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## **Standards**

Damage to Buildings from Vibration – Reflections on  
Current Criteria

*D Malam MIOA*

## **Legislation**

Vehicle Noise Legislation – An Overview

*J M Dunne & I C Yarnold*

The Noise and Statutory Nuisance Act 1993

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## **Technical Contributions**

Underwater Rain Noise – The Initial Impact Component

*H C Pumpbrey*

Developments in the Use of Cellular Foams in the Design of  
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Spectrum by Ear?

*A Miskiewicz*

Broadcasting and the Noise at Work Regulations

*A R Woolf MIOA*

## **Consultancy Spotlight**

The Novotel Hotel Complex, Heathrow

*J D Tate MIOA & W Stubbs FIOA*

## **Institute Affairs**

Noise Insulation Regulations for New Railways and Other  
Guided Systems

*H G Leventhall FIOA*

The Noise Council – A Brief History

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**BULLETIN**

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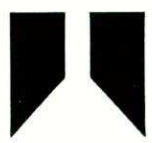
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## contents

### Standards

Damage to Buildings from Vibration – Reflections on  
Current Criteria

*D Malam MIOA*

p5

### Legislation

Vehicle Noise Legislation – An Overview

*J M Dunne & I C Yarnold*

The Noise and Statutory Nuisance Act 1993

*R Burnett & J W Tyler FIOA*

p11

p16

### Technical Contributions

Underwater Rain Noise – The Initial Impact Component

*H C Pumphrey*

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Design of Resilient Floors

*R K Mackenzie FIOA*

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Technical Listening: Can We Analyse the Sound

Spectrum by Ear?

*A Miskiewicz*

Broadcasting and the Noise at Work Regulations

*A R Woolf MIOA*

p19

p29

p33

p37

p42

### Consultancy Spotlight

The Novotel Hotel Complex, Heathrow

*J D Tate AMIOA & W Stubbs FIOA*

p47

### Institute Affairs

Noise Insulation Regulations for New Railways and

Other Guided Systems

*H G Leventhall FIOA*

The Noise Council – A Brief History

*R J Peters FIOA*

p51

p53

### Bulletin Board

Contributions

p58

### Publications

News from BSI

HSE Publications

Book Reviews

Hansard

p59

p59

p60

p61

### News from the Industry

New Products

News Items

p62

p64

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 two thousand 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, infrasound, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration. The Institute is a Registered Charity no. 267026.

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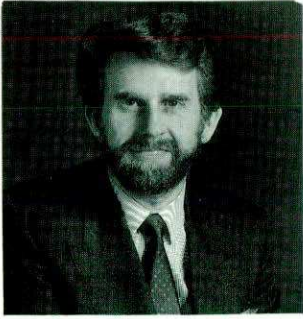
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*Dear Fellow Member*

*My term as President is nearly over – the two years seem to have flown! The period has seen major changes for the Institute including the move to our new home in Agriculture House, St Albans. This has been a great success, engendering a feeling of a real 'home' for the Institute. There is quite a different atmosphere to the Council and committee meetings held there – having the staff, office facilities and information to hand makes for more effective and speedier decisions.*

*In my first President's Letter I identified four key issues for the Institute – meeting the professional and technical needs of members in difficult economic times through our meetings programme, ensuring effective communications, enhancing our professional standing and continuing to play a role in the development of the engineering profession.*

*Although the frequency of formal meetings has been reduced, in terms of quality and relevance they continue to be highly successful with record attendances at some of our major conferences. There is no doubt that the Bulletin has gone from strength to strength over the past two years, thanks to the efforts of all concerned – contributors, advertisers, editorial team, advertising agent and the in-house DTP staff.*

*We have set up mechanisms for responding more consistently to legislative and regulatory consultations and through the European Acoustics Association we have strengthened our standing among our fellow European national societies. We have been able to maintain our role as an Engineering Council nominated body, an issue which has demanded much of my attention over the past two years to the detriment, perhaps, of other Institute activities. It remains Council's belief that we should take care to play our full part in the development of the profession during this time of change for engineering in the UK.*

*There are issues that still demand attention. Regional branch activities, the development of the Institute's library and information services and the recruitment of student members are among them.*

*In my work as President I have been supported admirably by Council and, in particular, by the Hon Treasurer, and my colleague at Salford, Geoff Kerry, whose tireless devotion to the Institute's well-being is unequalled. Finally, may I express my special thanks to all at the Institute office for making my term as President enjoyable. At Salford I shall hand over the chain of office to Alex Burd; I hope to continue to serve Council by taking over the stewardship of the Engineering Division from Vice-President Peter Lord, who retires from Council this year.*

*With all best wishes.*

*Peter Wheeler.*

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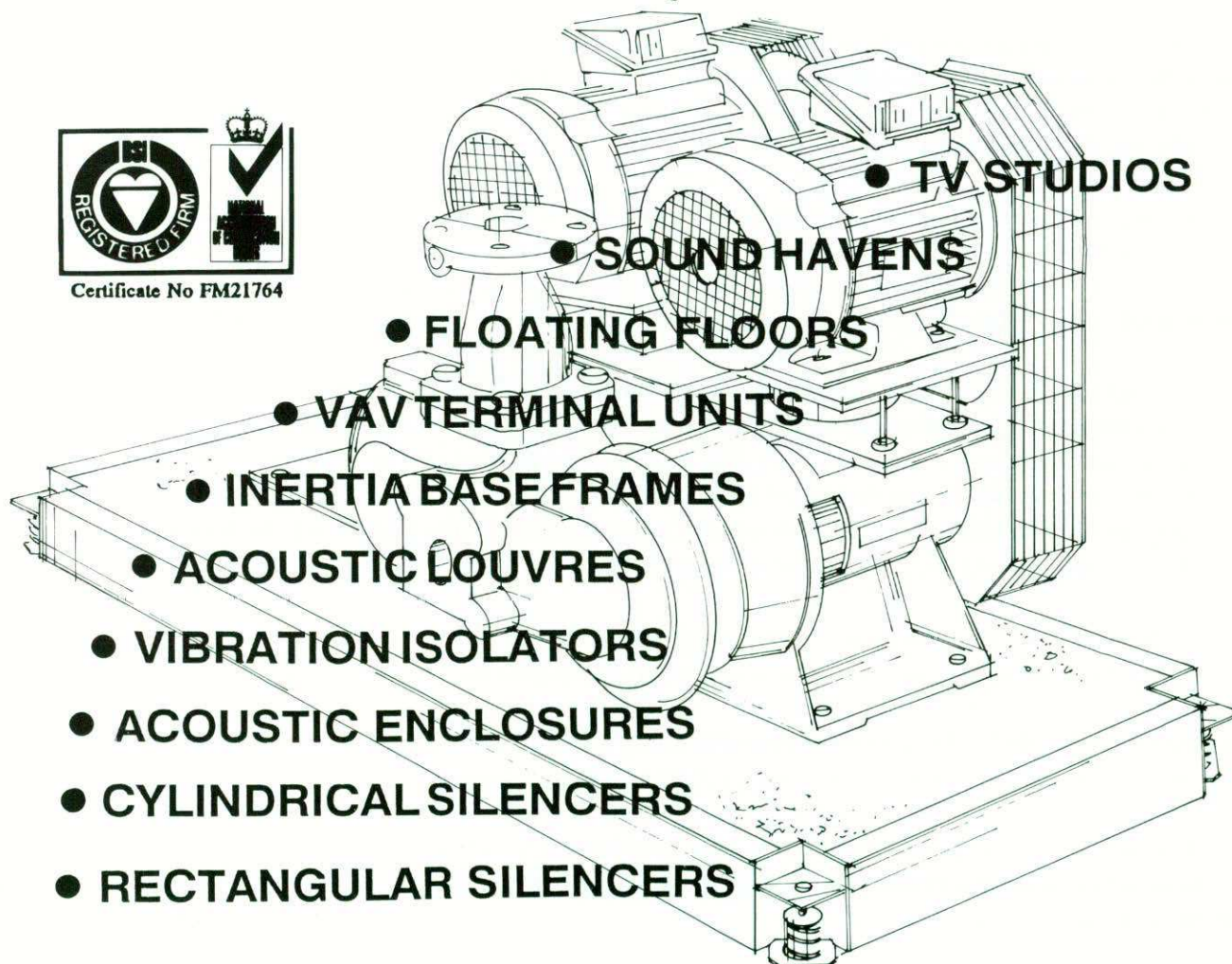
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# DAMAGE TO BUILDINGS FROM VIBRATION – REFLECTIONS ON CURRENT CRITERIA

David Malam MIOA

## Background

Vibration in buildings can disturb people and occasionally cause them to worry that their property is being damaged. Whereas work on the effect of vibration on people carried out before the second world war is still referenced in current literature 60 years on, the picture is different when it comes to the effect of vibration on the building structure. There appears to be a lowering of the 'acceptable' value, the more recent the publication, as pointed out by New [1]. Furthermore, while acceptable levels of vibration for people are generally agreed throughout the world, there is no such agreement for building tolerance levels. Even allowing for different types of building construction, different building codes and different ground conditions, it appears that crossing national boundaries, suddenly gives rise to different criteria. There is agreement on how building vibration should be measured in ISO 4866:1990 [2], after many year's discussion, but agreement on what everyone wants to know – acceptable levels – remains some way off.

The British Standard Committee – GME/21/3/2 – responsible for drafting guidance on this subject for application in the UK, began to consider the need for a national standard in this area in the early 1980s. The problem as then perceived was that codes developed in other countries were being used extensively in the UK, when the databases supporting European codes were not accessible or no better than the UK data. It was the general view of practitioners that some standards were too conservative and imposed an unnecessary economic penalty on industrial activity in the UK. It was also considered that the effects of vibration on people and buildings were confused.

A British Standard has now been developed which addresses the effect of groundborne vibration on buildings. This Standard – BS 7385 : Part 2 : 1993, [3] – was prepared in two stages, Stage 1 being the collation, expansion and evaluation of the available UK database, and Stage 2 being the preparation of the Draft BS in the light of international data and experience.

This article considers the scope of the UK standard, the data study supporting it, what it recommends and how it compares with other (mainly European) standards.

## Vibration-induced Damage

Vibration-induced damage can arise in different ways, making it difficult to arrive at universal criteria which will adequately and simply indicate damage risk. Damage can occur directly due to high dynamic stresses, due to accelerated ageing or indirectly when high quasi-static stresses are induced by, for example, soil compaction.

BS 7385 : Part 2 : 1993 considers only the direct effect of vibration on a building, since the other mechanisms are different. National standards in some European countries may include consideration of indirect vibration effects, which may partly account for differences between criteria.

For the purposes of BS 7385, damage is classified as cosmetic (formation of hairline cracks), minor (formation of large cracks) or major (damage to structural elements). Guide values given in the new BS are associated with the first category only – the threshold of cosmetic damage – usually in wall and/or ceiling lining materials.

It should be appreciated that all buildings crack due to many causes such as heat, moisture, settlement, occupational loads, pre-stressing forces, material creep and chemical changes. Any change in cracking rate or crack length will only be detected by careful inspection before and after (at the same time of day) the imposed vibration. Age, building condition and evidence of alterations are some factors to consider in assessing natural cracking. The problem is that damage due to these other factors may go unnoticed for some time, but becomes attributed to external vibration, which is as an unwanted intrusion into the houseowner's privacy. If the vibration magnitude is above the human annoyance threshold, a houseowner becomes naturally concerned about possible damage to his property.

## Case History Study in UK

An attempt was made by the BSI to assemble and assess data which was already available in UK reports. Information on the vibration source, the measured value (including position, frequency and magnitude), the building type and any comments regarding damage, where applicable were collected.

The sparsity of actual damage data became apparent even though 453 organisations were contacted [4]. The data collected was of variable quality and completeness which might be expected from information originally recorded for a variety of reasons and using different procedures. Blasting and piling were the most common sources of vibration to be measured and two storey domestic buildings were the most prevalent building type. In most cases structural surveys were not carried out before the vibration occurred, because of the cost involved and the fear of arousing public suspicion and anxiety, so that it was often difficult to substantiate the cause as vibration. It is sometimes cheaper, and more acceptable from a public relations point of view, for a company to settle small damage claims rather than question their validity.

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Only 5 of the 16 claimed cases of damage were thought to be directly induced by vibration, with some uncertainty still remaining for several of these. This lack of reliable damage data in the UK prevented definite guide values being drawn directly from the study except that it tended to support the view that there is greater risk of damage occurring above say 15 mm/sec ppv.

Although the UK database was limited, enquiry revealed no more substantial data supporting other European codes which gave quite definite guidance. The Committee decided therefore to continue with the preparation of a Draft BS, taking account of relevant UK and international experience, including the results of systematic field studies [5, 6], in the UK.

## Development of BS 7385 : Part 2 : 1993

BS 7385 : Part 2 deals with ground vibration from sources such as blasting, piling and other construction activities, machinery or road/rail traffic. Guide values for building vibration are based on the lowest vibration levels above which damage has been credibly demonstrated. The Standard covers the characteristics of building vibration, factors which influence response, measurement pro-

cedures, and assessment of measured vibration against guide values.

Excluded are the movement of loose objects within or on buildings, sensitive equipment or human tolerance, special structures such as tunnels, pipelines, chimneys and bridges, the effects of earthquakes, air overpressure, wind or sea actions. The levels of vibration at which adverse comment from people is likely are below levels of vibration which damage buildings, except at lower frequencies, which could account for the downwards trend in limits as people have become more environmentally aware.

The recommended measurement location is at the entry point to the building, and the standard applies to vibration transmitted through the ground from outside the building and not to internal sources. Peak particle velocity has been used to characterize structural vibration because it is the best single descriptor for correlating with case history data on the occurrence of vibration-induced damage, and it has a reasonable theoretical basis [1, 7]. Early research of a systematic nature [8, 9, 10] indicated a ppv limit for avoiding vibration-induced damage in the range of 50 – 75 mm/sec (2 – 3 in/sec, in fact). The

'method of halves' applied twice to improve the factor of safety to the lower end of this range results in 12 mm/sec, which is the UK opencast individual blast vibration limit [11]!

Since case-history data, taken alone, has so far not provided an adequate basis for identifying thresholds for vibration-induced damage, data from systematic studies [5, 6, 8–10, 12–14] using a carefully controlled vibration source in the vicinity of buildings has been used as the basis for defining damage thresholds. The vibration levels suggested are judged to give a minimal risk of vibration induced damage. Data from the US Bureau of Mines (Siskind et al [12]), which is a substantial and credible review of data at high magnitudes, suggests that the probability of damage tends towards zero at 12 mm/sec peak component particle velocity. This USBM dataset includes data from USA, Sweden, Canada and Britain for mainly blasting vibration and is notable in that it is all analysed statistically. This data is shown in Figure 1, where the data from the UK cumulative distribution is overlaid on the USBM dataset.

A frequency-based vibration criterion is given in the Standard because the relative displacements associated with cracking will be reached at higher vibration magnitudes with higher frequency vibration [15]. The dominant frequency to use for the assessment is that associated with the greatest amplitude pulse. Limits for primarily transient vibration, above which cosmetic damage could occur are given numerically in Table 1 and graphically in Figure 2. In the lower frequency region where strains associated with a given vibration veloc-

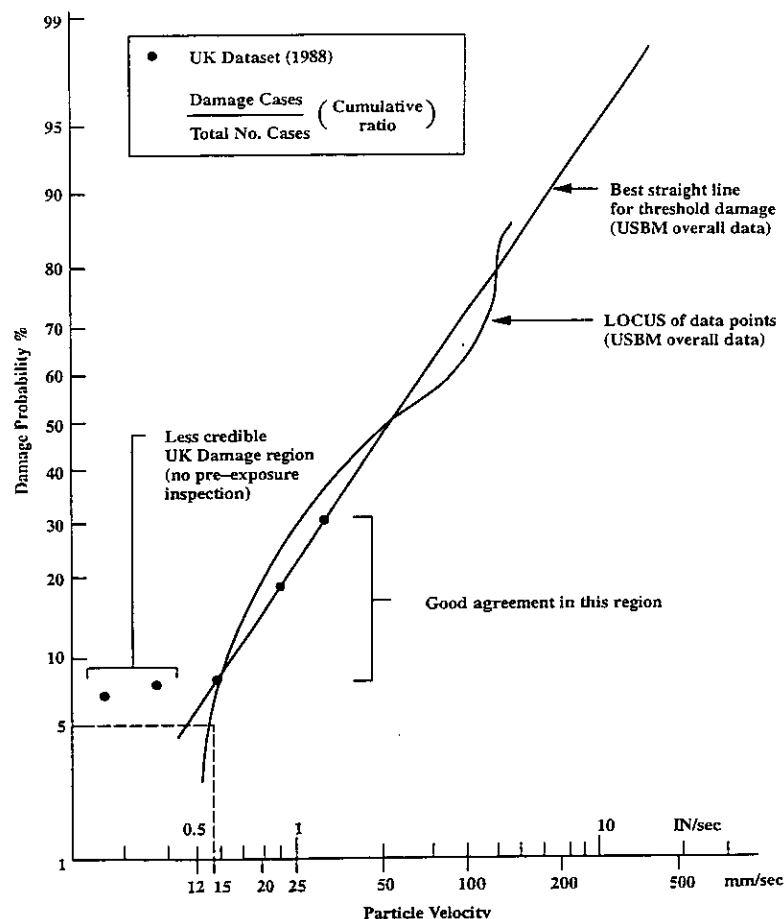


Fig. 1. Damage probability derived from uncorrelated UK data compared with USBM overall data

ity magnitude are higher, the guide values for the building types corresponding to line 2 are reduced. A 50% reduction in guide values is proposed (unsupported by data, but based on common practice [16]) for continuous vibration to allow for dynamic magnification due to resonance, where this occurs.

No allowance is specifically made for fatigue considerations as there is little probability, and a lack of verifiable evidence for fatigue damage occurring in residential building structures due to either blasting [15, 17], normal construction activities or vibration generated by either road or rail traffic. The increase of the component stress levels due to imposed vibration is relatively nominal and the number of cycles applied at a repeated high level of vibration is relatively low. However, more systematic research is required in this area. No automatic reduction in the guide values is recommended for building importance, age or condition – each case must be considered individually.

Damage to buildings can sometimes arise indirectly from vibration in certain ground conditions. Loose and especially water saturated cohesionless soils are vulnerable to vibration which may cause liquefaction. There are cases where the acceptable vibration limit may be set by considerations of soil-structure interaction, rather than distortion or inertial response of the building itself. The Standard points out the need to consider a lower limit for these special cases.

## Comparison With Other Standards

A comparison of various national standards [18, 19, 21–24] indicates that both the method of deriving acceptable limits and the ppv guide values vary considerably. Some criteria are frequency dependent, others are not. Criteria vary according to nature of peak particle velocity (ppv) – peak or resultant ppv, measurement location, type of building construction, type of wall lining, type of building materials, frequency of vibration, duration, ground wave propagation velocity and distance between source and receiver. A detailed review of the current European standards would take more time and space than is permitted here.

