



Review Article

Outdoor Sound Propagation - The Sound Field,
Micrometeorology and Topography
Tony F W Embleton

Technical Contributions

The Use of Impulsive Excitation Test Methods to
Evaluate the Performance of Underwater Viscoelastic
Acoustic Coatings
D J Townsend

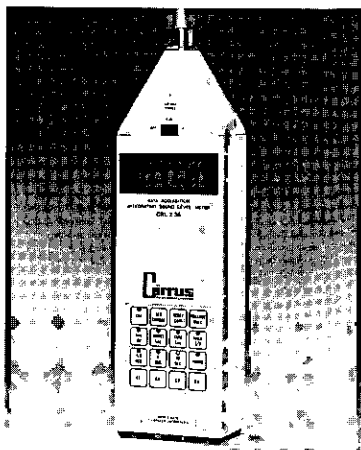
Microphone Calibration at Low Frequencies
R G Barham

Conference and Meeting Reports

Recent Advances in Underwater Acoustics,
Weymouth, May 1991

acoustics
BULLETIN

^a Volume 16 No 4
July-August 1991



**CRL
236A**

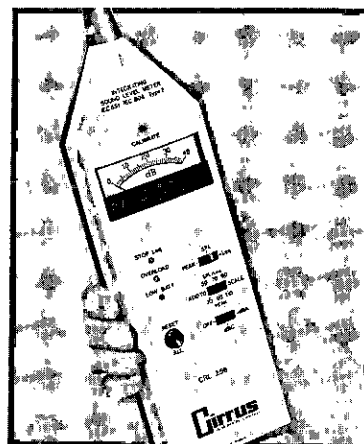
Cirrus

RESEARCH LIMITED

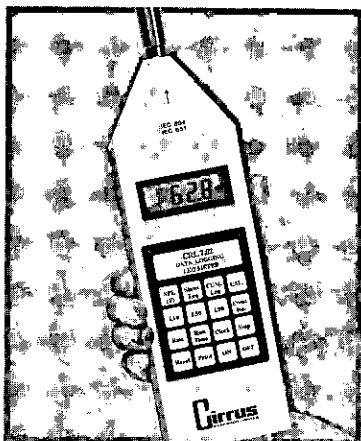
. THE QUIET ACHIEVER .

The world's first Short Leq meter is now more powerful – it's memory size is now over 900,000 Short Leq values and the base Short Leq period is now 1/16 second. Additionally, the CRL 236A can be remotely controlled using Cirrus software to download, operate and calibrate over modems, a positive boon in inaccessible locations where it becomes a mini-monitoring station.

The new 256 CRL is type 2 Leq and Sound Level Meter with the addition of TRUE PEAK measurement enabling all aspects of the European Communities directive to be monitored. The CRL 256 is a derivative of the best selling CRL 222, as used by the Health & Safety Executive, and the CRL 254, now the British Armed Services standard instrument. A type 1 variant, the CRL 255 will soon be available.



**CRL
256**

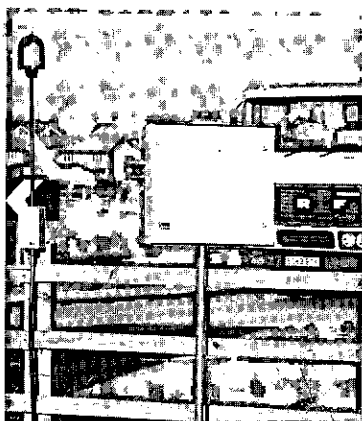
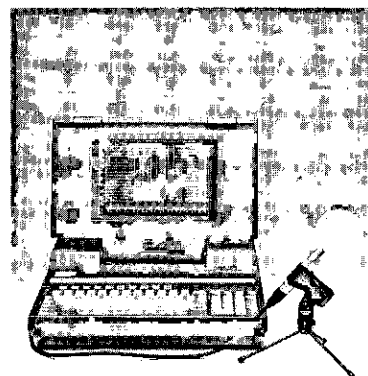


**CRL
702**

The CRL 702 is probably the world's most flexible precision Sound Level Meter. A type 1 CRL 702 can be configured to log environmental parameters such as L_{10} or L_{90} or to log dose related factors such as $L_{EP,d}$ or Exposure. The 702's power is further enhanced by it's ability to store up to 128,000 Short Leq values for later analysis using Acoustic Editor. The CRL 702 can be housed in a waterproof case to provide an outdoor monitoring station as used on the UK's National Noise Survey.

ARIA is a digital signal processor card housed in a laptop computer to provide a portable acoustic measurement system by adding appropriate software modules. ARIA's module's consist of elements such as FFT analysis (dBARIA), audio event capture (dBTRIG), building acoustics (dBIMPULS), and acoustic power determination (INTAC01). Naturally, this power is harnessed to stringent technical performance – ARIA is the world's first software system to be approved to IEC 804 type 1.

ARIA



NMT

Cirrus' new CRL 240 series of Noise Monitoring Terminal's combine proven computer know-how with instrumentation excellence. This provides a series of units capable of permanent remotely controlled noise monitoring such as those supplied to the Australia's Sydney and Brisbane airports. These Noise Monitoring Terminals are also highly applicable for blast monitoring or continuous recording duties when allied to Cirrus' range of permanent outdoor microphone systems.

**Cirrus Research Limited, Acoustic House, Bridlington Rd, Hunmanby
YO14 0PH, UK Tel: (0723) 891655 Fax: (0723) 891742**

Cirrus Research Inc, Suite 170 6818 West State St, Wauwatosa W153213, USA
Tel: +1 414 258 0717 Fax: +1 414 258 0896

Cirrus Research France: 2 Rue du Dr Papillon, 69100 Villeurbanne France
Tel: +33 78 68 88 54 Fax: +33 78 84 96 94

Cirrus Research Inc, 148 East Emerson, Orange CA 92665, USA
Tel: +1 714 282 0929 Fax: +1 714 282 7765

Cirrus Research Germany Schlueterstrasse 29, Dresden, Deutschland 0 - 8021
Tel: +37 51 345 4370 Fax: +37 51 345 4349

Editor:

J W Tyler FIOA

Associate Editors:

J W Sargent MIOA

A J Pretlove FIOA

Editorial Board

W A Ainsworth FIOA

J A S Angus MIOA

R Challis

P F Dobbins MIOA

L C Fothergill FIOA

P M Nelson FIOA

G A Parry MIOA

I J Sharland FIOA

Contributions and letters to:

The Editor

11 Colwyn Close, Yateley, Camberley

Surrey GU17 7QH

Tel: 0252 871298

Books for review to:

A J Pretlove FIOA

Engineering Department

University of Reading

Whiteknights, Reading RG6 2AY

Information on new products to:

J W Sargent MIOA

Building Research Establishment

Garston, Watford WD2 7JR

Advertising:

Keith Rose FIOA

Brook Cottage, Royston Lane,

Comberton, Cambs. CB3 7EE

Tel: 0223 263800 (evenings)

Tel: 081 576 7190 (days)

Fax: 0223 264827

Published and produced by:

The Institute of Acoustics

PO Box 320, St. Albans

Herts. AL1 1PZ

Tel: 0727 48195

Fax: 0727 50553

Printed by:

Staples Press, Alban Park,

Hatfield Road, St Albans

Views expressed in *Acoustics Bulletin* are not necessarily the official view of the Institute nor do individual contributions reflect the opinions of the Editor.

Multiple copying of the contents or parts thereof without permission is in breach of copyright. Permission is usually given upon written application to the Institute to copy illustrations or short extracts from the text or individual contributions, provided that the source (and where appropriate the copyright) are acknowledged.

All rights reserved

ISSN: 0308-437X

Single copy £6.00 Annual subscription

(6 issues) £22.00

© 1991 The Institute of Acoustics

contents

Review Article

- Outdoor Sound Propagation - The Sound Field, p5
Micrometeorology and Topography
Tony F W Embleton

Technical Contributions

- The Use of Impulsive Excitation Test Methods to p17
Evaluate the Performance of Underwater Viscoelastic
Acoustic Coatings
D J Townend
- Microphone Calibration at Low Frequencies p23
R G Barham

Conference and Meeting Reports

- Recent Advances in Underwater Acoustics, p24
Weymouth, May 1991

Group and Branch Reports

- London Branch p25
Southern Branch
Eastern Branch
Speech Group

News from the Industry

- New Products p29
News Items p30

The Institute of Acoustics was formed in 1974 through the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is the premier organisation in the United Kingdom concerned with acoustics. The present membership is in excess of one thousand seven hundred and since 1977 it has been a fully professional Institute. The Institute has representation in many major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental, industrial and architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration.

Institute Council

Honorary Officers

President

M S Ankers FIOA
(Manchester City Council)

President Elect

Professor P D Wheeler FIOA
(University of Salford)

Immediate Past President

Professor C G Rice FIOA
(ISVR)

Hon Secretary

Dr D C Hothersall FIOA
(University of Bradford)

Hon Treasurer

G Kerry FIOA
(University of Salford)

Vice Presidents

Dr W A Ainsworth FIOA
(University of Keele)

Professor P Lord FIOA
(University of Salford)

Dr B V Smith MIOA
(University of Birmingham)

Ordinary Members

S C Bennett FIOA
(British Coal)

B F Berry MIOA
(NPL)

Dr R C Chivers FIOA
(University of Surrey)

Dr R K Moore FIOA
(RSRE)

Dr P A Nelson MIOA
(ISVR)

Dr R G Peters FIOA
(NESCOT)

Dr B E Richardson MIOA
(University of Wales)

Ms S Ridler MIOA
(Arup Acoustics)

A D Wallis MIOA
(Cirrus Research)

Secretary

C M Mackenzie

Institute Sponsor Members

Council of the Institute is pleased to acknowledge the valuable support of these organisations

Key Sponsors

Bruel & Kjaer (UK) Ltd
Harrow, Middlesex

Cirrus Research Ltd
Hunmanby, N Yorks

Hakuto International (UK) Ltd
Waltham Cross, Herts

Lucas CEL Instruments
Hitchin, Herts

Sponsoring Organisations

Acoustic Consultancy Services
Glasgow

Admiralty Research Establish-
ment
Portland, Dorset

Aptec Computer Systems
Guildford, Surrey

Atmospheric Control
Manchester

Sandy Brown Associates
London

Burgess - Manning
Ware, Herts

EMCO Acoustics
Hayes, Middlesex

Gracey & Associates
Chelveston, Northants

Hann Tucker Associates
Woking, Surrey

LMS UK
Cheddar, Somerset

Loughborough Sound
Images
Loughborough, Leics

Mandoval Coatings Ltd
Nr Worksop, Notts

Monitor Acoustic Control
Glasgow

Morison & Miller Engi-
neering
Rutherglen, Glasgow

Oscar Faber Acoustics
St Albans, Herts

Redland Plasterboard
Horsham, W. Sussex

Scientific Atlanta
King's Langley, Herts

Zonic A & D Europe
Basingstoke, Hants

Applications for Sponsor Membership of the Institute should be sent to the Institute office. Details of the benefits will be sent on request.



Dear Fellow Member

It is a pleasure to welcome four new Sponsoring Organisations, Acoustic Consultancy Services, Burgess - Manning (incorporating Quietflo Engineering), Oscar Faber Acoustics and Zonic A & D Europe. The support our Sponsor Members offer us is very much appreciated by Council.

The down side of the otherwise widely welcomed decision of Council to produce six rather than four issues of the Bulletin each year is that I now have to increase the production of these letters by a corresponding 50%. Normally, I am not lost for words but my last letter covered many of our recent activities and I am now short of material!

I have therefore taken to looking back through previous copies of the 'old format' Bulletins (and its predecessor the IOA Newsletter) of which there were no fewer than 62 issues. I find there are two frequently repeated themes. The first is that successive holders of this office have exhorted the membership to contribute to and participate in the activities of the Institute. The other is that there has been reported a continuous, if occasionally lumpy, process of change in the depth and breadth of those activities. Since 1976 we have seen the establishment or incorporation, and occasionally the demise, of many special interest groups (there are at present seven) and of six active regional branches. The Institute's Diploma in Acoustics and Noise Control has not only become widely recognised, it is now being specified by potential employers. The Certificate of Competence in Workplace Noise Assessment, which was set up only 2 years ago, continues to attract an encouraging level of demand at the Centres accredited by the Institute.

The Institute's office in St Albans has increased somewhat in size through the acquisition of the remainder of the top floor of the rather small, terraced office unit we occupy. Cathy tells me that members are very welcome to visit 75 London Road if they are in the area, but sitting down might present a problem. Much dedicated work, by our staff (including painting and decorating!) and the installation of an auto-switching fax machine and other similar high technology equipment have provided us with a convenient and well-equipped base for our operations.

In order to strengthen the place of the Bulletin in the activities of the Institute, I am pleased to announce that a new Editorial Board has been formed to assume responsibility for all of the Bulletin's content, alas with the exception of the President's letter.....which, as I was saying.....

Best Wishes

Milce Aulic





ECOMAX ACOUSTICS

A major new voice in acoustics

Announcing the merger of Alpha dBk with Hedemora, the REDUC instant acoustic floor makers. The result - ECOMAX ACOUSTICS - now ranks among the leading suppliers of advanced acoustic products for industrial and building applications.

The merger successfully combines two of Europe's foremost acoustic products manufacturers - creating in the process one of the UK's most important providers of noise control solutions to architects and industry. The new enterprise is backed by the extensive resources and R&D facilities of Partek OY - the company's parent and Scandinavia's largest building products group.

With its doubled size and unrivalled expertise, ECOMAX ACOUSTICS is able to offer highly qualified advice on noise control and one of the most impressive product ranges in its field.

The portfolio of quality products includes -

Acoustic flooring Reduc Soundfloor Acoustic ceilings Sportspanel Hi-Clinic Cleansound Graphiti Logo Overture Acoustic walls Softsound	Industrial noise control Tufsound and 1379 panelling Control rooms and cabins Acoustic panel enclosures Doors Noise baffles	General purpose acoustic insulation Soundslab Other acoustic products Silencers Acoustic louvres Acoustic screens Profiled acoustic pads, isolation strips and long-span liner tray insulation
---	--	---

Find out more

For detailed product information or to arrange for free expert advice on noise control - and for copies of our new literature covering the complete Ecomax Acoustics range

**Ring (0494) 436345
or Fax (0494) 465274**

For specific information on Reduc Instant Acoustic Flooring and on Control Rooms

**Ring (0536) 201818
or Fax (0536) 201113**

or write to -
ECOMAX ACOUSTICS Ltd.
Gomm Road,
High Wycombe,
Bucks HP13 7DJ

OUTDOOR SOUND PROPAGATION - THE SOUND FIELD, MICROMETEOROLOGY AND TOPOGRAPHY

Tony F W Embleton

Introduction

One might think that sound propagation outdoors was a very simple problem - sound from a point source spreading in a hemispherical space above a more or less flat ground - but reality is far more interesting. The ground may not be flat, all grounds have finite acoustical impedance though some may be hard like concrete or soft like snow, and the atmosphere near the ground is horizontally stratified and is almost always turbulent. Many have contributed to this field over the years and a review can only touch on a few of the highlights.

Measurements of sound propagation outdoors go back at least to the 17th century. The Rev Dereham was the minister at a church in Upminster. He fired a pistol from his church tower and, with a fellow minister in another church about 5 miles away, measured the difference in time between the arrival of the flash of light and the sound.

In 1728 the speed of sound was measured under the auspices of the Academy in Paris - the value obtained then is within 0.5% of the currently accepted value, and that was 2.5 centuries ago. In the 1860's there was interest in fog signalling for ships. Tyndall in Britain borrowed a steam-driven horn from Joseph Henry - the first curator of the Smithsonian Institution in the United States - and set up his experiment on South Foreland, near Dover. There was considerable discussion with Stokes as to whether the signal was absorbed or scattered by water vapour or fog particles.

During the First World War the interest had shifted to the location of artillery; this is still a matter of interest to the military but today we have smaller and better microphones and do a lot of signal processing. In the 1930's the loss of brilliance of music in concert halls was too much to be explained by the absorption of surfaces. Knudsen noted that the magnitude of this effect was also observable outdoors and depended on the dryness of the air, so he undertook experiments to substantiate this. Meanwhile Kneser produced quantitative theory of absorption by molecular processes, and thus our knowledge of the oxygen-water vapour relaxation was born.

Since the 1960's noise produced by many forms of new and widely used technology, like jet aircraft, powered lawnmowers, and a great increase in motor vehicles has become an important political and social problem. In passing one should note that noise in society is not yet of any real concern in the Third World, although the serious possibility of a noise curfew at a few major airports is beginning to arise.

This past history indicates the range of possible applications of increasing knowledge and that what we have learnt has come from solving specific problems in several very different areas.

Geometrical Spreading and Molecular Absorption

These two mechanisms are always present. Simply stated, sound pressure levels or intensity levels decrease with increasing distance from the source as the available sound energy spreads over a wavefront of ever-increasing area. Depending on the measure used, and the type of sound source, this decrease is basically either 3 or 6 decibels per doubling of distance.

As sound waves propagate through air some of the ordered vibratory motion of the air molecules is converted

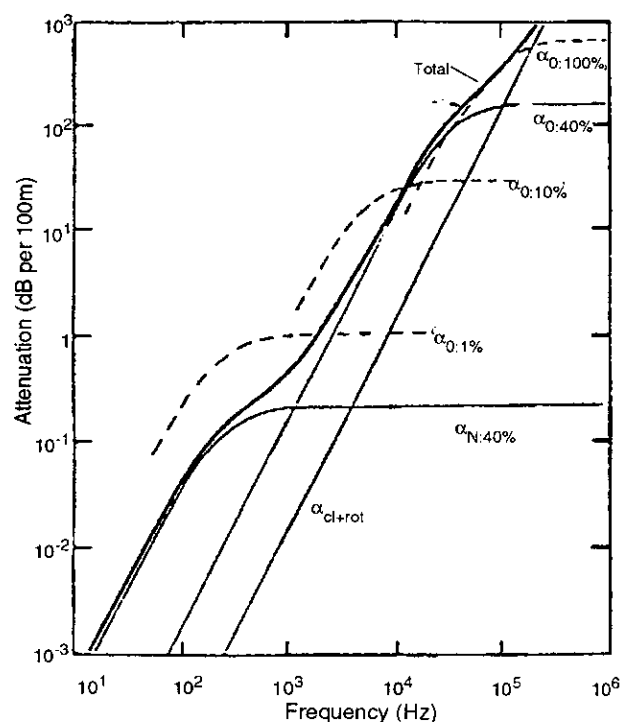


Fig. 1. The attenuation caused by molecular absorption: (---) due to oxygen relaxation at relative humidities of 1, 10 and 100%; (—) due to oxygen and nitrogen relaxations at 40% relative humidity respectively, and for absorption due to thermal, viscous and rotational processes. The thick curve shows the total absorption at 40% relative humidity and 20°C

into internal modes of vibration of the oxygen and nitrogen molecules. Above about 1 kHz the predominant mechanism of molecular absorption of acoustic energy is the oxygen-water vapour relaxation, see Fig. 1. The effect amounts to many decibels per kilometre above about 1 kHz, (the actual frequency depending mainly on relative humidity) and is negligible below that frequency. At frequencies in the range of 100 to 1000 Hz there is a lesser absorption of 1 to 3 dB per km due to the nitrogen-water vapour relaxation.

Reflection at a Flat Ground Surface

When both source and receiver are relatively near the ground, compared to their distance apart, the direct and ground-reflected sound fields are of comparable magnitude, see Fig. 2. Their interference at any point depends both on the difference in path length to the receiver and on the phase change on reflection at the ground. There are often significant phase changes on reflection, be-

the specific impedance ratio for air and ground.

