating strings at the bridge. From such measurements we can identify the lowest acoustic resonances of the soundboard. Measurements of pairs of strings confirm several of the predictions of Weinreich's recent theory for string vibrations on the piano, including the suggestion that the characteristic singing tone of a well-tuned piano can be attributed, at least in part, to the coupling between the strings at the bridge.

E7. Aperiodicity in Bowed-string Motion

M McIntyre and J Woodhouse
University of Cambridge

Abstract not available.

E8. Acoustic Spectroscopy using String Resonances

C Gough
University of Birmingham

A simple model for string resonances on a musical instrument is described. It is shown that a string will support two independent modes of vibration and that measurement of the frequencies and damping of these modes can be used to derive reliable values for the frequency, damping and coupling via the bridge of the acoustically important resonances of the instrument on which the string is mounted. Measurements of string resonances using a simple experimental technique will be shown, which illustrate the use of such measurements to derive information about the air-resonance, the main body resonance and other less strongly coupled resonances on a number of violins and cellos, all of which suffer from a pronounced wolf-note.

E9. Time Error in the Perception of Sound Brightness

J Smurzynski
Warsaw Academy of Music

This paper presents the results of experiments in perception of sound brightness. An investigation on the existence of the Time Error (TE) in the paired comparison method was made. The duration of the Inter Stimulus Interval (ISI) between two white noise signals was varied between 0.1 and 8 secs. No TE was observed for ISI's of 0.1 to 2 s. A small negative TE occurred for ISI longer than 4 s. The results obtained for noise stimuli limited in the low and high frequency ranges confirmed the same tendency.
For musical stimuli – a four bar fragment played on the accordian – results were very similar.

E10. Tonal Sequences, Melody and Music

A Watkins
University of Reading

This paper investigates the psychological status of some theoretical aspects of music. Melodies are constrained by numerous factors; three hypotheses are considered here.

1) The changes in pitch from note to note are likely to be small. This is necessary to increase 'coherence', to aid distinctions between 'voices', for ease in singing and so on.

2) Pitch values which have a large number of consonant pairs amongst their number will be more probable. Thus, extrapolating from the consonance of the '5th' (7 semitones) along the 'progression of 5ths' we obtain the 'diatonic' scale. These notes will be more probable than the remainder of the 12 note 'chromatic' scale.

3) The particular diatonic scale upon which the melody is based (ie the 'key' of the piece) should be clear to the listener. This consideration is based upon the 'classical theory of tonality'. Basically this means that large jumps *along the progression of the 5ths* will be less probable than small ones. Two rules are also applied in this context.

We investigated perception and memory for tonal sequences, generated using various combinations of these and 'control' constraints. Peceived 'melodiousness' was scaled by 'Paired comparisons' and the effect of the constraints was examined by analysis of variance of the 'melodiousness' scores. The results indicate that observers are quite systematic in their judgements and that the various constraints have perceptual significance. Memory for these sequences was tested using signal detection analysis of the observer's ability to discriminate 'same' and 'different' melody pairs. The work is currently in progress, and results will be available soon.

E11. Perception of the Timbre of Musical Instruments

R Shepherd and P J Simpson
University of Surrey

The perception of timbre has not been studied nearly so widely as that of pitch or loudness. Most of the studies of the timbre of musical instruments have investigated the relationship between perception and the physical characteristics of the acoustic signal based upon the analysis of instrument notes or the attempted synthesis of notes. The attack and decay transients, and the steady-state harmonic content and phase relationships have been shown to influence the perception of timbre to a greater or lesser extent.

In this paper some of the problems associated with these studies will be considered, along with some suggestions for improving experiments in this area. Many of the studies have reported more anecdotal than experimental findings, and they tend to have relied on using a small number of 'typical' notes (often only one) played on different types of instruments, without any regard to what constitutes a typical note or what sort of variations might be expected between notes played on a particular instrument. In order to understand more fully the perception of timbre of musical instruments it would be necessary to consider differences in the timbre of notes varying in pitch and loudness played on one instrument. Since the timbre of the notes is to an extent under the control of the player, it would also be useful to study the variation within and between players, and the skills at the disposal of the player for modifying performance. There are also factors related to the listener (or player) such as expectancy and constancy effects, which may lead to differences in perception with identical physical stimuli.

E12. The Theory and Practice of Sound Power Measurement (The Power of Musical Instruments)

Ms U Angster
Hungarian Academy of Sciences, Budapest

The problem of measuring the sound power of arbitrary sound sources is not solved sufficiently yet. There are two kinds of general methods being used in practice, namely the measurements carried out in the anechoic chamber and those in the reverberation room.

Making the measurement in an anechoic chamber, the main problem is that the sound intensity, $I = p\overline{v}$, cannot be measured directly. So in practice the sound pressure is measured by a number of microphones placed on a spherical surface around the source. Averaging the microphone signals the power can be calculated $W = \Sigma p_i^2 / \rho c$. This method is good for ideal sources (ie point-sources of spherical characteristic). In other cases phase differences arise by which the formula is changed as follows: $W = \Sigma p_i^2 \cos\phi_i / \rho c$. The bigger the phase angle is, the larger will be the error of the measurement. If the radiated sound is complex (as from musical instruments) the measurement will be more complicated.

Carrying out the measurements in a reverberation room the phase angles are taken into consideration only as a statistical average. By this method it is very important to know the physical characteristics of the room and of the sound field. Though the error of this method is also very big, it is more simple than the other one.

The reverberation room method was revised in the Acoustical Research Laboratory of the HAS. This new method is good for comparing the sound power of arbitrary sources. Measuring the absolute power of the sources in different reverberation rooms has not been investigated yet. The sound power of musical instruments has been measured in the reverberation room of the PTB. The results of these measurements are discussed in the paper.