There are some obvious differences in both the common types of building construction, and the geological conditions in various countries for which the criteria have been derived. Wood-framed buildings predominate in the USA, for example (although some masonry buildings

| Line | Type of building                                                             | Peak component particle velocity (mm/s) in frequency range of predominant pulse |                                                 |
|------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------|
| 1    | Reinforced or framed structures<br>Industrial and heavy commercial buildings | 50 at 4 Hz and above                                                            |                                                 |
| 2    | Unreinforced or light framed structures                                      | 4 Hz to 15 Hz                                                                   | 15 Hz and above                                 |
|      | Residential or light commercial type buildings                               | 15 at 4 Hz increasing to 20 at 15 Hz                                            | 20 at 15 Hz increasing to 50 at 40 Hz and above |

Table 1 Transient vibration guide values for cosmetic damage

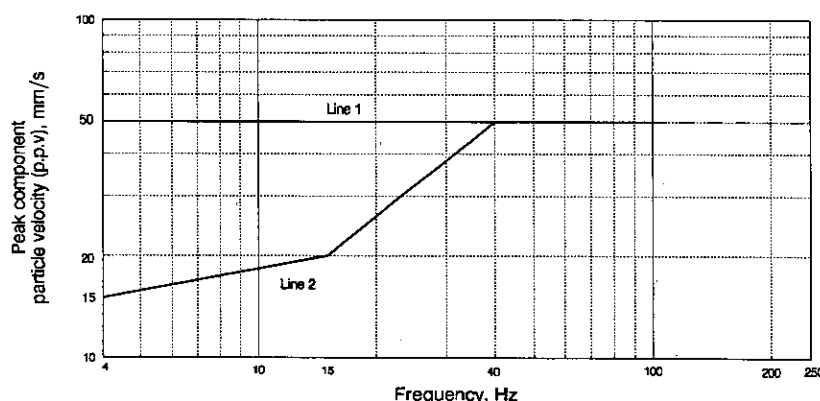


Fig. 2. Transient vibration guide values for cosmetic damage

were included in the USBM tests), and rock ground strata is common in Sweden. Notwithstanding factors which could warrant different limits, there still remains a divergence of technical opinion on what the thresholds of damage should be. This is partly due to certain limits being derived from considerations of overstressing, while others take fatigue into account, albeit in an undefined manner. Yet a further complicating conservatism is that indirect, as well direct damage mechanisms may be covered. The fact is that empirical codes cannot cover all types of damage mechanisms without setting unacceptably low limits.

## Conclusion

Different damage criteria have evolved in different countries, arising from differences in building practise, ground conditions, predominant vibration sources, measurement procedures, the national view of private property and also the experience and viewpoint of the principal investigators. Hopefully, the new British Standard, will promote the collection of test data in a standardized manner, and together with the results of systematic research, permit the further refinement of criteria for use in the UK when it comes up for the first review in 5 year's time.

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## **TABLE OF CONTENTS**

- |                                                    |                                                   |
|----------------------------------------------------|---------------------------------------------------|
| <b>1. NOISE</b>                                    | <b>5. THE ACOUSTIC EFFECT OF STUDIO FURNITURE</b> |
| <b>2. SOUND INSULATION</b>                         | <b>6. TIMING OF ACOUSTIC TESTS</b>                |
| <b>3. ROOM ACOUSTICS</b>                           | <b>7. GLOSSARY OF ACOUSTIC TERMS</b>              |
| <b>4. GUIDELINES ON SOUND CONTROL ROOM LAYOUTS</b> | <b>8. INDEX</b>                                   |

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# VEHICLE NOISE LEGISLATION – AN OVERVIEW

J M Dunne & I C Yarnold

## Introduction

Ever since its introduction in the late 19th century the use of the motor vehicle has been on an ever upward spiral. As traffic density increases and road congestion worsens so environmental concerns, such as noise and emissions, take on a higher profile.

Of course, these environmental concerns are nothing new. As far back as 1929 the noise nuisance from vehicles was recognised and the Motor Cars (Excessive Noise) regulations [1] were enacted. Soon after this, in 1931, the first Construction & Use regulations introduced specific requirements for silencers.

This trend towards controlling vehicle noise has continued and five years before joining the European Community in 1973 the United Kingdom introduced noise limits for different classes of new vehicle. Since joining the Community, the UK has been at the forefront in introducing regulatory measures specifically aimed at reducing the noise pollution from road vehicles. The vast improvements in drive-by noise achieved by the vehicle manufacturers can be clearly demonstrated when considered in the light of the present standards embodied in EC directive 84/424/EEC [2]. The noise reductions achieved by this directive, coupled to other previous changes, have allowed the UK to reduce drive-by noise levels of new motor vehicles by up to 10 dB(A) in as many years. Considerable strides have been made, particularly with the heaviest trucks, where the perceived noise has been effectively halved over the last decade.

The Department of Transport recognises that the control of noise from motor vehicles is a multi-facetted problem. Taking the Utopian view then clearly the new vehicle standard should be enforced throughout the vehicle's life rather than just at type-approval. It has been argued that this could be easily achieved by introducing a metered noise check to the MOT test, supplemented by roadside enforcement checks. Unfortunately, experience suggests that it's not that simple!

By introducing a metered noise test into the annual test then the 'polluter' would be paying through an increased test fee. The difficulty is, so would every other motorist – most of whom maintain their vehicle and cause no significant noise pollution. This argument would not be lost on new car buyers who would also argue that the new vehicle purchaser is already saddled with the research and development costs of tighter new vehicle standards. By introducing a metered noise test into the MOT test, they would be doubly penalised by paying an increased test fee so that the minority of motorists who fail to maintain their vehicles, could be caught.

The legislator is, therefore, often caught between equally convincing arguments on all sides. This invariably

means that we have to adopt a compromise between achievable and cost effective standards for new vehicles on the one hand and environmentally acceptable provisions on the other, whilst not forgetting, of course, that the costs will have to be borne by someone – usually the motorist!

## Limit Values and Regulations

The Wilson Committee Report on Noise [3] in 1963 was one of the first reviews of environmental noise pollution with specific mention of road vehicles. Wilson's report concluded that for a vehicle's noise emission to be judged on the threshold between acceptable and noisy, then the low speed full acceleration limit would need to be reduced to about 80 dB(A).

Following this report, in 1968, amending Construction and Use regulations were introduced which for the first time provided maximum sound levels for all classes of road vehicle. The regulations not only introduced requirements for new motor vehicles, but also provided test procedures and limit values for vehicles whilst in-service. Noise levels were measured using the acceleration test procedure of British Standard BS3425 : 1966 [4].

In 1973, having joined the European Community, the UK adopted the standards of the existing Council directive 70/157/EEC [5], which were less severe than proposed changes to our domestic regulations. The directive used procedures similar to those of the British Standard, as used in our earlier 1968 regulations. Since the introduction of this directive, several amendments have been agreed which have introduced special provisions for the testing of exhaust systems, tightened limit values (twice) and introduced a major revision of the test procedure.

Very recently, another amendment to directive 70/157/EEC has been agreed to take effect in the mid 1990s. This directive, 92/97/EEC [6], introduces new limit values and several new items not before seen in any noise directive or regulation. Some of the more substantive changes will be dealt with in more detail later in the paper.

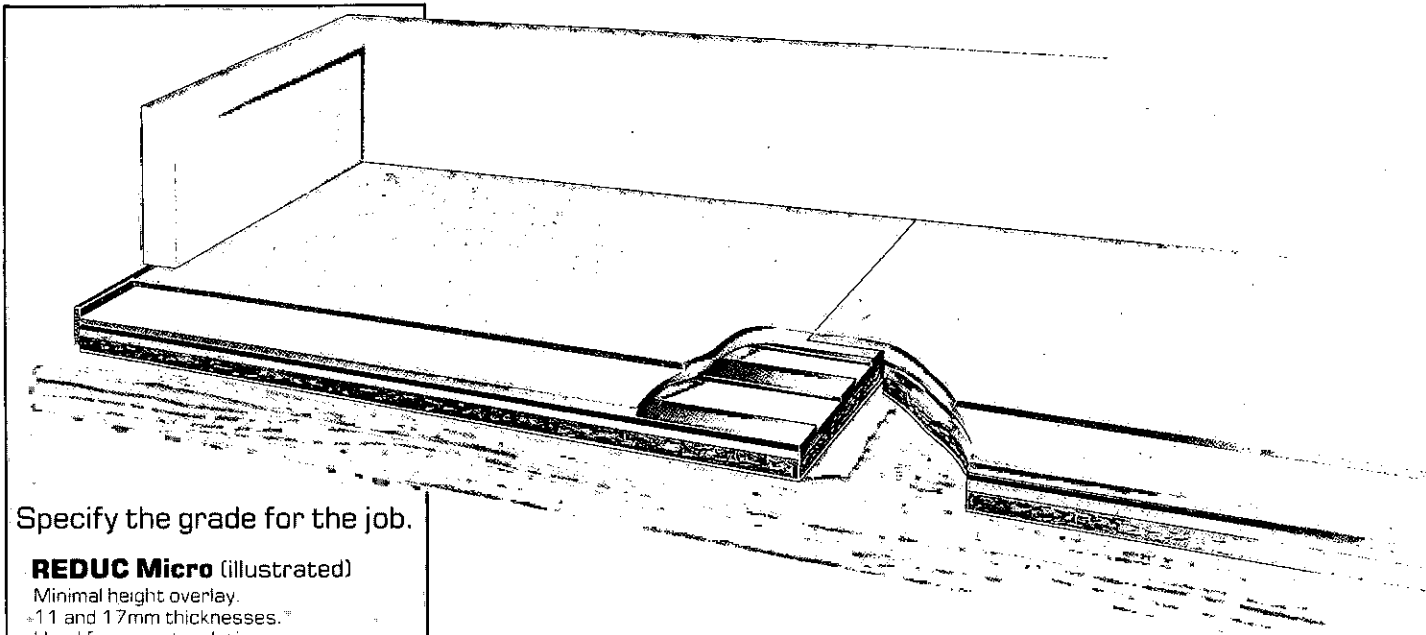
## Quiet Heavy Vehicle Project

In 1979, the then Minister of Transport, The Rt Hon (now Sir) Norman Fowler MP commissioned a wide ranging study into Lorries, People and the Environment [7] under the chairmanship of Sir Arthur Armitage. This Armitage Inquiry, as it came to be generally known, included recommendations that lorries be manufactured to a maximum noise level of 80 dB(A) by the year 1990. In response, the Government announced in its White Paper a collaborative research programme between Government and industry called the QHV-90 project (Quiet Heavy Vehicle for the nineties). This project followed on

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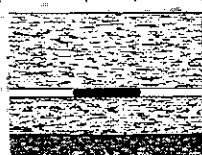
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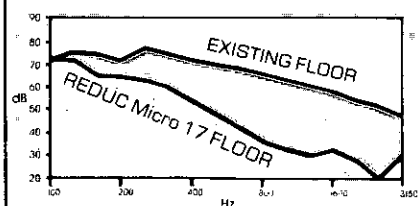
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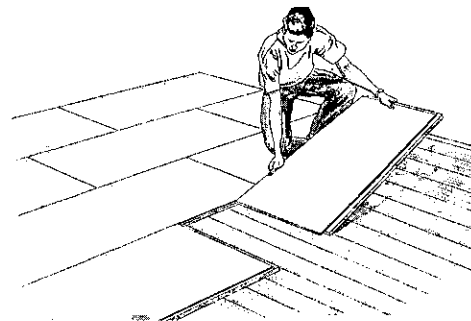
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from an earlier feasibility study [8] carried out by the Transport Research Laboratory (TRL) in 1978.

The £7 million QHV-90 project was equally funded by industry and the Government, with the Departments of Trade & Industry and Transport sharing the Government's £3.5M contribution. The project made significant headway in helping vehicle and component manufacturers find engineering solutions aimed at reducing the noise at source rather than applying remedial cures.

The DoT was particularly pleased with the outcome of the research as the project demonstrated that vehicles could meet lower limits without the need for extensive acoustic shielding or enclosures. These achievements supported the DoT's negotiating position in the European Commission's working group ERGA Noise (European Regulations Global Approach), during 1989/90, whose report culminated in directive 92/97/EEC.

## The Latest Amendment to Directive 70/157/EEC

The most recent motor vehicle noise directive was agreed by the European Council of Ministers on 10 November 1992 and has since appeared in the Official journal as directive 92/97/EEC. This new directive consolidates the previous amendments to directive 70/157/EEC and introduces new standards to take effect in the mid-1990s on a mandatory basis throughout the European Community.

The application dates are:

- from 1/10/95 the introduction of all new model types will have to be approved in compliance with the new directive
- from 1/10/96 all new vehicles sold in the Community will have to comply with the new directive.

Its main effects will be to introduce new limits for all classes of vehicle, to lay down a uniform standard for the test track surface by drawing upon the specification of an ISO standard, to introduce a manufacturing (conformity of production [CoP]) tolerance of 1 dB(A), to introduce a limit value and test procedure for the noise from air brake systems and, last but not least, to require Member States to make type-approval data widely available before 1 October 1994.

From the UK's point of view this directive represents a significant additional step in furthering the control of vehicle noise pollution. Notwithstanding the major advances of the new directive, there is an additional commitment in the directive which could have even greater ramifications on vehicle noise control, ie tyre noise.

## Tyre Noise

The type-approval test has always sought to limit the noise produced in a typical urban situation. This has inevitably focused attention on 'mechanical' noise rather than tyre noise through the use of the low speed full acceleration type test. As limit values have fallen so the contribution of tyre noise has become more significant during the type-approval test. The point may soon be reached where tyre noise could restrict any further lowering of limits in the future.

The new directive places a commitment upon the European Commission to present, by 31 March 1994, a proposal to The Council of Ministers to deal with the noise generated by the interaction of the tyre and road surface. During negotiations on the draft directive the UK insisted that safety must not be compromised in any directive aimed at reducing noise. Despite an uphill battle, we were successful in securing a revision to the articles to reflect due consideration of the safety aspects.

The contribution of tyre noise from vehicles travelling at constant high speed is well known, especially to those people living in close proximity to busy motorways. For this reason, the concept of regulating tyre noise seems a positive move. Our principal concern is to ensure that any move to limit the tyre noise does not have any ramifications on the primary safety aspect of tyres, ie that of being able to stop a vehicle quickly and safely. It is conceivable that the 'plating' of tyres with a noise limit could have two unfortunate knock-on effects. Firstly, the tyre manufacturers may be encouraged to compromise on safety features such as traction and wet grip in order to achieve a very low 'plated' noise number, and thus improve the marketability of their product. Secondly, the vehicle manufacturers may be tempted to fit such tyres in order to reduce the vehicle development costs needed to comply with the 'drive-by' noise standards. It is these aspects which will be taxing the minds of government officials and industry experts in the very near future.

## European Parliament

Under the EC co-operation procedure, The Council of Ministers are required to consider all Commission proposals in the light of the opinion delivered by the European Parliament. Parliament, having considered the new noise directive, suggested several amendments the most notable being considerable reductions in the drive-by limit values (see Table 1).

It is generally accepted that the lower limit values proposed by the European Parliament may be ultimately achievable, but the UK considered the Parliament's limit values to be impractical for two reasons; firstly, there is no certainty that the limits are achievable for production vehicles in the time scale laid down and, secondly, the limits would undoubtedly have led to an increase in the use of acoustic shields – something the QHV-90 project had sought to keep to a minimum – with the attendant in-service problems associated with such installations and, probably, at the expense of more permanent and longer lasting solutions.

However it has to be recognised, given natural technological development, that the Parliament's proposed limit of 71 dB(A) for cars may become a requirement in some extended time scale – possibly by the end of the century. Even so, it is highly likely that a substantial economic burden would be passed on to the end user, notwithstanding the technical, commercial and enforcement difficulties.

## ISO Test Track Surface

At the present time, the specification concerning the type-

| Vehicle Category                                                                                                                     | Current limits<br>1988/89/90<br>84/424/EEC | Directive<br>92/97/EEC<br>1995/96 | European<br>Parliament |
|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|-----------------------------------|------------------------|
| M <sub>1</sub> (Passenger Cars)                                                                                                      | 77 dB(A)                                   | 74                                | 71                     |
| M <sub>2</sub> > 3.5t & M <sub>3</sub> (Large Buses & Coaches (GVW > 3.5 t))<br>- engine < 150 kW:<br>- engine ≥ 150 kW:             | 80 dB(A)<br>83 dB(A)                       | 78<br>80                          | 75<br>77               |
| M <sub>2</sub> ≤ 3.4t & N <sub>1</sub> (Small Buses & LGV (GVW ≤ 3.5 t))<br>- GVW ≤ 2t:<br>- 2 t < GVW ≤ 3.5 t:                      | 78 dB(A)<br>79 dB(A)                       | 76<br>77                          | 72<br>74               |
| N <sub>2</sub> & N <sub>3</sub> (Heavy Goods (GVW > 3.5 t))<br>- engine < 75 kW:<br>- 75 kW ≤ engine < 150 kW:<br>- engine ≥ 150 kW: | 81 dB(A)<br>83 dB(A)<br>84 dB(A)           | 77<br>78<br>80                    | 77<br>77<br>78         |

Table 1. Limit values and enforcement dates

approval test track is only loosely defined in the directive. Variations of up to 4 dB(A) can and do exist between different test tracks in Europe and concern has been expressed that some vehicle manufacturers might be tempted to seek out tracks that will give the best result before applying for type approval, thereby achieving significant commercial advantage at reduced environmental benefit. The Commission and Member States, including the UK, recognised this problem and decided that the draft ISO standard, 10 844 [9], was suitable to incorporate into the directive.

The Commission also recognised that other factors, such as meteorological conditions, may influence the test result and have agreed to look at this area.

## Conformity of Production (CoP)

The UK opposed the introduction of the 1 dB(A) CoP tolerance to the new directive. In our view, CoP tolerances can and should be applied to allow for the vagaries of production systems providing that no overall increase in pollution occurs. With, for example, gaseous emissions, a high emitting vehicle can be balanced out by an equally low emitting vehicle with no overall detriment to the environment. In terms of noise each and every noisy vehicle constitutes a nuisance, and production tolerances allow even noisier vehicles onto the road.

An additional and unfortunate effect of this tolerance is to effectively deny the UK the achievement of its long stated aim of reducing the noise from the largest HGV to 80 dB(A) – we are, in practice, still 1 dB(A) adrift. However, whilst the UK abided by the majority decision of the Community to introduce the tolerance, 80 dB(A) still remains our policy goal.

## Loudness Measures versus dB(A)

Because of doubts about the continued use of the dB(A) scale as the most effective means of assessing vehicle noise, coupled to the Government's primary responsibility of lessening the noise nuisance of motor vehicles, the DoT sponsored a fundamental research programme aimed at

determining the most efficient method of judging a vehicle's subjective noisiness. This three-stage project is nearing completion at TRL.

Early results were encouraging, indicating that vehicles with equal dB(A) could differ in terms of subjective noisiness when assessed on a rating scale by panels of listeners. However, the concluding phase of the project (as yet unpublished) has shown that within similar vehicle groupings there is little benefit to be gained from changing to a loudness scale as opposed to the A-weighted scale. Consequently we will no longer be pursuing this avenue of research, although it was an interesting and useful exercise which clearly demonstrated the complexities involved with the public's perception of noise nuisance.

## In-service Controls

Beyond the scope of C & U regulations 98 & 99, dealing with the 'Avoidance of Excessive Noise' and the 'Use of Audible Warning Devices', there are presently no quantifiable measures of vehicle noise whilst in-service. Earlier regulations, dealing with in-service measurement which used a roadside 'vehicle in motion' test, were found to be extremely difficult to set-up. Suitable monitoring sites were few and far between and even when a check had been established, so few prosecutions resulted that the provisions were dropped from the 1986 regulations.

The DoT has recently been researching the possibilities for a revised in-service test. As part of this review the TRL has carried out a preliminary study looking at standards applied in other countries, existing international test methods, and how the new-vehicle stationary noise limit might be used for in-service assessment. The TRL report has confirmed that the stationary test included as part of the EC noise type-approval test could be relatively easily adapted to meet our needs. But even if the technological solution is eventually found, there remain a number of political concerns, not least of which is the impact on the immediate neighbourhood of regular in-service noise checks.

Other sources of in-service noise nuisances are also

being considered, including HGV 'body rattle' and the ramifications of removing acoustic shields and enclosures from HGVs.

The body rattle problem is the subject of another research project at TRL. The preliminary report was completed in March/April 1993 and as a result the project has been extended to look at ways in which the noise can be either isolated or reduced. Another consideration is to establish a code of practice with the vehicle/body manufacturers and operating engineers to try and overcome this particularly annoying source of noise nuisance.