The legacy from before 1940

Let us look now at the major steps leading to our present understanding of the properties of ground surfaces and how they relate to sound fields in air. In 1909 A N Sommerfeld [1] published a paper entitled 'Propagation of waves in wireless telegraphy' in which he dealt with the boundary problem of radiation from an electromagnetic dipole above a flat ground. He divided the theoretical solution into two parts. One was the contribution from geometrical ray theory, and the other was the necessary correction to this that was required by wave theory. Both items are necessary in order to satisfy Maxwell's equations, and later on for us to satisfy the wave equation in acoustics. The electromagnetic literature grew rapidly, but it was not until 1935 that Norton found a sign error in Sommerfeld's earlier work. This was significant because it allowed for the existence of a trapped surface wave,

locked to the ground surface and propagating as a cylindrical wave in the air. Norton's finding partly helped to explain some unusually large values of field strength found earlier by Rolf. It was also in 1935 that Weyl, van der Pol and others were developing theories for the electromagnetic field near a surface that could be dissipative. What we are left with from electromagnetic field theory of the 1930's, apart from the well known Weyl-van der Pol equation, is the idea that the field has three components:

- i) the direct field,
- ii) the reflected field which includes an appropriate Fresnel term to account for wave effects, the component we often call a ground wave, and
- iii) a surface wave, that exists only

under certain circumstances.

In 1947 Rudnick [2] adapted the earlier electromagnetic work to acoustic waves reflected at the plane boundary between two media, when the second medium was either non-absorbing or had a porous-type imaginary impedance. In 1951 Ingard [3] produced theory for the field of a point source near a plane boundary of finite admittance. Also in 1951, Lawhead and Rudnick [4] reported measurements of sound propagation above a locally reacting surface made from a close-packed array of vertically oriented drinking straws.

Acoustical Measurements

During the late 1950's there were several early systematic studies of sound propagation outdoors. Some related directly to ground effects, others included meteorological and other phenomena as well. Two that should be mentioned were both reported in 1959: 'Experimental study of the propagation of sound over ground' by Wiener and

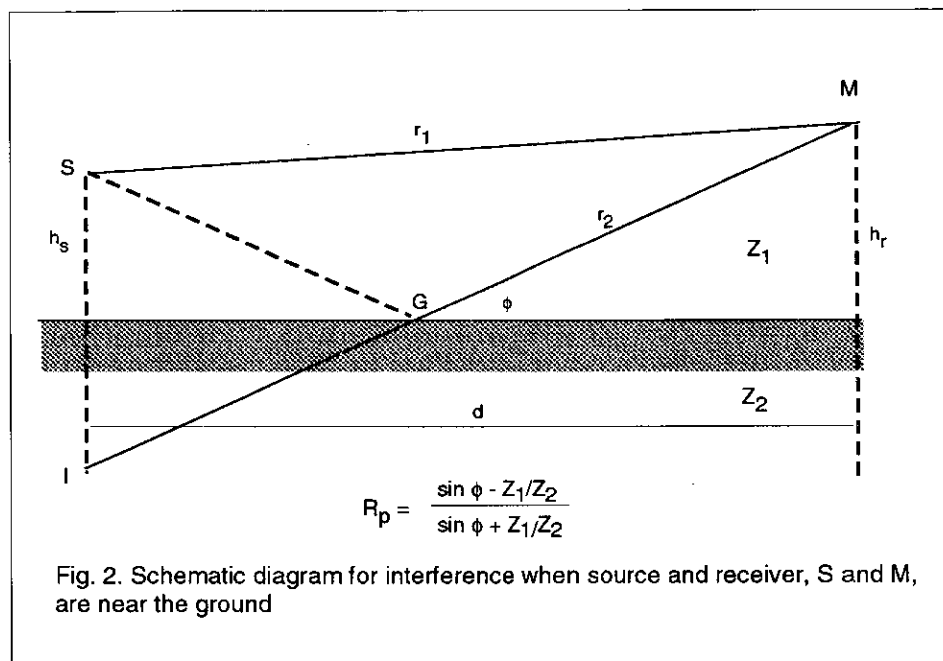


Fig. 2. Schematic diagram for interference when source and receiver, S and M, are near the ground

cause the acoustical impedance of the ground surface is complex and often within 10 or 20 times the characteristic impedance pc for sound waves in air. We now know that all ground surfaces are porous, or if not themselves porous behave as if they are porous, due to the thermal and viscous boundary layer on the surface. Apart from studying the complex impedance of various ground surfaces, these simple facts introduce us to the range of phenomena that have been the object of many studies during the past 25 years. To match boundary conditions, the sound field must include so-called ground waves if the impedance is finite and if there is any curvature in the wavefronts. Furthermore, porosity causes the resulting complex impedance to be 'capacitive' rather than 'inductive', and in most circumstances this leads to trapped surface waves travelling in the air just above the ground. Yet another effect of porosity is to cause the acoustic-to-seismic transfer of energy to be roughly three orders of magnitude greater than one would predict simply from

Keast [5], and 'Ground reflection of jet noise' by Howes [6]. The Wiener and Keast work produced a large body of measurements, including such non-ground effects as propagation between two mountain peaks about 2 miles apart.

In 1964 Parkin and Scholes [7] reported two extensive sets of carefully conducted and well documented field measurements on the horizontal propagation of sound over grass-covered airfields from a jet engine close to the ground. Their source was 1.8 m above the ground, the receiver 1.5 m, and at distances ranging from 35 to 1100 m. They classified results according to wind direction and vertical gradients of temperature. In more recent years we at NRC in Ottawa have often used Parkin and Scholes as a benchmark against which to test our theories or experimental results. One early example relating to ground impedance is interesting, from about 15 years ago.

Figure 3 shows a small sample of Parkin and Scholes' results. The horizontal range is 615 m. Focus your attention on the solid line labelled '0'. The broad dip of reduced sound pressure levels in the frequency range from

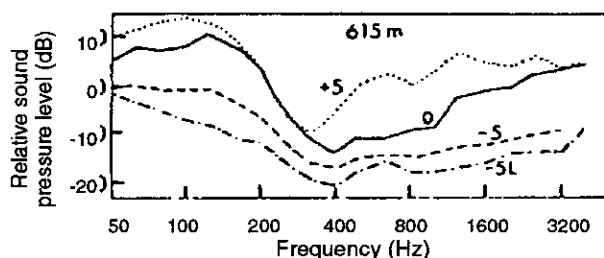


Fig. 3. Typical results for relative sound pressure level spectra [from ref 7] at 615 m range: +5, 0, -5 and -5L represent downwind (5 m/s), zero vector wind, upwind and upwind plus temperature lapse respectively

200 to about 1000 Hz is due to the finite impedance of the grass-covered ground. The strong signal below 200 Hz is due to the acoustic ground wave in air. Note the cut-off frequency of this ground wave, here about 200 Hz. Plotting cut-off frequency vs. distance, Fig. 4 shows consistency between our own results from 20 cm to 20 m and those of Parkin and Scholes from 35 m to 1100 m - a range of distances covering almost 4 decades. The slope of this curve implies that the magnitude of the ground impedance is inversely proportional to the square root of frequency. The position of the curve gives a value for the magnitude of the ground impedance, here about 4 or 5 times ρc for air at 1000 Hz and consistent with other results I shall show later.

Some other early work is that of Tillotson [8] who measured the attenuation of sound over snow-covered fields. He found that the characteristic impedance of fresh snow at 800 Hz was 1.83 times ρc for air and was accompanied by a small capacitive reactance.

1970 marked the onset of considerable increase in activity related to the measurement of ground impedance.

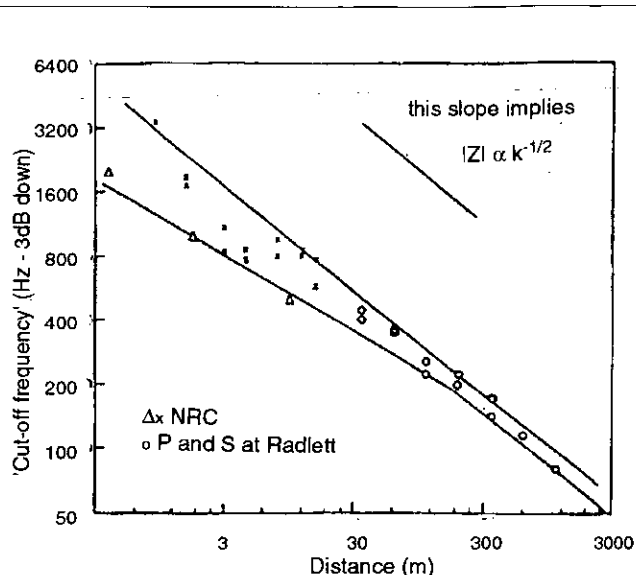


Fig. 4. Cut-off frequency of the ground wave vs distance from the source

People realized that the fact that it was finite, and often not many times greater than the characteristic impedance of sound in air, significantly affected sound levels during propagation outdoors. Evidence included sound barriers that were usually not as effective as predicted, and urban noise levels that were lower than predicted from geometrical spreading and molecular absorption alone.

In 1970 Dickinson and Doak [9] measured the impedance of a grass-covered surface using an impedance tube with a sharp edge pushed into the ground, Fig. 5.

Accurate measurement of ground impedance has proved to be remarkably difficult. Techniques that work well at high frequencies become inaccurate at low frequencies, or vice-versa; some techniques become inaccurate at large impedances or long wavelengths. Real-life environmental problems frustrate attempts to make adequately precise measurements. To illustrate the kinds of problems one can run into I want to quote from Dickinson and Doak's paper in the *Journal of Sound and Vibration*:

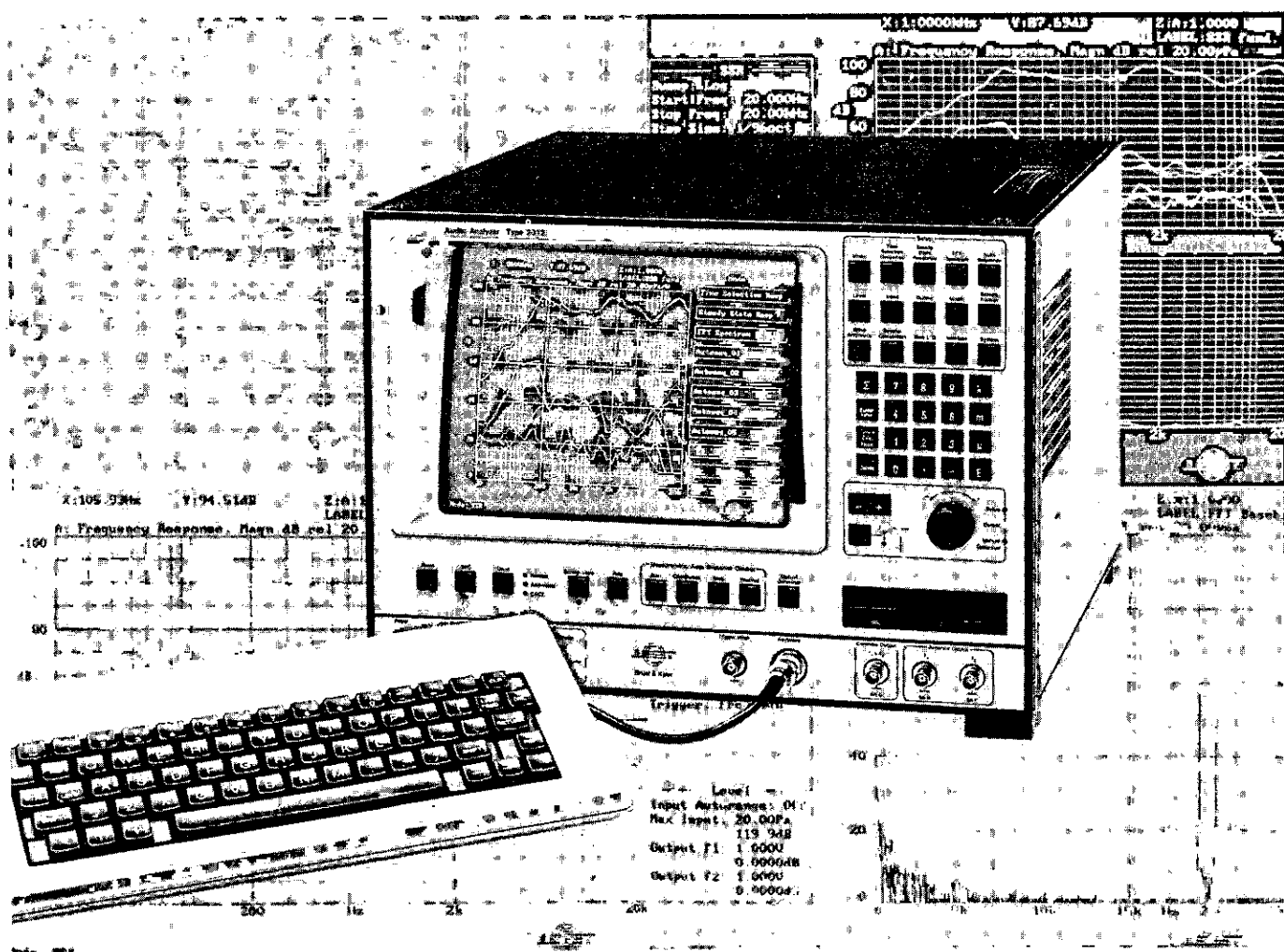
'Condensation quickly formed on the inside of the tube and sound pressures fluctuated throughout its length so that no standing wave could be plotted. After a few days, earth worm casts proliferated inside the tube, although few if any appeared outside, and the soil level inside had risen several millimetres. As a large amount of work was needed to screw the tube into the ground in the first place, this latter phenomenon could not be attributed to a subsidence of the tube itself. It became obvious that the tube severely altered the micro-climatic conditions around the plant, thus perhaps altering the plants' respiration and physical characteristics.'

So they developed another technique based on measuring the pressure profile along a line perpendicular to the surface, below a loudspeaker suspended several meters above the surface. The microstructure of the ground remained undisturbed and the sound field was unconfined. Selecting one typical example of their results, they found both the real and imaginary parts of the spe-



Revolution

introducing a new measurement technique:



Audio Analyzer Type 2012

in Audio Measurements

(SEPA) Serial Excitation – Parallel Analysis

With the new Audio Analyzer Type 2012, Brüel & Kjær introduces a new measurement technique which overcomes the classical limitations regarding choice of filter bandwidth and sweep rate in electroacoustic measurements. The new measurement technique SEPA – Serial Excitation - Parallel Analysis – combines the best of serial and parallel measurement technology. The swept sine excitation provides optimal signal/noise ratio, time and frequency selectivity, and optimal measurement capability for non-linear distortion.

SEPA provides fast and accurate measurement results of linear and non-linear transfer functions. It allows free-field measurements to be made without the need of an anechoic chamber, including selective measurements of harmonic distortion.

The Type 2012 Audio Analyzer also incorporates other innovations. Besides SEPA, the 2012 features two other measurement modes:

The Steady State Response (SSR) mode uses stepped sine excitation and an Adaptive Scan algorithm to measure the complex frequency response in a user definable frequency format. In addition, the SSR mode facilitates measurements of Harmonic Intermodulation and Difference Frequency Distortion. The second mode generates a 1600 line FFT spectrum.

The 2012 is easy to use with an Auto Sequence facility and extensive on-line help facilities. It includes a 3 1/2" disk drive for storage of measurement results. Up to 36 curves can be simultaneously presented on a 12" high-resolution colour monitor.

Although the 2012 has been optimized for electroacoustic measurements, it is also suitable for general signal analysis applications. The 2012 is already *two* steps forward – beyond the barriers of both serial and parallel measurement. Call Brüel & Kjær representative today and ask for a demonstration.

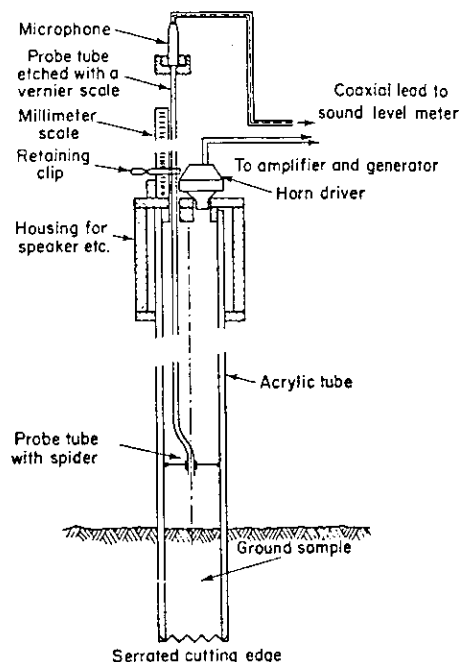


Fig. 5. Schematic diagram of early measurement of acoustic impedance of ground. [From Ref 9]

cific normal impedance ratio for a grass surface to be about four at 1 kHz.

Also in 1970 both Oncley [10] in the U.S. and Delany and Bazley [11] in Britain noted the so-called ground absorption dip at frequencies in the 200 to 600 Hz range for jet engine noise propagating over grass. This agreed with Parkin and Scholes. It was clear that the dip was related to phase changes during reflection at the ground surface, and further progress depended on better understanding of the complex impedance of the ground. It was observed statistically that increased moisture content and freezing in winter lowered the frequency of the ground-absorption dip.

Later Embleton, Piercy and Olson [12] measured the interference between the direct and reflected sound fields of a point source by moving a microphone along an inclined path. This defines a constant angle of reflection and is the three-dimensional analog of the one-dimensional impedance tube. One measures the pressure amplitude as a function of position and calculates the complex value of the ground impedance through the reflection coefficient at that particular angle of incidence. This method allowed measurements at oblique angles of incidence more appropriate to sound sources near the ground but measurements were restricted to frequencies greater than about 400 Hz because the distance between interference minima becomes very large at near-grazing angles of incidence.

In 1983 Zuckerwar [13] used a cavity, with one side of the cavity open and capable of being pushed into the ground surface, to obtain a direct pressure-vs-velocity, and hence impedance, measurement. A motor-driven mechanical source provides a known volume velocity

and a microphone measures the resulting pressure. This technique is restricted to frequencies below about 300 Hz both by the capabilities of the sound source and by the requirement that the sound wavelength be large compared with the dimensions of the cavity. More recently Daigle and Stinson [14] have used a two-microphone technique to measure pressure, phase and phase difference along a vertical line in the spherically spreading interference field below a source suspended several meters above the ground. Measurements in air have been made down to 30 Hz over grass-covered ground, and show some of the ground resonances for grass-covered surfaces that have been measured seismically and are predicted theoretically by Sabatier [15] and by Attenborough [16].

Measured values of the real and imaginary parts of the complex impedance of grass as a function of frequency are shown by the dashed curves in Fig. 6. Remember these are measured in different places, on different soils and different moisture contents. General features are i) the real and imaginary parts are roughly equal, ii) both decrease with increasing frequency, and iii) above about 300 Hz, both are less than about 10 times the characteristic impedance of air.

Theoretical Models

Also on Fig. 6 are several solid curves, again in pairs, one for the real and one for the imaginary part of the impedance. These are derived from some of the one to four parameter models that have been developed to describe ground surfaces.

In 1970 Delany and Bazley [17] developed expressions for the real and imaginary parts of characteristic impedance and of propagation constant for fibrous absorbent materials. These expressions were simple power-

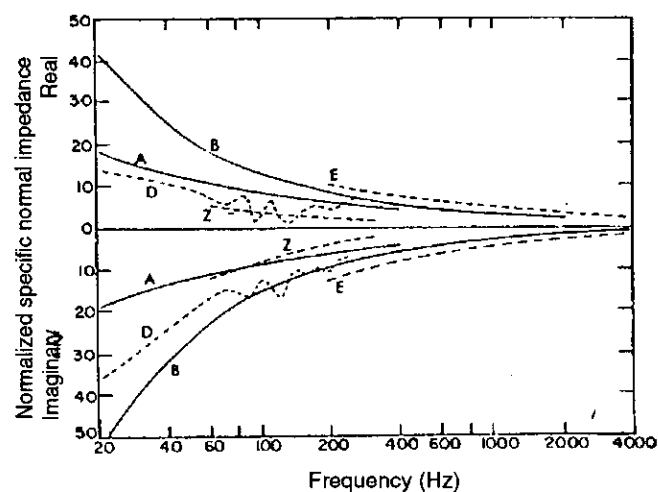


Fig. 6. Real and imaginary parts of normalised specific normal impedance of various grass-covered surfaces: (-----) experimental results from Embleton et al., Daigle & Stinson, and Zuckerwar; (—) predictions from theories by Chessell and by Attenborough.

law functions of a single parameter, namely flow resistance divided by frequency. Chessell [18] showed that Delany and Bazley's theory for fibrous materials also provided a description of the Embleton, Piercy and Olson results for grass-covered surfaces at all frequencies, horizontal ranges, and source and receiver heights. He ascribed an effective flow resistivity to these surfaces of about 200 to 300 cgs rayls (200,000 to 300,000 MKS units). Chessell also matched the field measurements of Parkin and Scholes using a flow resistivity of 150 rayls. Chessell's work provided a great simplification to our picture of surface impedances as a function of frequency.