E14. The Sound Insulation of Small Studios

D Fleming
Bickerdike Allen and Partners, London

This paper describes the design, construction and performance of a suite of small practice rooms, recently completed for a London music college with average sound insulation between adjacent rooms of 70 dB. Problems in clarifying the brief and setting the required standard of sound insulation are explored. Details of the construction and practical difficulties on site are described and accompanied by measurements. The sound insulation achieved has been measured and an analysis of the transmission paths is tentatively presented. Mention is made of the room acoustics.

E15. Music and Music Rooms

Discussion forum.

Open Poster Session

Session F is an open poster session.

Active Control of Noise and Vibration

16 February 1981, Birbeck College, London

Active Attenuators: An Historical Review and some Recent Developments

H G Leventhall
Chelsea College, University of London

Active attenuators have a long history, early proposals dating from 1933. However, these were not put into practice until about 20 years later when Olsen made a large number of suggestions for the application of active attenuators and carried out laboratory experiments. At about the same time Conover attempted active control of noise from a large transformer and had some success, but not sufficient for the work to be pursued. In the same period there was early work on active ear defenders. A major development came in the mid 1960s with the work of Jessel. He introduced an absorptive attenuator which used a complex source. Previously only monopole sources had been suggested and these operated by interference. An alternative absorptive attenuator was proposed by Swinbanks. However, the rapid improvements in electronic processing over the past few years have led to renewed interest in monopole systems in which the acoustic disadvantages are overcome by signal processing. At the present time, active attenuation of noise in ducts is a practical possibility and attention is being given to control of transformer noise. The problem of attenuation in three dimensions is, at the present time, not solved and it is likely that solutions will be only for limited conditions due to the difficulty of reconstituting the wave form in space.

An Active Noise Reduction System for Aircrew Helmets — Flight Trials in Strike Aircraft

P D Wheeler and S G Halliday
University of Southampton

An active noise reduction system (ANR) has been developed for use in aircrew helmets, in which the acoustic noise field inside the ear defender is detected using a miniature microphone, and an antiphase signal is fed back to a communications telephone within the ear defender. The objectives for this development have been to improve speech intelligibility, and to reduce noise exposure.

Developed under contract to the Ministry of Defence (Procurement Executive), by the University of Southampton, the ANR system has been comprehensively tested in a series of laboratory trials, followed by flight trials in a number of aircraft.

In order to eliminate user controls, an adaptive control facility has recently been added, which optimises the degree of noise cancellation to compensate for variations in helmet fit between wearers.

The current design provides 15 — 20 dB active attenuation over a working range from below 50 Hz to beyond 2 kHz and the effect of this additional attenuation is to reduce in-flight noise levels at air-crew members' ears by 15—20 dB(A) depending upon aircraft type. type.

Active Control of Repetitive Noise and Vibration

G B B Chaplin and R A Smith
University of Essex, Colchester

Noise and vibration which is of a repetitive nature — such as noise produced by a diesel engine exhaust, and vibration transmitted through its mounting pads — can be cancelled without the need to sense it, process it, or use linear transducers or actuators.

This is accomplished by the use of a self-adaptive system, which also reduces installation and commissioning costs, and applications are limited only by the power rating of available actuators. Even using currently available loud-speakers, the exhaust noise of engines of several thousand horsepower can be cancelled.

Self-adaptive methods complement, rather than compete with, passive methods. By taking advantage of the special features of repetitive noise and vibration, self-adaptive systems can be built which combine simplicity with stability, are very tolerant of defects in transducers and actuators, and are capable of solving problems hitherto considered intractable.

Monopole Systems for Active Attenuation of Noise in Ducts

Kh Eghtesadi
University of Abadan
H G Leventhall
Chelsea College, University of London

In the monopole system the noise from the primary source is detected by a microphone and the signal delayed to allow for the travel time from microphone to secondary source. The secondary source is then energised in antiphase to the travelling wave. There is cancellation in the downstream direction but the upstream wave adds to the noise at the microphone forming a feedback system. There are instabilities at frequencies determined by the wave length corresponding to the microphone-loudspeaker spacing.

There are several ways of overcoming the limitations. a) More complex, unidirectional sources may be used to reduce the feedback. b) Microphone isolation may be achieved by placing it centrally between the components of a dipole attenuator, as in the Chelsea Dipole. c) The feedback may be incorporated as part of the total system. d) The microphone-loudspeaker spacing may be reduced to increase the range of operation.

Stability Considerations and Performance Limits in Multiple Source Cancellation

I Roebuck
Admiralty Underwater Weapons Establishment, Portland, Dorset

In the one-dimensional problem the performance is limited by 'noise' in the form either of the non-coherent part of the perceived uncontrolled field or of the incorrectly replicated control source field. An extension is the study of the enhanced potential for cancellation by the simultaneous control of two independent components of a perceived acoustic field propagating via different paths. The more precisely the individual components can be identified, the more the performance improves. The paper considers the quantification of these improvements and discusses the stability considerations inherent in simultaneous feedback control.

Design of a Broadband Active Sound Control System

C F Ross
Department of Engineering, Cambridge

Hitherto the filtering techniques used in active sound control systems have been analogue: these are rapidly becoming obsolete because of their lack of stability and versatility. The microprocessor gives digital techniques an edge on grounds of both convenience and economics; moreover the performance of digital filtering is far superior to that of analogue methods.

An algorithm is presented which can be used to assess the optimum filter characteristics required for active sound control systems with a single degree of freedom. In the process the system is subjected to three random noise tests which directly yield the characteristics of the filter. The algorithm has been tried out in practical applications and shown to be both quick and convenient to use.

Active Silencing of a Transportable Generator Set

P D Wheeler
University of Southampton
T S Parramore
MOD (Army), Military Vehicles and Engineering Establishment, Christchurch

The major low frequency noise source associated with the internal combustion engines of fighting vehicles and field generator sets is the engine exhaust noise. This component, at the engine firing frequency and its harmonics, will, in general, control the aural detectibility of the engine in its operational role.

Although conventional reactive mufflers can provide adequate attenuation for constant frequency exhaust components, this may not be the case for variable speed engines, or for the run-up phase of a generator set.