During discussions on directive 92/97/EEC, the UK made proposals to ensure that any new vehicle fitted with acoustic enclosures or shields would be designed to ensure that they were kept in place for the effective life of the vehicle. By a combination of thoughtful design coupled with appropriate marking, it should be possible to deter end-users from simply discarding removable panels at the time of first service. Unfortunately we were unable to finalise suitable provisions for inclusion within this directive. The Commission, however, have agreed with the principle and indicated that they will consider the problem when making fresh proposals through the committee for adaptation to technical progress. The effect of removing acoustic shields will also be considered in the TRL research project looking at in-service noise controls during 1994/5.

## Conclusions

Legislators and manufacturers alike have progressed a long way towards providing quiet and efficient motor vehicles. However, as technology advances and traffic density increases, so do the aspirations of the general public to see even greater improvements in their immediate environment. Further reductions in overall noise are inevitable and a new round of proposals to limit vehicle noise is already under consideration for introduction towards the end of the century.

In terms of the present type approval procedure, we are rapidly reaching the point of diminishing returns. It is slowly becoming accepted that simply playing the numbers game and knocking a few more dB off present limits will impose substantial costs on the industry and the buying public with little benefit in lowering perceived noise. More wide ranging measures are needed.

By the end of the decade, the Community legislators will have taken reduction of mechanical noise sources almost to their limits, and will start addressing areas which have, to date, received little attention. Some form of tyre test, possibly coupled with tyre limit values, will certainly be introduced. In-service controls will also be given greater prominence, either at national level or in those areas in which the Commission has a remit. Also, wider use of road surfaces with high acoustic absorption properties, such as porous asphalt, is now being actively considered – but that is a whole new subject outside the scope of this paper.

Overall, the skill and inventiveness of the acoustic engineer will be required for some years to come. Past co-operation between the industry and the legislator has

proved very successful in civilising the motor vehicle. It is fully expected that this close co-operation will be maintained in the coming years to ensure that progress continues to the benefit of industry and the environment alike.

*Since this paper was presented at the Institute's meeting on External Vehicle Noise in 1993 the consideration of tyre noise issues has continued. In line with the concerns expressed on tyre safety in the paper, the Department commissioned the Transport Research Laboratory (TRL) to carry out a fundamental study to examine the relationship between tyre noise and tyre safety.*

*This research was completed in November 1993 and the results were presented by Dr P M Nelson FIOA of TRL to the ERGA-Noise Working Group in Brussels in December. The research showed clearly that there was a distinct relationship between the noise generated by rolling tyres and their safety performance; generally, tyres which gave higher levels of noise were safer tyres. The results of this research underlined concern that tyre safety should not be compromised as a result of limits placed on tyre noise. The Secretariat of the ERGA-Noise committee agreed to consider the views of the UK delegation and to take into account the results of research carried out at the TRL.*

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## The Noise and Statutory Nuisance Act 1993

### Introduction

The Noise and Statutory Nuisance Act 1993 (the 1993 Act), introduced as a Private Members Bill by Basingstoke MP Mr Andrew Hunter and reported on in the Hansard section of earlier Bulletins, received Royal Assent on 5th November 1993 and some of its provisions came into force on 5th January 1994. This note aims to summarise the main points of the Act and readers should consult the actual document for a detailed analysis of its contents. Whereas in England and Wales the new Act amends the Environmental Protection Act (the 1990 Act), in Scotland, where the 1990 Act does not apply, the amendments refer to the Control of Pollution Act 1974 (the 1974 Act). Part III of the 1990 Act (and the equivalent part of the 1974 Act in Scotland) provides local authorities with wide ranging powers to deal with problems of noise nuisance provided the noise is emitted from premises (which includes land). The main purpose of the 1993 Act is to respond to criticism that noise nuisance which arises on the street, for example from misfiring vehicle alarms, persistent DIY car repairs and noise from generators and refrigerated vehicles, was outside the scope of the 1990 and 1974 Acts.

### Provisions

The Act consists of four main elements as follows:

(i) **Noise in the Street:** 'Street' is defined as meaning a highway and any other road, footway, square or court that is for the time being open to the public.

The Act extends to Local Authorities powers to deal with certain types of noise nuisance in the street, ie, noise emitted from or caused by a vehicle, machinery or equipment (VME) in a street with the exception of that used in conjunction with political demonstrations or campaigns, that used by the three forces of the Crown, visiting forces and also traffic. It also provides special abatement procedures in circumstances whereby nuisance is caused by VME which is unattended. This includes the power of entry to effect necessary remedial measures and in exceptional cases the authority to remove the VME to a secure place. The expenses incurred are recoverable.

Possible scenarios where this may apply include car alarms, repair to cars in the road, parked HGV's, taxis on taxi ranks, buses at a terminus and buskers. It could also be used to control picketing where tannoy's are used.

(ii) **Loudspeakers in the Street:** This will enable Local Authorities to adopt provisions to grant consents to operate loudspeakers, under appropriate circumstances, in the street outwith the time band specified in Section 62 of the Control of Pollution Act 1974, ie from 9 pm to 8 am.

If adopted the Local Authority will want to consider the location, adjacent activities, time period, proposed number of loudspeakers with their output power and any other relevant matter. The granting of the consent does not provide an exemption from nuisance procedures.

(iii) **Audible Intruder Alarms:** These provisions replicate those contained within the London Local Authorities Act 1991 with a few minor differences. They will permit Local Authorities to require persons utilising audible intruder alarms to comply with various requirements. They also provide for offences and to powers of entry to deactivate alarms. However, these provisions are not yet in force and will need to be commenced by order together with any associated regulations.

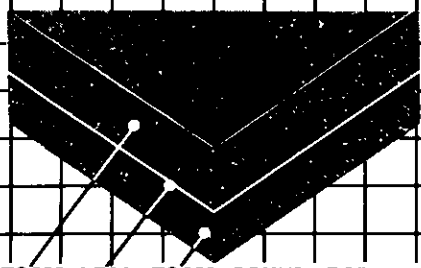
(iv) **Charges on premises:** (this applies to England and Wales only) Section 10 of the 1993 Act gives local authorities the power to recover expenses reasonably incurred in preventing or abating a statutory nuisance by putting a charge on the premises provided the current owner of the premises was the person responsible for the nuisance. This power gives a more certain way of recovering the cost of works and may prove to be more convenient than pursuing a debt through the courts.

### Resource implications for local authorities

The main duty and power in the 1993 Act to investigate and deal with problems of certain types of noise in the street may increase expenditure but some of these costs will be recoverable.

*R Burnett & J W Tyler FIOA* ♦

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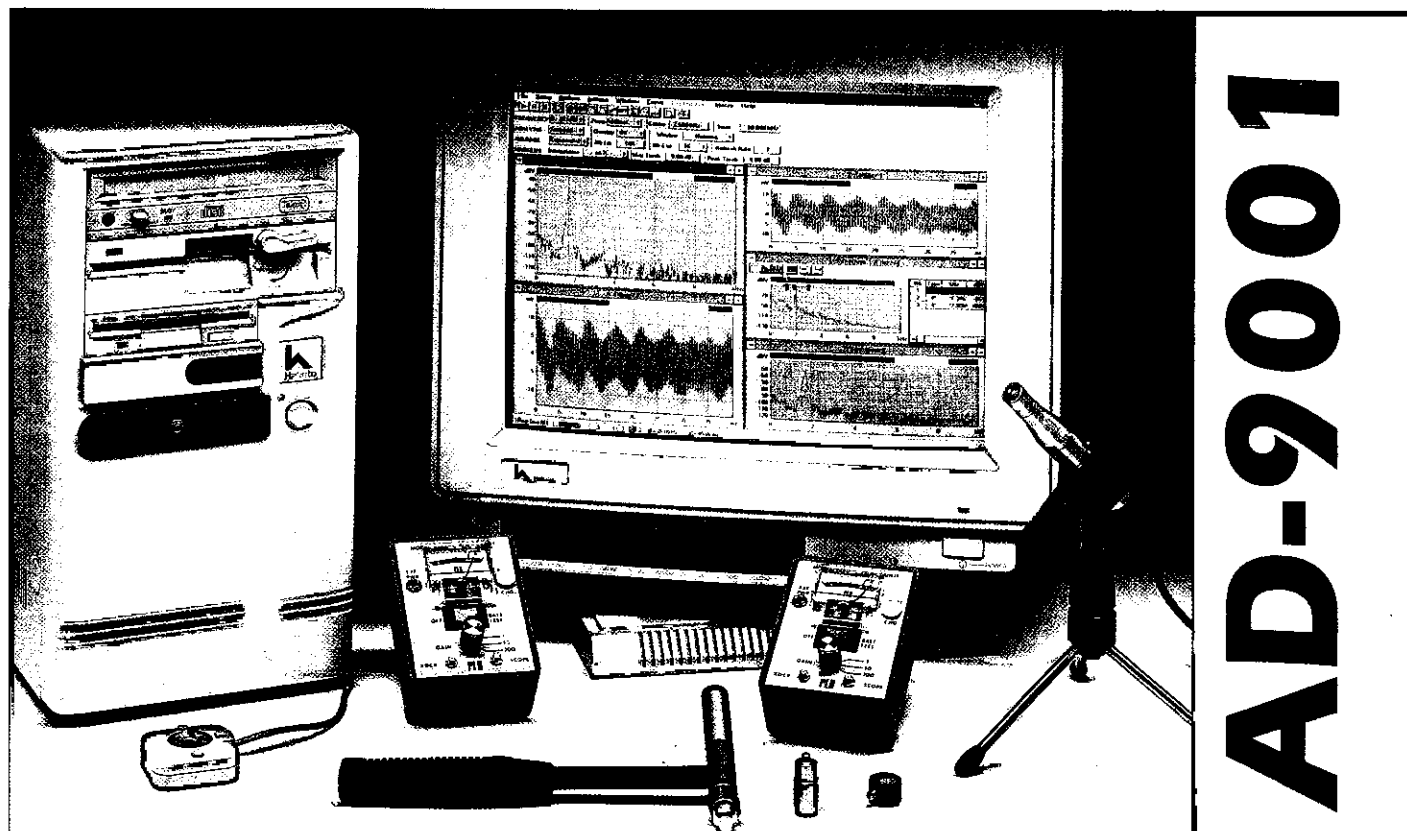
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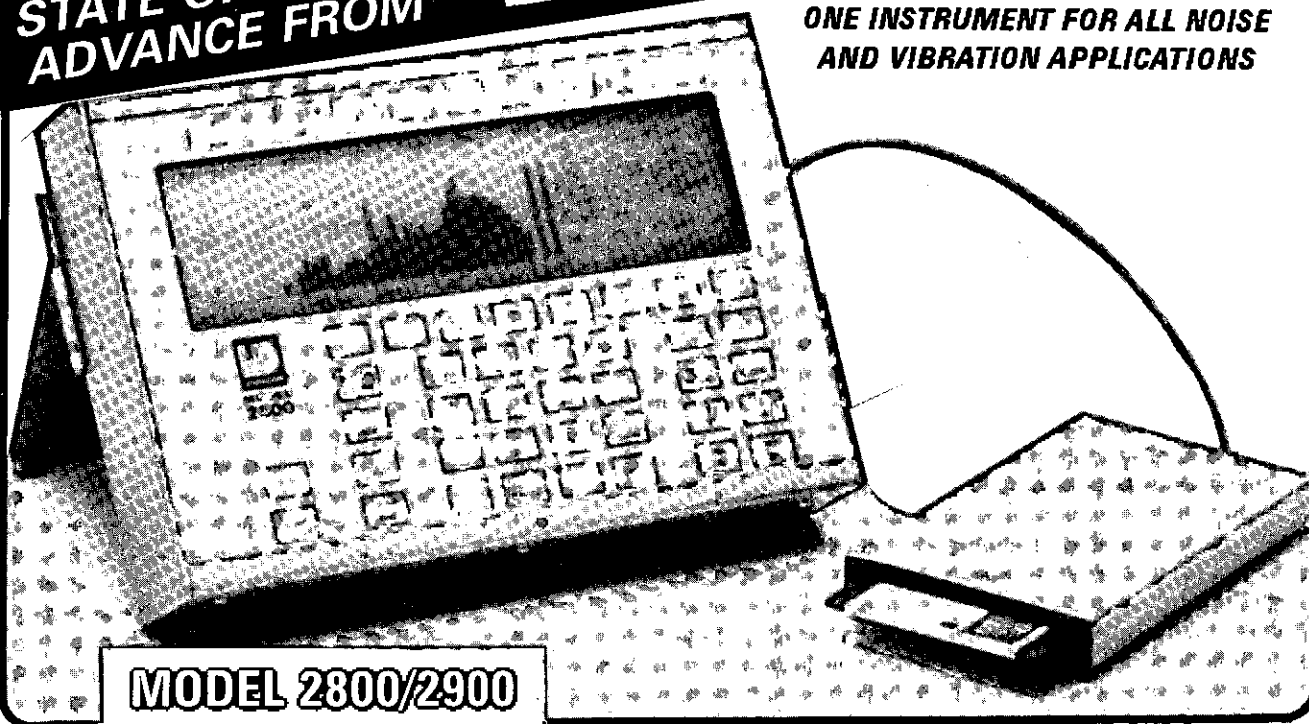
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# UNDERWATER RAIN NOISE – THE INITIAL IMPACT COMPONENT

H C Pumphrey

## Introduction

### History

The sound made by rain falling onto water has been a much-investigated subject recently. There are two main reasons for this, one is simply the general desire to understand ambient noise in the ocean because of its detrimental effects on sonar. The other reason is the hope that the sound could be used as a method of measuring the amount of rain which falls onto the world's oceans. This is a matter of interest to climate modellers, but is very difficult to measure by traditional methods such as rain gauges.

Progress has been made on two distinct and complementary fronts, the first being studies of the sound produced by real rain falling onto lakes or the sea, the second being laboratory experiments on the sounds of single water drops. The first discoveries of any real importance were made by Franz [1], who showed that an impacting water drop can produce sound in two distinct ways. The first sound is generated by a 'water hammer' effect at the moment of impact, while the second is radiated by a bubble, which is entrained in the water by the splash. Franz considered bubbles to be unimportant because they are only produced occasionally, while the initial impact sound occurs for every drop. He also made measurements of the sound of a spray of drops, and attempted to predict the sound of rain from the results. His predicted spectra were not like those obtained with real rain, but as no good real-rain data was available at the time, he had

no way of making this comparison.

The first reliable data on the sound made by real rain appeared about six years ago [2 – 4], and provoked a great deal of interest. The spectra showed a very persistent peak at a frequency of 14 kHz, as shown in Figure 1. The peak appeared in all types of rain, but was less obvious if the rain was heavy. At least one attempt [3] was made to explain this peak in terms of the initial impact sound alone; Franz's conclusion that the bubbles were sporadic and therefore unimportant was almost taken as read. I have shown, however, in previous papers, that the 14 kHz peak is not caused by the initial impact at all, but by bubbles. The bubbles are entrained by a different mechanism from that described by Franz. The important difference is that the new process is repeatable and predictable; I have therefore named it 'regular entrainment.' For drops of any given size, the process occurs only for a certain range of impact velocities; it does not occur at all for drops with diameters greater than 5 mm. For drops within the active range, a bubble will be entrained by every drop, moreover, successive drops of the same size and speed tend to entrain bubbles of the same size, and which radiate sound with the same intensity.

Raindrops all impact at their terminal velocity, which is a function of drop size and is well known and easily calculated. My results suggest that raindrops with diameters between 0.8 mm and 1.1 mm (and which therefore have speeds between 3.3 m/s and 4.4 m/s) will cause

regular entrainment. Furthermore, the bubbles entrained will have a range of resonance frequencies which are all above 12 kHz, with 14 kHz being the commonest frequency. It is these bubbles which give rise to the spectral peak. This phenomenon is now well understood and has been extensively described in the literature [5 – 11].

The role of the initial impact sound has remained relatively poorly understood. There are few results in the literature, and those which are available do not agree at all well with

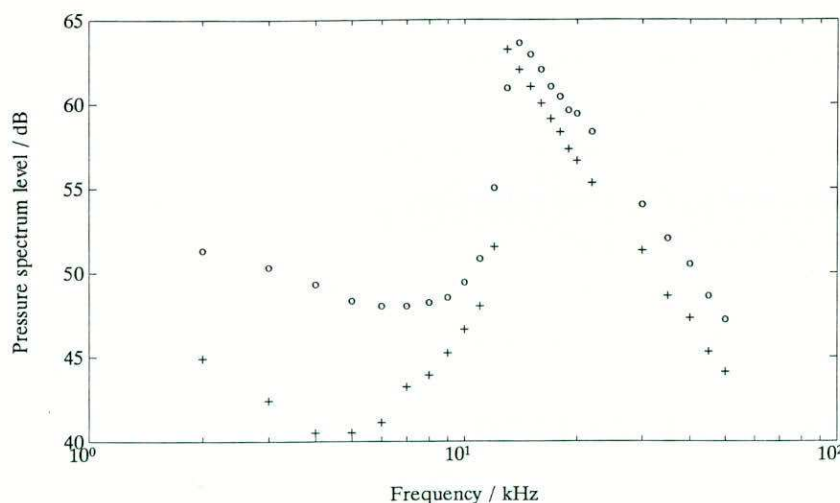


Fig. 1. Sound power spectra of the noise made by light rain falling onto a lake. The data was taken by Scrimger et al [4] in a lake in British Columbia. The circles represent a heavier shower than the crosses, with a higher proportion of large drops; note the relative increase in level at lower frequencies. The spectrum level is in dB re  $1 \mu \text{Pa}^2/\text{Hz}$ .

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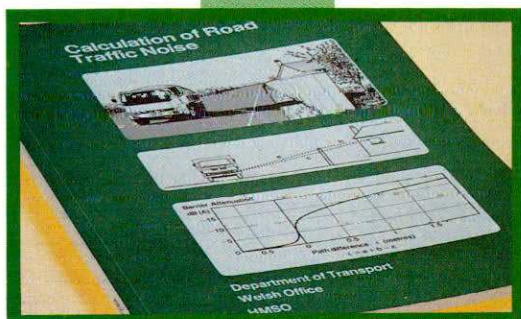
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each other, suggesting that this is not an easy problem to tackle, either experimentally or theoretically. In this paper, I shall describe some experiments in which I attempted to measure the pulse shape of the initial impact sound and how the pulse parameters depend on the drop size and impact velocity. The experimental problems will be discussed, and I shall also examine how they relate to previous work and why that work seems to contain so many anomalies.

## Preliminary theory

The water surface is effectively a pressure release surface, so any sound field which is generated at a point close to it has to be a dipole field. This means that the pressure perturbation must be of the form

$$p = p_0 \cos \theta \frac{\partial}{\partial r} \left\{ \frac{-\psi(t-r/c)}{r} \right\} \quad (1)$$

where  $r$  is distance from the source,  $\theta$  is the polar angle, measured from vertically downwards,  $c$  is the speed of sound,  $t$  is time and  $\psi$  is any function [12]. The negative sign is included for convenience, as the equation reduces to:

$$p = p_0 \cos \theta \left\{ \frac{\psi(\tau)}{r^2} + \frac{\phi(\tau)}{r} \right\} \quad (2)$$

where  $r$  is the retarded time  $t - r/c$  and is given by  $\phi = (1/c)(d\psi/d\tau)$ . Note that the pressure consists of a near-field component  $\psi$  and a far-field component  $\phi$ , it is only the latter which is of interest to us as the near-field is only detectable close to the splash and does not consist of energy being radiated away from the source region.