The one-parameter model in terms of flow resistivity predicts too large a value for both components of ground impedance below about 300 Hz. Also, the one-parameter model requires a value of flow resistivity approximately one half the directly measured value of flow resistivity.

Donato [19] considered the incidence and reflection of spherical waves on a plane surface whose surface impedance was derived from an exponentially increasing or decreasing flow resistivity with depth. In 1977 Thomasson [20] published what was essentially a many-parameter model in terms of material parameters, and an extensive set of field measurements with which there was excellent agreement.

In the early 1980's Attenborough [21] adapted theories on flow in porous materials into several forms that were useful to acoustics. This theory predicts the curves labelled 'A' in Fig. 6. Basically it is a four-parameter theory for which the parameters are flow resistivity, porosity, grain shape factor and pore shape factor. These parameters can be readily understood and one or two of them can be measured directly or calculated simply. For example the effective flow resistivity mentioned earlier, as the parameter in the one-parameter model of Chessell, and Delany and Bazley, is the flow resistivity that one could measure in a flow-resistance apparatus multiplied by the porosity.

In 1980 Bass [22] and his co-workers investigated the surprisingly large signals from airborne sounds using buried geophones. Geophones respond to movement of the ground matrix and the large acoustic-to-seismic transfer function cannot be explained by modelling the ground as a simple homogeneous material having the surface-impedance values actually measured. The currently accepted model has been developed by Sabatier [23], Attenborough [24] and their colleagues. It assumes that the ground is an air filled, porous elastic solid. The model is derived from earlier work by Biot [25]. In very simple terms, the air-filled pores couple very readily with the sound field above the ground and support a slow wave. The solid matrix has much larger elastic constants and so supports a fast wave. Viscous and thermal effects couple these wave types so that they interact.

At low frequencies these wave types are separate and can interfere, have their own wave speeds, attenuation rates and other features. This produces so-called seismic resonances that are generally in the frequency range of about 50 to 200 Hz. These resonances are clearly observable using geophones buried in the ground. As men-

tioned earlier, these resonances have also been observed by Daigle and Stinson as fine structure in the surface impedance of grass-covered ground and its effects on the airborne sound field.

Near-surface Micrometeorology

Refraction

Vertical gradients of wind speed and temperature are usually strong within the first metre of the ground and less so at greater altitudes. It is convenient to think of a horizontally layered atmosphere. When the sound speed increases with height, the sound field curves downwards, as in a temperature inversion (common at night) or during sound propagation downwind. When the sound speed decreases with height the field curves upwards, as in a temperature lapse (a common daytime condition) or during propagation upwind. In this latter case geometrical ray theory suggests that there is a sound shadow beyond a certain distance. Sound levels are reduced in such shadow regions but some sound does penetrate by diffraction especially at low frequencies.

During downward refraction the grazing angle of incidence of the field at the ground surface is increased compared with the situation in an atmosphere of constant sound speed. This reduces the phase changes on reflection and reduces the destructive interference caused by the finite and relatively small values of ground impedance. Sound levels at a distance then increase; that is why the sound of a distant source such as an aircraft on the ground or a train usually sound louder at night than during the daytime. (In the daytime the more common presence of a sound shadow enhances the sound reduction caused by finite ground impedance.) There is also the possibility of multiple sound paths reflected at the ground [26] in addition to the direct field. This leads to sets of reflected paths, each set having different angles of reflection and reflection coefficients, see Fig. 7. This model has been investigated and theoretically can lead to an increase in sound pressure level, compared to a neutral atmosphere, of about 1.5 dB for typical grass surfaces.

These are simple theories that assume constant vertical gradients of sound speed over large areas of open, flat terrain. In practice gradients of wind speed and temperature, and hence sound speed, vary significantly with height and other phenomena such as focussing can occur. This allows much greater increases to occur sometimes at some locations; however focussing on one place is accompanied by defocussing and reduced sound levels in another. In urban areas the presence of buildings changes the wind distribution and creates turbulence behind buildings, uneven temperature distributions occur due to shading of solar radiation, and the concept of a horizontally stratified atmosphere ceases to exist. It is better to assume that, on average, the atmosphere is isotropic at least to the height of the buildings and that sound propagation is dominated by reflection and scattering from the building facades and the ground. In forested areas, beneath the canopy of the foliage, there is very little air motion due to wind and also little selective heating of the ground by radiation, so here also the atmosphere is iso-

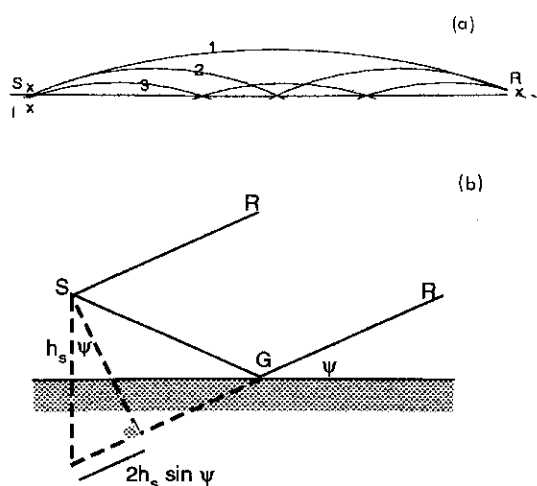


Fig. 7. (a) The multiple ray paths, 1, 2, 3 etc from source to receiver possible during temperature inversion or downwind; (b) the constituents of a source S and its image I that form a composite field associated with one of the ray paths of part (a). The angle ψ is different for each path.

tropic; Price [27] has shown that sound propagation is dominated by scattering from tree trunks and foliage and by the low acoustical impedance of the ground.

Diffraction

Sound propagation involves waves whose wavelengths are often comparable with other linear dimensions involved, for example the heights of source, receiver, a barrier or other scatterer. Furthermore phase relationships are coherent at least over distances of a few metres, even in a turbulent atmosphere, and so adjacent parts of the sound field can mutually affect each other. Processes of diffraction allow sound waves to penetrate across the sharp shadow boundaries predicted by ray theory to an extent that is more pronounced at low frequencies than at high. Thus noise-reducing barriers are more effective at high frequencies, and tree trunks and other small obstacles scatter more sound energy at high frequencies than at low frequencies. Reflection can be regarded as the extreme case of diffraction, for example the side of a building reflects sounds of high frequency whereas low frequency sound can often diffract around the ends of the building or over the roof.

Upward refraction is caused by an atmosphere in which the sound speed decreases with increasing height. Sound therefore travels fastest if it travels through the layer of air that is closest to the ground (the hottest layer). This is the path by which the sound can reach a distant receiver that is relatively close to the ground, including locations deep within the shadow zone. This process involving a 'creeping wave' has been studied recently by Pierce [28]; the sound propagates in a wave near the ground, sound energy is continually shed upwards, and that which is shed at the appropriate point travels along a path predicted by the sound speed structure of the at-

mosphere to reach the receiver location of interest. This path is shown schematically in Fig. 8(e). The strength of the creeping wave, the rate at which it sheds energy, the paths followed, and hence the sound level at any height and distance within the shadow zone can all be predicted.

In recent years so-called fast field programs, FFP, have been adapted from work in underwater sound. When the sound field is known, for example near the source, over some surface, or at a grid of points, the FFP uses fast algorithms to construct the field over related surfaces progressing in sequence further away from the source [29,30]. In this way the whole sound field can be mapped. The FFP can allow for any arbitrary sound speed structure of the atmosphere and any acoustic impedance of the ground surface.

Turbulence

In describing interference, refraction and diffraction of sound waves near the ground it has been assumed implicitly that the sound speed is either the same throughout the field, or if it varies in layers to produce refraction and diffraction then at least it is constant with time. However, the atmosphere is almost always turbulent. Wind-generated turbulence arises as the moving air passes obstacles and temperature-generated turbulence is caused as some patches of ground (and the air layer immediately above them) become either hotter or colder than others; the hot air then rises to be replaced by an inflow of cold air that is sinking elsewhere. This is the 'source region' of large-scale turbulence; its shape, size and occurrence are usually unpredictable. The turbulent flows are unstable and break down into a larger number of smaller eddies, which in turn break down into still more smaller eddies. This cascade process continues, producing a statistically predictable and stable spectrum of eddy sizes, called a Kolmogorov spectrum. Ultimately the turbulent energy is converted into heat as the smallest eddies of the order of a millimetre in diameter dissipate through viscous processes [31,32].

The effect of turbulence on acoustic wave propagation is significant because the size of turbulent eddies is similar to the wavelength of sounds in the frequency range of usual interest. One can consider turbulence as random variations of an otherwise homogeneous propagation medium, which degrade the predictable phase relationships in the sound field. Alternatively one can consider turbulence as a changing random array of scattering vortices. The phase and amplitude of sound waves vary, both with time and with location, and must be described by mean values and standard deviations. In turn, the standard deviations can be related theoretically to the strength and scales of the spectrum of turbulence [33]. As a sound wave propagates through a turbulent medium one would expect the fluctuations to increase with increasing distance. Figure 9 shows the results [32] of such measurements on various occasions, many different distances (up to about 200 m), at various frequencies between about 500 and 5000 Hz; and show that the phase fluctuations (open circles) increase without limit and the measured val-

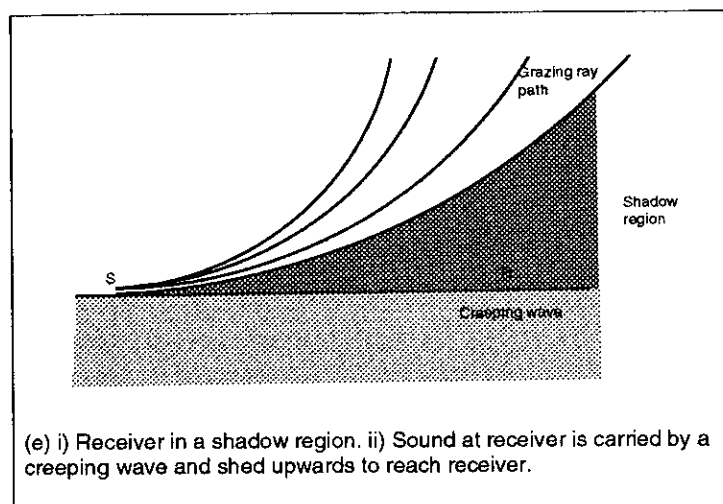
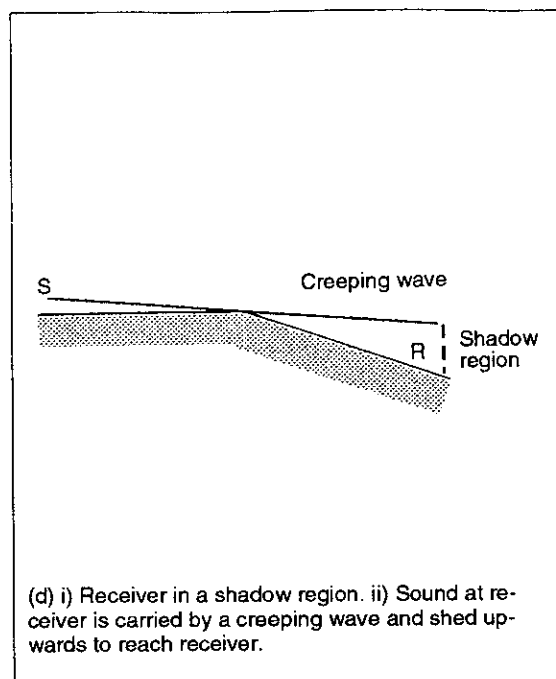
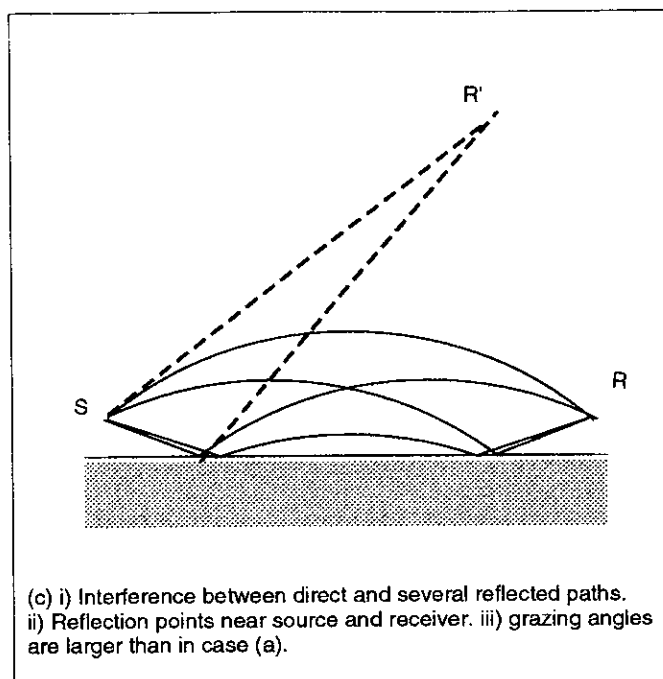
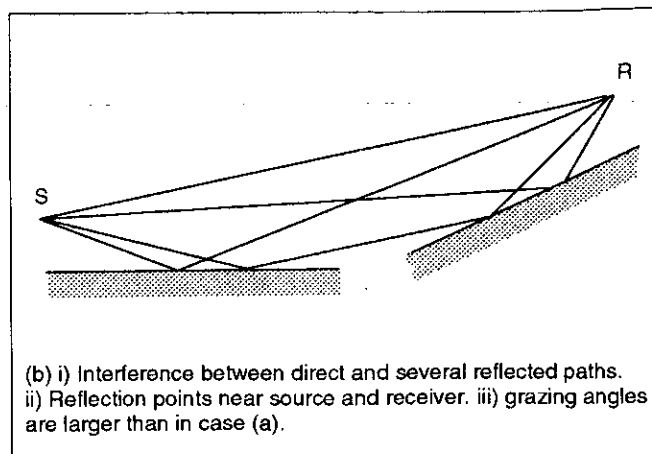
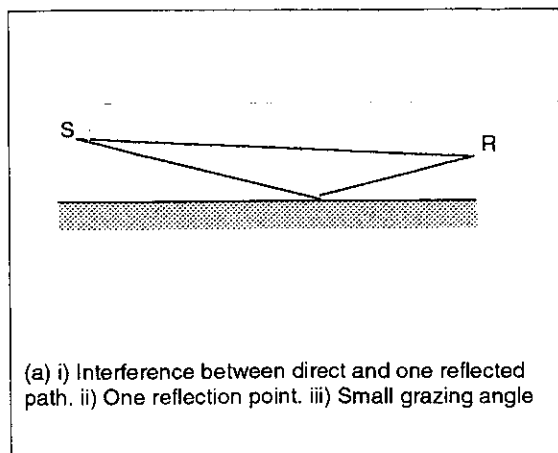


Fig. 8. An analogy based on ray paths: (a) flat ground and an acoustically neutral atmosphere (constant sound speed and straight ray paths); (b) rising hillside and neutral atmosphere; (c) flat ground and downward refraction (analogous to b); (d) falling hillside and neutral atmosphere; (e) flat ground and upward refraction (analogous to d). Both (d) and (e) have shadow regions that can be penetrated by creeping waves.

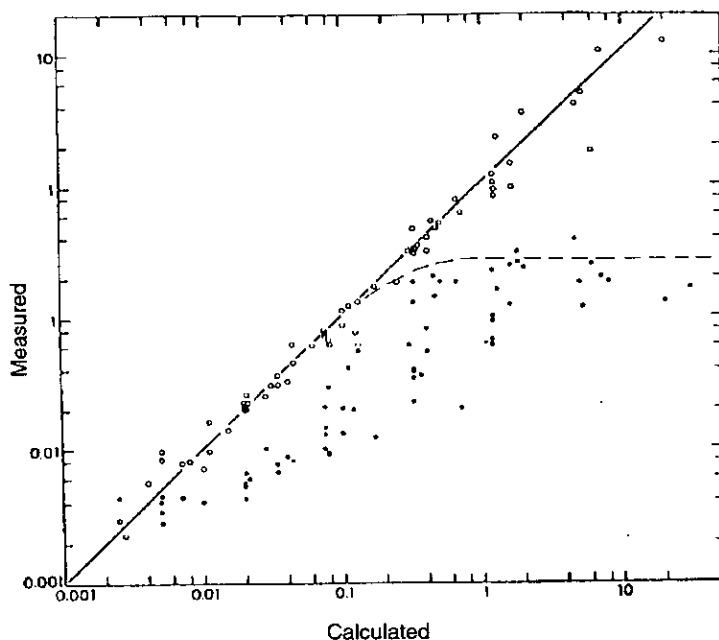


Fig. 9. The measured mean-square log-amplitude (solid points) and phase fluctuations (open points, values are rad^2) vs their calculated values obtained through simultaneously measured meteorological variables related to turbulence. Phase fluctuations increase without limit, log-amplitude fluctuations clearly saturate.

ues agree with those predicted. The measured values of amplitude*fluctuation (solid circles) however are usually smaller than those calculated for the particular circumstances of distance, frequency, and strength of turbulence, and furthermore appear to saturate at a certain limit.

The practical effect of turbulence is to degrade the wave propagation phenomena that depend on exact or constant phase relationships in a sound field. This is particularly noticeable experimentally in shadow regions, or near interference minima. The sound pressure levels, in regions of otherwise reduced sound levels, are increased in a turbulent medium compared to the values predicted for a steady medium (see later in Fig. 11).

Non-flat Terrain

It is difficult to study effects of shape of ground surface (topography) on sound fields under the carefully controlled conditions that are necessary to understand the processes involved. A few measurements have been made at specific sites but in general this work has not been extrapolated to other locations because limits on the validity of extrapolation have not yet been delineated in useful form. However there is a close analogy between a flat ground and curved ray paths in an inhomogeneous atmosphere, and a curved ground surface above which there is an acoustically neutral atmosphere.

Figure 8 describes the analogy; Fig. 8(a) is the basic diagram for a flat ground and neutral atmosphere, there is one ray path designating a single reflection at the ground surface. Figure 8(b) considers the change in this basic concept when either source or receiver is above a

rising hillside, but still in a neutral atmosphere. In general there are now 3 ground-reflected rays of different path lengths, and they have reflection points that are close to the source or receiver. For example, when the receiver is on a hillside 100 m high and 5 km from a source that is about 1 m above the ground, two of the reflection points are 50 to 100 m from the source. This implies that, in the rising-hillside case, the most significant areas of the ground are those relatively near the source and receiver, and that most of the intervening ground may not have much influence on the sound propagation.

Figure 8(c) is the analogy to Fig. 8(b). Both the ray paths and the ground shape are 'bent downwards' compared with Fig. 8(b). The formerly straight ray paths become concave downwards and the ground, formerly concave upwards, becomes flat; this is appropriate for sound propagation either downwind or in a temperature inversion. In both Figs. 8(b) and (c) the grazing angle of reflection is larger than in Fig. 8(a) as shown by the dashed lines in Fig. 8(c). Calculations and a few observations for a hillside 50 to 100 m high at ranges of 4

to 6 km agree reasonably well, both show increases in the A-weighted sound level of a jet engine of 10 to 14 dB.