This work has been concerned with the development of a broad-band active silencing system for the exhaust noise components of internal combustion engines, with the ability to cope with varying source frequencies in the low frequency range. The exhaust duct was subdivided vertically into two equal sections in order to ensure dominance of plane-wave mode propagation in the frequency range of interest. Each section houses a 'virtual earth' active silencing system comprising a flush-mounted loudspeaker unit, and a centrally-mounted sensing microphone.

Under maximum stable gain conditions, a reduction of 14 — 16 dB in engine firing frequency harmonics in the range 75—125 Hz is achieved, as measured in the duct, and at the duct exit.

SPEECH PERCEPTION

Speech Group Meeting, 17 December 1980

Seven papers were presented at this half-day meeting held in the Department of Psychology, University of York. About 35 people attended the meeting, which was chaired by Mr J N Holmes.

Chris Darwin (C J Darwin and Mark Pearson: *Perception of voice onset*) opened the meeting by describing experiments designed to assess the perceptual importance of various acoustical correlates of voicing in the specification of 'voice' onset for the voice-onset time dimension.

Quentin Summerfield (Quentin Summerfield, John Foster and Mark Haggard: *Perceiving vowels from 'flat spectra': preliminary findings*) reported some preliminary experiments on the importance of spectral amplitude change in vowel perception, arising out of their finding that vowel percepts can be induced by flat spectra presented in the context of 'vowel complements' (spectral patterns with vowel formant peaks replaced by valleys, and vice versa).

Stuart Rosen (Stuart Michael Rosen and Peter Howell: *Rise time perception*) presented data from some attempts to replicate the findings of Cutting and Rosner (Perception and Psychophysics (1974), 16, 564-570) that in perception of rise-time in non-speech sounds (pluck-bow), discriminability was maximal at the category boundary established by identification tests; in contrast, these new data obtained with improved stimuli showed a difference between the region of highest discriminability (which tended to be at the shortest rise-times) and the location of the category boundary.

Martin Roberts (Martin Roberts and Quentin Summerfield: *Visual adaptation in speech perception*) described a selective adaptation experiment exploiting McGurk and Macdonald's (Nature (1976), 264, 746-748) demonstrations of audio-visual speech perception, to achieve a neat dissociation of auditory and phonetic levels of processing; the results showed that adaptation effects in phonetic perception occur prior to audio-visual integration, at an auditory level of processing.

Bill Ainsworth (W A Ainsworth: *Some effects of contrast and adaptation in speech perception*), also concerned with perceptual adaptation in speech, reported some experiments showing phoneme boundary shifts after only a single presentation of an adapter, a result represented better as a contrast effect, and unlikely to involve fatigue.

> We apologise for the differences in printing which some readers may have noted in this Bulletin. These were due to production difficulties and are not expected to recur.

A different approach to specifying the basis for phonetic discrimination was outlined by Anthony Bladon (R A W Bladon: *Towards a dynamic measure of phonetic distance*), in which the difference between speech sounds is based upon a measure of spectral distance, obtained by integrating the differences between auditory spectra over frequency and time.

Finally, Peter Bailey (Peter J Bailey and John Seton: *Local influences on perception of silent intervals after* [s]) presented some data from experiments investigating the influence of rate of speech in precursor phrases on perception of silent intervals after [s], in target words like /split/, and how these effects interact with more local influences due to the spectro-temporal properties of the [s] segment. □

Peter J Bailey

Review

Acoustics Demonstration Tape
Fifty minute cassette tape
HMSO £8.50

This tape, which is accompanied by a short explanatory leaflet, contains a total of twenty-four items. On the first side the first ten consist of demonstrations of a fairly straightforward nature ranging from a frequency sweep, through a demonstration of frequency discrimination and loudness discrimination, to various kinds of filtered music, speech and noise. The next three items compare reverberant and anechoic conditions for different types of sound source (speech, music and a gunshot), and then are shown the effect of wall attenuation on music, different harmonic structure in synthesised musical notes and the effect of noise-induced hearing loss. The second side starts with an impressive demonstration of the Haas effect, then shows the effect of windows upon traffic noise, has four recordings of various industrial and transport noises and finally nearly fifteen minutes of kerb-side-recorded traffic noise.

This is a very convenient collection of ready-prepared examples of many different acoustical demonstrations, and subject to some reservations I would recommend it to anyone wanting such an item. Because it is so potentially useful it seems a pity that it is marred by several unfortunate features. The main criticism is that for a technical product the detail given in the accompanying leaflet is not nearly as complete as it should be; for example, there is no indication of the level of hearing loss being simulated in the hearing loss demonstration, and no detailed information is given of the harmonic content of the synthesised musical notes. The spoken commentary (normally on one of the two channels, the demonstration items being on the other unless stereo effects are required) is rather stilted and not always well placed relative to the item being introduced. For example, in the demonstration of octave band filtered speech there is a five-second gap between each five-second segment of speech, but the commentary (about two seconds per segment) occurs right in the middle of the speech. On a stereo player it can of course be removed by altering the balance control, but then the information it gives is lost also.

At £8.50 the tape seems rather expensive, but on the other hand the effect of a goods train (recorded 5 m from the track) rattling in stereo through your living room is certainly impressive! □

S J Flockton

Reflections on Recording

A standard microphone works best in free space where there are no reflected waves to distort the main sound signal. The distortion results from the way in which the relative phase of the main and the reflected waves varies over the spectrum: while some frequencies are reinforced, others are much reduced. However, there is a narrow zone (the 'pressure zone'), next to any reflective boundary, where the incident and reflected waves are approximately in phase whatever the wavelength, and here there is constructive interference and low distortion. This phenomenon has been put to good use in a new device—the pressure zone (PZ) microphone—invented by Edward Long and Ron Wickersham of Crown International, Indiana, USA (*New Scientist* 1980 **87** 716). Their PZ microphone picks up acoustic signals exclusively in this zone. The device can withstand sound levels of 150 dB(A) and so can be mounted within musical instruments. In addition its response is insensitive to movement so that a singer wearing one can walk about without affecting the recording quality in any way. □

Reprinted from Physics Bulletin Vol 31, 1980.