The form of  $\phi$  is not easy to deduce by theoretical means. We suppose that the process is basically a water hammer, and hence the pressure in the source region should be proportional to  $\rho cv$ , where  $\rho$  is the density of the water and  $v$  is the drop impact velocity. The problem is complicated greatly by the geometry, a recent attempt [13] succeeded mainly in showing exactly how difficult it is. Most of the real progress has therefore been made by experimental or computational means, but a number of theoretical guidelines have been suggested, usually on

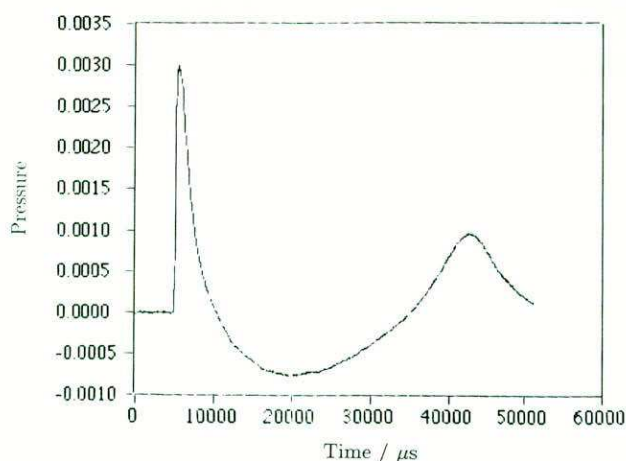


Fig. 2. The pressure pulse measured at a depth of 45 mm below a drop impact. Units of pressure are arbitrary.

dimensional grounds. In particular, both Franz [1] and Oguz and Prosperetti [10] have said that the far-field pulse should be of the form

$$p \propto \frac{\rho v^3 d \cos \theta}{r} u\left(\frac{\tau v}{d}\right) \quad (3)$$

where  $d$  is the drop's diameter, and  $u$  is a universal function. This tells us how we should expect the pulse length and amplitude to scale with  $d$  and  $v$ ; we shall see how well it agrees with experiment. It does not, however, give us any help as to the shape of the pulse; it is therefore necessary to resort to experiments, some of which are described below.

## Experimental Method

Impact sounds were studied in a large water tank (4.5 m x 1.3 m x 1.3 m deep); the tank was not anechoic, but was large enough to ensure that reflections were at a manageable level. The drops were produced by allowing water to flow slowly through hypodermic needles of various sizes. The velocity,  $v$ , was calculated from the drop diameter  $d$  and the height  $h$  from which the drop fell;  $v$  is given by [6]

$$v = v_T \left( 1 - e^{-2gh/v_T^2} \right)^{1/2} \quad (4)$$

In this equation,  $v_T$  is the terminal velocity of the drop, calculated by a power law fit to the drop diameter [14]. The sounds were detected by a miniature hydrophone (Brüel and Kjær 8103), which was placed vertically below the splash. They were then amplified by a suitable charge amplifier (Brüel and Kjær 2635); the resultant signals were analysed on a Macintosh IICI computer, using a National Instruments digitising card (model NB-A2000) and LabView software.

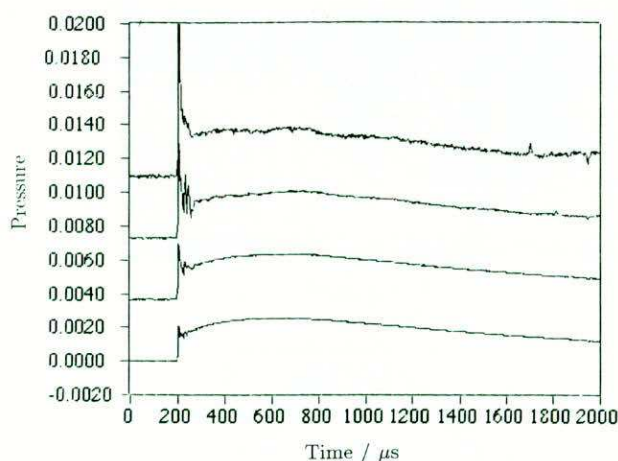


Fig. 3. The pressure perturbation below a drop impact at four depths: 30 mm (bottom), 50 mm, 100 mm and 180 mm (top), multiplied by  $(\text{depth})^2$ . Units are tens of Pascals multiplied by  $(\text{metres})^2$ . Note that as depth increases, the spike at the beginning of the pulse gets larger, but the whole trace gets noisier, and reflections are seen near the right-hand edge of the figure. The drop had a diameter of 2.9 mm and an impact velocity of 4.6 m/s.

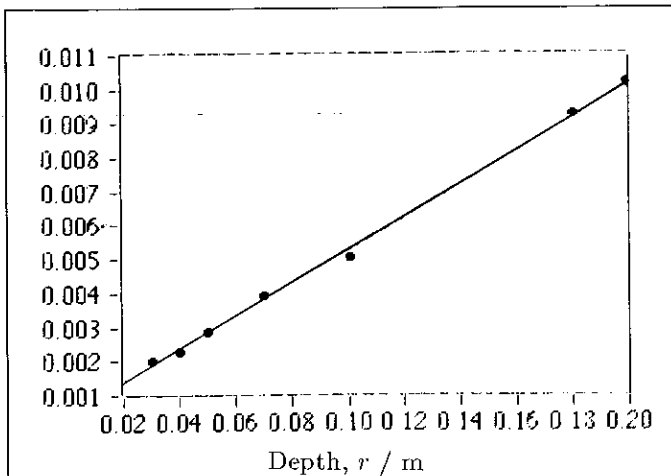


Fig. 4. Plot of  $r^2p$  against  $r$ . The slope of this graph is the value of  $\phi$  at a time of approximately  $4 \mu\text{s}$  after the drop impact. The intercept is the value of the near-field pulse,  $\psi$ . One of these plots is made for each point on the trace of Figure 5.

## Results

A typical drop impact pulse is shown in Figure 2; this is the raw signal as it comes from the hydrophone and an unwary investigator might be tempted to assume that this is the form of the radiated sound pulse,  $\phi$ . This is not actually the case, the far-field pressure must drop off as  $1/r$ . Most of the pulse shown in Figure 2 drops off as  $1/r^2$  and is therefore the near-field pulse,  $\psi$ .

If we look at the pulse on a smaller timescale, we can see that the first part of it does contain a significant radiated component. This is shown in Figure 3, in which the pressure pulse multiplied by  $r^2$  is shown for various values of  $r$ . The near-field part remains constant from one trace to another, but the spike at the beginning of the pulse becomes relatively larger as the distance increases; this spike is therefore the far-field pulse,  $\phi$ .

The big experimental problem is that if one moved the hydrophone to a large distance, in order to eliminate the near-field component, then the signal would become so contaminated with noise and reflections as to be quite useless. The solution which I adopted was to measure the

pulse shape at various depths and combine the measurements to produce the far-field pulse. Suppose that the total pressure  $p$  at retarded time  $\tau$  is given by Equation 2. If we have measurements of  $p$  for several values of  $r$ , then we can plot  $r^2p$  against  $r$  for each value of  $\tau$ , obtaining a straight line of slope  $\phi(\tau)$  and an intercept on the  $r^2p$  axis of  $\psi(\tau)$ .

If this is done for the data of Figure 3, we obtain a collection of graphs like Figure 4; if the slopes of these graphs are calculated and plotted against time, we obtain the required far-field pulse as shown in Figure 5.

Franz describes another way to extract the far-field pulse, which does not require data to be taken at several depths. It relies on the fact that  $\phi = (1/c)(d\psi/d\tau)$ . Consider a simple high-pass RC filter as shown in Figure 6, and for which

$$\frac{d}{dt}(v_i - v_o) = \frac{v_o}{RC} \quad (5)$$

If  $v_i$  happens to be of the form  $\psi + (r/c)(d\psi/d\tau)$  and  $r/c$  happens to be equal to  $RC$ , then we have

$$\frac{d\psi}{d\tau} + \frac{d}{dt}\left(\frac{r}{c} \frac{d\psi}{d\tau}\right) = \frac{cv_o}{r} + \frac{r}{c} \frac{d}{dt} \frac{cv_o}{r} \quad (6)$$

and therefore

$$v_o = \frac{r}{c} \left( \frac{d\psi}{d\tau} \right) = r\phi \quad (7)$$

The filter can be implemented digitally and applied to the data of Figure 3, a typical result is shown in Figure 5; it compares well with that of the multi-depth method.

Note that the pulse is positive-going; the pressure does not cross the axis and go negative on the timescale shown. This means that the power spectrum of the pulse will be monotonically decreasing in the range of frequencies shown; it will not have any peaks, this is shown in Figure 5. This does not imply that the pressure never goes negative, or that the spectrum has no peaks, but that the first zero crossing is at a time greater than  $0.5 \text{ ms}$  after the impact and that any spectral peaks are at frequencies below  $1 \text{ kHz}$  (certainly not near  $14 \text{ kHz}$ ). The exact form of the pulse is rather difficult to infer, but we

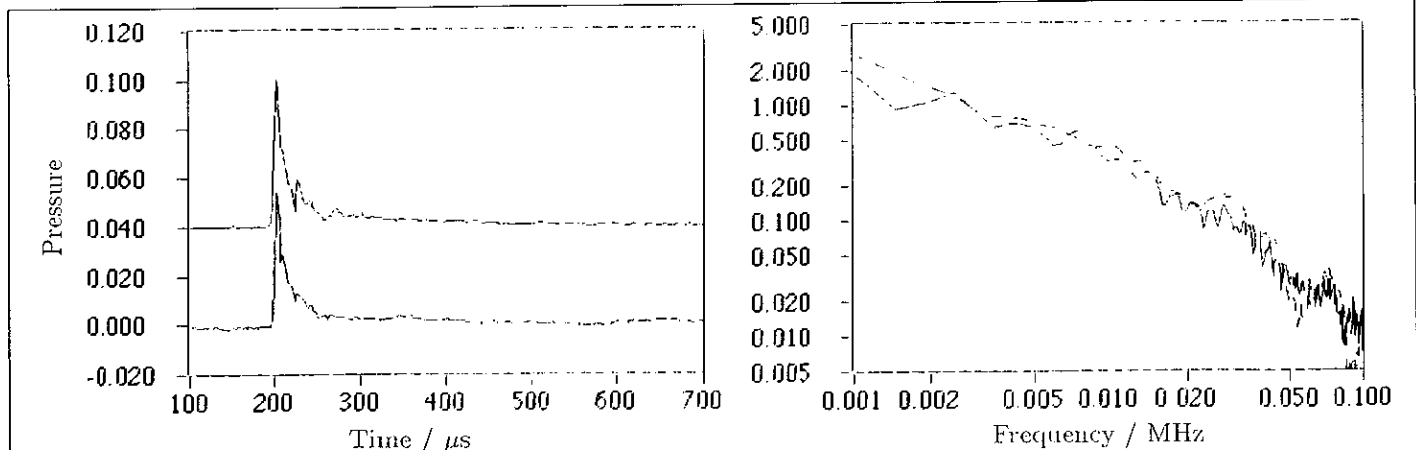
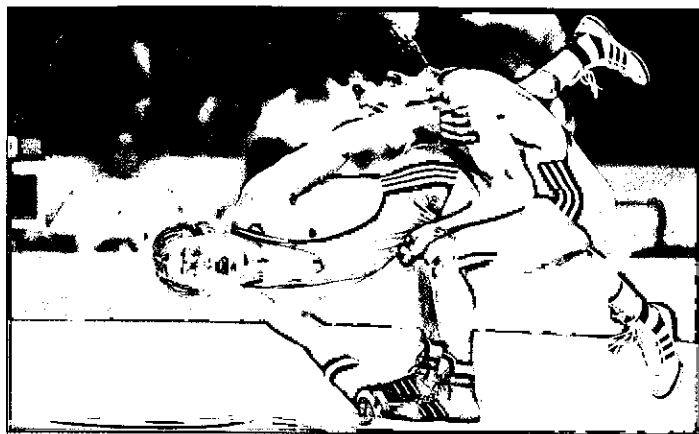


Fig. 5. Left: this shows the far-field pulse,  $\phi$ , extracted from data taken at various depths (bottom) and by Franz's filter method from data taken at a depth of  $50 \text{ mm}$  (top). Units are (tens of Pascals)(metres). Right: the energy spectra of these two traces in arbitrary units; the dashed line corresponds to the filter method.

# Sound

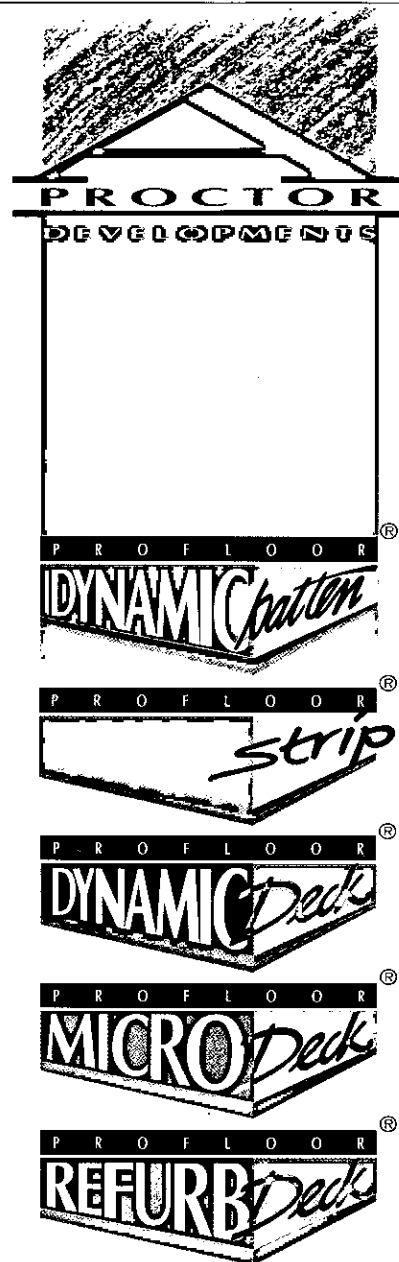


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might model it with one of the following functions:

$$\phi = A \left( \frac{\delta}{\tau + \delta} \right) \quad (8)$$

or

$$\phi = Ae^{-br} \quad (9)$$

These functions have the following energy spectra:

$$|\tilde{\phi}(f)|^2 = A\delta \left( ci(f\delta)^2 + si(f\delta)^2 \right) \quad (10)$$

and

$$|\tilde{\phi}(f)|^2 = \frac{A}{b^2 + 4\pi^2 f} \quad (11)$$

where  $ci$  and  $si$  are the sine-integral and cosine-integral functions [15]. These spectra are also shown in Figure 7; equations 8 and 10 seem to give a better agreement with the experimental results of Figure 5, at the expense of being more of a nuisance to calculate.

We now consider how the pulse amplitude  $A$  and timescale  $\delta$  depend on the drop size and impact velocity. There is no experimental data on this in the literature, but my own experiments suggest that  $A \propto v^\alpha d^\beta$ , where  $\alpha = 2.8 \pm 0.2$  and  $\beta = 1.5 \pm 0.2$ . This is in tolerable agreement with the suggestion of Franz and Prosperetti (Equation 3), that  $\alpha = 3$  and  $\beta = 1$ . We shall therefore compare amplitudes by calculating the dimensionless peak pressure  $p_d$ , given by

$$p_d = \frac{2p_p rc}{\rho d v^3 \cos \theta} \quad (12)$$

where  $p_p$  is the peak pressure. By using drops with sizes between 2.93 and 4.13 mm, and impact velocities between 2.5 and 4.5 m/s, I obtain an average value for  $p_d$  of about 7 with an error of about  $\pm 2$ .

The timescale proved rather difficult to determine experimentally; some rather crude attempts to measure the time taken for the pressure to drop to a quarter of its peak value suggest that  $\delta$  decreases with  $v$  and increases with  $d$ , in line with the requirement that  $\delta \propto d/v$ .

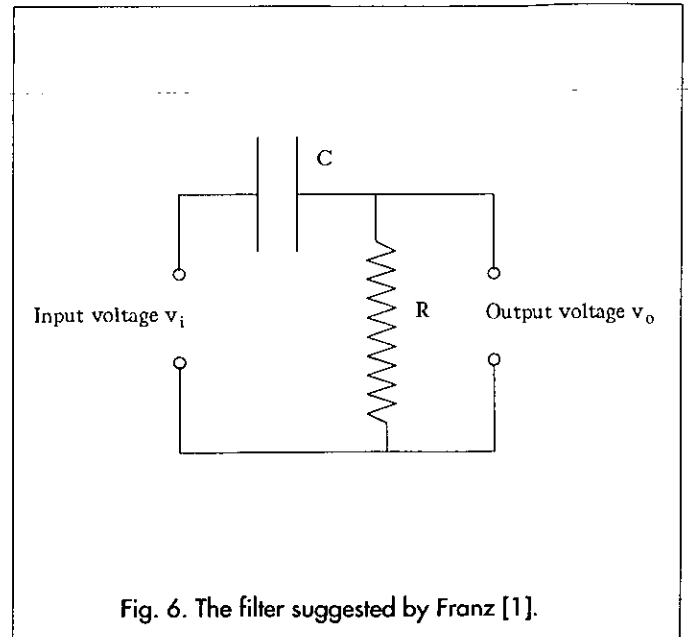


Fig. 6. The filter suggested by Franz [1].

## Comparison with Previous Results

There have been several previous attempts to measure or calculate the form of the initial impact pulse, in this section the results are compared to those presented above. The graphs in this section have been copied by hand into a computer, and their energy spectra calculated. Some inaccuracy is therefore inevitable, but the main features are certainly preserved.

### Franz [1]

This was the first study of the sound of drop impacts; Franz recognised from the beginning that the near-field sound was likely to be a problem, and he devised a cunning method to remove it, as described in the section above. He presents the pulse in a dimensionless form which I have converted to real units of time for a drop of 3 mm diameter impacting at 4 m/s (Figure 8). There are two major differences between this and my own result: Franz's pulse goes negative by a substantial amount, and it occurs over a much longer timescale. This would give a spectral peak at 600 Hz. The dimensionless peak pressure is 1.8, only a quarter of the value which I obtained.

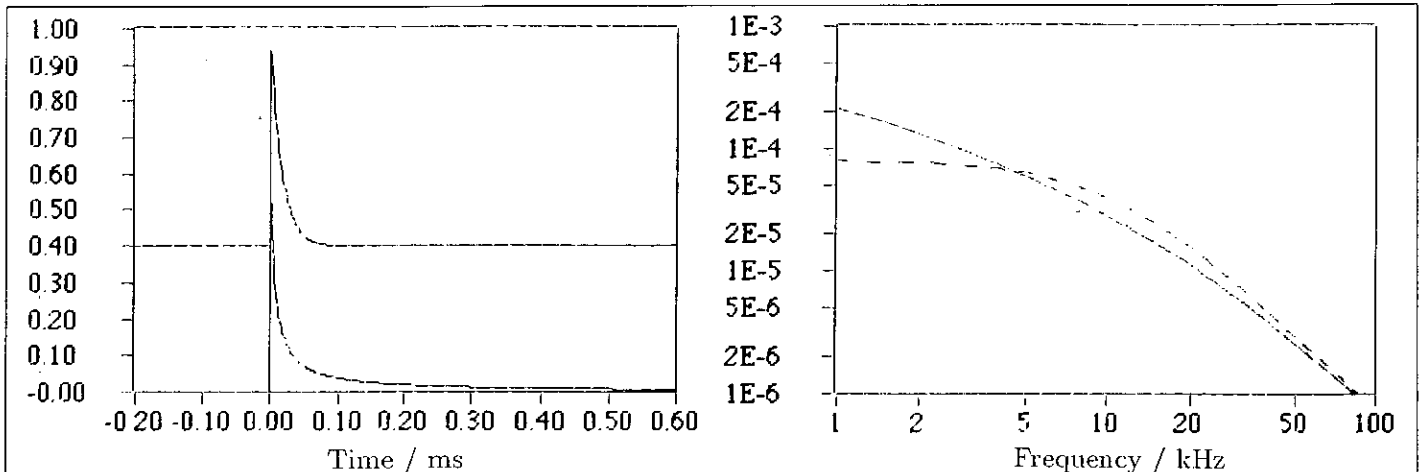


Fig. 7. Possible approximations to the pulse shape and their spectra. Left: pulse shapes of Equations 8 (below) and 9 (above); Right: Spectra of Equations 10 (solid) and 11 (dashed).