Figure 8(d) shows the opposite case of a falling hillside, as when source and receiver are separated by the brow of a hill. The receiver is now in a shadow region behind a topographical barrier and direct sound from the source cannot reach it. At this point we must drop the simple-minded picture of ray paths and remember that we are dealing with wave propagation and that sound waves have finite wavelengths. There is a principle of least time that states that some sound energy reaches the receiver via the path that takes the minimum time from source to receiver. This is the so-called 'creeping wave' of diffraction or scattering theory that was described earlier. For the configurations shown in both Figs. 8(d) and (e) this sound energy will travel via the creeping wave above the ground surface and at some point be shed upwards to reach the receiver.

Some carefully controlled measurements carried out over a curved surface in a large building in which the atmosphere was homogeneous and non-turbulent are shown [34], in Fig. 10. The three configurations a, b and c are shown by the small sketch and are respectively above, on, and below the geometric shadow boundary.

The dashed curve in Fig. 10(a) is calculated by assuming a direct and reflected wave, but accounting for reflection from a rigid curved surface: the curve shows the effect of interference due to path-length difference. The short portion of solid curve is calculated from a residual series solution for the creeping wave. The calculation is only carried to ten terms and therefore ceases to

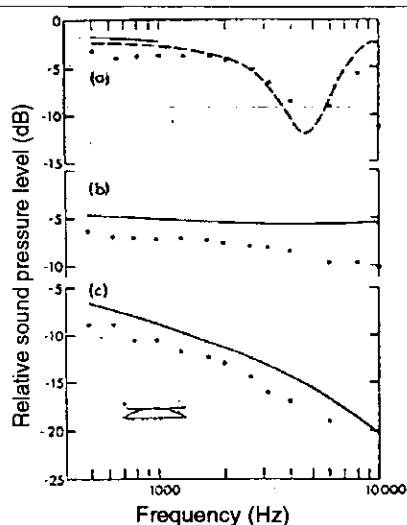


Fig. 10. Relative sound pressure level spectra for propagation over a rigid, acoustically hard, cylindrical surface of radius 5 m. Source-to-receiver distance is about 4 m: (a) (b) and (c) are respectively for the receiver above, on, and below the geometrical shadow boundary. (•) experimental values, (—) creeping wave theory, and (----) simple interference between the direct and reflected waves, using the reflection coefficient for a curved surface.

converge beyond about 1000 Hz. The results in (b) were measured on the limiting ray and the solid curve is creeping wave theory. A systematic discrepancy between theory and experiment is observed in all the results in the vicinity of the shadow boundary. The theoretical calculation has converged at all frequencies and, therefore, adding more terms does not improve the agreement. The discrepancy is still observed below the shadow boundary in 9(c). Deeper within the shadow, however, the theory agrees with all the measurements to within 0.5 dB, and in most cases this agreement is obtained with only one term in the theory.

The results just discussed were for ideal atmospheric conditions, and a rigid hard surface indoors. Outdoors one expects the same theory to apply for similar configurations, but with values for finite ground impedance. Figure 11 shows experimental results (points) for two receiver heights in the shadow region behind a small grass-covered hill of almost perfect cylindrical shape the two sets of points (open and solid) are respectively for two different curvatures of the hill. The dashed curves are predicted for the case of a perfectly hard ground, and the solid curves are the prediction for ground having the typical impedance of a grass-covered surface. There is a discrepancy above about 1 kHz in the lower set of results that was not found indoors. The higher frequencies deep within the shadow are normally where the best agreement is expected and observed indoors. Therefore the origin of the discrepancy at the higher frequencies differs from the one observed close to the shadow boundary in the case of the indoor measurements. It is usually speculated that energy scattered by atmospheric turbulence is contributing to enhance the levels here (as noted earlier in the section on turbulence).

A Final Comment

Barriers

One topic not mentioned either under diffraction of sound fields or under topography is the effect of barriers to reduce the level of sound. The performance of thin barriers impervious to sound can be calculated using any one of several theories of diffraction for thin screens, and the presence of the ground on either side of the barrier should be taken into account. In general terms, the presence of the ground reduces the effectiveness of the barrier in reducing sound, compared with the predicted diffraction loss for the direct path only. Furthermore, in practice one usually does not measure more than about 15 dB of loss however much more is predicted. The above discussion of theoretical predictions, measurements over grass-covered earth berms outdoors and the general agreement between the two, at least down to insertion losses of about 40 dB at high frequencies, indicates that more noise reduction can be achieved with earth berms than with thin barriers, see Fig. 11.

References

- [1] A N SOMMERFELD, 'Propagation of waves in wireless telegraphy', *Ann. Phys. (Paris)* 28, 665, (1909)
- [2] I RUDNICK, 'Propagation of an acoustic wave along a boundary', *JASA*, 19, 348-356, (1947)
- [3] K U INGARD, 'On the reflection of a spherical wave from an infinite plane', *JASA*, 23, 329-335, (1951)
- [4] R B LAWHEAD & I RUDNICK, 'Acoustic wave propagation along a constant normal impedance boundary', *JASA*, 23, 546-549, (1951)
- [5] F M WIENER & D N KEAST, 'Experimental study of the propagation of sound over ground', *JASA*, 31, 724-733, (1959)
- [6] W L HOWES, 'Ground reflection of jet noise', *NACA Tech. Note* 4260, 56 pp, (April 1958)
- [7] P H PARKIN & W E SCHOLES, 'The horizontal propagation of sound from a jet engine close to the ground at Radlett', *J. Sound Vib.*, 1, 1-13, (1964); & '....at Hatfield', *J. Sound Vib.*, 2, 353-374, (1965)

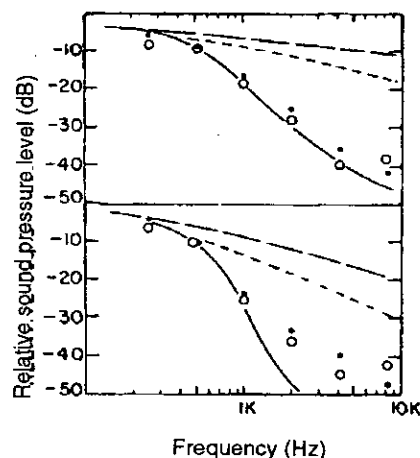


Fig. 11. Results measured outdoors over two cylindrical grass-covered surfaces. (—) creeping wave theory using impedance values for grass surfaces, (----) creeping wave theory assuming an acoustically hard surface, and (— · —) diffraction at an equivalent thin screen.

- [8] J G TILLOTSON, 'Attenuation of sound over snow-covered fields', JASA, 39, 171, (1966)
- [9] P J DICKINSON & P E DOAK, 'Measurements of the normal acoustic impedance of ground surfaces', J Sound Vib., 13, 309-322, (1970)
- [10] P B ONCLEY, 'Low-frequency sound-propagation anomaly', JASA, 47, 389-390, (1970)
- [11] M E DELANY & E N BAZLEY, 'A note on the effect of ground absorption in the measurement of aircraft noise', J. Sound Vib., 16, 315-322, (1971)
- [12] T F W EMBLETON, J E PIERCY & N OLSON, 'Outdoor propagation over ground of finite impedance', JASA, 59, 267-277, (1976)
- [13] A J ZUCKERWAR, 'Acoustic ground impedance meter', JASA, 73, 2180-2186, (1983)
- [14] G A DAIGLE & M R STINSON, 'Impedance of grass-covered ground at low frequencies measured using a phase difference technique', JASA, 81, 62-68, (1987)
- [15] J M SABATIER & H E BASS, 'Resonances in the impedance curves for outdoor ground covers', JASA, 79, S20, (1986)
- [16] K ATTENBOROUGH, 'Airborne sound to seismic coupling: Present understanding', JASA, 82, S76, (1987)
- [17] M E DELANY & E N BAZLEY, 'Acoustical properties of fibrous absorbent materials', Appl. Acoust. 3, 105-116, (1970)
- [18] C ICHESSELL, 'Propagation of noise along a finite impedance boundary', JASA, 62, 825-834, (1977)
- [19] R J DONATO, 'Impedance models for grass-covered ground', JASA, 61, 1449-1452, (1977)
- [20] S-I THOMASSON, 'Sound propagation above a layer with a large refractive index', JASA, 61, 659-674, (1977)
- [21] K ATTENBOROUGH, 'Acoustical characteristics of rigid fibrous absorbents and granular materials', JASA, 73, 785-799, (1983)
- [22] H BASS et al, 'Coupling of airborne sound into the earth: Frequency dependence', JASA, 67, 1502-1506, (1980)
- [23] J M SABATIER et al, 'The interaction of airborne sound with

- the porous ground: The theoretical formulation', JASA, 79, 1345-1352, (1986)
- [24] K ATTENBOROUGH et al, 'The acoustic transfer function at the surface of a layered poroelastic soil', JASA, 79, 1353-1358, (1986)
- [25] M A BIOT, 'Theory of propagation of elastic waves in a fluid-saturated porous solid', JASA, 28, 179-191, (1956)
- [26] T F W EMBLETON et al, 'Propagation in an inversion and reflections at the ground', JASA, 59, 278-282, (1976)
- [27] M PRICE, 'Sound attenuation in woodland', PhD Thesis, Open University, Milton Keynes, UK, (1986)
- [28] A D PIERCE, 'Acoustics: An introduction to its physical principles and applications', (McGraw-Hill), Chapter 9, 'Scattering and diffraction', 424-507, (1981)
- [29] T L RICHARDS & K ATTENBOROUGH, 'Accurate FFT-based Hankel transforms for predictions of outdoor sound propagation', J. Sound Vib., 109, 157-167, (1986)
- [30] S W LEE et al, 'Impedance formulation of the fast field program for acoustic wave propagation in the atmosphere', JASA, 79, 628-634, (1986)
- [31] P A MANDICS, 'Line-of-sight acoustical probing of atmospheric turbulence', Tech. Rep. 4502-1, Radio Science Lab., Stanford University, USA, (1971)
- [32] G A DAIGLE et al, 'Line-of-sight propagation through atmospheric turbulence near the ground', JASA, 74, 1505-1513, (1983)
- [33] R F LUTOMIRSKI & H T YURA, 'Wave structure function and mutual coherence function of an optical wave in a turbulent atmosphere', J. Optical Soc. Am., 61, 482-487, (1971)
- [34] A BERRY & G A DAIGLE, 'Controlled experiments of the diffraction of sound by a curved surface', JASA, 83, 2047 - 2058, (1988)

This article is based on the 1989 R W B Stephens Lecture. The author was formerly at the National Research Council of Canada ♦

SENIOR ACOUSTICS ENGINEER

Salary range £16k - £25k

BREL - THE ONLY ORGANISATION WITH OVER 150 YEARS OF EXPERIENCE IN THE MANUFACTURE, REPAIR AND MAINTENANCE OF HIGH QUALITY RAILWAY STOCK AND EQUIPMENT. A DYNAMIC COMPANY OPERATING AS TWO KEY GROUPS - THE NEW CONSTRUCTION GROUP AND THE MANUFACTURE & REPAIR GROUP.

A VERSATILE ACOUSTICS ENGINEER IS REQUIRED TO JOIN A SMALL TEAM RESPONSIBLE FOR ALL ASPECTS OF THE ACOUSTIC DESIGN OF RAILWAY VEHICLES. THE WORK INVOLVES INTERPRETATION OF CUSTOMER REQUIREMENTS, THEORETICAL ANALYSIS AND PRACTICAL NOISE AND VIBRATION CONTROL.

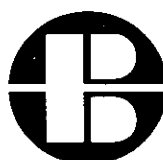
A THOROUGH UNDERSTANDING OF THE PRINCIPLES OF ACOUSTICS AND VIBRATION ISOLATION IS ESSENTIAL. THE SUCCESSFUL CANDIDATE SHOULD BE CAPABLE OF APPLYING

THESE PRINCIPLES TO A WIDE RANGE OF SITUATIONS AND SHOULD HAVE BROAD-BASED ACOUSTICS EXPERIENCE, NOT NECESSARILY IN THE RAILWAY INDUSTRY.

A FORMAL ACOUSTICS QUALIFICATION OR MEMBERSHIP OF THE INSTITUTE OF ACOUSTICS IS DESIRABLE BUT NOT ESSENTIAL.

AN ATTRACTIVE FINANCIAL PACKAGE IS OFFERED WITH THE OPPORTUNITY, IN CERTAIN CASES, TO TRANSFER EXISTING PENSION RIGHTS. THERE IS ASSISTANCE AVAILABLE, IN APPROVED CASES, WITH RELOCATION EXPENSES TO THE DERBY AREA.

PLEASE SEND YOUR CV TO COMPANY PERSONNEL MANAGER, BREL LIMITED, ST PETER'S HOUSE, GOWER STREET, DERBY DE1 1AH. BREL OPERATES AN EQUAL OPPORTUNITIES POLICY.



BREL LIMITED

MEETING NOTICE

MODERN MEASUREMENT TECHNIQUES FOR ENVIRONMENTAL NOISE & VIBRATION

18 September 1991

South Bank Polytechnic

09.45 *Registration & coffee*

10.10 Welcome by the Chairman, Professor H G Leventhall FIOA

10.15 EXPONENTIAL OR LINEAR AVERAGING - DOES IT MATTER?

A Miles, Lucas CEL Instruments Ltd

10.45 ROLE OF SHORT-TERM L_{Aeq} IN PROBLEM AREAS OF ENVIRONMENTAL NOISE MEASUREMENT

B F Berry MIOA, NPL & A D Wallis MIOA, Cirrus Research Ltd

11.15 *coffee*

11.30 A COMPREHENSIVE SYSTEM FOR ENVIRONMENTAL NOISE ANALYSIS

D Marsh FIOA, Industrial & Marine Acoustics Ltd

12.00 MODERN TECHNIQUES FOR VIBRATION MEASUREMENT

R J Peters FIOA, NESOT

12.30 *lunch*

14.00 AUTOMATIC NOISE SOURCE IDENTIFICATION

I H Flindell MIOA and P Wright, ISVR

14.30 REMOTE MONITORING MADE LESS REMOTE

C P Stollery AMIOA, Cirrus Research Ltd

15.00 *tea*

15.30 SUITABLE MEASUREMENT PERIODS FOR ENVIRONMENTAL NOISE

J P Sellar MIOA

16.00 Discussion

MEASUREMENT TECHNIQUES

Please register me as a delegate

Name:

Organisation:

Address:

Tel no. for contact

I enclose a cheque for the meeting fee of ☐ £75 + £13.12 VAT= £88.12 (members) or ☐ £90 + £15.75 VAT= £105.75

Please invoice me for the meeting fee of ☐ £75 + £13.12 VAT= £88.12 (members) or ☐ £90 + £15.75 VAT= £105.75

I shall not attend. Please send a copy of the Proceedings: a cheque is enclosed for ☐ £20 (members) or ☐ £27

Return to the Institute of Acoustics, PO Box 320, St Albans AL1 1PZ Tel 0727 48195, Fax 0727 50553

Joint IOA/IOP Physical Acoustics Group Meeting DEVELOPMENTS IN ACOUSTICS AND ULTRASONICS

24 - 25 September 1991

University of Leeds

This meeting seeks to present to delegates an overview of progress in acoustics and ultrasonics in the physical, medical, biological, chemical, food and oceanographic sciences. Developments in physical acoustics and ultrasonic methods are increasingly taking place outside the traditional physics and electronic engineering environments from which they originally emerged. Many disparate disciplines now employ these techniques, frequently causing them to develop further. Since each discipline has developed ultrasound techniques as a tool to another end, rather than as an end in itself, these developments are in danger of not being communicated beyond a small circle. This meeting is designed to counter this.

The draft programme includes the following contributions:

Ultrasound measurements in high T_c superconductors/Evaluation of the kinetics of complex reactions in solution using ultrasonic relaxation methods/Ultrasound propagation in heterogeneous biological materials/Broad-band techniques for the ultrasonic study of materials/Ultrasonic velocity and attenuation studies of bones/Ultrasound Doppler flow measurement/Acoustic scattering and shoals of fish/Ultrasound developments in the study of foods/Ultrasound measurement in meat/New directions for ultrasound/Ultrasonic measurement of cleaning in emulsions/What do ultrasound measurements in fruit and vegetables tell you?/An overview of ultrasound scattering in dispersed systems/ Accuracy in ultrasound measurement

For further information contact: Malcolm Povey or Julian McClements, Department of Food Science, The University, Leeds LS2 9JT. Tel/Fax: 0532 332980

INSTITUTE MEETINGS

September 13

Speech Group Meeting
NEURAL NETWORKS
BT, Martlesham Heath

September 18

IOA Formal Meeting
MODERN MEASUREMENT
TECHNIQUES FOR ENVIRONMENTAL NOISE
South Bank Polytechnic

September 18

London Branch Meeting
DRAFT CoP - OFF ROAD
MOTOR CYCLE NOISE

September 24 - 25

IOA/IOP Physical Acoustics
Group
ANNUAL REVIEW OF
PROGRESS IN PHYSICAL
ACOUSTICS & ULTRASONICS
University of Leeds

October 16

Eastern Branch Meeting
Dr Roy Patterson, lecture

October 16

London Branch Meeting
MITCHELL REPORT & AGM

October 16

Joint IOA/IOP Meeting
UNSTEADY COMBUSTION &
COMBUSTION/ACOUSTIC
INTERACTION
University of Hull

October 21

IOA Formal Meeting
RAILWAY NOISE & VIBRATION
English Speaking Union, London

October 31 - November 3

REPRODUCED SOUND 7
Hydro Hotel, Windermere

November 13

Eastern Branch Meeting & AGM

November 13

London Branch Dinner
The National Theatre

November 21 - 24

AUTUMN CONFERENCE,
NOISE IN THE NINETIES -
A QUIETER BRITAIN?
Hydro Hotel, Windermere

December 11

London Branch Meeting
SAFE WITH SOUND

1992

January

PC PROGRAMMES IN
ACOUSTICS
London

May 19

Institute AGM

September 14 - 18

IOA International Conference
EURONOISE 92
Imperial College London

CALL FOR PAPERS

SOUND '92

Heathrow Penta Hotel
February 1992

Organised by the
Institute of Sound and
Communications Engineers

Contributions are invited for technical papers of 30-minutes duration on the following topics:

- Audio Measurement
- Acoustic Measurement
- Sound System Design for Public Places
- Case Histories of Sound Systems for Public Places

Abstracts of 60 words by
31 August 1991 or requests for
further information to:-

Institute of Sound and
Communications Engineers
4B High Street
Bumham,
Slough SL1 7JH
Tel: 0628 667633
Fax: 0628 665882

MEETING NOTICE

RAILWAY NOISE AND VIBRATION

21 October 1991

English Speaking Union, Dartmouth House, London

09.45 *Registration & coffee*

10.30 PREDICTION AND ASSESSMENT OF GROUNDBORNE NOISE FROM UNDERGROUND RAILWAYS

J G Walker (1) & S A Ridler (2), (1) ISVR, Southampton, (2) Arup Acoustics

11.00 DEVELOPMENT OF A NOISE SPECIFICATION FOR DIESEL LOCOMOTIVES

A E J Hardy, British Railways Board

11.30 NOISE AND VIBRATION FROM LUDGATE RAILWAY WORKS

C J Manning, Arup Acoustics

12.00 COMMUNITY RESPONSE TO NOISE FROM THE DOCKLANDS LIGHT RAILWAY

B Shields, L Matthews & A Zhukov, South Bank Polytechnic

12.30 *lunch*

14.00 RAILWAY NOISE - CALCULATION AND MEASUREMENT

G Rock, Somerset Scientific Services

14.30 VIBRATIONS AND NOISE FROM TRAINS IN TUNNELS

R Hood & R Greer, Ashdown Environmental

15.00 *tea*

15.30 A STUDY OF RAIL NOISE AFFECTING NEARBY RESIDENCES

R Heng, Sheffield City Polytechnic

16.00 PLANNING AND DESIGN OF NEW RAILWAYS - NOISE AND VIBRATION CONTROL

R M Taylor, Consultant

RAILWAY NOISE AND VIBRATION

Please register me as a delegate

Name:

Organisation:

Address:

Tel no. for contact

I enclose a cheque for the meeting fee of ☐ £75 + £13.12 VAT= £88.12 (members) or ☐ £90 + £15.75 VAT= £105.75

Please invoice me for the meeting fee of ☐ £75 + £13.12 VAT= £88.12 (members) or ☐ £90 + £15.75 VAT= £105.75

I shall not attend. Please send a copy of the Proceedings: a cheque is enclosed for ☐ £20 (members) or ☐ £27

Return to the Institute of Acoustics, PO Box 320, St Albans AL1 1PZ Tel 0727 48195, Fax 0727 50553

CALLS FOR PAPERS

REPRODUCED SOUND 7

Hydro Hotel, Windermere, 31 October - 3 November 1991

(In collaboration with SCIF, AES, ABTT and APRS)

Incorporating an International Seminar on COMPUTER AIDED DESIGN OF SOUND SYSTEMS

Formal & Poster Sessions on

Broadcasting and Motion Picture Sound Developments

Listening versus Measurement - Exploring the Mythology

Electromagnetic Compatibility and the 1992 Regulations

Transducer Developments at Both Ends of the Sound Reproduction Chain

Advances in the Technology and Practical Applications of Digital Sound

Invited speakers include Martin Colloms and Bob Stuart

Offers of contributions with 100 word abstracts to the Programme Committee Chairman, Dr Malcolm Hawksford FIOA, Department of Electronic Systems Engineering, University of Essex, Wivenhoe Park, Colchester CO4 5SQ.