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:

An Introduction to Microprocessors and their Use in Acoustics
Open University, Milton Keynes, 9 June 1981
Meeting Organiser: Mr N Heap MIOA,
The Open University Faculty of Technology, Walton Hall,
Milton Keynes, MK7 6AA
(200 word abstracts as soon as possible)

Non-Verbal Auditory Communication
ISVR, Southampton, July 1981
Meeting Organiser: Dr P Wilkins
ISVR, The University, Southampton SO9 5NH
(200 word abstracts as soon as possible)

Photo-Acoustic Spectroscopy
Chelsea College, London, 21 - 22 July 1981
Conference Organiser: Dr R W B Stephens FIOA
Department of Physics, Chelsea College, Pulton Place, London SW6 5PR
(200 word abstracts as soon as possible)

Industrial Applications of Ultrasound
Birkbeck College, London, November 1981
Meeting Organiser: Mr A W Crawford FIOA
DDS Engineering Co Ltd, West Ham Lane East, West Ham,
Basingstoke, Hants RG22 6PP
(200 word abstracts by 30 June)

Sound Propagation Outdoors
Open University, Milton Keynes, December 1981
Meeting Organiser: Dr K Attenborough FIOA,
Faculty of Technology, Open University, Milton Keynes MK7 6AA
(200 word abstracts by 31 July)

New Products

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

New Microcomputer Controlled Building Acoustics Analyser

The B & K 4417 is a microcomputer controlled serial analyser for the automatic measurement and subsequent calculation of the common quantities of interest in building acoustics, and also for precision sound power measurements. It is primarily intended for the measurement of sound insulation in new buildings but can also be used in noise control and for investigations of building materials, auditoria and concert halls.

When used with a minimum of accessories (ie a microphone, loudspeaker and a power amplifier) the 4417 can be programmed to measure and retain in its memory data for three sound pressure level spectra and one reverberation time spectrum. When used in conjunction with a rotating microphone boom, or an array of microphones and a multiplexer, the 4417 enables spatial averaging to be performed automatically.

From the measured data and the entered values of the room's volume and the room's (or wall's) surface area, the 4417 will calculate any or all of nine important spectra in twenty third-octave bands covering the frequency range 100 Hz to 8 kHz, eg impact and airborne sound insulation, sound power, normalised and standardised levels. The results can be presented digitally on the 4417's liquid crystal display, graphically via a level recorder, printed via an alphanumeric printer or stored on a digital cassette recorder.

Eight-Channel Microphone Multiplexer

The Brüel & Kjaer eight-channel microphone multiplexer Type 2811 is primarily intended for use with their Sound Power Calculator Type 7507. It scans up to eight microphone or direct input channels controlled manually, automatically from a built-in clock (nine dwell times), or externally. Up to four 2811s may be combined to multiplex a total of 32 channels. A built-in IEC 625-1 compatible interface permits external scanning by controller and independent scanning of a second multiplexer built into the 2811. Under IEC bus control the multiplexer can stop and start ancillary equipment such as a noise generator or a sound power source for reverberation time measurements. Also included are facilities for by-passing or selecting individual channels and resetting scan. Each channel has ± dB channel sensitivity adjustment and a dual LED tuning-type indicator for calibrating. Frequency response is 2 Hz - 200 kHz ± 0.5 dB, crosstalk is better than − 80 dB up to 20 kHz and -60 dB up to 200 kHz.

B & K Prepolarised Condenser Microphones

The prepolarised Condenser Microphone Type 4155 is intended for noise and sound level measurements according to IEC 651 Type 1 and Type 4175 for measurements according to IEC 651 Type 2. Both are half-inch free field types with high sensitivity (50 mV/Pa) and wide frequency range (4 Hz to 20 kHz for Type 4155, and 5 Hz to 12.5 kHz for Type 4175).

BRÜEL & KJAER (UK) LTD, Cross Lances Road, Hounslow TW3 2AE. Tel: 01-570 7774.

Machine Noise Suppressed by Patented Low Cost Acoustic Curtain

This new system offers the advantages of high sound absorption on both front and back surfaces, full vision, plus complete and rapid access.

Highly absorptive glass-fibre sections are covered with a special washable, durable plastic laminate and framed in galvanised steel (called Hush Tubes). The Hush Tubes are bolted back to back, three inches apart sandwiching a full length 40 mm thick transparent flexible plastic sound barrier, which allows vision and also becomes a folding hinge.

As the Hush Tubes are mounted on both sides of the barrier, both the areas inside and outside the enclosure are exposed to up to 91% absorption.

The acoustic curtain system is manufactured by Acoustic Standards Inc, California, and marketed by Environprint Ltd, 66 King Street, Southall, Middlesex UB2 4DD. Telephone: 01-571 2116.

A Digital L_{eq} Meter

The Pulsar Digital Integrating Sound Level Meter Model 228 has a total integrating range from 40 to 140 dB(A) with six 40 dB display ranges and ten preset measuring times. These times range from 2 seconds to 16 minutes.

The Model 228 automatically re-sets and re-starts at the end of each period whilst the display holds the previous period's L_{eq} measurement. This means that the output can be used to drive a paper recorder to give the long-term L_{eq} subject only to the 40-hour battery life of the equipment. The LCD digital display has indicator tags for battery status, overload and insufficient data, plus a direct reading with a 0.1 dB resolution. Price £449. Pulsar Instruments, 40-42 Westborough, Scarborough, North Yorks YO11 1UN. Telephone: 0723 71351.

Multichannel Filter for Computer-Controlled Signal-Processing Systems

A new multichannel variable filter system from Kemo, the VBF/25, is specifically designed for computer-controlled signal-processing and measurement applications. Featuring a 16-channel mainframe with individual channel addresses, the VBF/25 will interface via a 16-bit parallel word to virtually any computer, and provision is made internally for a general-purpose printed-circuit card to accommodate any special requirements.