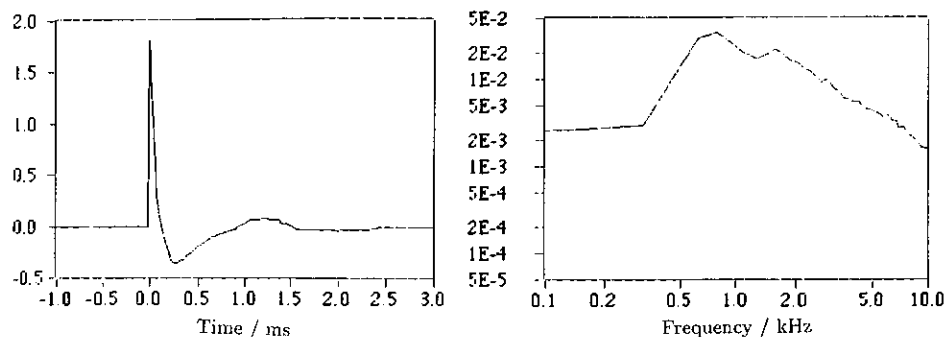


Fig. 8. Franz's pulse, and its power spectrum, calculated for a drop of 3 mm diameter, impacting at 4 m/s, for comparison with Figure 5. Pressure is in the dimensionless units of Equation 12.

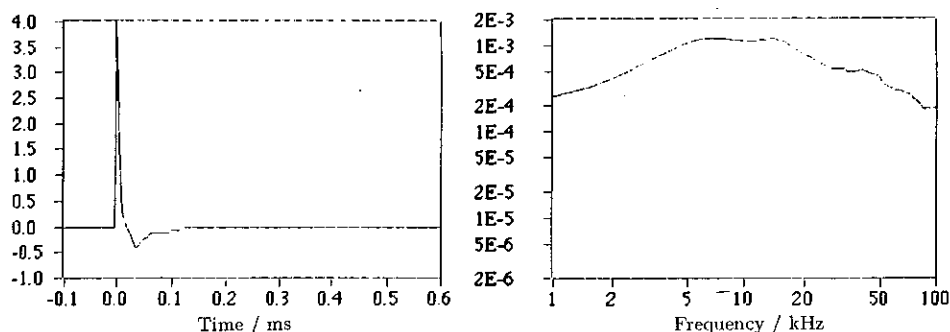


Fig. 9. This is the pulse described by Nystuen and Farmer in [16]. Drop diameter is 3 mm, velocity is 4 m/s, as in Figure 8.

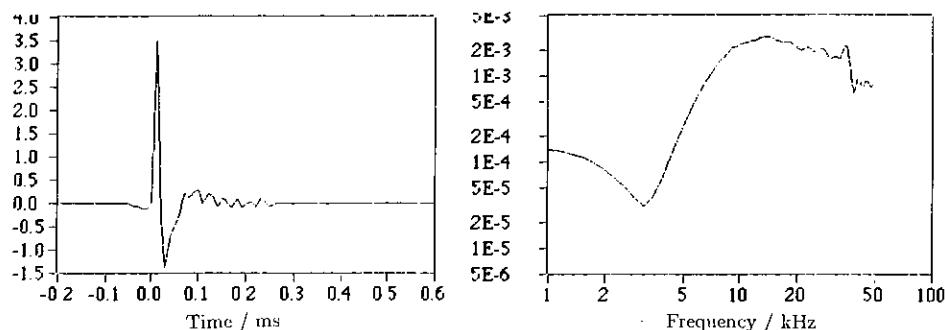


Fig. 10. From Nystuen and Farmer [17]. Drop diameter is 2 mm, velocity is 6 m/s.

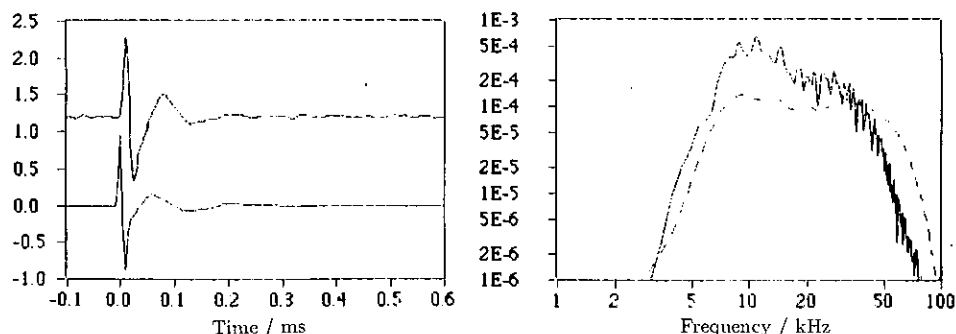


Fig. 11. This shows a pulse copied from [18] (below, left) and the power spectrum which I calculated from it (dashed line, right). It differs in some respects from the power spectrum shown in [18], for instance; the cutoff appears to be at a lower frequency here, this is probably due to inaccuracy in copying. The figure also shows the pulse which I obtained by passing a pressure pulse from a hydrophone situated 180 mm below a drop impact through a bandpass filter (above, left) and its spectrum (solid line, right). The drop details were as in Figure 3; the filter was a digital 3rd-order Butterworth filter with cutoff frequencies set at 8 kHz and 50 kHz. All units of pressure are arbitrary.

One is forced to conclude that although Franz's ideas and method were valid, the equipment available to him in 1959 did not have sufficient bandwidth or accuracy.

**Nystuen [3], Nystuen and Farmer [16]**

In these papers, a remarkable computer simulation of the drop impact is described. In the first paper, only the near-field pulse is shown, together with a power spectrum which shows a very small (3 dB) peak at 10 kHz. As they were unaware of the bubble mechanism, the authors then attempted to use their result to explain the spectral peak of real rain noise (which is 30 dB high, at 14 kHz). The second paper is similar, but includes a far-field pulse, shown in Figure 9, note that this too goes negative, and that it is on a somewhat shorter timescale than my own results. Its power spectrum has a peak at 10 kHz, again this is too small and at the wrong frequency to explain the real rain peak. The value of  $p_d$  is 35, five times larger than my own result.

**Nystuen and Farmer [17]**

This paper shows a drop impact pulse, but gives no detail on the equipment with which it was measured. The pulse and its spectrum are shown in Figure 10; note the peak, at 20 kHz this time, and that the overall timescale of the pulse is reasonably similar to my own results. No units are given on the pressure axis.

**Medwin, Kurgan and Nystuen [18]**

This paper shows a pulse and its power spectrum (Figure 11). The authors admit that they filter their signal, removing components below 8 kHz and above 50 kHz.

Figure 11 also shows that their result can be duplicated by feeding a raw hydrophone signal into a bandpass filter, we therefore conclude that the pulse shape shown in this paper is probably spurious and it should not be taken to mean that the impact pulse shows one or more cycles of oscillation, or that its spectrum shows any noticeable peaks. In view of this, it seems possible that the pulse shape in Nystuen and Farmer [17] has also been modified a certain amount. The amplitude of the peak is believable, leading to a value of  $p_d$  between 8 and 14.

These results teach us a few salutary lessons. It is clear that the pulse is very sharp, and has a very broad spectrum, which means that the observed pulse shape is very likely to be modified by the response of the hydrophone, amplifier, and any filters which are used. In view of this, it is probably wise to treat even the present results with a certain amount of caution.

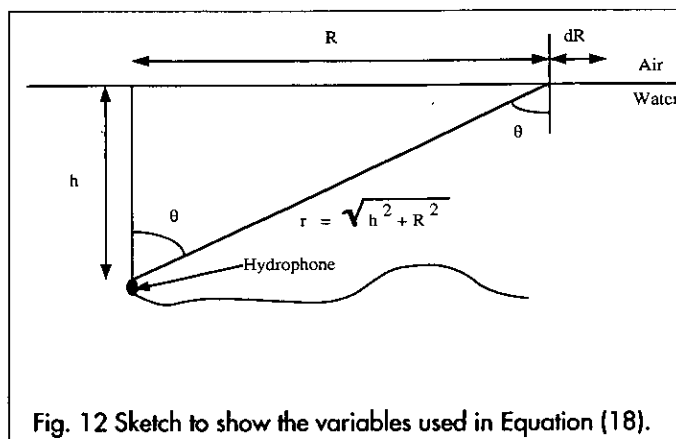


Fig. 12 Sketch to show the variables used in Equation (18).

## The Impact Contribution to Rain Noise Spectra

The contribution which the observed impact pulse would make to the rain noise spectrum was calculated; the procedure was similar to that in References [9] and [10]. We assume that a single drop produces a sound pressure

$$p(r, \theta, \tau) = \frac{A(v, d)}{r} \Phi(\tau, v, d) \cos \theta = \frac{\phi(\tau, v, d)}{r} \cos \theta \quad (13)$$

Dimensional requirements and experimental results suggest that we should assume

$$A(d, v) = \frac{\rho v^3 d}{2c} p_d \quad (14)$$

and that

$$\phi(\tau, v, d) = \frac{\delta}{\tau + \delta} \quad (15)$$

where  $\delta$  is proportional to  $d/v$ . Raindrops impact at their terminal velocities, which are known as a function of  $d$ , so we can calculate  $\phi$  for any value of  $d$ . We let the hydrophone be a depth  $h$  below the surface of an infinitely large and deep ocean, as shown in Figure 12. If the pressure at the hydrophone due to a single drop is given by (13), the energy spectrum of that pulse is

$$|\tilde{p}(f, d)|^2 / \rho c = \frac{\cos^2 \theta}{\rho c r^2} |\tilde{\phi}(f, d)|^2 \quad (16)$$

where the symbol  $\sim$  implies the Fourier transform. We let the number of drops which strike unit area of surface per second and which have diameters between  $d$  and  $d + dd$  be  $n(d) dd$ . The intensity spectrum  $dI(f, d, r)$  at the hydrophone due to a ring-shaped region of area  $2\pi R dR$  is then

$$dI(f, d, R) = \frac{|\tilde{p}|^2}{\rho c} n(d) dd 2\pi R dR \quad (17)$$

To find the total spectral intensity at the hydrophone,  $I(f)$ , we must integrate this over the whole surface of the lake (see Figure 12) and over all drop sizes, thus:

$$I(f) = \frac{2\pi}{\rho c} \int_0^\infty \left( \int_0^\infty \cos^2 \theta \frac{R}{r^2} dR \right) |\tilde{\phi}(f, d)|^2 n(d) dd \quad (18)$$

By using the substitutions  $r^2 = h^2 + R^2$  and  $\cos^2 \theta = h^2 / (h^2 + R^2)$ , the  $R$  integral in the brackets can be shown to be equal to one half, irrespective of the value of  $h$ . The intensity spectrum is therefore given by

$$I(f) = \frac{\pi}{\rho c} \int_0^\infty |\tilde{\phi}(f, d)|^2 n(d) dd \quad (19)$$

This integral may be estimated rather approximately for the data of Scrimger et al, because that paper supplies values of  $n(d)$  for several of the spectra it presents. In addition to this information, there are two parameters,  $p_d$  and  $\delta$ , which were estimated from experimental results. These results were not very accurate and so the values used are little more than realistic guesses which give reasonable results. We use a value of 14 for  $p_d$ ; this is rather at the large end of the experimental range. We let  $\delta =$

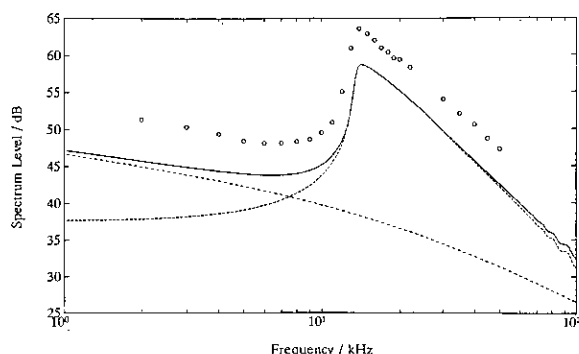


Fig. 13. The contributions of bubbles and impacts to the rain noise spectrum. The dashed line is the spectrum due to regularly entrained bubbles, as calculated in [9], the dot-dash line is the impact spectrum described above. The solid line is the sum of these. The circles are the relevant data from [4]; they are louder than the calculated values by about 4 dB, possible reasons for this are detailed in the text. The spectrum level is in dB re  $1 \mu \text{Pa}^2/\text{Hz}$ .

$1.6 \times 10^{-3} (d/v)$ ; this is also rather larger than the majority of the experimental values. A typical result of the calculation is shown in Figure 13, together with a calculated spectrum for the bubble sound [9]. Note that by including the initial impact sound, we get a much better fit to the experimental data at the lower frequencies. The data is uniformly 4 dB louder than the calculations, even those for the bubble spectrum, which I believe to be quite accurate. Various reasons have been suggested for this, one possibility is that the lake where the measurements were made was very reverberant. Another possibility is that the instrument used to count the raindrops failed to detect a certain percentage of the drops.

## Conclusions

The acoustic pressure pulse which is emitted when a drop touches the water surface has been investigated experimentally, and has been shown to be a single pulse with a sharp front edge and a rapidly decaying tail. Its power spectrum decreases monotonically with frequency, at least above 1 kHz; the initial impact can therefore contribute nothing to the spectral peak at 14 kHz. I believe that statements to the contrary in the literature can mostly be attributed to injudicious filtering of the signal, or to the inaccuracy of computer simulations.

Superposition of the impact spectrum onto the bubble spectrum shows that the impact sound is probably a significant contribution to the spectrum of rain noise at frequencies below 7 kHz, in moderately light rain. It is produced much more efficiently by large drops, which contain most of the volume of water in rain. This would explain why this part of the spectrum is better correlated to the total rainfall rate than is the 14 kHz peak. It seems likely that the impact sound may be important at higher frequencies in heavy rain, partly obscuring the bubble peak. It is true that the accuracy with which the absolute amplitude of the pulse was measured is not sufficient to enable us to state exactly how important the impact sound is, or whether it is the only important contribution in the low kHz frequency range, but we may be reasonably confident about the above description of the

pulse shape; this should provide a sound basis for any further research. This paper has not addressed the question of what happens if the raindrops impact the surface at some angle away from the vertical. Other work [18] has, however, shown that oblique incidence tends to make the initial impact slightly louder, and that it greatly reduces the occurrence of regular entrainment. It is therefore likely that in real life, the initial impact sound has a greater importance relative to the bubble sound than the results in this paper suggest. This sensitivity to impact angle (and therefore to wind) is another reason why the 14 kHz peak is badly correlated with the total rainfall rate, and why, if one wished to measure the rain rate acoustically, a frequency of about 4 kHz would probably be the most suitable.

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This paper was originally presented at an Underwater Acoustics Group conference on Recent Advances in Underwater Acoustics in Weymouth, May 1991. Dr Pumphrey is in the Meteorology Department at the University of Edinburgh. ♦

# DEVELOPMENTS IN THE USE OF CELLULAR FOAMS IN THE DESIGN OF RESILIENT FLOORS

Robin K Mackenzie FIOA

## Introduction

Derived from the Latin word 'cella' meaning a small enclosure, cellular materials have been available for use, in natural forms such as cork and sponge, for many thousands of years. In recent years, however, man-made, polymeric foams have largely replaced these natural materials and are widely used for applications involving the absorption of sound and the isolation of impacts. New developments in the manufacturing techniques associated with flexible cellular foams have opened up exciting new possibilities in the design of products incorporating these new materials. Research at Sheffield Hallam University during the past twenty years by Hilyard et al [1] has helped to characterise the mechanical properties of cellular foams. This paper summarises those mechanical properties and describes the use of cellular foam in the manufacture of resilient flooring products, with particular reference to laminated and co-planar applications of open and closed cell foams.

## Mechanical Properties of Cellular Foams

Upon compression cellular foams typically exhibit the stress/strain relationship illustrated in Figure 1.

At low stress, linear elasticity (cell wall bending) occurs followed by a large increase in strain for little increase in stress (elastic buckling of cell walls) and finally a steep rise in stress with strain as the matrix polymer is itself compressed following collapse of cells in the foam. Foams can be of open or closed cell form and the treatment of each is described here. In both types the effect of the fluid filling the cells needs to be taken into account. Gibson and Ashby [2] have characterised the mechanical behaviour in the following way.

### Linear Elasticity

With elastomer foams, the initial linear rise of stress with strain is followed by non-linear elastic deformation. Elas-

tic because the strain is recoverable. In open cell foams there is a long plateau as strain increases rapidly with little or no increase in stress. With closed cell foams there is an increase of stress with strain caused by gas enclosed in the cells and the cell walls themselves.

Linear elastic behaviour may be characterised by a set of moduli. Of primary importance are Young's Modulus ( $E^*$ ), Shear Modulus ( $G^*$ ) and Poisson's ratio ( $\nu^*$ ). The approach of Gibson and Ashby is to express the above moduli in terms of cell wall (base polymer), modulus and the foam's relative density ( $\rho^*/\rho_s$ ).

(NB The superscript '\*' refers to the bulk foam whereas the subscript 's' denotes the base polymer.)

### Open Cell Foam

Figure 2 illustrates cell wall bending for an open cell foam.

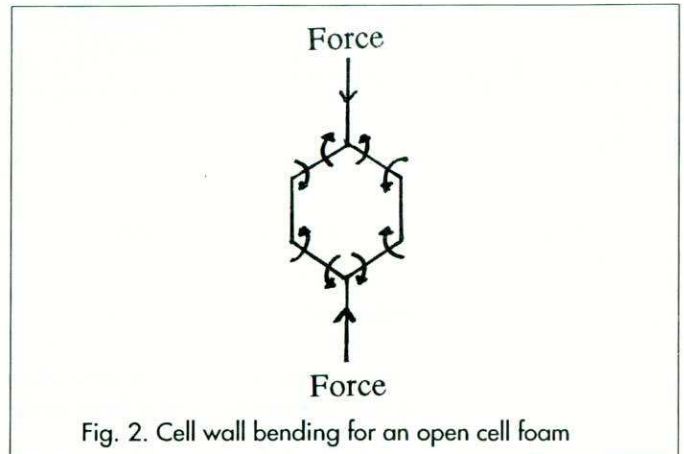


Fig. 2. Cell wall bending for an open cell foam

Figure 3 shows the cell model used to estimate the moduli with each cell joined to another by a strut in the middle of one of its beams.

Relative density of the cell ( $\rho^*/\rho_s$ ) and moment of inertia are related as follows:-

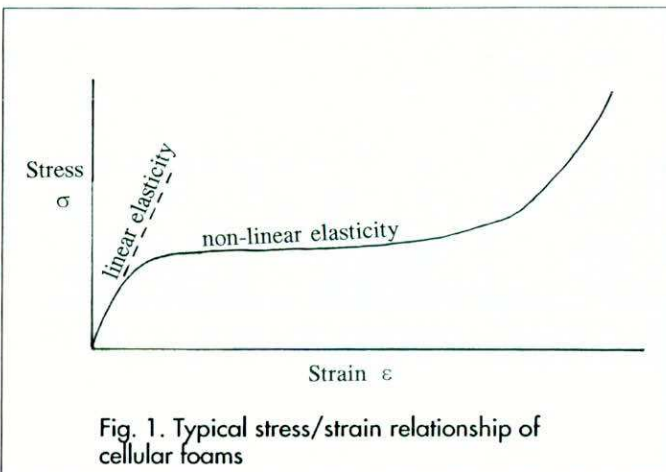


Fig. 1. Typical stress/strain relationship of cellular foams

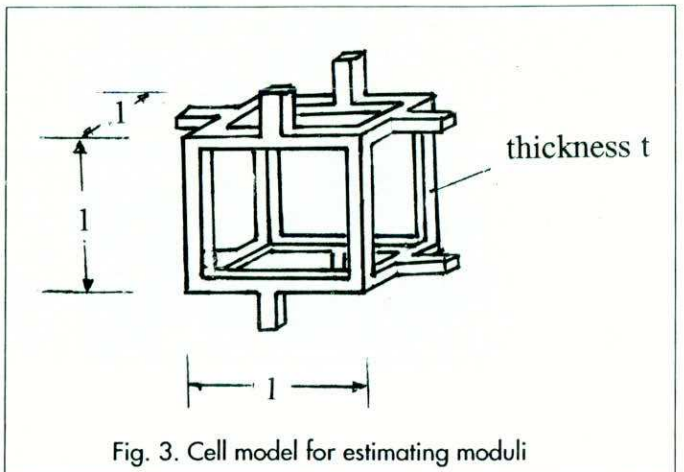


Fig. 3. Cell model for estimating moduli

$$\frac{\rho^*}{\rho_s} \propto \left(\frac{t}{l}\right)^2 \quad (1)$$

with

$$I \propto t^4 \quad (2)$$

For a beam of length  $l$  and thickness  $t$ , loaded at its mid-point, Timoshenko (1970) has given the deflection as follows:

$$\delta \propto \left(\frac{Fl^3}{E_s I}\right) \quad (3)$$

## Closed Cell Foams

Closed cell foams are more complicated than open cell foams. The effects of material in the faces and fluid contained in the cell must be considered as well as the contribution of the cell edges. The situation is illustrated below in Figure 4.