NOISE IN THE NINETIES: A QUIETER BRITAIN?

Hydro Hotel, Windermere, 21 - 24 November 1991

Formal & Poster Sessions on

Issues Arising from the Batho Report

Entertainment and Neighbourhood Noise

Criteria for the Assessment of Environmental Noise (eg Inaudibility Re-visited?)

Revision of BS 4142 (Comparisons, Case Studies)

Sound Insulation in Buildings (10/73, Building Regulations, Construction Techniques, Test Methods)

EC Directives on Machinery Noise, and Techniques for Controlling Noise

Transportation Noise (Including Railway Noise and the Mitchell Report)

Problem Areas (eg Background Noise Measurements, Low Frequency and Impulsive Noise)

New Techniques for Predicting, Monitoring and Controlling Environmental Noise

Offers of contributions with 100 word abstracts to the Conference Organiser: Jeff G Charles FIOA, Bickerdike Allen Partners, 121 Salusbury Road, London NW6 6RG. Programme Committee Chairmen: Dr L Fothergill FIOA (Building Acoustics Group) and Dr R J Peters FIOA (Industrial Noise Group).

PC PROGRAMMES IN ACOUSTICS

London, January 1992

Topics include

Data Collection and Manipulation

Prediction for Road Traffic, Railway and Aircraft Noise

Sound Insulation and Sound Power Measurement

Environment Noise Monitoring

General Utilities for Acousticians

Offers of contributions with 100 word abstracts to the Meeting Organiser: John Seller MIOA, Institute of Environmental Engineering, South Bank Polytechnic, Borough Road, London SE1 0AA

Contributions of sufficient technical merit presented in both formal and poster sessions in each of the above will be published in Volumes 13 or 14 of the Proceedings of the Institute of Acoustics (1991,2) and available to delegates on arrival.

The Use of Impulsive Excitation Test Methods to Evaluate the Performance of Underwater Viscoelastic Acoustic Coatings

D J Townend

Introduction

Underwater acoustic coatings have many uses in both military and civilian applications. Frequencies of interest span many decades stretching from a few tens of Hertz to greater than 1 MHz. The majority of these coatings are based on a polymeric matrix, and as a result, the acoustic properties are frequency and temperature dependent. Mathematical models have been developed to predict the acoustic performance of complex multilayer systems but the coating designer also needs accurate measurements, made under controlled laboratory conditions, to validate his computer predictions.

In principle, measurements at high frequencies are straightforward, wavelengths are short, diffraction effects are minimal and adequate time domain resolution can be achieved in small test tanks. However at low frequencies measurements become more difficult. Diffraction effects cannot be ignored and in restricted volumes of water multipath reflections make it difficult to isolate the signals of interest. Whilst measurements can be carried out under free field conditions, sea trials are expensive and they require expensive test panels of large lateral dimensions to minimise diffraction effects. Sea state conditions and temperature are beyond the control of the operator and such trials are only used to validate the performance of fully optimised coatings.

At ARE (HH) a number of methods for evaluating coating performance have been developed, both for free field and laboratory measurement. This paper will confine itself to two laboratory techniques. The first of these is the pulse tube and the second is a high frequency parametric array.

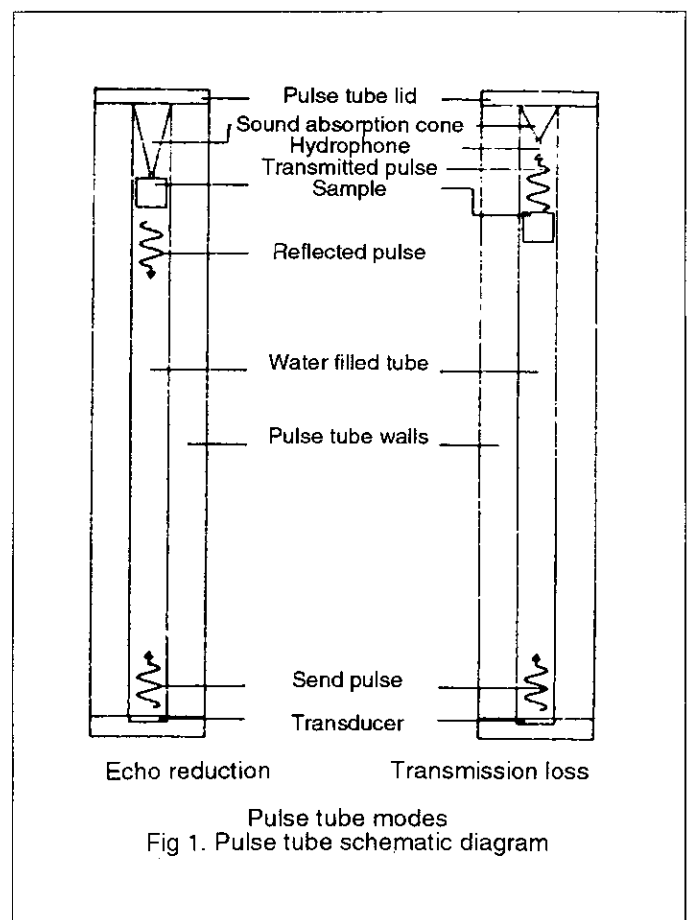
Pulse Tube Measurement

During the second world war the Germans realised that submarines could be camouflaged against an active sonar threat by coating the outside of the submarine with an 'anechoic' coating. These early, resonant cavity, coatings were code named 'Alberich' after a mythological dwarf whose magic hat rendered him invisible. In order to evaluate the performance of these coatings the Germans developed the first pulse (or impedance) tubes. These were simply long steel tubes with a projector (used in the send/receive mode) at one end, with the sample introduced at the other end. By measuring the signal reflected from the sample and comparing this with the signal reflected from a perfect reflector (the air interface at the top of the tube) it was possible to calculate the reflection coefficient or echo reduction ER) for the sample.

The major advantage of the pulse tube is that it

behaves as an acoustic wave guide. Below the cut-off frequency (determined by the diameter of the tube) only a plane compressional wave will propagate [1]. Provided the steel walls are massive the effects of tube wall compliance are negligible [2]. The temperature of the water in the tube can be controlled by the addition of a cooling/heating jacket and the tube can be pressurised to simulate deep immersion.

Figure 1 shows a schematic diagram of a typical pulse tube configuration. As well as measuring the ER of samples it is also useful to be able to measure the transmission (or insertion) loss (TL). At low frequencies all materials that are thin compared to a wavelength will have low reflection coefficients (high ER) because most of the incident energy penetrates the sample (ie TL is low). This will happen irrespective of whether the sample is designed as an absorber or not. By summing the transmission and reflection coefficients a measure of the energy dissipated by the sample can be deduced. With a lossless sample the sum of these two coefficients will of



course be unity. The terminating cone at the top of the tube is present to absorb any energy transmitted through the sample to prevent it being reflected from the top of the tube and being re-transmitted back through the sample to interfere with the signal of interest reflected from the front face of the sample. This effect poses the first limitation on the low frequency performance of the tube. It is not possible to manufacture a termination that has adequate absorption at very low frequencies and interference between the signal reflected from the front face of the sample and the signal reflected from the top of the tube results in a measured ER that is a composite answer for the sample and cone combined. This effect can become a major problem at frequencies lower than 1 kHz.

In order to overcome this limitation the measurement technique has been modified. Hydrophones have been embedded in the wall of the tube at points $1/3$, $1/2$ and $2/3$ along its length. The sample is suspended on a nylon monofilament thread just below the top hydrophone ie some distance down the tube. The absorbing cone is dispensed with so that the reflection from the top of the tube is clearly defined. The transducer at the bottom is now only used as a projector. The top hydrophone is used to monitor the signal transmitted through the sample whilst the bottom hydrophone monitors the incident and reflected signals. The signals from these two hydrophones are sampled with 16-bit precision and time domain averaging is used to improve the signal to noise ratio. By using a $1/10$ th cosine taper window arbitrarily positioned on the traces the incident, reflected and transmitted components can be isolated from the bottom and top hydrophone signals. After transformation to the frequency domain the transmission loss and echo reduction can then be computed, the need for blank measurements from a perfect reflector is eliminated and since the ER and TL values are derived from the same incident signal, accu-

racy and consistency are greatly improved.

Excitation Signals

When acoustic measurements are made in pulse tubes or small water tanks high time domain resolution, ie signals that are short in duration, is required to enable incident reflected and transmitted signals of interest to be isolated from unwanted multipath reflected and diffracted signals. With traditional techniques using tone bursts the reflection coefficient was calculated by dividing the peak amplitude in the reflected tone burst and comparing it with the peak level of the signal reflected from a perfect reflector, eg an air interface. Figure 2 illustrates the limitations imposed by this method.

Figure 2 shows high (~ 5 kHz) and low (~ 1 kHz) frequency incident and reflected tone bursts measured in the ARE pulse tube. It can be seen that for the high frequency signal, steady state conditions have been achieved for both incident and reflected components and a value for the reflection coefficient can be computed. However for the low frequency signal, steady state conditions have not been achieved for the reflected component. Incident and reflected signals are starting to overlap and it is becoming difficult to separate the two components. The reflected signal cannot be used to give a meaningful answer for the reflection coefficient of the sample and the low frequency limit of resolution for the tube has been reached. Apart from limited low frequency resolution, a tone burst only yields an answer at one frequency therefore it is necessary to repeat the experiment at many other frequencies to obtain a wide frequency range plot of acoustic performance.

Acoustic coatings of whatever type may be regarded as low pass, high pass or band pass acoustic filters and the properties of interest, eg ER or TL, are fully defined by their impulse response in the time domain or by their

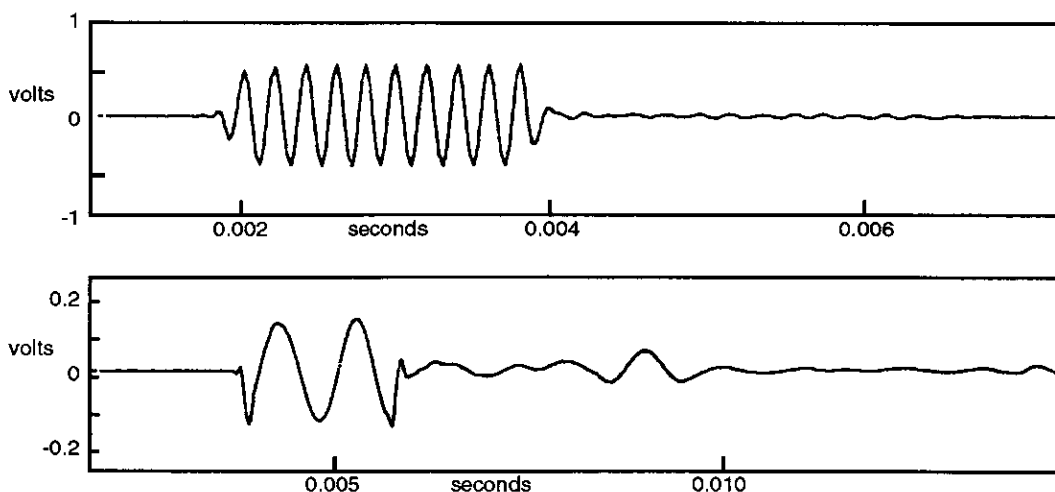


Fig 2. High and low frequency tone bursts

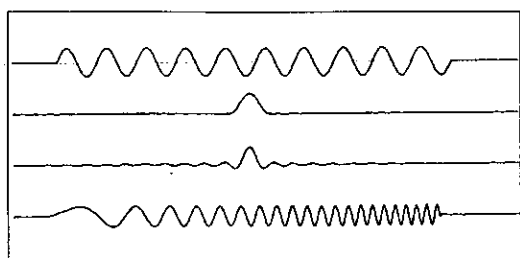


Fig. 3. Various time domain excitation signals. From the top: tone burst, haversine, $\sin x/x$, chirp.

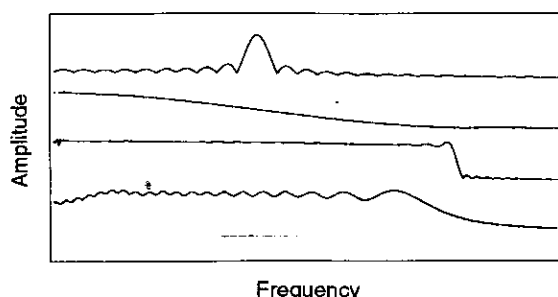


Fig. 4. Spectra of various excitation signals. From the top: tone burst, haversine, $\sin x/x$, chirp.

transfer function in the frequency domain. Modern signal processing techniques allow data to be sampled with high precision (16-bit) at high sampling rates. FFT techniques applied to the resultant time series allow easy transformation from time to frequency and vice versa whilst polynomial waveform synthesizers allow complex waveforms used to excite the sample to be generated easily.

Figure 3 shows a number of time domain signals that have been used for performing measurements at ARE (HH) and Figure 4 shows their corresponding spectra. The limitations of the tone burst have already been discussed and this method is no longer used. The haversine ($0.5(1 - \cos)$) has very high time domain resolution allowing diffracted or multi-path reflections to be isolated from the signal of interest and this excitation source is preferred for pulse tube and small tank measurements. Its spectrum has the characteristics of a low pass filter. The $\sin x/x$ function has the advantage that more energy can

be projected into the water, whilst the time domain resolution is relatively poor its spectrum is an ideal band-limited boxcar. The chirp (swept sine wave) allows even more energy to be coupled into the water but again time domain resolution is poor. However these two latter signal types have proved useful in sea trials where multi-path reflections are not a problem.

Practical Considerations

Figure 5 shows the incident signal and the signal reflected from an absorbing cone in a 7.5 m long pulse tube, the incident signal being a 5 kHz haversine impulse. It can be seen that the reflected signal has been considerably stretched in time, distinct components from the front and rear surfaces of the cone are apparent indicating strong resonant behaviour in the frequency domain. Between the incident and reflected signals a number of small perturbations are apparent, these are caused by reflections from discontinuities in the tube walls resulting from the insertion of the side mounted hydrophones and other defects unfortunately built into the tube at manufacture.

Not immediately apparent in Figure 5 is a very low level signal travelling in the steel wall of the tube (it is just visible as a slight ripple prior to the arrival of the incident signal). Energy from the water born wave is continuously coupled into the steel wall where it travels, virtually undamped, up and down the tube at ~ 5000 m/s. All these various artefacts have been analysed and found to be high pass filtered attenuated facsimiles of the incident signal. Some of them cannot be eliminated using current signal processing techniques and they set the limit on the dynamic range of the tube. At 5 kHz the present dynamic range is >70 dB whilst at 10 kHz this falls to ~ 25 dB. Work is currently underway to improve this high frequency limit to an acceptable level (~ 40 dB). However in spite of these limitations the use of an impulsive excitation source has dramatically improved accuracy, dynamic range and frequency bandwidth. The high time domain resolution resulting from the short (~ 250 μ s) impulsive signal has allowed the various artefacts described above to be isolated and analysed, something which is virtually impossible to envisage using tone burst excitation.

Acoustic coatings have varying levels of performance. Although the designer may strive for the highest levels of

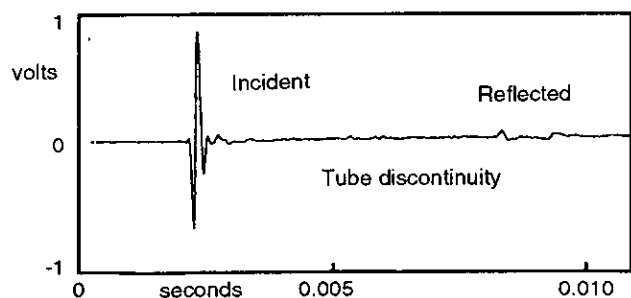


Fig. 5. Incident and reflected signal from terminating cone in 7.5m tube, 5 kHz haversine excitation signal.

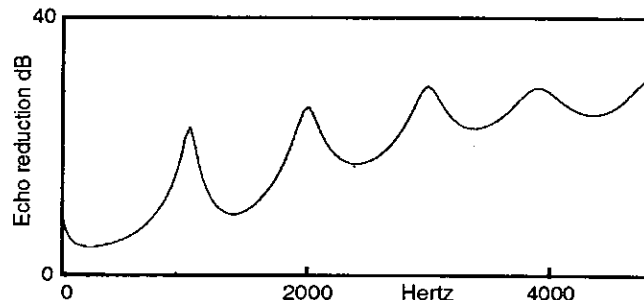


Fig. 6. Echo reduction of viscoelastic terminating cone.

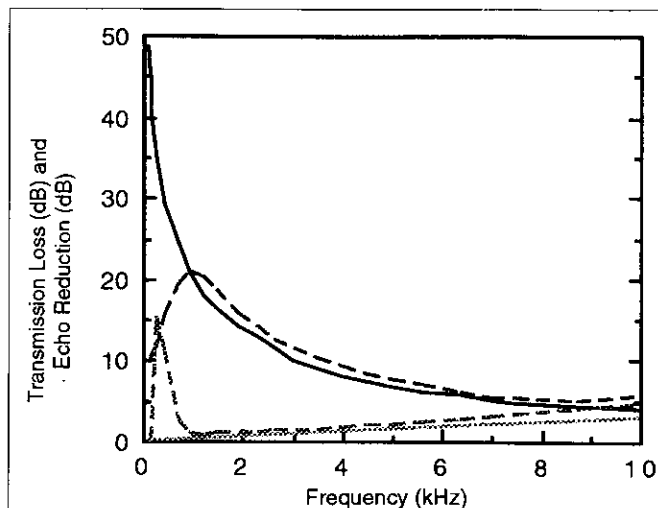


Fig. 7. Theoretical and experimental ER and TL performance of 6 mm thick steel plate.

performance, increased sophistication may be overridden by other important parameters such as cost, weight, ease of application, and hydrodynamic considerations. Hence the coating designer must be able to measure both high and low levels of performance accurately. Figure 6 shows the excellent ER performance of a terminating cone used in the pulse tube computed from the time domain record in Figure 5. The time domain window used has set a lower frequency limit of ~ 250 Hz. The strong resonant behaviour associated with cones and wedges is clearly visible and the increased viscoelastic damping associated with polymers operating in their main chain transition region manifests itself in the gradually reducing Q of the higher frequency resonant peaks. Figure 7 shows the ER

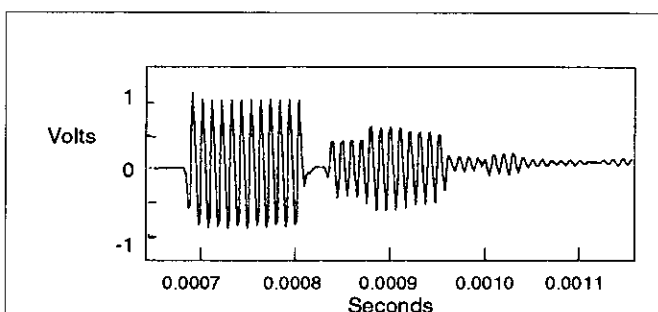


Fig. 8. Tone burst reflected from two separated Perspex sheets

and TL of a 6 mm thick steel plate (hatched line) compared with the predicted values (solid line). Agreement is good between ~ 500 Hz and 6 kHz. The lower limit was set by the time window used and the higher limit was influenced by the tube discontinuities mentioned previously. Between 500 Hz and 6 kHz summation of the transmission and reflection coefficients yielded a value of 1.08. Clearly some systematic errors still exist but this result is considerably better than anything that was achieved using tone burst excitation.