Kemo Limited, 9-12 Goodwood Parade, Elmers End, Beckenham, Kent BR3 3QZ.

Model 2822 Velocity Reading Monitor

A new Modular Monitor has been introduced by Environmental Equipments Ltd, compatible with the Machine Health Monitoring Modular System introduced last year. This new Monitor measures true RMS vibration velocity and will operate directly from any vibration transducer producing a signal of 100 mV/g.

The Monitor is specifically designed for rotating plant use and provides a display on the front panel of velocity in mm/sec, contains an internal test oscillator which totally checks the operation of the monitor, and also contains two independent alarm circuits for alarm and trip operation of a machine.

Outputs from the Monitor are available for driving into vibration analysers, oscilloscopes etc and a 4-20 mA output is available for connection directly to a chart recorder.

Each Monitor is mains powered and therefore does not rely on a system power supply for its integrity of operation. The Monitor can be used in intrinsically safe applications where Zener barrier assemblies are provided.

Environmental Equipments Limited, Eastheath Avenue, Wokingham, Berkshire RG11 2PP.

Metrosonics Noise Dosemeter

The two component system consists of the MetroLogger 301 and the MetroReader 651 or 652. The MetroLogger is the portable unit carried by the employee. It accumulates in its digital memory a record of 1-minute L_{eq} samples in the form of either a time history or a statistical distribution (dependent on which programme unit is plugged in). The MetroReader is an office-based readout unit (or a portable, mains or battery operated unit in the case of the 652) which converts the logged information in the MetroLogger into a hard copy printout in easily interpreted format. Naturally, it is economic to service several MetroLogger units from a single MetroReader.

The system is available for hire from General Acoustics in either time history or statistical distribution configuration.

Kletek Damage Monitor for Rotating Machinery KS 310

The machine damage monitor, KS 310, is a portable instrument which uses the input from an acoustic emission transducer over the frequency range 100 Hz to 50 kHz to give various forms of signal presentation. These measurements, from a knowledge of the performance of a machine in perfect condition, can be used to identify the limit at which unacceptable deterioration has occurred and can in many cases even identify which component of the machine is causing the unserviceability.

Film Faced Absorbent Foam

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Material for the July issue of Acoustics Bulletin should reach Mrs F A Hill at 25 Elm Drive, St Albans, Herts AL4 0EJ no later than 22 May.

Acoustic Pattern Recognition

A Joint Meeting of the Institute of Acoustics and the British Pattern Recognition Association

Many problems in acoustics seem, at first sight, to belong to the domain of pattern recognition, yet most texts on that subject pay scant attention to acoustics. On 15 December 1980, therefore, 49 members of the Institute and of the Association, together with other colleagues, met at the University of Surrey in Guildford to hear a selection of papers chosen to explore possible areas of contact.

THE MEETING was organised by Dr J M Bowsher of the University of Surrey on behalf of the Institute, and by Dr M J Underwood of International Computers Ltd on behalf of the Association. They put together seven papers by a wide range of authors; three of the papers discussed problems in speech analysis, one was on the identification of sources of noise nuisance, one on problems of tissue characterisation in medical ultrasonics, one on faulty weld identification in the manufacture of nuclear energy pressure vessels, and one on the ways in which melodies are perceived and remembered. There will be no printed collection of papers, but a set of abstracts has been gathered and copies may be obtained from either of the organisers.

The meeting opened with a brief address of welcome from Dr Underwood, who acted as chairman and explained the aims of the organisers to those attending; he pointed out that there should be plenty of time for discussion from the mixed audience. Some speakers, though, still overran and discussion carried over to lunch and tea.

The first paper, by P Moukas of the City University, was entitled *An Instrument for the Automatic Identification of Sources of Noise Pollution*. He reviewed existing techniques and told us that it was necessary to obtain recognition scores above 95% for sounds above a prescribed level (usually 70 dB(A) for aircraft) to avoid the need for continuous observer interaction. One point which aroused interest was the way that the modulation of the spectrum of a moving sound by ground reflections and doppler shifts could be used as an aid to recognition.

He was followed by J S Bridle of the Joint Speech Research Unit in Cheltenham, who gave a most stimulating and comprehensive review of *Developments and Challenges in Automatic Speech Recognition*. He reminded us that isolated word recognisers will soon be available in chip form for as little as $10 but felt that real challenges still presented themselves in continuous word recognition, even though in some ways that problem is conceptually easier. We shall soon see connected word recognition systems commercially available, for use with specialised, limited vocabularies, and the way seems open for more dramatic advances to be made. Finally he reminded us that one of the major unsolved challenges of automatic speech recognition was how to assess the performance of various systems.

A short paper on *Pattern Recognition of Acoustic Emission from Artificial Defects introduced into Fusion Welds of Steel Plate* by P G Bentley of the UKAEA, Riseley, showed a completely new and fascinating application to many of the audience. Certain types of welding defects can be detected by the acoustic emission they produce at the time of welding. A problem in using this acoustic emission to detect welding defects is the simultaneous occurrence of noise from the welding process and pattern recognition techniques are being used to help in distinguishing the defect acoustic emission and the process noise. The acoustic emission signals are processed to extract features of potential significance, for example their source position, time of occurrence and some functions of the transient wave shape.

After lunch a paper called *Pattern Recognition: an Empirical Bridge between Technology and Human Perception in Diagnostic Ultrasonics* by R C Chivers of the University of Surrey was read by a colleague, J Aindow. This paper really served to explain the problems attaching to the identification and classification of texture in images of various human organs produced by ultrasonic means. Clinicians make considerable diagnostic use of texture when they appraise images, yet image-processing techniques which could serve to enhance particular features of the texture seem to encounter resistance. The author felt that insufficient allowance was still being made for the pattern recognition abilities of the human brain in medical ultrasonics and made a plea for more research in this field. Discussion centred on the problems of making clinicians aware of and willing to accept the techniques of image processing and there is no doubt that the paper sowed seeds of thought in many minds.