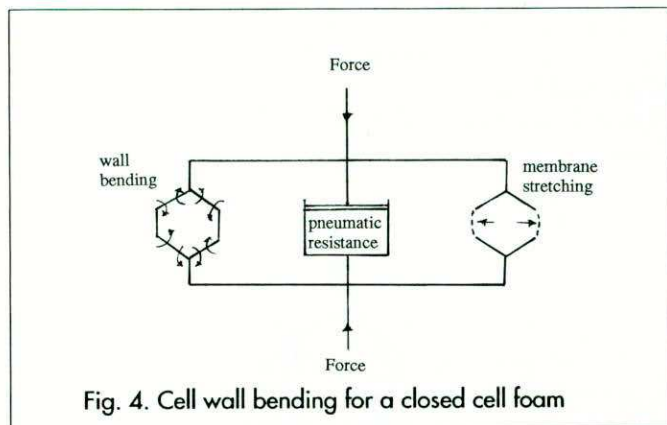


Fig. 4. Cell wall bending for a closed cell foam

## Non-Linear Elastic Behaviour

### Open Cell Foams

The non-linear deformation of these foams is controlled by the elastic buckling of the cell edges. The critical buckling load is given by Euler's formula:

$$F_{crit} = \frac{n^2 \pi^2 E_s I}{l^2} \quad (4)$$

where

$l$  = beam length;  $E_s$  = Young's modulus;  $I$  = 2nd moment of area.  $n^2$  describes the degree of constraint at the ends of columns. The stress  $\sigma_{el}^*$  at which buckling occurs is obtained from:

$$\sigma_{el}^* \propto \frac{F_{crit}}{l^2} \propto \frac{E_s I}{l^4} \quad (5)$$

### Closed Cell Foams

With closed cell foams elastic buckling is modified by the gas contained in the cells and probably by the cell faces as they fold over themselves. As cell walls buckle then the pressure of the gas can be expected to increase which suggests an explanation of post buckling behaviour. The foams exhibit an increase in the gradient of stress/strain graphs. Gibson and Ashby propose the following description of post buckling behaviour:

$$\frac{\sigma_{el}^*}{E_s} = 0.05 \left(\frac{\rho^*}{\rho_s}\right)^2 + \frac{\rho_0 - \rho_{at}}{E_s} \quad (6)$$

where  $\rho_0$  and  $\rho_{at}$  are original and atmospheric pressure respectively.

For these foams, usually  $\rho_0 = \rho_{at}$  but as compression increases  $\rho_0$  is modified to  $\rho^1$  where:

$$\rho^1 \approx \frac{\rho_0 \epsilon}{1 - \epsilon - \left(\frac{\rho^*}{\rho_s}\right)} \quad (7)$$

The post collapse stress/strain behaviour is therefore described by:

$$\frac{\sigma^*}{E_s} = 0.05 \left(\frac{\rho^*}{\rho_s}\right)^2 + \frac{\rho_0 \epsilon}{E_s \left(1 - \epsilon - \left(\frac{\rho^*}{\rho_s}\right)\right)} \quad (8)$$

Gibson and Ashby have shown that by removing the sec-

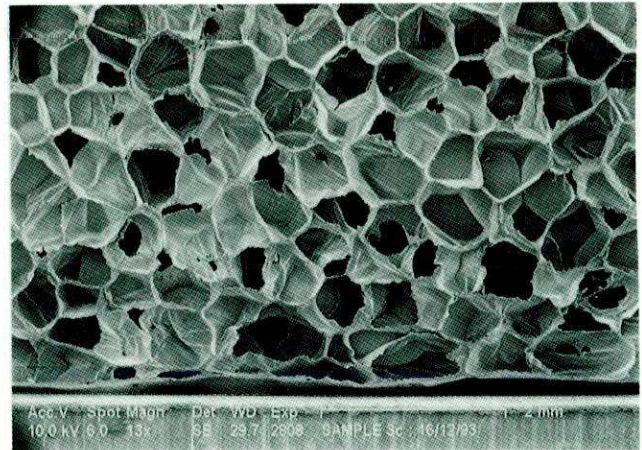
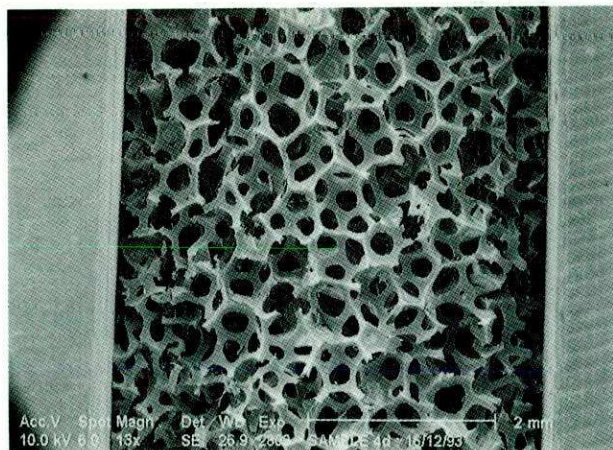


Fig. 5. Micrographs showing the different cellular structure of open cell (left) and closed cell (right) polymer foam.

and term on the right-hand side of equation 8, the stress/strain curves of closed cell foams give a curve which matches the behaviour of open cell foams.

## Resilient Layers for Building Use

The advantages of open cell polymer foams for use as resilient layers has already been described in earlier publications [3 – 8]. The characteristic difference between closed cell and open cell foam under an applied load is found in their relative static deflections. A closed cell foam strip, 12 mm thick, under normal domestic loading, is unlikely to deflect by more than 1 mm compared to a figure of 6 mm obtained with open cell foam of similar thickness.

Closer examination of the movement of open cell flexible foams under dynamic loading has indicated that it is the cellular structure which dictates the rate of deflection whereas it is the polymer material itself which determines its resilience or ability to return to its original state.

The main problem with rock (ie mineral wool) or glass fibre quilts is that they comprise of strands of brittle material (ie glass state) which achieve resilience by means of interweaving in free form or by resin bonding. Over a period of time these fibres break and in low density form are frequently ground to dust.

Open cell polymer flexible foams do not exhibit such brittle fracture because of the elastic behaviour of the soft co-polymer. The only problem which can arise, therefore, is due to a breakdown in the chemical bond or a change of chemical state. Under normal domestic loading, bond breakdown is extremely unlikely and virtually impossible where cross-linking has been carried out. A change of state is, however, a possibility, with some materials more susceptible than others. Natural rubber will oxidise and

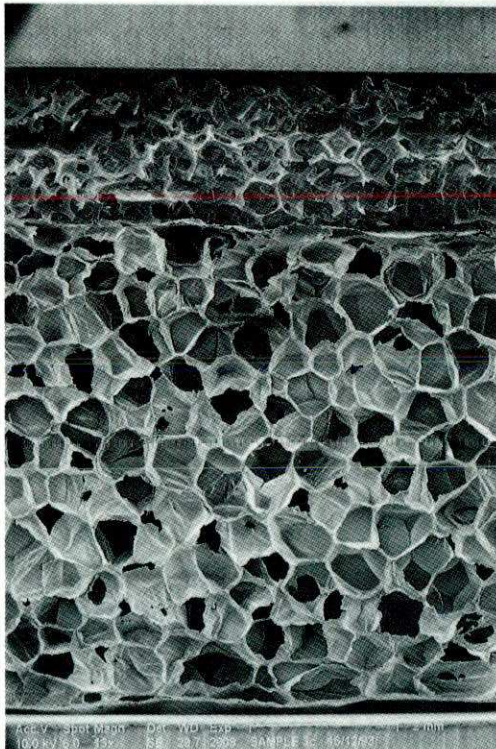


Fig. 6. Compression of the Profloor Dynamic Strip under normal domestic loading. Courtesy: Proctor Group



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after a period of time lose its resilience. This, however, is a slow process in an underfloor location where catalysts such as UV light are absent. The polyester-urethane copolymer is essentially unstable and through being hydrolytic will, in a damp or humid environment, gradually lose its compressive strength giving rise to creep. In terms of dynamic behaviour, chemical stability and cost, polyether based polyurethane open cell foam is the most suitable material.

## Applications in Floating Floors

Laminations of open-cell and closed-cell foam strips have

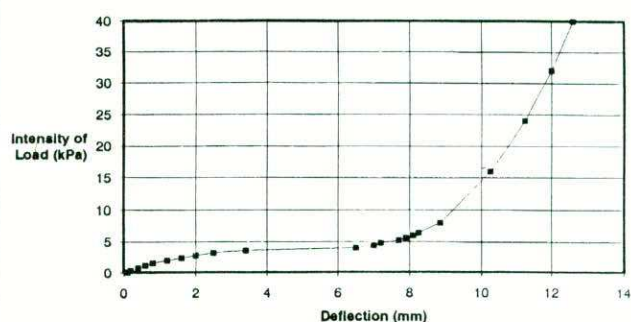


Fig. 7. Deflection of Laminated Cellular Foam Strip

been utilised in the design of resilient timber battens or strips [9, 10]. The micrograph in Figure 6 shows the compression under normal domestic loading of a 10 mm open cell strip laminated to a 10 mm closed cell strip.

The 12 mm thick open cell foam deflects by up to 6 mm under normal domestic loading to provide a suitable isolation efficiency against impact sound. Further deflection is resisted by a combination of the elastomer in the open cell foam together with the pneumatic resistance provided by the entrapped air within the closed cell strip.

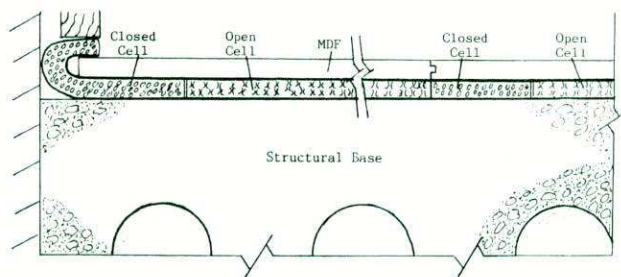


Fig. 8. Section through Shallow Profile Platform Floor

The elastic behaviour under normal domestic loading, <4 kPa, is clearly shown in the plateau in Figure 7, between 2 mm and 6 mm deflection.

A natural extension of the technology involved in the laminated foam strip was to produce a flooring system for use in the upgrading of timber and concrete floors in refurbishment projects. Designs have been produced involving the use of open cell polyurethane foam as the resilient layer [11]. Such decks have limited airborne attenuation properties and additional treatment [12] is desirable in order to provide a balanced upgrade in terms of both airborne and impact sound reduction.

The question of stability of very thin boards is a major problem especially with high compliance resilient layers. This has been overcome in the design by incorporating a closed cell peripheral foam, 50 mm wide, around two adjacent sides of each board so that each joint is supported by a low deflection strip as shown in Figure 8.

A shallow profile floor has been designed with both excellent walking stability and acoustic performance, giving an 18 dB weighted impact sound improvement as calculated in accordance with Annex A of BS 5821:1984.

## Acknowledgements

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**Professor Robin Mackenzie FIOA is Head of the Division of Building at Sheffield Hallam University and Senior Partner in the Robin Mackenzie Partnership, Acoustical Consultants**



# MEETING NOTICE

## Noise Nuisance and the Law

(Organised by the London Branch and the Environmental Noise Group of the Institute of Acoustics)

**Church House Conference Centre, London**

**Wednesday 18 May 1994**

### Programme

- 9.15 Registration and coffee
- 10.00 Chairman's welcome
- 10.10 NOISE NUISANCE - THE CURRENT LAW, Philip Barnes, *Stephenson Harwood*
- 10.40 OVERVIEW ON CODES OF PRACTICE, Nick Antonio, *Building Research Establishment*
- 11.10 Coffee
- 11.40 CONTROL OF COMMUNITY NOISE THROUGH STATUTORY NUISANCE AND PLANNING POWERS: A COMPARATIVE ASSESSMENT, David Horrocks, *Environmental Health Services*
- 12.10 NOISE NUISANCE FROM CONSTRUCTION SITES, Colin Cobbing, *TBV Science*
- 12.40 Lunch
- 14.00 PRACTICAL ASPECTS OF PROSECUTING FOR NOISE NUISANCE, Rosalind Malcolm (1) & Bob Chivers (2), (1) *Department of Linguistics and International Studies* and (2) *Physics, University of Surrey*
- 14.30 UNATTENDED TAPE RECORDINGS FOR ASSESSING NUISANCE, John Hinton, *Environmental Protection Unit, Birmingham City Council*
- 15.00 Tea
- 15.30 THE SCOTTISH PERSPECTIVE: THE NEED FOR OBJECTIVITY IN NUISANCE ASSESSMENT, Richard Burnett, *Environmental Health Department, City of Glasgow District Council*
- 16.00 Panel Discussion
- 16.30 Depart

Meeting Organisers: P T Freeborn, FIOA & S W Turner, MIOA, TBV Science, The Lansdowne Building, Lansdowne Road, Croydon, CR0 2BX Tel: 081 401 5800 Fax: 081 401 5862

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# NON-INSTITUTE MEETINGS

## 1994

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1 - 4

NOISE-CON 94, Fort Lauderdale, Florida, USA

1 - 6

IES 40th Annual Technical Meeting, Chicago, USA

2 - 6

3rd French Congress on Acoustics, Toulouse, France

12 - 15

ISCE Weekend Conference, Leicester

16 - 20

1994 Symposium on Aircraft Noise Receiver Technology, Maryland, USA

19 - 20

1994 European Voice Processing Conference - Personal Voice Processing, London

24

Noise Regulations - are they falling on deaf ears?, SCIF, London

22 - 26

6th Spring School on Acousto-Optics and its applications, Poland

30 - 3 June

31st Conference on Acoustics, Prague

### June

5 - 6

127th Meeting of the Acoustical Society of America, Massachusetts, USA

6 - 8

Scandinavian Acoustical Meeting, Aarhus, Denmark

13 - 15

3rd International Congress on recent developments in air and structure borne sound and vibration, Montreal, Canada

18 - 22

Short Course on Mechanics of Musical Instruments, Italy

23

Royal Society Lecture

The Acoustics of Concert Halls, London

27 - 30

Annual Transportation Convention, South Africa

28 - 30

ENVIROMAN '94, St Albans

### July

4 - 8

2nd European Conference on Underwater Acoustics, Denmark

8

XXII International Congress of Audiology, Canada

11 - 14

International Conference on Flow Acoustics: A technology audit, Lyon, France

18 - 21

5th International Conference on recent advances in structural dynamics, Southampton

19 - 21

Electronic engineering in oceanography, Cambridge

### August

1 - 5

3rd World Congress on Computational Mechanics, Chiba, Japan

23 - 25

WESTPAC 5, Seoul, S Korea

29 - 31

INTER-NOISE 94, Yokohama, Japan

31 - 3 Sep

2nd International Conference on Motion and Vibration Control, Yokohama, Japan

### September

5 - 9

30th Polish Solid Mechanics Conference, Poland

5 - 9

1st International Conference on Flow Interaction, Hong Kong

13 - 16

IEEE OCEANS 94, Brest, France

12 - 14

International Seminar on Model Analysis, Leuven, Belgium

### October

4 - 6

2nd International Symposium on Transport Noise and Vibration, Russia

24 - 27

Environmental Protection '94, Blackpool

### November

3rd week

11th International FASE Symposium, Valencia, Spain

9 - 11

Australian Acoustical Society Annual Conference, Canberra, Australia

10 - 13

Audio Engineering Society, 97th Convention, San Francisco, USA

15 - 18

Noise Protection in Building and Public Works Exhibition, Paris, France

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| <p><b>18 APRIL</b><br/><b>ACOUSTICS '94, 4 days</b><br/><i>University of Salford</i></p> <p><b>20 APRIL</b><br/><b>Institute AGM</b><br/><i>University of Salford</i></p> <p><b>27 APRIL</b><br/>London Branch mtg:<br/>Noise Incidence Survey of England and Wales.<br/><i>St Albans</i></p> <p><b>30 APRIL</b><br/>Eastern Branch Dinner<br/><i>Woodbridge</i></p> <p><b>12 MAY</b><br/>IOA Membership, Meetings and Education Committees<br/><i>St Albans</i></p> <p><b>18 MAY</b><br/>London Branch mtg, Noise Nuisance and the Law<br/><i>London</i></p> <p><b>20 MAY</b><br/>IOA CofC in Workplace Noise Assessment exam<br/><i>Accredited Centres</i></p> <p><b>25 MAY</b><br/>Eastern Branch mtg: Overview of Low Frequency Environmental Noise Survey<br/><i>Colchester</i></p> <p><b>26 MAY</b><br/>IOA Medals &amp; Awards, Publications, Council<br/><i>St Albans</i></p> | <p><b>10 JUNE</b><br/>IOA CofC in Env Noise M'ment exam<br/><i>Accredited Centres</i></p> <p><b>16 JUNE</b><br/>IOA Diploma exams, 2 days</p> <p><b>22 JUNE</b><br/>London Branch mtg: Outdoor Sound Propagation<br/><i>NESCOT, Ewell</i></p> <p><b>24 JUNE</b><br/>IOA CofC in W'place Noise Ass't Advisory Committee<br/><i>St Albans</i></p> <p><b>8 JULY</b><br/>IOA CofC in Environmental Noise Mm'nt Advisory Committee<br/><i>St Albans</i></p> <p><b>28 SEP</b><br/>Eastern Branch mtg: Acoustic Design of Broadcasting Studios<br/><i>Cambridge</i></p> <p><b>29 SEP</b><br/>IOA Meetings Committee<br/><i>St Albans</i></p> <p><b>6 OCT</b><br/>IOA Medals &amp; Awards, Membership, Publications, Council<br/><i>St Albans</i></p> <p><b>14 OCT</b><br/>IOA CofC in Workplace Noise Assessment exam<br/><i>Accredited Centres</i></p> | <p><b>26 OCT</b><br/>Eastern Branch mtg: Sound Quality<br/><i>Norwich</i></p> <p><b>3 NOV</b><br/><b>Reproduced Sound</b><br/><b>10, 4 days</b><br/><i>Windermere</i></p> <p><b>4 NOV</b><br/>IOA CofC in Env Noise M'ment exam<br/><i>Accredited Centres</i></p> <p><b>10 NOV</b><br/>IOA Education Committee<br/><i>St Albans</i></p> <p><b>11 NOV</b><br/>IOA CofC in W'place Noise Ass't Advisory Committee<br/><i>St Albans</i></p> | <p><b>24 NOV</b><br/><b>1994 Autumn Conference</b><br/><b>Speech &amp; Hearing, 4 days</b><br/><i>Windermere</i></p> <p><b>1 DEC</b><br/>IOA Meetings Committee<br/><i>St Albans</i></p> <p><b>2 DEC</b><br/>IOA CofC in Environmental Noise Mm'nt Advisory Committee<br/><i>St Albans</i></p> <p><b>8 DEC</b><br/>IOA Membership, Medals &amp; Awards, Publications, Council<br/><i>St Albans</i></p> |
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### Postscript

Through an oversight, the name of Mr F J Ball from Cornwall College, who passed two extra modules in addition to the one he already held, was omitted from the 1993 Diploma pass list published in the January/February Bulletin.