High Frequency Parametric Array

As mentioned previously a pulse tube will only support a

plane compressional wave below cut-off. However above cut-off radial modes can propagate and, since these effectively bounce off the side of the tube as they propagate up the tube, they arrive at a fixed hydrophone site delayed in time relative to the normal mode.

Since these radial modes have delays which are too short to allow windowing out, high frequency pulse tube results tend to be difficult to interpret.

A much more satisfactory technique at higher frequencies, >10 kHz, is to use a parametric array. Again the excitation signal used to modulate the primary is impulsive. In this case a 40 kHz triangular waveform, (a single cycle of a triangular wave with its start phase shifted by 90°) is used rather than a haversine, in order to enhance the high frequency content of the secondary signal.

Figure 8 shows a tone burst (~ 100 kHz) incident on two 6 mm thick Perspex plates separated by a 25 mm water gap. Multiple resonances between the two plates results in a complex reflected signal. Quite clearly steady

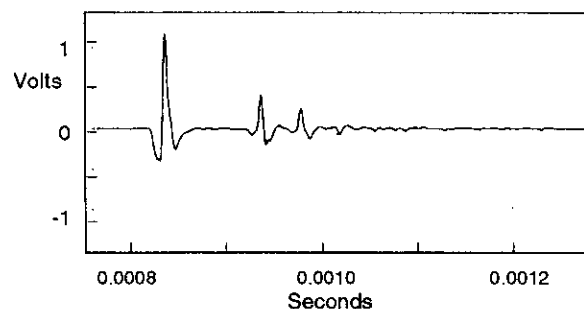


Fig. 9. Haversine impulse reflected from Perspex sheets

state conditions have not been reached and it is not possible to detect whether the reflected signal contains low level diffracted and reflected components.

Figure 9 shows the incident and reflected signals from the two Perspex sheets when the 1 MHz primary is modulated with a triangular waveform. The structure of the reflected signal is clearly seen as a series of decaying multiple reflections.

Using a $1/10$ th cosine window to separate the incident and reflected components and correcting for spherical radiation effects yields the result for echo reduction (hatched line) shown in Figure 10. The theoretical result is shown as a solid line. Agreement in the range 10 kHz to 100 kHz is good. The discrepancy between experiment and theory in this case is almost certainly due to a lack of accurate information on the loss factor of Perspex in this frequency range.

Conclusions

The use of impulsive excitation is applicable to both low frequency pulse tube measurements and high frequency

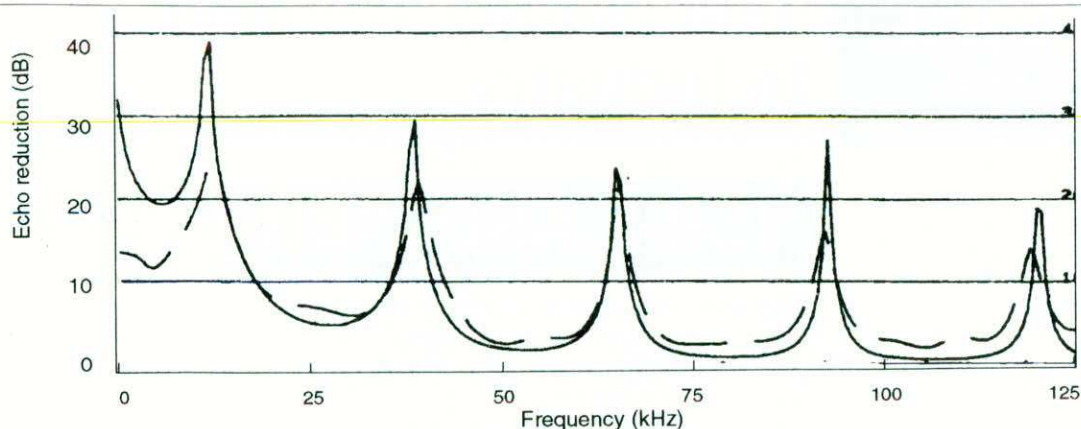


Fig. 10. Theoretical and experimental echo reduction for two 6 mm Perspex sheets 25 mm apart

parametric array measurements. A single 5 kHz Haversine yields a bandwidth of 10 kHz in the pulse tube and a 40 kHz triangular waveform yields a bandwidth from 10 kHz to 250 kHz in the parametric array. Although the impulsive method yields low sound pressure levels time domain averaging can greatly enhance the signal to noise ratio. The high time domain resolution can greatly improve the ability to discriminate against and identify the source of unwanted signal components resulting in a much improved dynamic range.

References

- [1] L E KINSLER, A R FREY, A E COPPENS & J V SANDERS, 'Fundamentals of Acoustics', J Wiley & Sons, ISBN 0-471009410-2 1982.
- [2] M C JUNGER, 'Wave Motions in some Composite, Porous and Layered Media', JASA 88 (1), July p368-373 1990.

D J Townend is at the Admiralty Research Establishment, Holton Heath, Poole, Dorset BH16 6JU (C) Crown Copyright 1991/MOD

VIBRATION CONTROL BY DESIGN

Do you need to specify, supply or install steel spring or rubber isolators for the control of structure-borne noise and vibration?

Do you need proper analysis and calculations to demonstrate correct selection to avoid excessive vibration amplitudes or machine noise transmission?

Are you particularly interested in isolating television and sound studios, heating and ventilation machinery or diesel generators?

Christie & Grey have over 75 years experience and the latest computer techniques for solving the problems of structural isolation.

We also manufacture, supply and install the isolators.

CHRISTIE & GREY LIMITED
Universal House,
Morley Road
Tonbridge
Kent TN9 1 RA.
 Tel: 0732 366444
 Fax: 0732 770048

MSc/Dip in ACOUSTICS VIBRATION and NOISE CONTROL

by Distance Learning Video Instruction

A two-year course, starting in October, with modules covering; Basic Acoustics, Building Services Noise, Environmental Noise, Industrial Noise, Architectural Acoustics, Vibration Control, Signal Processing and Data Analysis, Noise Control Engineering, Transportation Noise, Law and Administration.

HERIOT-WATT UNIVERSITY



Further details and application forms are available from:

Charlie Fleming,
 Department of Building Engineering,
 Heriot-Watt University,
 Edinburgh EH14 4AS,
 UK.
 Tel 031 449 5111 x 4626

NOISE AND VIBRATION UNIT

This unit offers specialist advice on a broad range of road traffic noise and vibration topics and has developed particular expertise in the areas of prediction modelling, psycho-acoustics, environmental monitoring and quiet vehicle development and testing. The unit is well equipped with up-to-date instrumentation and specially commissioned laboratories to provide a high quality research service with full commercial confidentiality

Traffic Noise

Prediction of traffic noise levels, including advice on the use of the DTp method 'Calculation of Traffic Noise' which was developed in the Unit

Design of roadside noise barriers, including the use of computer models to predict performance and to optimise costs

Noise impact assessment of road schemes

Tyre/road surface noise

Monitoring and analysis of traffic noise

Road construction noise and vibration

Monitoring traffic noise ►



TRRL's ISO test surface ◀

Vibration

Assessment of the impact of traffic vibration

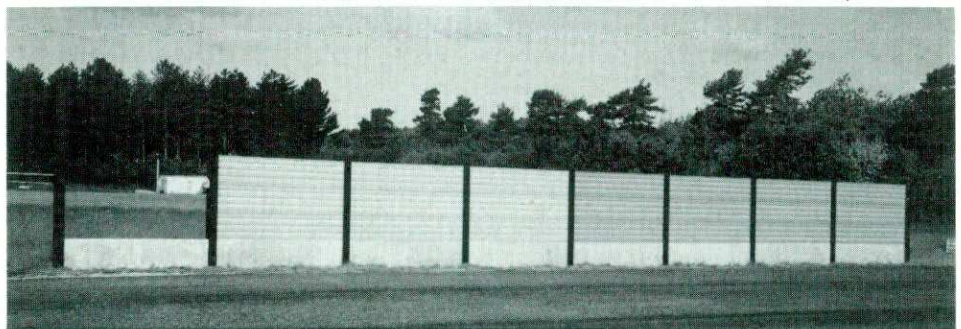
Damaging effects of vibration on buildings

Prediction of air and ground-borne vibration

Control of vibration from vehicles

Protection of vibration sensitive equipment

Noise barrier test facility ▼



Vehicle Noise Control

Quiet vehicle engineering

Motorcycle noise

Vehicle testing and test track design

Vehicle noise assessment scale development and noise quality considerations

Experimental Facilities

Secure test track facilities which include a vehicle noise test track conforming to the latest ISO standard

Listening room laboratories for psycho-acoustical studies

Anechoic chamber

Time and frequency domain analysis; measurements of loudness

More Information

Noise and Vibration Unit
Transport and Road
Research Laboratory
Crowthorne
Berkshire RG11 6AU

Tel 0344 770022/770650

Telex 848272

Fax 0344 770356

MICROPHONE CALIBRATION AT LOW FREQUENCIES

R G Barham

Standards for low-frequency acoustics

There are many situations in acoustics that call for the measurement of sound at very low audible, and even infrasonic, frequencies. Examples include the measurement of noise from sonic booms and the launching of rockets, from quarry blasting and from the wind. The so-called reciprocity method of microphone calibration is the internationally-agreed method of realising the standard of sound pressure over most of the audible frequency range. However, the accuracy of the reciprocity method worsens towards low frequencies, and this has prompted the development at NPL of a quite different method of microphone calibration, based on an instrument called a laser pistonphone.

The NPL laser pistonphone

The NPL laser pistonphone is used for the absolute calibration of microphones in the frequency range from 1 Hz to 250 Hz. The instrument incorporates a closed cylindrical cavity of length and diameter equal to 60 mm, with a piston 15 mm in diameter operating in one end face of the cavity. The piston is driven sinusoidally with an amplitude of about 1 mm to produce (sound) pressure variations in the cavity. The magnitude of the sound pressure can be calculated from the dimensions of the cavity and the displacement and area of the piston. The piston has a mirrored face which is located in one arm of a Michelson interferometer (consisting of the laser beam, beam splitter, mirror and the moving piston), and its displacement is determined by fringe counting. The test microphone is exposed to the known sound pressure by inserting it into a port in the side of the cavity. The output voltage of the microphone is measured and the sensitivity of the microphone calculated. Sound pressure levels in the range 90 dB to 130 dB (0.63 Pa to 63 Pa) may be generated in the cavity, although higher levels (comparable to those produced a few meters from a jet engine) can be produced over a reduced frequency range.

Calibration uncertainties

At the very low frequencies at which the laser pistonphone operates, the pressure changes in the cavity are not adiabatic (that is heat flows in to and out of the walls of the cavity during the acoustic compressions and

rarefactions). The leakage of air around the piston is also not negligible. Corrections to the basic theory must be made to allow for both of these effects and the uncertainties in these cause the uncertainty in the sound pressure in the cavity to increase from 0.06 dB (0.7%) at 30 Hz (and above) to 0.3 dB (3.5%) at 1 Hz. Other factors in the uncertainty include the small additional volume elements associated with the test microphone and the microphone port which can be difficult to estimate precisely, and the uncertainty in the cross sectional area of the piston.

Wider applications

The laser pistonphone is not simply adapted to the absolute calibration of microphones: there are many other applications for an instrument that can provide a uniform sound pressure in a fairly large cavity. These include the calibration of other transducers such as hydrophones and pressure transducers, measurement of the relative phase response of pairs of microphones (which is important in

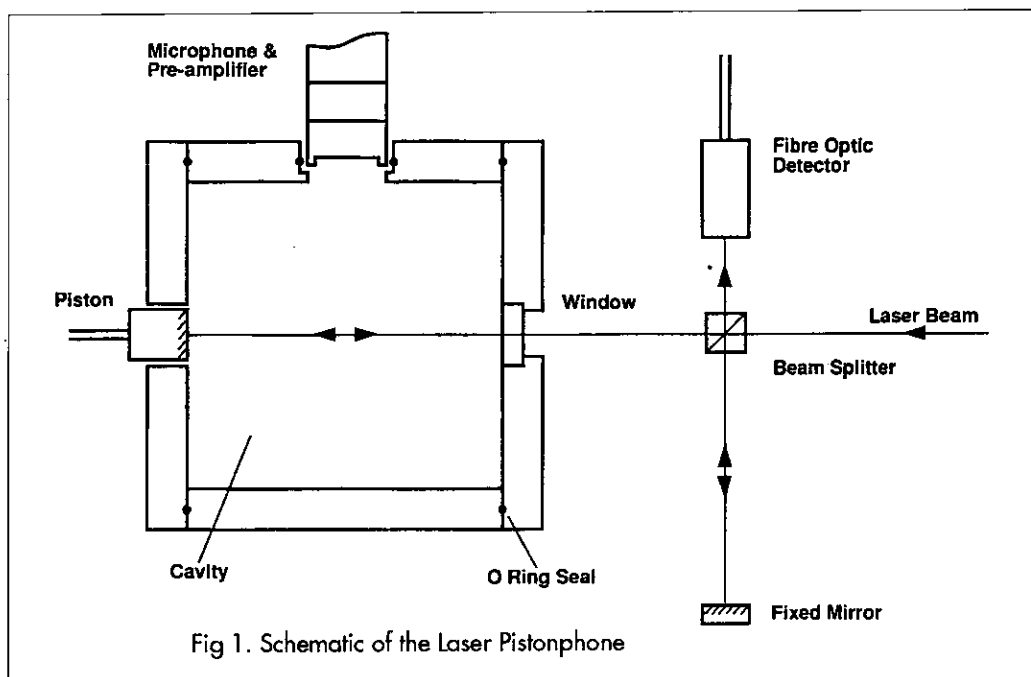


Fig 1. Schematic of the Laser Pistonphone

sound intensity measurement), and the study of the spatial distribution of sound pressure in cylindrical cavities (which has applications in other areas of acoustical standards). Several interchangeable cavities have been manufactured for the NPL laser pistonphone to cater for these various possibilities.

For further information, contact R G Barham on 081 977 3222 Ext 6725.

R G Barham is in the Acoustics Branch at NPL. This article originally appeared in NPL News and is Crown Copyright. The Editor gratefully acknowledges permission to reproduce it in Acoustics Bulletin.

Recent Advances in Underwater Acoustics

Weymouth, 20 - 22 May 1991

This was in fact the first Underwater Group conference to be held in Weymouth for many years, although, as it was pointed out other conferences with very similar titles have been held in the area!

The venue for this latest meeting was the Hotel Prince Regent, which is ideally situated on the sea-front at Weymouth. The efficiency and helpfulness of the hotel staff, combined with the idyllic weather we had to suffer for the duration of the conference provided a relaxed and informal setting.

Out of a total of 41 abstracts received, 24 were selected to typify recent advances in International underwater acoustics. Presentations included papers from the UK, USSR, USA, Canada, France, Germany, Norway and Denmark.

A further six papers were received from authors in the USSR which, although it was not practical for them to be presented at the conference, were deemed to be of sufficient interest to be included in

the Conference Proceedings.

The conference itself was formally opened by Dr Brian Smith and was subdivided into nine sessions:- Acoustic scattering, Propagation through bubbly media, Acoustics and the sea-bed, Shallow water propagation, Remote sensing, Acoustics and the Arctic, Theoretical studies, Damping and decoupling processes and Ambient noise measurements.

The majority of the presentations were of a high standard and greatly appreciated by the conference delegates.

Whilst it is not customary to single out particular authors, I would like to give my special thanks to the two invited speakers Professor Andrew Seybert of the University of Kentucky (Hybrid boundary element - finite element applications in underwater acoustics) and Dr Jacques Guigne of C-CORE (Interactive acoustic mapping of the sea-bed) for their support and excellent presentations.

A small exhibition, with a total of seven exhibitors, was held concurrent with the conference in order to demonstrate some of the advances made in hardware and software in the underwater acoustics field. In addition two poster sessions were provided, one on AUV's - sensor platforms of the future and one on fast signal processing methods.

As the organiser, it is perhaps not appropriate for me to comment on the success or otherwise of the conference. However, my observations are that delegates did appear to be very satisfied with the arrangements and the program ran exceedingly smoothly. Certainly, the conference dinner (deliberately informal) seemed to be enjoyed by all concerned.

This was the first conference I have organised and the help I received (particularly from Dr Richard Brind of the DRA) proved invaluable. For any other members of the Institute who are thinking of organising a conference for the first time I have one word of advice - ensure that you have a good secretary! My secretary, Mrs Katie Cappello, proved excellent and without her organisational and administrative abilities, the conference would not have run as smoothly as it did!

G W Neal MIOA

Acoustics Bulletin Advertisement Rates

Whole Page	£350 + VAT
Half Page	£225 + VAT
Quarter Page	£160 + VAT

Rates for special positions, colour, series etc, six issues per year

Enquiries to:

Keith Rose FIOA
Brook Cottage
Royston Lane
Comberton
Cambs CB3 7EE

Tel: 0223 263800 (evenings)
081 576 7190 (daytime)
Fax: 0223 264827

Traffic Noise Calculations

are easy on your office PC with

dBEL

- Comprehensive
- Easy to use
- No special equipment
- Fully complements CRTN

Details from

MUNIDATA
12, Maxim Road
London N21 1EX
Tel: 081 360 0802

London Branch

Meeting on EC Noise Directives for Construction Equipment and Machinery

The last London Evening Meeting before the summer break was a highly informative talk from Bill Osborne, of the Department of Trade and Industry, on the current situation regarding the EC noise directives for machinery such as compressors, generators, concrete breakers and earth movers. Bill started with a brief history and an explanation of the past problems since the 1957 Treaty of Rome which required freedom of goods and services within the Common Market. There were two main problems involved in deciding on a common objective ie:

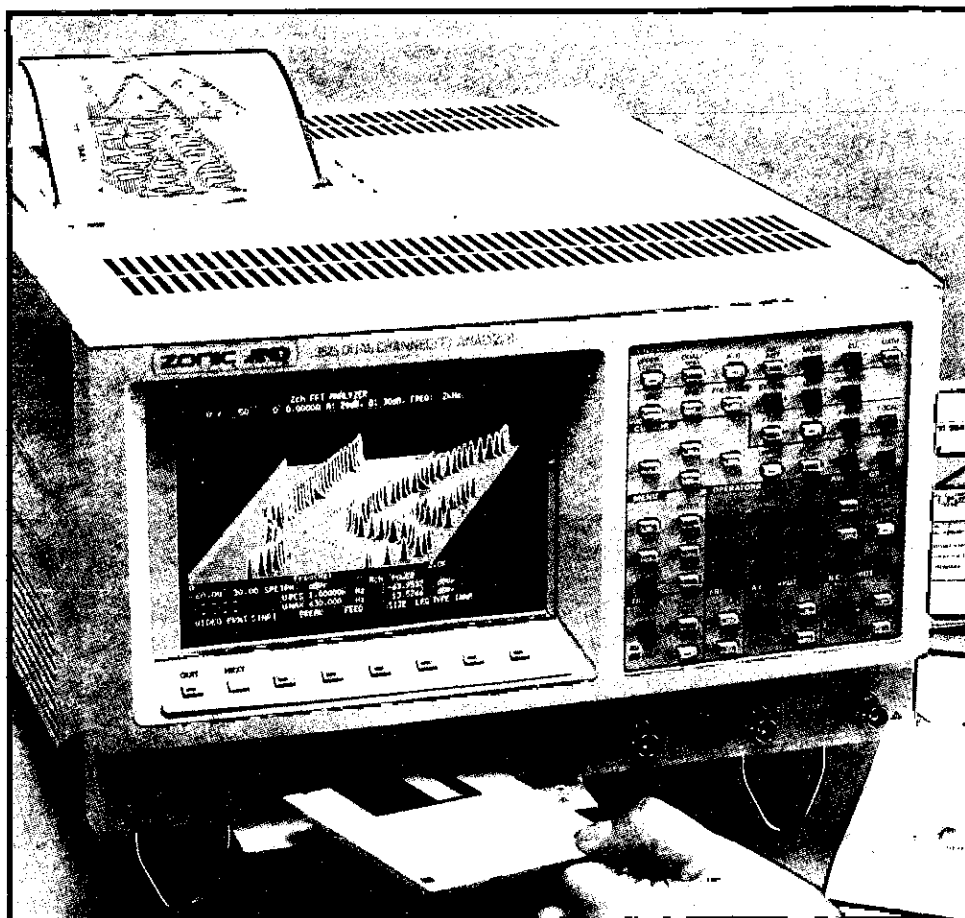
(i) too much technical detail on individual machines

(ii) unanimity

These problems produced long delays in any decision making process and in 1985 a new approach to technical harmonisation and standards was adopted. The new approach was to agree the essential requirements rather than technical detail. The Single European Act (1985) allowed a majority vote rather than unanimity and the technical standards were referred to the European Committee for Standardisation (CEN).