Monira Aba El-Ata from the Thames Polytechnic then described her work on *A Speech Recognition System using Walsh Analysis with a Small Computer.* In a detailed and careful presentation she discussed how a limited vocabulary (mainly of English, French and Arabic spoken digits) could be recognised very well by a small computer after suitable training. This paper aroused much discussion about the relative utility of Walsh and Fourier Transforms but all agreed that at less than $1,000 including microcomputer the system certainly was attractively cheap.

The next paper, by A J Watkins from the University of Reading Psychology Department, showed the great range of ideas that is included in Acoustic Pattern Recognition. It was entitled *Approximations to Melody* and described some experiments on the way we perceive and remember tonal sequences computed in various ways. Remembering that most of the audience was not musically trained, the author described the construction of musical scales and outlined the Classical Theory of Tonality and how it sets certain rules and probabilities on transitions between notes. Judges performed systematically and the various constraints on the generation of melodies were shown to have perceptual significance. The way that pattern recognition ideas fit into a musical framework aroused great interest and there was extensive general discussion of this paper.

The final paper of a busy and varied day, by P D Green and P J Grace of the North Staffordshire Polytechnic, was entitled *Foundations of a Descriptive Approach to M/C Perception of Speech.* This was a statement of intent of what may become a major investigation by both authors following the ideas put forward for the machine recognition of visual images by Marr. Their approach to the understanding of an utterance utilises Minsky's idea of frames so that eventually a compatible sequence of frames may be found to match an utterance's symbolic description.

Once again there was extensive discussion and there is no doubt that the meeting as a whole had proved very useful to all participants. People who do not normally come together at the same meeting because of their different disciplines had met, exchanged views and made friends. Several of the audience suggested that a further meeting would also be successful. Plans are in hand, therefore, for a second joint meeting of the two organisations in about two years time. □

J M Bowsher

Active Control of Noise and Vibration

Birkbeck College, 16 February 1981

The 60 delegates who attended this Conference sat patiently in a cold lecture theatre; cold because of a breakdown of the heating system at Birkbeck. Their endurance was rewarded by a number of interesting papers in this important and rapidly developing area of noise control. Summaries of the papers are given elsewhere in this issue of the Bulletin whilst the Proceedings may be purchased from the Edinburgh office.

In an historical review of the subject the Conference Organiser, Geoff Leventhall, traced its development from the early 1930s up to the present time. Over the past few years modern advances in electronic techniques have made possible the design of workable active attenuators coupled with simplification of the acoustic input systems. Peter Wheeler's description of an active noise reduction system for air-crew helmets was an illustration of how modern electronics has enabled success to be achieved in an area in which previous attempts had failed. The enormous power of adaptive microprocessors was described by Professor Barrie Chaplin and a demonstration given of an adaptive silencer for engine noise.

The present tendency is towards monopole systems, rather than the use of complex attenuating sources as had been current from the mid 1960s until recently. The characteristics of monopole systems were outlined in a paper by Kh Eghtesadi and Geoff Leventhall.

Ian Roebuck, in opening his paper on stability considerations and performance limits in multiple source cancellation, felt that the post-lunch spot was not the best time for a theoretical paper! However, his clear exposition and interesting results retained delegates' attention. The application of digital methods to system characterisation and design of compensating filters were described by Colin Ross. Noise sources are used to determine system transfer functions and the results enable the digital filter controller to be specified. The application to a practical system was described. The final presentation by Peter Wheeler showed how an active silencer can be used to complement an absorptive silencer in order to counteract specific deficiencies in the absorptive system. An additional 14-16 dB attenuation of engine firing frequency harmonics in the range 75-125 Hz was achieved for a diesel generator set.

The feeling in the discussion periods was that active attenuators have an important part to play in noise control and are likely to be the big new development in the 1980s. However, it is likely that they will not be used initially in mass products, but will be applied to specific problems in which conventional methods have not succeeded. The design of active attenuation into noise control at the early planning stages will be a later development. □

H G Leventhall

Structural Methods of Controlling Wind-Excited Vibration

This Symposium is to be held at Loughborough University of Technology by the Society of Environmental Engineers in conjunction with the Plastics and Rubber Institute. Six papers will be presented, covering the use of elastomeric materials to increase the level of damping in structures; the mechanical and chemical properties of 'rubbery' materials suitable for use in civil engineering applications; design considerations in the use of dynamic vibration absorbers in large towers; and a case history of the vibration of a large regenerator column. The work discussed should be of value to civil and structural engineers as well as to those concerned in controlling the vibrations of structures.

The Symposium is to take place on 7 July 1981; enquiries should be addressed to the Secretary, The Society of Environmental Engineers, Owles Hall, Buntingford, Herts. □

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Transducers for Sonar Applications

This was a successful and well organised meeting arranged by the Underwater Acoustics Group and held at the Department of Electronic and Electrical Engineering of the University of Birmingham on 16 and 17 December 1980. The lecture programme started at 2 pm on the first day, the morning period providing an opportunity for interested delegates to see the acoustical facilities in the department.

The first day lecture programme was concerned with receiving applications and particular interest was shown in the use of the plastic film, polyvinylidene fluoride (PVDF), as the active element in hydrophones. These hydrophones were designed to withstand high hydrostatic pressures and provide good S/N ratios at low audio-frequencies. By using the film in thickness extension coupling the hydrophone sensitivity is reduced but a very broadband frequency response up to 100 MHz is attainable. Another paper dealt with the Fibre Optic Hydrophone which makes use of a number of different mechanisms due to the mechanical stress in the fibre produced by the sound field. The main effects are changes in the fibre dimensions and the stress-optic effect which produces a change in refractive index. As a consequence a corresponding change is brought about in the phase of coherent light emerging from the fibre.

The meeting on the second day was chiefly concerned with transmitting applications, dealing with a variety of topics such as fluid-filled tube projectors, boomer acoustic sources, transducer arrays etc. Workers in the field unable to attend the conference are strongly recommended to obtain their copies of the Proceedings from: Mr J Mills, Publications Secretary, Bell Electronics, John Scott House, Bracknell, Berks. □

RWBS

BRANCH AND GROUP NEWS

Industrial Noise Group
Visit to Coventry Climax Ltd, 15 October 1980

The Industrial Noise Group were fortunate to be the guests of Coventry Climax Ltd who provided a lecture and demonstration of one of their new quiet fork lift trucks.