Professor Howard Dorey, Chairman of the UK Microengineering Common Interest Group wishes to contact members working in the micro-engineering and microsystems field. Please fax the Institute office if interested.

IOA are co-sponsoring an International Symposium on Fisheries and Plankton Acoustics, 12 - 16 June 1995 at Aberdeen. Call for papers available from the IOA office.

Who didn't spot the April Fool spoof in the Daily Telegraph on systematic variations in the geographical and temporal influences on the audibility of Bow Bells over the centuries? Ask for details of the Diploma course!

# COMMUNITY RESPONSE TO NOISE FROM LIGHT AIRCRAFT

D Smeatham AMIOA, P D Wheeler FIOA & G Kerry FIOA

## Introduction

There is evidence to suggest that people perceive noise from light aircraft differently than noise from jet aircraft. In terms of noise level, annoyance threshold at small general aviation facilities may be lower for a number of different reasons including, different operation patterns, lower background noise levels and different hours of operation.

The Department of Applied Acoustics at the University of Salford are involved in a project investigating the noise nuisance caused by light aircraft and microlights. This project involved a survey of Local Authorities throughout Britain, carried out to collate their experience in the assessment of this type of noise. The aim of the survey was to focus on the role of the Environmental Health Officers and determine in what form environmental noise impact statements should be prepared with respect to this type of noise. The results provided a countrywide view of the problems associated with the noise nuisance from light and microlight aircraft and the procedures used to alleviate these problems.

The initial part of this article will review some of the key research on the annoyance due to environmental noise and noise from light aircraft and the remainder will address the results from the survey of local authorities giving reasons why people become annoyed with light and microlight aircraft, the actions local authorities can take to alleviate the problems and the various methods available to deal with complaints.

## Literature Review

Many researchers have attempted to predict the sound level at which people can be expected to complain about noise sources in the environment.

Shultz [1] analyses data from surveys covering many types of environmental noise to establish a level of noise at which people will be annoyed. Using Shultz's estimation method 5% of people will be highly annoyed with an  $L_{dn}^*$  of 55 dB(A). Birnie et al [2] studied the relationship between noise level and social survey data from general aviation airports in Canada and found that an estimated 14% of people will be highly annoyed with a  $L_{dn}$  of 55 dB(A). This hypothesis is confirmed by Harris [3] who carried out a study at eight general aviation airports and found that complaints against normal operations started

at  $L_{dn}$  55 dB(A) and for 'touch and go' operations at  $L_{dn}$  50 dB(A).

An assessment of the annoyance due to noise from general aviation with the requirement to establish the difference in public attitude and reaction to business and non-business general aviation sectors [4] concludes that; People perceive different categories of flying and attach very different levels of importance to them and that within the range of noise levels encompassed in the study, reaction to general and business aviation noise are significantly higher than those to air transport. This report also states that 'Although the community annoyance increases with aircraft noise level, aircraft noise level does not play a dominant role in determining community reaction to aircraft noise around general aviation airports.' From the results of this work the authors suggest one possible way of reducing community reactions to aerodromes is to have better communication between the aerodrome and local residents.

From these references it can be seen that people clearly react differently to general aviation noise compared to other types of environmental noise. The uncertainty about the assessment of light aircraft noise led the University of Salford to undertake a survey of Local Authorities to find out how this noise is dealt with in practice in Britain.

## Survey

A letter was sent to all the Chief Environmental Health Officers in Britain asking them for relevant experience in dealing with the annoyance of microlight and light aircraft. Information was sought regarding:

- (1) The use of light aircraft and microlights within the area of the local authority jurisdiction and the history of any complaints.
- (2) The procedures adopted by the local authority to deal with the complaints and any local planning procedures.
- (3) The levels of noise, in the opinion of the local authority at which light and microlight aircraft becomes intrusive. The threshold at which complaints can be expected.
- (4) The outcome of any complaints.

## Causes of Annoyance

Various reasons were given to explain how relatively quiet operations, compared to the noise from major international airports, seem to annoy people. The responses suggest the annoyance of light and microlight aircraft is not only due to the noise level of the aircraft but also the operations and manoeuvres they perform.

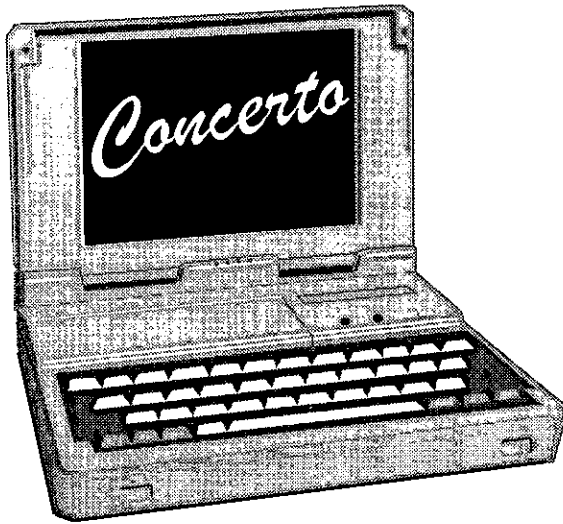
## Noise

Information from our survey of Local Authorities suggests that the relatively long duration of fly over and the tonal

\*Although the values given in these papers refer to sound levels given in  $L_{dn}$  (Day Night Level), in general light and microlight aircraft rarely fly at night therefore  $L_{dn}$  is equivalent to a day time  $L_{eq}$ .

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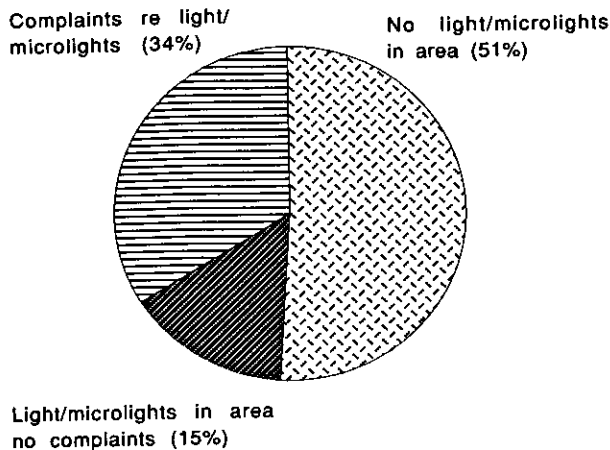


Fig. 1. Percentage of replies from Local Authority with experience in light and microlight noise.

content of the noise from light and microlight aircraft make this type of noise annoying. Also, the fact that many of the airfields are situated in rural areas with low background noise levels makes the noise even more intrusive. Many replies stated that where the air traffic is mixed (light aircraft and jet aircraft) the major problem lies with the jet aircraft noise. However, some replies implied that where light aircraft is mixed with military jet aircraft complaints against the jets are low compared with the light aircraft due to the acceptance of the need for military flying.

Some local authorities have found that restricting the use of aircraft with three or four propeller blades at airfields can reduce the noise level and hence reduce complaints.

#### Operation

We stated above that the annoyance of light and microlight aircraft is not only due to noise nuisance but also the operations and manoeuvres of the aircraft. In fact many replies to this survey include the opinion that the annoyance of the aircraft has very little to do with its actual noise level. Instead the annoyance is due to the aircraft invading people's privacy and the safety aspects of having the aircraft fly at low level over property.

Particularly annoying were thought to be; flying for recreational purposes, circuit flying, the use of roads and airstrips as navigational aids increasing the flying activities over certain areas, 'touch and go' operations and weekend and evening flying.

#### Planning Permission

Local councils are limited in the action they can take against the use of aerodromes within their jurisdiction. The only action available against the use of light and microlight aircraft is to refuse planning permission for airfields or to lay down conditions on the use of the land at

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the planning stage. Planning permission is required under the Town and Country Planning General Development Order 1988 if the land is used for certain activities for more than 28 days in a calendar year. Therefore the local council can control this sort of activity only if the site is used for more than the specified number of occasions.

In the survey 20 local councils said they had experience of planning applications. Of these; six were refused, nine were approved subject to conditions, five are ongoing.

## Planning Permission Refused

Planning permission is in general refused on the grounds that the site would cause environmental damage. Environmental Impact Surveys are conducted to predict the effect on the community from the presence of the airfield. This generally involves both the measurement of the noise levels and meetings to assess the attitude of the local population to the proposals.

It is well recognised that BS4142 is applicable for the assessment of noise levels at residential properties from industrial noise. However in the absence of any other way of assessing the noise at residential property BS4142 has been used to assess the impact of the airfield on local residents in the community. BS4142 says that if the noise level is 5 dB  $L_{eq}$  above the  $L_{90}$ \*\* the noise will be noticeable and if the  $L_{eq}$  is 10 dB above the  $L_{90}$  it will cause annoyance.

## Planning Permission Accepted

The only method of controlling the use of airfields is to lay down conditions on which Planning Application is approved. The conditions applied to the planning applications are summarised below.

- (1) Limit the aircraft movements per day or year
- (2) Aircraft to use specific flight paths.
- (3) Aircraft to reach a certain height before overflying property.
- (4) Regular changing of flight patterns.
- (5) Restrictions on the type of aircraft that can operate from the airfield.
- (6) Restrict flying to certain hours of the day.
- (7) Airfield used by club members only.
- (8) Restrictions on times when maintenance and testing can be carried out.
- (9) Oil and chemicals to be stored correctly.
- (10) Airfield to record all movements.
- (11) No unauthorised landings from other airports.
- (12) No training/instruction to be carried out on airfield.
- (13) No 'touch and go' operations.
- (14) Make records of all take-offs and landings.
- (15) Set up a Consultative Committee to deal with complaints

## Dealing with Complaints

Although a number of different actions can be taken to deal with complaints from individuals who are annoyed by aircraft noise, the action taken by a local authority

\*\* $L_{90}$  is statistical parameter which is often used to describe the background noise level.  $L_{90}$  is the sound pressure level exceeded for 90% of the time.

varies depending on whether the authority has the relevant experience to deal with the complaint.

The actions available include:

- (1) Investigation by Environmental Health Officer
- (2) Complaints referred to the Airport Manager
- (3) Complaints referred to the Civil Aviation Authority
- (4) Complaints referred to the British Microlight Association
- (5) Discussions between Landowner, Club, Airport Manager and Health Officers.

## Conclusions

A survey of the experience of Environmental Health Officers with the annoyance of microlight and light aircraft has provided much useful information. The replies to the circulated letter indicate that annoyance is as much due to the presence of light and microlight aircraft as the noise they produce. Annoyance is also dependent on the type of manoeuvre the aircraft performs, for instance circuits and bumps seem to be more annoying than normal landings and take-offs. When people do complain about the noise it is its long duration, highly tonal nature which appears to annoy people. The loss of privacy and safety aspects of low level flight annoy people just as much if not more than the noise itself. This implies that when making an environmental impact survey it is important to address such things as the flight paths, the height at which aircraft overfly property, hours of operation and the types of operations carried out on the airfield as well as an assessment of the noise.

Local Authorities have little power to deal with the noise from light and microlight aircraft. The only official way of controlling the situation is to either refuse planning permission or to lay down conditions on planning approvals which limit the use of the airfield. Consultative committees are useful so that local residents and personnel from the airfield can discuss the operation of the airfield.

Complaints from local residents can be dealt with by the local EHO or the Airport Managers or referred to the CAA or the British Microlight Association.

## Acknowledgements

The authors would like to thank the Environmental Health Officers who replied to the questionnaire, for their invaluable contribution to this project and the assistance of members of staff at the CAA.

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- [2] S E BIRNIE, F L HALL & S M TAYLOR, 'Community response to noise from a general aviation airport', Noise Control Engineer, 15, (1), pp 37-45, (1980)
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The authors are in the Department of Applied Acoustics at the University of Salford. ❖

# TECHNICAL LISTENING: CAN WE ANALYSE THE SOUND SPECTRUM BY EAR?

Andrzej Miskiewicz

## Introduction

Subjective assessment of the perceived characteristics of a sound is an integral part of various activities in acoustics. Sound engineers, room acousticians who design concert halls, designers of electroacoustic systems and other professionals in various branches of acoustics rely on subjective evaluation as an ultimate indicator of the sound quality. People who evaluate sound have to possess highly refined listening abilities which include acute sensitivity to changes in sound quality and accurate auditory memory.

The listening skills required for evaluating sound can be developed by systematic training. A special course for training technical listening skills, called 'Timbre Solfege' has been developed at the Sound Engineering Department at the Chopin Academy of Music in Warsaw, Poland [1]\*. The programme of Timbre Solfege deals with various aspects of subjective sound evaluation. The main topics included in the syllabus are as follows:

- Sensitivity and memory for timbre
- Commonalities in speech perception and sound evaluation
- Perception of loudness in music
- Relationship between timbre, loudness, and pitch
- Masking effects
- Detection of distortion in sound recordings
- Spatial hearing
- Evaluation of the quality of musical recordings
- Assessment of audio equipment quality

The course's main goal of developing listening skills is achieved by special laboratory sessions, which consist of various listening tasks. General characteristics of the Timbre Solfege programme have been described in previous papers [1, 2]. The present article discusses in more detail a part of the course which teaches how to identify timbre and detect various characteristics of the sound spectrum by ear. This part of the programme should be of interest not only to sound engineers but also to anybody in the field of acoustics who faces the problem of subjective evaluation of sound.

## Timbre vs Sound Spectrum: What Is There To Listen For?

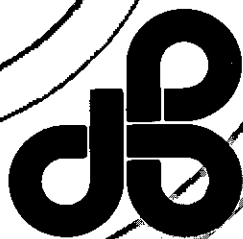
It is well known that timbre depends primarily on the spectral distribution of sound energy [3]. The characteristics of a sound spectrum may therefore be identified by ear on the basis of timbre perceived by the listener. In order to establish what the listener hears when presented with a sound having a certain spectrum, a terminological system for describing the sensation of timbre is needed. Although timbre is a commonly acknowledged attribute

of sound, no standardised system of terms has so far been introduced for describing timbre characteristics. The main difficulty in describing timbre is its multidimensional character. The concept of timbre encompasses a large variety of interrelated characteristics, so the number of timbre categories that can be perceived as separate qualities is virtually unlimited. No one-dimensional scale – such as the scales used for describing pitch or loudness – can be applied for classifying timbre.

Among various spectral characteristics of sound that determine timbre quality, formants (peaks of energy in certain frequency bands) appear to have special significance [4]. A formant-frequency scale of timbre categories is used in the Timbre Solfege programme as a teaching tool for training the listening skills. This scale refers the qualities of timbre to certain combinations of formants along the frequency continuum. The basic timbre categories used as a reference for identifying a variety of timbre qualities correspond to nine 1/3-octave formant bands centred at 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000 Hz. The centre frequencies of the formant bands correspond to the standard frequency bands used in filters and spectrum equalisers [5].

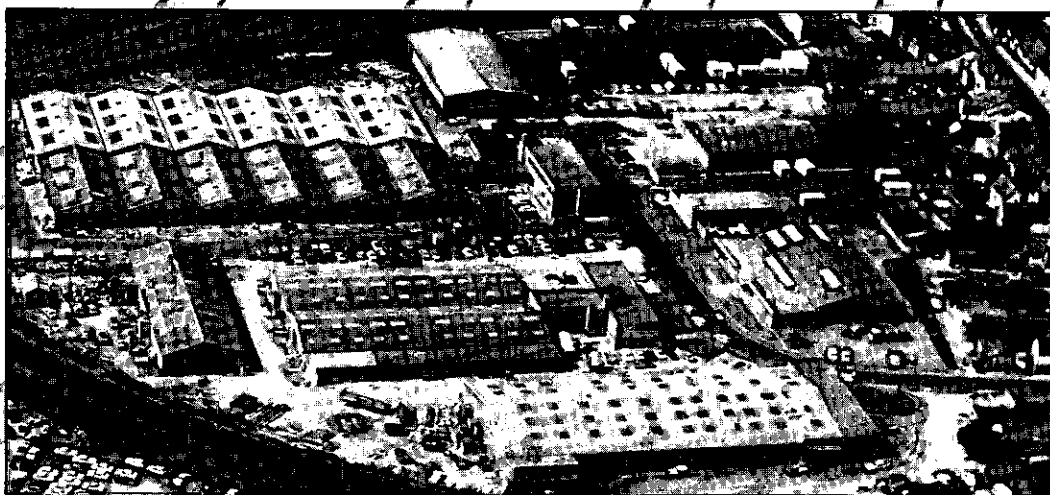
At the initial stage of training students are presented with examples of the nine standard formants imposed over the spectra of various steady-state and time-varying sounds. The sound examples demonstrate that each of the formant bands may be associated with a specific quality of timbre which is common for a variety of sounds, including music, speech, and noise. The students have to memorise the timbre qualities corresponding to the nine basic formant categories. Those nine formant standards are used in further tasks as a reference for identifying more complex changes in the sound spectrum.

A very effective aid in memorising timbre categories associated with certain formant frequencies is based on the vowel-like quality of sound. The idea of describing timbre on the basis of its similarities with vowel sounds is well known and has been discussed by several authors [eg 4, 6]. The spectrum of a vowel sound consists a series of formants; each vowel is thus acoustically defined by the frequency distribution of its dominant formants [7]. However, the vowel-like character of sound can be identified quite easily on the basis of only one of its formants. Depending on the vowel, this perceptually dominant formant may correspond to the position of the first, second, or even third formant along the frequency scale. When a formant of the same or close frequency is imposed over the spectrum of any other sound (eg music), the sound quality becomes vowel-like and resembles that particular vowel.



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Table 1 specifies the vowel sounds associated with the formant standards used in the Timbre Solfege listening tasks. It should be noted that only five of nine formant standards produce a vowel-like quality of sound; the remaining four standards have to be memorised and identified on the basis of other cues. The formants centred at 63 and 125 Hz are recognised as loudness boost of low-frequency components, while the 8000 and 16000 Hz formants are identified as a boost of very high frequencies. Since the 63 Hz and 16000 Hz formants are located in the frequency ranges being close to the bounds of hearing, they are easy to distinguish from their adjacent formant category.

As the training proceeds, the nine basic formant categories are expanded to 27 one-third-octave bands extending from 40 to 16000 Hz. The timbre qualities at the centre frequencies added in the expanded set of formants are identified by their relative locations in respect to the nine standards. The transition from one vowel-category to another is gradual, therefore, a formant centred at a frequency being between the main categories listed in Table 1 results in an intermediate quality of timbre, eg shifting the centre frequency of a 500 Hz formant down to 250 Hz changes the vowel-like colouration from /ɔ/ (as in bought) to /u/ (as in tool). A formant centred at 400 Hz would produce an intermediate vowel sound, between /ɔ/ and /u/. By referring such an intermediate vowel sound to the adjacent formant standards the listener can realise that the colouration corresponds to a formant frequency between 250 and 500 Hz.

| centre formant frequency | vowel sound        |
|--------------------------|--------------------|
| 63 Hz                    |                    |
| 125 Hz                   |                    |
| 250 Hz                   | /u/ (as in tool)   |
| 500 Hz                   | /ɔ/ (as in bought) |
| 1000 Hz                  | /a/ (as in car)    |
| 2000 Hz                  | /ɛ/ (as in get)    |
| 4000 Hz                  | /i/ (as in feet)   |
| 8000 Hz                  |                    |
| 16000 Hz                 |                    |

Table 1. Centre frequencies of the 1/3-octave-band formant standards used for timbre classification. Vowel sounds associated with certain formant bands.

Most students use the vowel cue only at the initial stage of training. As the students acquire greater skills in evaluating timbre, they become capable of recognising the basic formant standards in an absolute way, without any reference to speech sounds.