Approximately twelve EC Directives have been issued since 1984 requiring a limit on the sound power of various machines, which are then permanently labelled. In addition noise information is required where the L_{Aeq} exceeds 70 dB, the peak exceeds 130 dB and where the sound power exceeds 85 dB(A) at workstations. Sound pressure measurements at specific positions can also be accepted for very large machinery where sound power measurements may prove too difficult.

The EC Directive on machinery safety (89/392/EEC) requires information which includes sound pressure levels at workstations, the sound power level and the methods used to measure these levels. The technical committee 211 of CEN is working to produce European stan-



Field portable with comprehensive analysis capabilities... the Zonic A&D 3525™.

- ☐ A high performance full function 2 channel Spectrum Analyzer with PC Interfacing capabilities.
- ☐ Capable of almost every type of Signal Analysis with ranges to 100 kHz.
- ☐ MS DOS based Modal, Modification, and Forced Response Software.
- ☐ Built-in, PC compatible floppy disk drive.
- ☐ Full and 1/3 Octave Acoustic Analysis.
- ☐ Built-in thermal printer with variable plot size.

ZONIC A&D

ZONIC A & D LIMITED, 1 Stable Court, Herriard Park, Basingstoke, Hampshire RG25 2PL England

Interested? We'll make it easy. Pick up your phone and call 0256 810644.

dards on methods of measuring the noise emitted by machinery and also the principles of reducing noise emission. Three new standards will be issued on methods of measuring emission sound pressure levels at workstations. These are based upon a complete revision of the existing standard ISO 6081. Formal voting on these standards is expected to occur in CEN by December 1992.

Eleven new standards will be issued on methods of determining sound power levels which will be based on complete revisions of the existing ISO 3740 to 3747, together with two new standards for sound power determination from sound intensity measurements which will have the reference ISO 9614. Voting on the former is expected to occur by September 1991 and the latter by September 1992.

At least three completely new standards will be issued, dealing with reduction of noise emission from individual machines, reduction of noise within workshops, and measuring the noise-attenuation performance of devices such as hoods, screens and mufflers. Formal voting on these standards, in the CEN, is expected to occur by December 1992.

A lively discussion followed Bill's talk which was completed in the local public house.

Ken Scannell MIOA

Southern Branch

Evening Meeting

After a false start in the snowstorms of February the Southern Branch finally managed to go ahead with their evening technical meeting on 'Entertainment and Recreation Noise'. Held at the Winchester Guildhall on 5 June 1991 the meeting attracted some 30 members of the Branch and was honoured to have in attendance the Secretary of the Institute, Cathy Mackenzie. Cathy was undoubtedly checking that the Southern Branch Committee were not slacking in their duties and as always it was a pleasure to have her company.

The meeting commenced with Dr Chris Hill (known as Prof to his friends) explaining the work of his

Noise Section at Surrey County Council and their particular involvement in the framing of noise guidelines for the use of the District Planning Authorities and for the guidance of developers. Chris explained in detail his work on a diverse range of leisure activities including clay-pigeon shoots, hill-climbing and motorised water sports. The wealth of experience of the Surrey Noise Section had enabled them to draw up comprehensive guidelines for all forms of development activity and these are of course well known to many other LPA's who have relied on Surrey's standards at Public Inquiry. The new standards would be available from Surrey CC for the princely sum of £5.00, although Chris explained that due to pressure of work in the Planning Department these were unlikely to become Committee approved policy in the foreseeable future. Dr Hill's talk resulted in a great deal of interest in particular in respect of standards to be adopted for clay pigeon shoots and it was interesting to note that he believed that they would eventually move away from an absolute noise standard to an impact assessment based on some measure of the pre-existing noise level. The talk was rounded off by a series of slides illustrating the various leisure sports involved including some which looked curiously like twin UFO's but which Dr Hill explained were in fact clays emerging from a trap.

After a suitable break for coffee Jim Griffiths of Travers Morgan explained with a very professional overhead and slide presentation his experience in entertainment noise ranging from the design of discotheques to the staging of large rock concerts. It was interesting to note his company's differing remit ranging from the designing of discotheques with built-in quiet rest areas for those finding 100-110 dB(A) occasionally a little tiresome, to the requirement to reduce the likelihood of annoyance at nearby residential communities. Of particular interest was the computerised control system for Wembley Stadium which allowed the full PA system to be util-

ised to apply localised sound enhancement thus reducing to some extent the overall noise levels required from the central stack systems. Jim Griffiths also explained some of the techniques which could be implemented using cone-speakers pointing down towards the audience which could result in reductions of 3 dB(A) to the nearby residential communities.

At the end of the meeting both speakers were thanked warmly for their contributions to the evening and the discussion was continued in a nearby hostelry.

The Secretary for the Southern Branch extends his grateful thanks to Dr Ian Flindell for organising the meeting and ensuring that it was so successful.

Graham A Parry MIOA

Eastern Branch

Visit to CEL Hitchin

CEL hosted 13 members of the Eastern Branch on the evening of the 22 May to a visit to the Hitchin site. Ian McDonald opened the evening after suitable refreshment of the travelling visitors.

The position of CEL in the Lucas group was outlined and then Ian McDonald gave a very instructive and informative presentation explaining the market led philosophy of the Hitchin operation. The company have adopted many of the more progressive management techniques in order to achieve their objective of customer satisfaction. The result of Product production cells, Canban material control and a commitment to quality, as just some examples, has meant that CEL has become a market, rather than a sales/product led organisation. The reduction in many of the product lead times may well help all who endure the end of financial year purchasing rush. Customer satisfaction has clearly become a driving force behind the company operation.

The group were then treated to an excellent buffet during which the CEL staff were quizzed enthusiastically by the visiting group. This was followed by a tour of the factory and office areas. The logical layout of the production areas was

clear to follow. The evening closed with a talk on the CEL involvement in standards work and the reasoning behind the decision to create the NAMAS laboratory. Members were impressed by the standard of operation at the Hitchin site and the commitment to the customer.

Peter Hunnaball MIOA

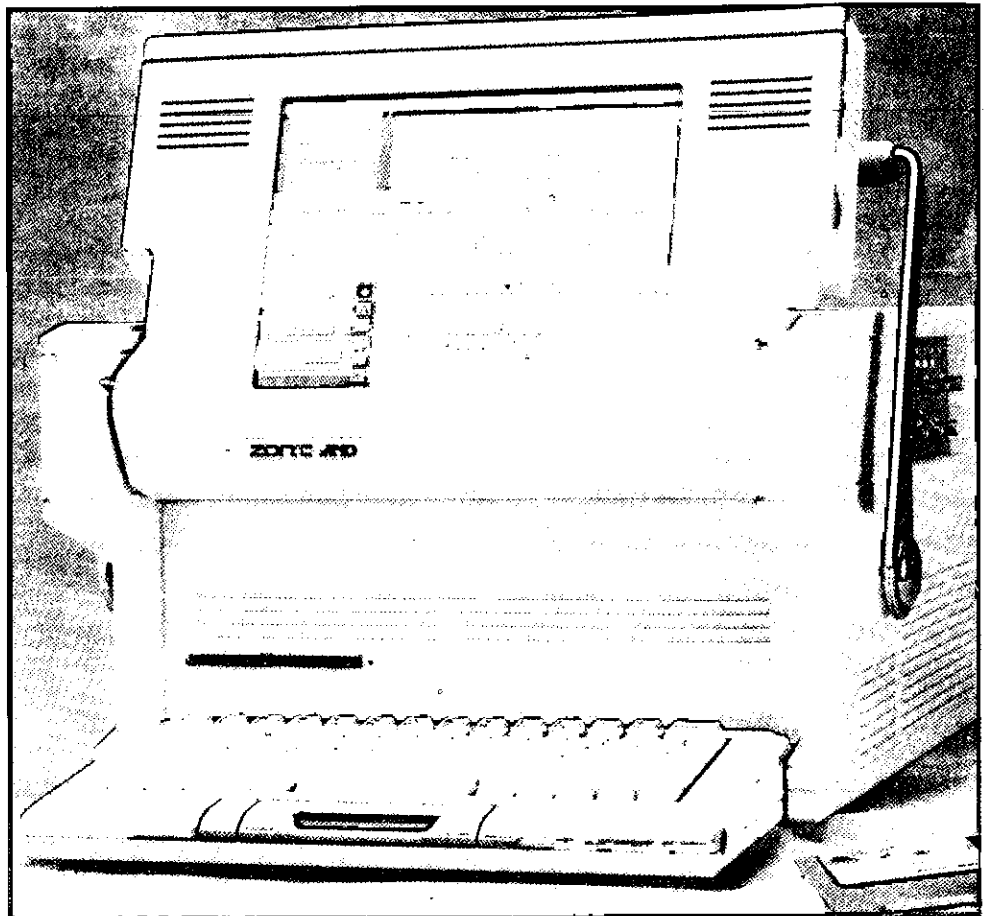
Speech Group

Text - Phonetics Correspondences and Conversion

On Monday 1st July the Speech Group held a technical meeting at the IBM UK Scientific Centre in Winchester, Hampshire, on the theme of 'Text-phonetics correspondence and conversion'. About 20 people were present: from IBM; from universities such as Southampton, Cambridge, York and Edinburgh; and from research establishments such as RSRE and CERIL (France). Six talks were given, followed by a demonstration of the latest version of IBM's 'Tangora' PC-based speech recogniser.

Bob Damper (Southampton), spoke on the inductive inferencing of text-phonetics correspondences, giving an overview of the various approaches that have been tried. John Coleman (York), spoke on rule-based formalisms for text-to-speech and speech-to-text, proposing a new kind of formal notation. Richard Sharman (IBM) spoke on Markov modelling for phonetic transcription, proposing a probabilistic approach to the text-to-phoneme problem. Briony Williams (CSTR, Edinburgh) spoke on a multi-level data structure and rule formalism for use in the ESPRIT project POLYGLOT, pointing out its advantages in text-to-speech synthesis. Eric Laporte (Centre d'Etudes et de Recherches Informatiques Linguistiques) spoke on phonemic-to-phonetic conversion with local finite-state transducers. Robert Luk (Southampton) spoke on stochastic transduction for text-phonetics conversion, hoping to combine a formal grammar with statistical modelling.

The meeting was organised by Bob Damper (Southampton) and Richard Sharman (IBM).
Briony Williams MIOA



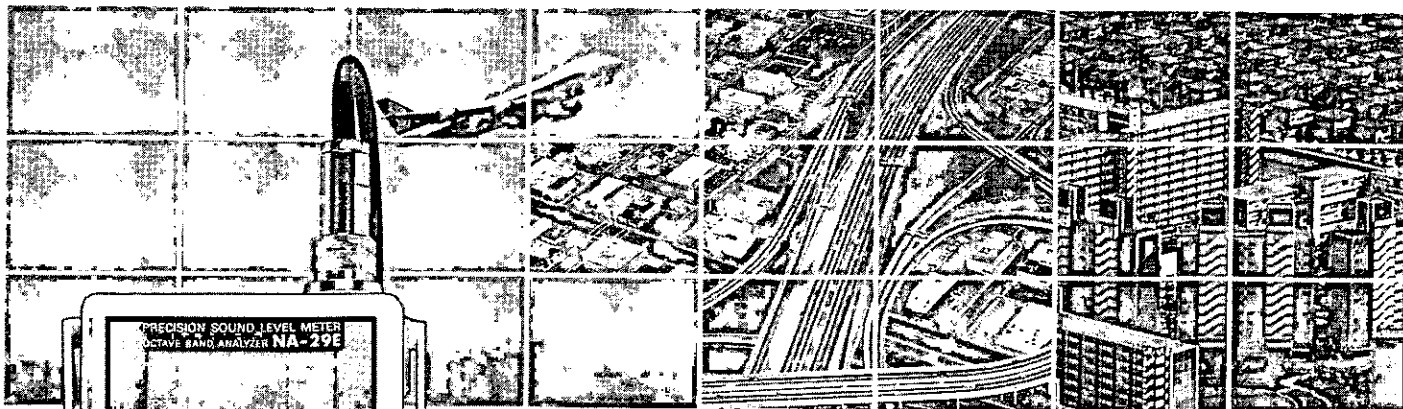
Carry our WCA™ portable Macintosh® based FFT analyzer with you!

- ☐ An Apple® Macintosh computer and a powerful multi-channel digital processor in a compact, portable package.
- ☐ Expandable from 1 to 16 channels at 40 kHz bandwidth.
- ☐ High resolution, built-in TFT Flat screen colour display.
- ☐ Built-in RPM Tracking/Order Analysis capabilities.
- ☐ Continuous data storage to high speed throughput disk.
- ☐ Full range of application software for Structural Analysis.
- ☐ Built-in pointer device replaces mouse for ease of use in the field.
- ☐ Automated testing via command file "batches".
- ☐ Lightweight and portable; fits in aircraft overheads.

ZONIC A/D

ZONIC A & D LIMITED, 1 Stable Court, Herriard Park, Basingstoke, Hampshire RG25 2PL England

**Interested? We'll make it easy. Pick up your phone
and call 0256 810644.**



Precision Sound Level Meter with Real-time Octave Band Analyser

Quantitech Ltd, the ambient air monitoring specialist, has entered the sound and vibration market with a range of Type 1 and Type 2 Sound meters and Octave and $\frac{1}{3}$ Octave Band Analysers from RION of Japan.

The revolutionary RION NA 29-E, for example, comprises a precision sound level meter with a real-time octave band analyser in a single, compact, powerful and reasonably priced instrument. The NA-29E with

its 60 dB range, large memory, 1500 LCD displays and RS 232E interface, is a complete industrial and environmental noise analyser.

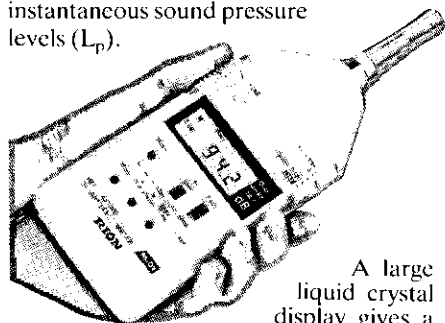
This hand held instrument will save Industrial Hygienists considerable time by measuring L_{eq} and SEL over every period, in all octave bands, simultaneously. Environmental Health Officers will find many functions to simplify the measurement and statistical analysis of environmental and traffic noise.

Full details from Keith Golding at Quantitech.

Integrating Sound Level Meter

The RION NL-02 hand held, Type 2 meter from Quantitech, has many functions, and is ideally suited for measuring factory, traffic and community noise, especially where a large fluctuation level is expected.

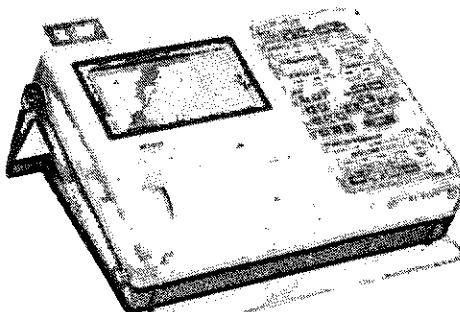
Continuous A-weighted sound pressure levels (L_{eq}) and single event noise exposure levels (L_{AE}) are easily measured over manual or preset measurement times from 10 seconds to 24 hours. The integrating capabilities can be used to determine the average in space as well as time. The RION NL-02 will also measure instantaneous sound pressure levels (L_p).



A large liquid crystal display gives a clear reading with four display modes – L_p , L_{eq} , L_{AE} and Elapsed Time. AC and DC signal outlets are provided for data analysis and recording.

Details from Keith Golding at Quantitech.

One Third Octave Band Analyser



At the top of the RION range of noise and vibration monitors from Quantitech is the SA-27, a complete, real-time

octave and one-third octave analyser, with built-in printer, suitable for sound pressure analysis, vibration and acoustical measurements. This new instrument meets IEC 225 standards, and offers a large frequency range. A non-volatile memory stores 1000 third-octave band spectra and may be extended with memory cards. A built in noise generator and optional hard-noise unit with programmable frequency weighting curves facilitate sound pressure and vibration analysis.

Further information from Keith Golding at Quantitech.

Vibration Meter

The pocket size Riovibro VM-65 vibration meter by RION of Japan combines a shear type piezoelectric accelerometer and meter in a single compact unit. By simply pressing the instrument against a surface, displacement (mm : P-P), velocity (cm/s : RMS) and acceleration (m/m² : Peak) measurements can be obtained.

The instrument has many potential applications involving on-site vibration measurements for industrial equipment maintenance and safety.



Full details from Keith Golding at Quantitech.

Quantitech Ltd 75 Garamonde Drive, Wymbush, Milton Keynes, Bucks, MK8 8DD Tel: (0908) 564141 Fax: (0908) 260554

Quantitech

New Products

ANTHONY BEST DYNAMICS LTD

Free Running Plato

Anthony Best Dynamics have announced an addition to their PLATO software for rotating machinery noise and vibration analysis. PLATO software is currently used for gearbox and axle noise measurement and analysis. It is a multi-channel system for spatially averaged order analysis. Its main application is on test rigs and rolling roads where noise is measured during preset acceleration and deceleration runs.

The FREE RUNNING PLATO software eliminates the need for preset test schedules and thus makes testing very flexible. Now any sort of test schedule can be accommodated by recording the measured data in up to 8 Mbytes of RAM then processing it after recording.

The FREE RUNNING PLATO software allows many analysis variations to be carried out, but for further processing the results can be transferred to Lotus 1,2,3 or similar spreadsheets for even more manipulation. PLATO software requires a CED 1401 intelligent data interface plus an IBM PC or compatible. For mobile work a laptop computer is ideal, which means that the whole system can be run off batteries. Anthony Best Dynamics can supply the software or complete systems. The software and hardware are both flexible and can be expanded to meet customers' specific requirements.

Further information on this and associated packages is available from Anthony Best Dynamics, Holt Road, Bradford on Avon, Wiltshire BA15 1AJ. Telephone Andrew Middleton or Andy Rumble on 02216 7575 or Dick Widenka on 081 423 3293.

ATELLUS LTD

Heraklith Sound Insulation Board

Heraklith Sound Insulation boards are a purpose made prod-

uct, which it is claimed, can improve the airborne sound insulation index of a solid 250 mm brick wall by 13 dB.

The boards, 25 or 35 mm thick, are a laminate of layers of Heraklith -M-Original magnesite-bound wood wool incorporating a flexible foam core. It is the careful balance between dynamic rigidity of the core and the weight of the surface layer which prevents significant resonance incursions.

Heraklith Sound Insulation boards are applied to existing walls by adhesive or dowel fasteners and their M-Original surface may be directly plastered or have plasterboard attached.

The boards are marketed by Atellus Ltd who offer technical advice on applications and installation of the product. For further information contact James Muir of Atellus Ltd, Park House, Marlow Road, Maidenhead, Berkshire. SL6 6NR. Tel: 0628 34563.