Following a brief introductory chat by Mr B Wakefield, his colleague Mr A Wheeler described the relative merits of electric, diesel and petrol driven fork lift trucks and their noise levels in comparison with other vehicles, such as cars and lorries.

Actually measuring the noise of fork lift trucks is apparently not so readily carried out with Government recommendations being in terms of L_{eq}, as are those of the Fork Lift Manufacturer's Association, whilst client companies often have very different personal standards. The situation is further complicated by the need to specify load conditions during the measurements.

Having described the problems of noise measurement and establishing standard load conditions, Mr Wheeler explained how they had dealt with the major noise sources on their internal combustion engine fork lift trucks, namely, induction, exhaust, hydraulics and cooling system. The results of their endeavours were appreciated by the fifteen members present during a practical demonstration and inspection of one of their prototype trucks.

T Kelly

South West Branch

On 4 October 1980 a meeting was held at Exeter University and the bases for the formation of a new regional branch were laid down. The new Branch was formally approved by the Council of the Institute on 23 October 1980.

Following the business meeting on 4 October, Bill Gracey gave us an interesting insight into the microchip age; this was followed by a hard-fought discussion over the controls society exercises over industry.

As this is a rather far-flung area, we do not see that it would be practical for this Branch to hold a great number of meetings each year but propose to have two or three large meetings per year. The next meeting is to be held on 11 June 1981, at The Post Graduate Medical Centre, Plymouth General Hospital, Greenbank Road, Plymouth, and is a whole day meeting. As this is the International Year of the Disabled the theme is *Health and Noise '81.* The programme commences with control of noise at source and progresses to protection, medical conditions, legal compensation, diagnostic techniques and the placement of the aurally disabled back into employment. It should be of particular interest not only to Acousticians but also to Environmental Health Officers, Safety Officers, Trade Union Safety Reps, insurance companies and the medical profession.

The cost of the meeting is £10 per head, exclusive of lunch, and I feel this is one meeting you really cannot afford to miss. Anyone wishing for more information concerning either the new Branch or the meeting on 11 June should contact me: M J Squires, Hon Secretary S W Branch IOA, 1 Feebers Cottage, Westwood, Broadclyst, near Exeter, Devon. Tel: Work: Exeter 77888 (ext 2476), Home: Whimple 822118.

M J Squires

Speech Group

After the Speech Group Meeting of 17 December at York, reported elsewhere in this Bulletin, an Annual General Meeting was held. A committee election took place with the following result: Chairman: W A Ainsworth (University of Keele), Secretary: R Beresford (University of Newcastle upon Tyne), Treasurer: R K Moore (RSRE), Committee Members: P Bailey (University of York), L S Moye (Standard Telecommunications Laboratories, Harlow) and M Underwood (ICH, Stevenage). A vote of thanks was expressed to the retiring Chairman, J N Holmes (JSRU), and to the retiring Treasurer, M Underwood.

The proposed meeting on Speech Audiometry (6 April) was cancelled. Forthcoming meetings of interest include Session D, Speech and Hearing, at the Spring Conference at Newcastle upon Tyne University (22 - 24 April) and the Speech Group Meeting on Speech Aids for the Handicapped, to be held on 23 September at Bedford College, London. Abstracts for the latter meeting should reach Dr W Edmunson at the Psychology Department, Bedford College, by 31 May. □

R Beresford

Elastic Waves and Microstructure

This conference, held at Oxford University on 16 and 17 December 1980, was jointly sponsored by The Metals Society, The Institute of Physics and The Institute of Acoustics and there were over eighty registrants.

Twenty papers were read during the two days, about half of which were concerned with acoustic emission and occupied the first day. J Simmons of National Bureau of Standards, Washington, gave an invited paper in which he dealt in detail with waveform analysis and compared the measured with the theoretical waveform, using the Fourier transformation. The subject of the contribution by P McIntyre (CERL, Leatherhead) and D Harris (British Steel Corporation, Sheffield) was the use of amplitude distribution measurements in investigating the factors influencing acoustic emission during stable ductile crack extension in steels. Their observations indicated that the onset of ductile cracking was distinguishable from ordinary deformation in steels by a pronounced increase in the number of high amplitude acoustic emissions.

T J C Webborn (Unit Inspection, Kingston-upon-Thames) and R D Rawlings (Imperial College London) showed how their optical and scanning electron microscopy studies of microstructure and cracking, at brittle phases in steels and Fe-C alloys, correlated with acoustic emission observations. They found that inclusions in the alloys played the chief role and suggest that these could provide the objective for a further study of acoustic emission phenomena in other alloys. A paper of considerable interest given by S Wen (I B M, Yorktown Heights, New York) dealt with the metallurgical viewpoint of the possible mechanism of the acoustic emission during a martensitic transformation.

The opening paper of the second day was by K Goebbels and H Williams (Fraunhöfer Institut, Saarbrücken, FRG) who showed how ultrasonic scattering measurements provided both a quantitative (grain size) and qualitative (homogeneity) characterisation of microstructure. The scattering of Rayleigh waves enables surface structure characterisation to be investigated.

A paper by M G Silk (A E R E, Harwell) dealt with some relationships between metallurgical texture and ultrasonic propagation, an important field of enquiry, having in mind the recent studies of the large variations of ultrasonic attenuation in austenitic welds.

A distinctive topic was the contribution of M G Scott (Sussex University) and A Kursumovic (Institute of Physics, Sarajevo, Yugoslavia) who used elastic waves to investigate relaxation in metallic glasses. These materials are produced by suitable quenching of certain metal alloys that on subsequent annealing undergo a number of subtle structural changes, which are usually described as 'structural relaxations'. The results obtained by monitoring the changes in Young's Modulus of Elasticity during the relaxations were discussed in terms of the topological defects and chemical short-range ordering.

This meeting provided the means of bringing together metallurgists and physicists and a good standard of content and presentation was sustained throughout the meeting. □

RWBS

Letter to the Editor

Dear Madam,
BS2750: 1980

Having read Mr Randall's letter in the January Bulletin, the thread of which is not easily followed, I am left wondering who or what he is getting at.

His assumptions on the legal standing of BS2750: 1956 relative to the 1980 version are a little naïve in that the Building Regulations Division of DOE are unlikely to believe that tests conducted to the new standard are less credible than those made to the old one. It is well accepted that any self-respecting organisation working to BS2750: 1980 using a reasonable test procedure in a responsible manner will also have effectively worked to BS2750: 1956.

There is, however, one small anomaly in that Part G4(1) calls for octave band values in the statement of impact sound insulation results, an antiquated practice which has been dispensed with in BS2750: 1980. This small problem is easily overcome by adding 5 dB to Standardized Impact Sound Pressure Level values when tests are performed to comply with Building Regulation requirements.

So far as his statement 'that Legal Standard of Measurement of Sound Reduction Index in Britain, BS2750: 1956' is concerned, I know of no authority which insists on retaining references to the old standard for Laboratory tests when a new one is available.

The precision requirements in BS2750: 1980 are directed at present solely towards laboratory measurements since this is an area where test conditions are well laid down and, therefore, such statements can be made. The values given, although questionable in the middle frequency range (repeatability 1 dB), are ones which can be achieved using a well disciplined test procedure. See Proceedings of IOA meeting 26.11.80, *Revision of ISO 140/II Statement of Precision Requirements*—P Royle.

Requirements for field measurements have not been included, since at the time of writing no information was made available to generally quantify the precision of this test type which is made under a wide range of conditions. This section (Part 2) of the standard is at present the subject of an ISO working group, which will review its content and possibly update and thus revise it. Any data which will be of assistance in this task would be much appreciated and should be sent to the Secretary of BSI Committee EPC/1/6.

In this area Mr Randall's sentiments are obviously in the right direction and so perhaps he would like to put forward a proposal for consideration by the ISO working group.

Finally I would add that the revision of the document was not just a formality due to the previous one being rather old. The objective, which I believe has been reasonably met, was to provide a more concise document which will assist the user in his aim of producing credible results for whatever his purpose.

Yours sincerely,
C Walker,
Chairman, BSI sub-committee EPC/1/6,
Building Acoustics.

International Congress on Recent Developments in Acoustic Intensity Measurement

This International Congress is to be held in Senlis, near Paris, on 30 September - 2 October 1981 in French and English with simultaneous translation. The programme will include Fundamental aspects; Present state of the art of instrumentation; Application to the characterisation of sound sources; Sound power determination in industrial environments; Energy propagation in structures and fluids; Outlook; and exhibition and demonstration of instrumentation. The Congress is sponsored by the Groupement des Acousticiens de Langue Française and the co-ordinator for the UK is Dr F J Fahy of the ISVR, Southampton. □

Non-Institute Meetings

1981		
21-24 April	4th FASE Symposium on Acoustics and Speech	Venice, Italy
18-22 May	Acoustical Society of America	Ottawa, Canada
7-11 June	25th ETAN Conference	Yugoslavia
8-10 June	Noise Con 81 (US Conference on Noise Control Engineering)	North Carolina, USA
15-18 June	International Symposium on Underwater Acoustics	Tel-Aviv, Israel
22-25 June	Acoustic Remote Sensing of the Atmosphere and Oceans	Calgary, Canada
30 June - 2 July	Ultrasonic International	Brighton
6-7 July	Ultrasound (20th International Conference on Acoustics by the Czechoslovak Committee for Electrical Engineering)	Prague, Czechoslovakia
20-24 July	9th International Symposium on Nonlinear Acoustics	University of Leeds
17-22 August	Ultrasound in Medicine	San Diego, USA
20-23 September	8th Vibration Conference (American Society of Mechanical Engineers)	Hartford, Connecticut USA
6-8 October	Inter-Noise 81	Amsterdam, Netherlands
1982		
16-19 May	Inter-Noise 82	San Francisco, USA
13-17 September	3rd FASE Congress	Federal Republic of Germany

Institute of Acoustics Meetings

1981			
21-24 April	M	**SPRING CONFERENCE—ACOUSTICS '81** (Including sessions on Speech and Hearing; Musical Acoustics; Structural Dynamics and Industrial Noise)	University of Newcastle
23 April	LEM	Trouble Shooting in Moving Air Systems	County Hall, London
15 May	M	Noise Source Location	Portsmouth Polytechnic
18 May	M	The Computer Recognition of Speech (Joint with IEE, Electronics Division)	Savoy Place, London
21 May	LEM	25 Years in a Shaky Business (by L F Moore of Leslie F Moore Associates)	County Hall, London
9 June	M	An Introduction to Microprocessors and their use in Acoustics	Open University, Milton Keynes
21-22 July	M	Photo-Acoustic Spectroscopy	Chelsea College, London
July	M	Non-Verbal Auditory Communication	ISVR, Southampton
23 September	SG	Speech Aids for the Handicapped	Bedford College, London
24 September	LEM	Noise and Health and Safety at Work	County Hall, London
September	M	Generation, Measurement and Effects of Sound over 140 dB (Joint with the Society of Environmental Engineers)	University of Birmingham
29 October	LEM	(P) A talk about railway noise	County Hall, London
November	M	Industrial Applications of Ultrasound	Birkbeck College, London
26 November	LEM	Communication in a High Noise Environment (relating to Aircraft)	County Hall, London
December	M	Sound Propagation Outdoors	Open University, Milton Keynes
1982			
5-9 April	M	**SPRING CONFERENCE—ACOUSTICS '82**	University of Surrey

Key
M = Meetings Committee Programme
LEM = London Evening Meeting
SG = Speech Group
(P) = Provisional

Further details from:
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