BRUEL & KJÆR (UK) LTD

FFT for B&K 2143 Realtime Analyser

Brüel & Kjær offers a retrofittable FFT analyser option for its 2143 Portable Realtime Analyser.

This firmware enhancement means that the 2143, introduced by Brüel and Kjær to transport laboratory performance in digital signal analysis into the field, will also offer faster FFT analysis than most mains-powered alternatives. Calculation of a 400 lines spectrum takes less than 40 milliseconds which means that, irrespective of the frequency range or span selected, the analyser always works in realtime.

The Type 7637 option provides baseband analysis to 25.6 kHz, with variable transform size to provide 50 to 400-line spectra, and 10x or more realtime zoom for high-resolution analysis throughout the frequency range.

Single-channel operation allows autospectrum, instantaneous spectrum and time record measurement modes. A dual display function enables both amplitude/phase and real/imaginary part of the instan-

taneous spectrum to be displayed simultaneously. A delta cursor is provided for calculation of the energy or power of the spectrum or any part of it, and a harmonic cursor for identifying all harmonics in a signal where the fundamental frequency is known.

Linear and exponential averaging can be selected. The input signal can be A-weighted, and there is a choice between Rectangular and Hanning windows. Auto calibration and an interactive softkey approach make operation simple. The extra features of the FFT analyser are accessed through the 2143 help page system.

For further information contact Les Minikin, Brüel & Kjær (UK) Ltd, 92 Uxbridge Road, Harrow, HA3 6BZ. Tel: 081 954 2366. Telex: 934150 BK UK G. Fax: 081 954 9504.

Brüel & Kjær (UK) Ltd is a KEY SPONSOR of the Institute.

FABERT S.A

Stabren Anti-vibration Pad

The Stabren anti-vibration pad has been developed by the French company FABERT after ten years of research. It has a high absorption over a wide frequency range and is available in standard form as a square pad measuring 200 mm x 200 mm.

It consists of two shaped Neoprene sheets exactly fitting into each other. In cross-section, each has a sinusoidal internal profile, which gives them their highly absorbent properties. On their outer faces they consist of 390 trapeziums. The two sheets are normally supplied with differing hardnesses. Vibration is absorbed owing to the fact that the degree of compression of the sheet depends on the amplitude of the vibration. The resilience of the sheets' structure (shock resistance) means that the trapeziums can be greatly compressed or expanded. Part of the energy from the incoming wave is thus absorbed. The sinusoidally varying hardness produced by the two sheets makes the waves travel at an angle, thus absorbing even more energy across the whole

spectrum.

The compressibility of the lower trapeziums also produces an extremely effective anchor for machines, removing the need for them to be secured. Depending on their hardness, Stabren pads can support from 2 to 10 tonnes each. In addition, cutting the pads does not affect their properties, and they therefore can be cut into squares, circles or strips as required.

Stabren pads are resistant to attack from a large number of aggressive chemicals, are effective over a wide temperature range and are resistant to aging.

Fabert SA, 42 rue Fabert, 75007 Paris, France. Tel: (010 33 1) 45 55 60 26. Fax: (010 33 1) 45 56 05 24.

SARGENTS ACOUSTICS

New Air Conditioning Modules

Sargents Acoustics has introduced a range of special ducting modules known as turning vanes which are said not only to improve the flow of air around bends in air moving systems but to dramatically cut the amount of noise such systems generate and transmit.

Sargents' vanes are formed into an aerofoil section, using perforated, pre-galvanised mild steel as the outer skin, and packed with an acoustically highly-absorbent infill.

ATVs can be installed in any bend wider than 300 mm and may be constructed to any height to suit ductwork dimensions.

Further information from the Marketing Department, Sargents Acoustics, The Alders, Mereworth, Maidstone, Kent, ME18 5JG. Tel: 0622 812861.

SIDERISE

RPG Acoustic Treatment Products

Siderise Ltd have recently been appointed UK distributors for the RPG range of acoustic treatment products.

As well as the well known 'Diffusor' and 'Abffusor' designs the range includes several new products - the 'VAMPS' portable performance shell system; the 'Omniffusor' and

'Omniffusor Terrace' omnidirectional diffusors; the 'Diffactal', a no-compromise solution that offers both superb high and low frequency diffusion characteristics; the cement-based 'DiffusorBlox' that can be used in actual construction, thus enabling walls to perform as effective diffusor systems; and a new range of ultra-lightweight 'QRD Diffusors' manufactured from 'Kydex' which is a tough new thermo-plastic formulation.

For further information on RPG products contact Kelvin Holt of Siderise Ltd. Tel: 081 549 6389 Fax: 081 546 2246.

News Items

ZONIC A & D EUROPE

A new sales and support office has been opened in Basingstoke covering all signal processing products from Zonic Corporation and A&D.

Previously sales and support were carried out separately by each company through offices in the UK and Germany. Increased co-operation between the two companies has led to a merging of the two product lines to give an unmatched range of signal processing systems for applications in noise and vibration analysis, structural testing, rotating machinery analysis, and control system testing.

Zonic Corporation is an American company which has produced several generations of multi-channel systems. The most recent is the System 7000, a powerful computer-based parallel processing system allowing a very wide range of configurations from 8 channels to more than 1000 channels. Electro-hydraulic excitation systems also form an important part of Zonic's business.

A&D Company is a Japanese company that has concentrated on small, advanced single- and dual-channel spectrum analysers.

Zonic and A&D now work closely together to offer the widest possible range of signal processing equipment, ranging from 1 channel to 1000 channels.

For more information contact

Andy Bates at Zonic A&D Europe Ltd, 1 Stable Court, Herriard Park, Basingstoke, Hampshire RG25 2PL, or call 0256-810644.

Zonic A&D Europe is a SPONSORING ORGANISATION of the Institute.

INDUSTRIAL & MARINE ACOUSTICS

Industrial & Marine Acoustics have announced an agreement with US-based Technology Integration for the UK support of its Airport Noise and Operations Monitoring System (ANOMS). This system matches noise data from permanent or portable microphones with flight tracks to identify the noise source. Data is automatically traced to particular aircraft movements as an aid to enforcement and noise abatement procedures.

ANOMS uses inputs from Larson-Davis microphones and community noise analysers. This is said to allow Industrial & Marine Acoustics to offer and support a turnkey service to UK airport users.

For further information contact Industrial & Marine Acoustics, 16 Scardale Crescent, Scarborough, North Yorkshire, YO12 6LA. Tel: 0723 364495.

CIVIL ENGINEERING DYNAMICS

The established noise, vibration and environmental consultancy practice of Civil Engineering Dynamics Ltd have moved to new offices at 33 Louisville Road, London SW17 8RL. Tel: 081 672 8298, Fax: 081 672 7582, Freephone: 0800 181 945.

They continue to offer professional advice on environmental matters and make noise, vibration and air-pollution equipment available for hire.

TEST HOUSE DIRECTORY

John Seller MIOA is collecting information for the third edition of this Directory which will be published in the autumn. Over 5000 copies of the second edition have been distributed. He wishes to hear from organisations that are either involved in conducting testing or are manufacturers of test equipment. Contact

John Seller MIOA, 1 Marlborough Rise, Hemel Hempstead, Herts HP2 6DW.

COMMINS-INGEMANSSON

This practice has announced a 3-day course entitled Random Vibrations and Noise: Applications to Aerospace, Automotive, Ocean and Oil Drilling Structures which will take place in Paris on 14 - 16 October 1991. Further information from Commins-Ingemansson SA, 33 Rue des Petits Ruisseaux, 91371 Verrieres - Le - Buisson, France. Tel: 331 60 13 32 50. Fax: 331 60 13 32 80.

HERIOT - WATT UNIVERSITY

The University has announced the award of a £60,000 Industrial Fellowship, one of nine Fellowships awarded annually in the UK by the Royal Society and the Science and Engineering Research Council. Since its introduction in 1981, only five of these Fellowships have been

awarded to Scottish universities; this is both the first awarded to Heriot-Watt University and the first in the UK awarded in the field of building science research.

The primary objective of the Fellowship scheme is to enhance communication in science and technology and their application between industry and the academic community, to the benefit of both. The Royal Society/SERC contribute £60,000 and the industrial partner, in this instance Proctor Insulation Ltd of Blairgowrie contribute a matching sum partly in equipment and facilities.

Dr Robin Mackenzie FIOA, Reader in the Department of Building Engineering and Surveying at Heriot-Watt University will hold the Fellowship for two years and engage in research on product design for the building industry with the industrial partner. The proposed research is aimed at developing more efficient and cost-effective forms of floating floors for dwellings. This involves the use of open-

cell polymer foams which replace the need for expensive and less efficient mineral-fibre quilts

At a ceremony to mark the award Dr Mackenzie said "Building product design is now at a watershed. On 27 June 1991 the European Communities Construction Products Directive became part of UK law, heralding a flood of new regulations and guidelines from Brussels.

Progress during the initial phase is likely to be slow while over 3000 British Standards are 'harmonised' with their European counterparts, but in two years we shall begin to see a flood of new regulations and guidelines from Brussels. British designers and manufacturers must use this 'breathing space' to design and develop new products to counter the influx of new building materials from other EC countries and the possibility of cheap product competition from southern Europe".

Items for the New Products section should be sent to J Sargent, BRE, Garston, Watford WD2 7JR

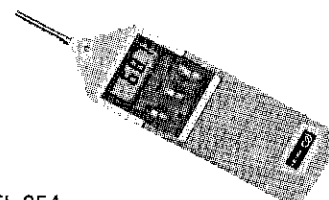
NOISE IN THE 1990's

industrial

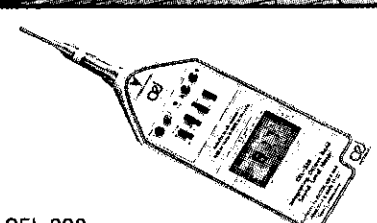
Make the first step towards meeting the 1990's regulations by sending for the new CEL Industrial Instrument catalogue.

For noise or vibration measurements - long or short term applications - the catalogue can provide the answer.

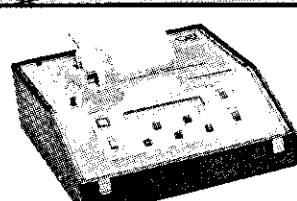




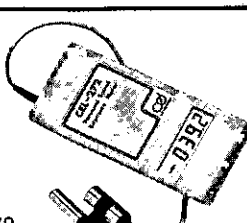
CEL 254



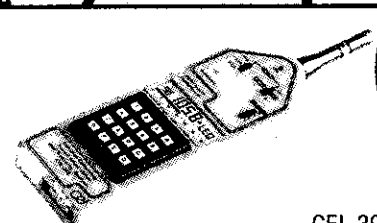
CEL 328



CEL 238



CEL 272




CEL 393

1990/91 EDITION

FREE

NOW AVAILABLE



Lucas CEL Instruments 35-37 Bury Mead Road Hitchin Herts SG5 1RT England

Tel: 0462 422411 Fax: 0462 422511



**University
of Southampton**

**Institute of Sound and
Vibration Research**

Highfield
Southampton
SO9 5NH

Fax (0703) 593033
Telex 47661 SOTON G

POSTGRADUATE COURSES IN ACOUSTICS AND VIBRATIONS

The Institute of Sound and Vibration Research (ISVR) is widely acknowledged as one of the world's foremost centres for research, teaching and consultancy in the increasingly important fields of acoustics and vibrations. In addition to a comprehensive programme of postgraduate research leading to the degrees of M.Phil. and Ph.D., the Institute also offers the following one-year full time postgraduate courses. All three M.Sc. courses include a six month instructional course followed by a six month period of research. Students may also register for instructional courses of six months duration leading to the award of Diploma of the University of Southampton.

- **M.Sc./Diploma in Sound and Vibration Studies**

Taught courses include basic training for students from a range of backgrounds, followed by specialization in either Engineering Acoustics, Structural Dynamics, Applied Digital Signal Processing or Human Response. The entry requirements are generally a first degree in a scientific or engineering discipline. The course gives an ideal preparation for work in a wide range of professional occupations.

- **M.Sc./Diploma in Automotive Engine and Vehicle Design Technology**

A course aimed at providing students with the knowledge and technical ability to take up a position in the Industry. Emphasis is on environmental aspects but basic engineering and design are also taught. The course is also suitable as a conversion course from other disciplines to automotive engineering and is recognised by the SERC for studentships.

- **M.Sc./Diploma in Audiology**

Aimed primarily at training Audiological Scientists to work in the NHS. It covers all relevant aspects of diagnostic and rehabilitative audiological theory and practice, including a major clinical practical component based on the ISVR Audiology Clinic. Applicants should have a good degree in any of the physical, natural or behavioural sciences.

For further information, contact the Admissions Office, ISVR, The University, Southampton SO9 5NH, Telephone: Southampton (0703) 592309

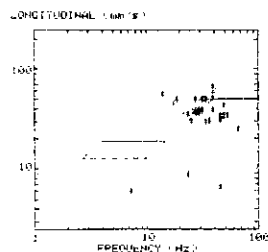
VIBRATION & NOISE TEST EQUIPMENT SALE OR HIRE (£180 p.w.)

Tel: 081-672 8298
Fax No: 081-672 7582
FREEPHONE 0800 181 945

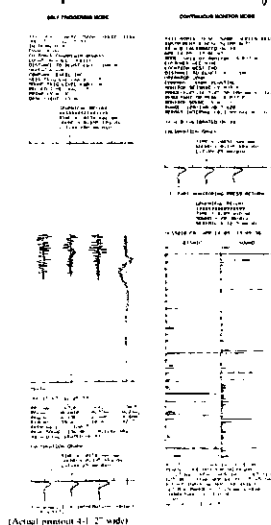
CONSULTING ENGINEERS:

Vibration
Noise
Air Quality
Environmental Assessment

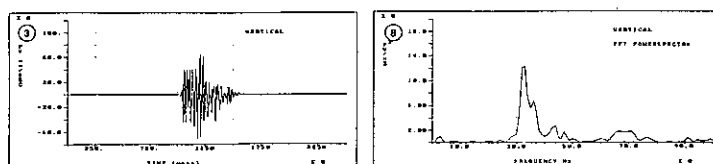
*USBM/OSMRE FREQUENCY PLOT



Graphical Format

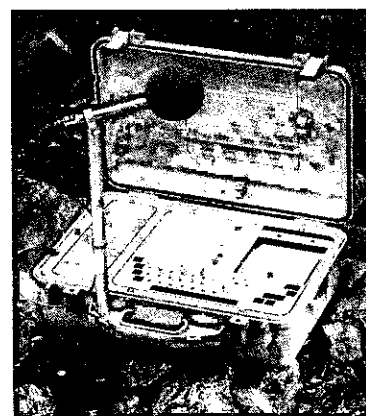


WAVEFORM ANALYSIS SOFTWARE



CIVIL ENGINEERING DYNAMICS

33 Louisville Road,
London SW17 8RL



**NOMIS
DIGITAL SEISMOGRAPH**



Ecophon®

— ceiling systems —

Despite the recession, acoustic ceiling specialists **Ecophon International** achieved and maintained a growth rate of 54% in 1990, a very difficult year for the Building Industry and the trend seems set to continue throughout the rest of the 90s.

General Manager Geoff Billett attributes the Company's success to a number of factors:

"Whilst there has been an overall drop in demand for products in the building trade generally, there has been an increase in public awareness of the need to improve the environment. Noise pollution is a constant problem and its control remains a priority.

Specifiers are now insisting on high quality, high performance products and end users are only too keen to avoid the costly mistake of buying cheap, shoddy products that are not made to last.

Here at Ecophon we are constantly testing and updating our acoustic ceiling systems and there is an on-going programme of research and development to ensure we stay ahead of the competition".

Another important factor which has contributed towards Ecophon's success is the excellent working relationship which the Company has developed with Specifiers and Ceiling Contractors to ensure that the quality of the installation does justice to the products used.

Ecophon recently set up an Approved Contractors Scheme to establish a register of Contractors who had experience and training in the installation of Ecophon products.

A key feature of the scheme was substantial investment in new training and conference facilities, made possible by the acquisition of an adjoining property on the Ramsdell site,



ACOUSTICS CEILINGS BOOM

which effectively doubled the size of Ecophon's UK headquarters.

The conference room is a showpiece for Ecophon's products. "Focus" panels in the ceiling are trimmed with a border of painted "Festival" tiles at the windows and curved "Quadro" panels link the ceiling to Ecophon wall panels in "Colorado Grey" finish. Luminaires from Ecophon's own Ecolux range are set into the ceiling.

An adjoining demonstration area has been set up for practical training in the use of Ecophon products. Here, Ecophon Approved Contractors learn the best way to handle and cut the tiles as well as gaining practical experience in installing, cleaning and other maintenance techniques. Contractors also have the opportunity of working with some of Ecophon's specialist systems, like "S Line" and "Super G".



The facility is also used to show Architects and clients "mock-ups" of ceiling systems and the different effects that can be achieved by combining different edge details and lights.

"Measures like these are reinforcing confidence in our products and helping us to stay at the top of the acoustic ceiling market," says Geoff Billett, "and because more and more people are appreciating the benefits of specifying Ecophon, business is continuing to grow steadily".



ACOUSTIC TEST REPORTS ARE AVAILABLE ON ALL ECOPHON PRODUCTS

ECOPHON CEILING SYSTEMS, ECOPHON INTERNATIONAL, RAMSDALL, BASINGSTOKE RG26 5PP.
TELEPHONE: 0256 850977. FAX: 0256 850600

- ACOUSTIC ENCLOSURES
- WEATHER RESISTANT ACOUSTIC LOUVRES
- VIBRATION CONTROL DEVICES
- FLEXIBLE CONNECTORS & EXPANSION JOINTS
- STUDIO DESIGN & BUILD
- ABSORPTIVE NOISE ATTENUATORS
- PULSATION DAMPENERS
- BLOW DOWN SILENCERS
- GAS PRESSURE REDUCTION SILENCERS
- REACTIVE BLOWER & COMPRESSOR SILENCERS
- ISOLATED FLOORS, WALLS & CEILINGS
- JACK UP FLOATING FLOORS
- ACTIVE NOISE CONTROL
- ISOLATED INERTIA BASES
- AUDIOMETRIC BOOTHS
- ANECHOIC & REVERBERATION CHAMBERS
- PACE ROOMS
- ACTIVE NOISE CONTROL

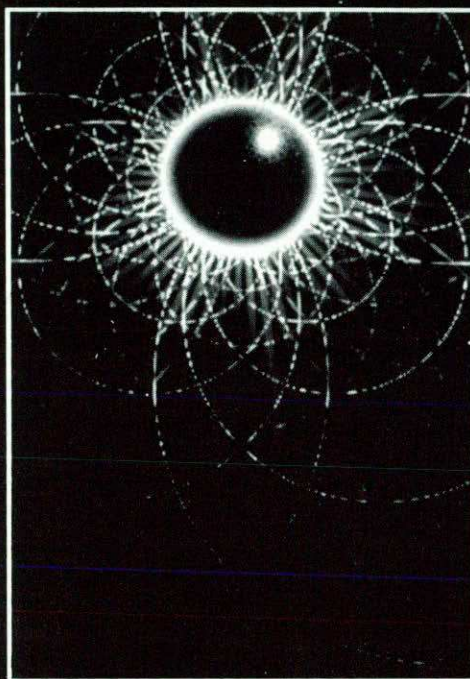
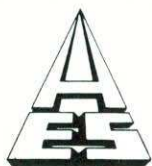
QUALITY ASSURANCE TO B.S. 5750

Usually working in conjunction with the clients design team, AES have conceived many thousands of Industrial and Environmental Noise Control schemes in the UK and Overseas.

Subsequent manufacture and supply of the hardware, by AES, has turned good theoretical practice into a successful, cost effective and practical solutions.

If you require this service, we have nationwide technical coverage ready and able to advise on most aspects of acoustics and vibration control.

Please contact us for further information and advice.



ACOUSTIC ENGINEERING SERVICES

**Acoustic Engineering
Services Limited**

**Allied House
Abbot Close
Oyster Lane
Byfleet
Surrey KT14 7JN**

**Tel: 0932 352733
Telex: 946695
Fax: 0932 355265**