The modifications of sound spectra applied in the listening tasks include also low-pass and high-pass filtering at various cut-off frequencies. The sound examples are filtered using a 1/3 octave graphic equaliser. Low-pass filtering consists in attenuating all the 1/3 octave bands above a certain centre frequency; typically, six steps are used, ie attenuated are all bands above 12.5, 10, 8, 6.3,

5, and 4 kHz. High-pass filtering consists in attenuating all the bands below a certain centre frequency and includes six steps which are 315, 250, 200, 160, 125, and 100 Hz. Changes of timbre related to filtering are easy to memorise and identify. To aid in estimating the frequency band, various associations with the quality of sound reproduction encountered in real-life situations may be helpful. For example, attenuating the 1/3 octave bands above 4 kHz produces a sound quality that resembles an AM radio, attenuating the low-frequency components is associated with a portable transistor radio. Various cues for identifying the width of the frequency band of music recordings may be found when one listens to timbre changes in individual instruments.

## Practical Listening Tasks

The Timbre Solfege classes are held in a listening room designed to fit the acoustical requirements for sound-quality evaluation [8]. The apparatus used for training consists of high-quality sound-reproduction equipment and a number of signal-processing units [2]. The sound stimuli used for teaching include electronically generated signals (tones and noises), recordings of speech and sound effects, and a large variety of music recordings.

The part of the programme which deals with the changes of timbre related to variations of the sound spectrum includes listening drills called passive and active tasks. Passive tasks consist of specially transformed recordings which are played to demonstrate timbre qualities associated with certain modifications of the sound spectrum. The main purpose of the passive tasks is to familiarise the students with the reference categories of timbre associated with the nine standard formant bands. In addition, students are presented with sound examples demonstrating the effects of low- and high-pass filtering at various cut-off frequencies. The students' task in passive drills is to identify the transformation of the sound spectrum in the recording. At the beginning, the passive tasks are simple and the students only have to identify the centre frequency of a single formant imposed over the spectrum of noise, speech or music recording. Later tasks become more complex and include two or more modifications introduced at the same time (eg two formants or one formant and low- or high-pass filtering). The passive tasks employ a limited set of formant frequencies and include only the nine basic formant standards. The expanded set of 27 one-third octave formant bands is used only in the active tasks, as described below.

During the active tasks, the sound is transmitted through two 1/3 octave graphic equalisers in parallel. The instructor uses one of the equalisers to modify the spectrum of the sound that is played back. The transformations set by the instructor are unknown to the student. The student uses a switch to listen alternately to the sound from the outputs of both equalisers, and, by adjusting the controls of the second equaliser, tries to make both output signals perceptually identical. In another of the active tasks, two graphic equalisers are set in series. The student compares the sound modified by the instructor with the original sound (with no trans-

formations). Using the other equaliser, the student has to introduce an opposite transformation, to neutralise the modifications of spectrum set by the instructor.

Initial active tasks are simple, the instructor introduces typically two transformations at the same time, which include two formants of the nine basic standards, or one formant and low- or high-pass filtering. As the training progresses, the transformations of the sound spectrum become more complex and subtle. The number of transformations increases to three or four and the set of formants is expanded to 27 one third octave bands. The timbre qualities related to the intermediate formant centre frequencies included in the expanded set of formants are identified by their relative locations in respect to the nine basic standards. Typically, the boost of a 1/3 octave band is set at a constant level. Occasionally, in more advanced tasks, two or three levels are used (eg 3, 6, and 12 dB).

Due to the very large number of changes that can be made with a 1/3 octave-band equaliser, adjusting timbre by guessing is practically impossible. In order to identify complex modifications of the sound spectrum, the student listens alternately to the sound transmitted through each of the two equalisers and follows a sequence of activities such as those listed below.

1. Identification of the number and character of transformations (formants, low-pass and high-pass filtering).
2. Attenuation of the extreme low or extreme high 1/3 octave bands (if low- or high-pass filtering is present); once the frequency range has been properly set, it is easier to identify formants.
3. Estimation of the formant frequencies by recalling the memorised nine reference qualities of timbre. If all the 27 bands are used, the student may be able only to identify the frequency ranges in which the formants are located rather than point at the exact 1/3 octave bands.
4. Introduction of formants in the estimated bands and adjustment of their centre frequencies. If the procedure permits more than one level of boost, the student has to adjust the gain of the formant bands.

Using this strategy, most students are able to identify three modifications in the sound spectrum and adjust timbre in less than one minute. The active tasks are usually well received by students since they resemble real situations encountered by the sound engineer.

## Summary

Our experience with the Timbre Solfege programme makes it evident that certain characteristics of the sound spectrum may be identified by ear, on the basis of timbre perceived by the listener.

The listening abilities necessary for analysing timbre may be developed by training. At the initial stage, training of the listening skills should be based on a limited number of timbre standards which can be easily memorised and serve as reference for identifying other timbre qualities in more advanced tasks. The formant-frequency scale is an effective tool for describing timbre and makes it possible to refer the quality of timbre to the characteristics of the sound spectrum.

## Acknowledgement

The author is indebted to Dr Tomasz Letowski for his critical reading and comments on the manuscript of this paper.

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\* The programme of Timbre Solfege was initially developed by Andrzej Rakowski, Tomasz Letowski, and Krzysztof Szlifirski. Several topics and listening tasks were added to the programme later by Barbara Okon-Makowska, Tomira Rogala, Mieczyslaw Kominek, and the author.

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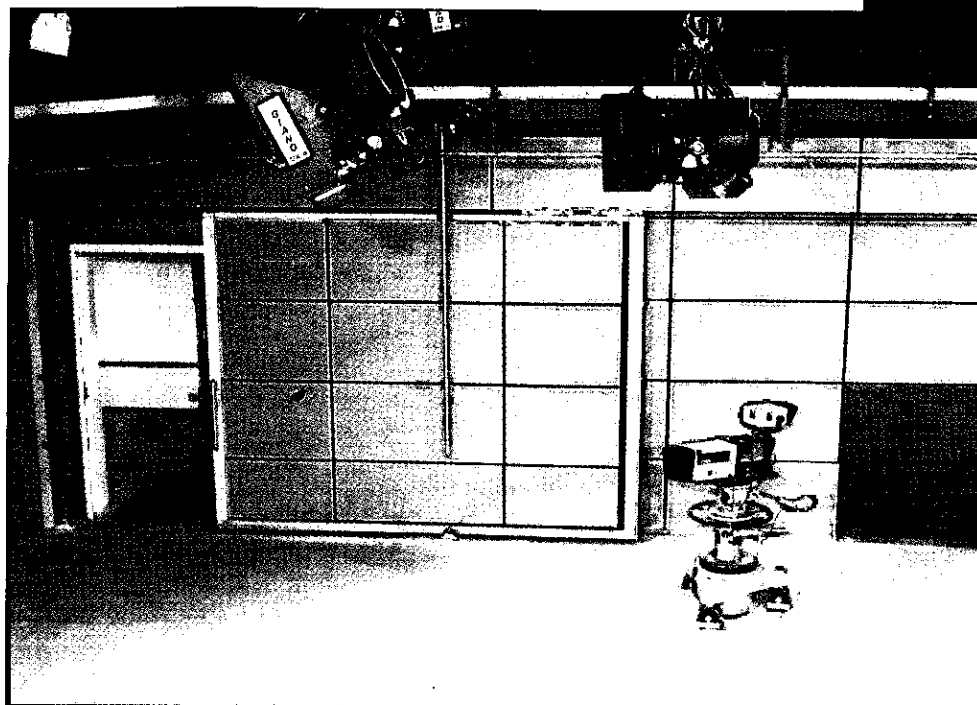
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# BROADCASTING AND THE NOISE AT WORK REGULATIONS

A R Woolf MIOA

## Summary

This paper considers some strategies and options in implementing the Noise at Work Regulations 1989 in a broadcasting environment. It is to some extent a personal view and every item in it should not be taken as representing official BBC policy. It must also be noted that no policies or practices mentioned have been approved or agreed by the HSE, or tested in court.

## General Background

The BBC has known for many years that the ordinary day to day work of broadcasting might expose some staff to high sound levels. When the Noise at Work Regulations 1989 [1] – here called, for short, the Regulations – came into force, the BBC already had some noise control measures in place. These had gradually been introduced following the code of practice on industrial noise of 1972 [2]. Despite this experience we found it far from plain sailing when we came to implement the Regulations. In this paper I will look at some of the problems. I cannot give all the answers: in some cases the BBC's policy is still the subject of internal debate or problems remain to be resolved.

## Music or Noise: The Old Chestnut

When an acoustic or safety consultant first discusses with managers the question of noise control on speech and music, the starting point will inevitably be the old chestnut of whether the sound that you want to hear is as damaging as unwanted sound. Of course one can simply say that the law (or at least, the HSE, which is much the same thing in practice) says music and noise are the same, and that's the end of it.

However, more pragmatically, you can be fairly sure that managers will not be committed to enforcing health and safety measures unless they themselves believe that a real risk exists. The very idea that there may be danger from something enjoyable, which gives no pain or obvious symptoms, and which is a major leisure activity of much of the population, seems obvious nonsense to some. Opposed perceptions can lead to mutual distrust, and in trying to overcome this, it can be useful to remember that most people have literally no idea of how their ears work. High intelligence and a good education seem no bar to an un-articulated belief that noise induced hearing loss is a psychological rather than a physical phenomenon. A little information can go a long way to help matters.

### What is 'Likely'?

The next step is to make noise assessments; and this will not be straightforward. Studio engineers and production

staff tend to have a wide range of activities, listening to loudspeakers and on headphones in various places on different types of programme material. The Regulations are of course based on a single day's exposure, and according to the HSE, if the exposure is variable one should base the assessment on the 'worst likely' exposure [3].

This can lead to the apparently odd result that the assessment, which is presumably intended to be a guide to the risk, may bear little relation to it. For example, anyone who regularly works on outside broadcasts might be required to work in the pits at a motor race, where the day's exposure might be over 100 dB(A). Whoever actually does the work should of course have appropriate training and instruction and ear protection equipment as the law demands. So unless you are prepared to restrict who does what, there is a good argument that everyone who might do the job should have the same assessment, even though many of them might work on nothing noisier than golf tournaments.

There is an argument, possibly equally good, that the assessment is meant to bear some relationship with risk, and therefore only those who have actually been exposed to high sound levels should have a high assessment, whatever might be considered their 'worst likely' exposure. Provided that all staff get the necessary training and equipment, the latter seems a reasonable course. However it can be hard to escape a feeling that neither the regulations nor the HSE's guidance are well framed to cope with people with only a moderate probability of occasional high exposure.

## Assessment and Self-control

Having dealt with this conceptual difficulty, you can begin analysing work patterns and measuring the exposure acquired during various activities. You will soon run up against a fundamental problem: many of the exposures are governed by the position of a volume control, set in some cases by the employee you are trying to assess, and in others by a colleague of his or hers.

Of course you can try to be reasonable about this; in BBC Radio we found that in studios dealing exclusively with speech, daily noise exposures from loudspeakers would not be a hazard unless the volume was turned up so high that the neighbours (ie the next door studios) complained. However, if the exposure can approach anywhere near one of the action levels, (and in studios dealing with any sort of popular music this is not unlikely) how can you be sure that the levels you measure are representative for all staff?

There are two fundamentally different possible

approaches. Either you can do a lot of measurement and some statistical analysis in an attempt to assess the 'worst likely' exposure. This has the considerable advantage that it will tell you what is actually happening. However the measurements will not predict the future: the next new recruit might happen to like it louder. Also you may well find that the 'worst likely' assessment is above the first action level, and some further action will then be required.

Alternatively you may decide that listening conditions vary so much that measurements can give only a general indication of the likely dose. Instead you can try to put in place limiters to control the exposure positively, or warning signals that will allow staff to control it themselves. This may give greater security, but may require considerable investment in technical modifications.

## How to be Unpopular

The idea of controlling the maximum sound level that monitoring loudspeakers can produce, does not go down well with the audio practitioners. The sound engineer and producer will be most concerned at the idea of any device connected in the loudspeaker feed, that can make what they hear in any way different from what they are sending to the listener at home. On hearing something not quite right, they will, they say, immediately start to worry about whether it was a technical fault or merely the protection circuit operating. If this distracts them, or makes them miss something they should have heard, the programme will suffer. For many engineers who do music recording the very idea of interposing any alien equipment into the system that they are using to assess the delicate adjustments by which their professional competence is judged, is anathema.

## Dose Control or Level Control?

When you are considering how exactly to control the exposure without unduly annoying the 'golden-eared', some helpful person will probably point out that the quantity which the Regulations require to be controlled is not level, but dose – the total A-weighted sound energy over the working day. It is tempting to try to control this quantity directly, because the daily exposure to sound from loudspeakers will often be for a period less than eight hours, and not all the time at the highest level; so a correspondingly higher maximum could often be permitted.

Against this must be set a number of factors. Firstly, staff would have to stop work when their dose reached the relevant action level – which could be awkward in the middle of the 9 o'clock news. Secondly, an individual's daily noise dose may be acquired during a number of different activities in different places, so the only valid check would be to give everybody an individual dose-meter. The initial cost, additional administration and cost of maintenance and calibration, as well as the well known problems of getting reliable dosimeter readings, make this impractical.

Finally, dosimeters would not measure exposure from headphones. Overall, the seemingly attractive option of controlling total dose gives more problems than it solves.

However, since maximum level is so manifestly the

'wrong' thing to measure and control, it is also often suggested that it is better to control or indicate  $L_{Aeq}$  over a fairly short time such as five or ten minutes. Unfortunately, in practice the effect of integration is such that, after a period of high level that does not quite operate the circuit, what finally nudges it over the edge may well be a relatively low level item. This makes such a system incomprehensible to the non-technical user, and infuriating to everybody.

BBC Network Radio is currently continuing with the system that has been used for many years, of high sound level warning lights in control rooms where it has been found that there is a reasonable likelihood of exceeding the first Action Level of exposure. (In practice these are exclusively rooms dealing with popular music.) The lights are sensitive to maximum A-weighted level as this gives immediate feedback to the operator on the effect of changing the level.

This system has the advantage that the high sound level detection and warning system has no electronic connection with the rest of the studio equipment. A microphone set into the ceiling or suspended above the operator's position detects the sound, and is calibrated with reference to the level at a typical listening position. Amber 'warning' and red 'action' lamps are provided, with operating levels separated by 5 dB. Similar systems are commercially available.

This does put the onus on the individual operator to take notice of the lamps and reduce the volume when the appropriate lamp flashes. However this is in principle little different from requiring a machine operator to ensure that the appropriate guards are in place when the machine is running.

## Headaches from Headphones

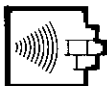
Headphones pose their own special problems. It has been found that it is difficult to judge sound level from headphones, and many people will set the level higher than they realise. Listening is private; there is no immediate evidence that the level is high, and the neighbours will not be disturbed.

Most headphones have high overload points, so that a small innocuous-looking pair of 'cans' may potentially give greater noise exposures than a pair of large rock music monitor loudspeakers, depending only on the amplifier to which they are connected. Low impedance headphones often need only a small voltage to give high sound levels. Unless care is taken, it is by no means impossible to produce systems which can exceed not only the first and second action levels of the Regulations, but even, where there can be loud clicks from switching, the peak action level of 200 Pascals.

### Headphones: Problems of measurement

Measuring sound exposure from headphones is itself not simple. Annex 1 to the Regulations, in defining the sound pressure that is to be used in calculations, refers to:

... the time-weighted value of A-weighted instantaneous pressure in Pascals in the undisturbed field in air at atmospheric pressure to which the person is exposed .... or the pressure of the disturbed field adjacent to the per-



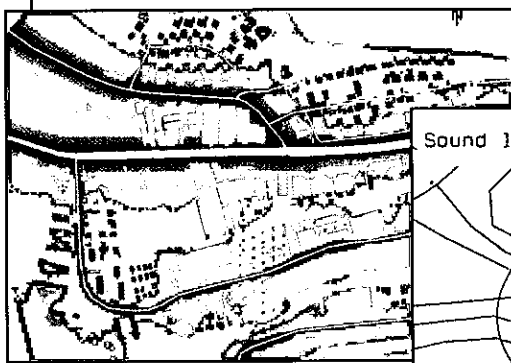
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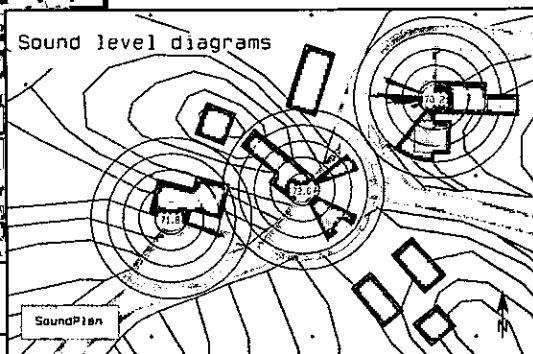
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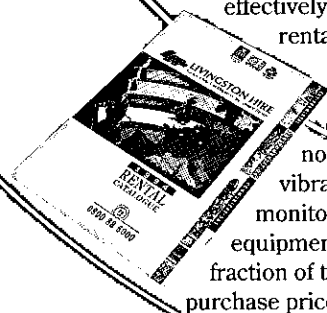
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son's head adjusted to provide a notional equivalent undisturbed field pressure.

One cannot sensibly measure sound level from headphones as 'undisturbed field', so the 'disturbed field' (ie in the presence of a head) must be measured and the result 'adjusted'. There is no published guidance on how one should measure and suitably adjust the result, although the HSE specialists can give useful advice. (The advice in the HSE's Noise Guide No 3 [4] may mislead some, as it refers only to the use of a miniature microphone under a headset, whereas the use of an 'ear simulator' may in many cases be the best method [5]).

To do the job properly requires unusual equipment, and will be beyond the capabilities of a person whose only specialist acoustic training is a standard Competent Person's course lasting a few days. In other words, it will not be cheap.

In television, the widespread use of insert earphones, and their high sensitivity and potential for giving high sound levels, demands a method of measurement that will cope with them. Some form of coupler or ear simulator is essential and considerable correction of the results will be necessary.

## Headphones: Controlling Levels

In a very small broadcasting organisation, it may be possible to standardise on one type of headphone and to modify all possible outlets into which headphones can be plugged to limit the maximum drive voltage. Even in this easiest of situations, this strategy will lead to continuing difficulties; for example when the chosen type of headphones becomes obsolete and you end up with a mixture of different types, and when some equipment is inevitably found difficult to modify. Nowadays much listening takes place in offices, and often on domestic equipment, so a comprehensive policy must include all the headphones used by production staff.

In a large broadcasting organisation, the quantity, variety, and rate of change of equipment into which headphones can be plugged, is so enormous that no strategy based on modifying headphone outlets is practical. The BBC realised this a long time ago, and developed sound level limiters [6] that can be fitted to the headphones themselves. These BBC designed limiters are now commercially available.

Pressure by some European countries for safer headphones for domestic listening may eventually lead to commercial headphones with built-in limiters. In that case, if the HSE also accepts that such devices will automatically keep the user within the law, it will make life much easier. However there are many problems to be overcome before this happy state arrives.

## Headphones: Problems in Use

It must be admitted that until recently, only a fairly low percentage of BBC headphones has been fitted with limiters. This is mainly due to the problems outlined below. However the situation is rapidly changing; for example the fitting of limiters to over 1000 pairs of headphones used in the Network Radio directorate, is scheduled for completion in the first half of 1994.

For the headphone users, high sound level limiters

present several practical difficulties. Firstly there are problems associated with the programme material itself. When editing, it is often necessary to listen to quiet items next to loud ones – for example, a quiet intake of breath or faint rustles preceding the start of a piece of music, or the end of a musical die-away. Attention to such detail is fundamental to quality editing. Yet constantly adjusting a volume control is awkward and slows down what people have learnt, over many years, to do as a smoothly flowing process.

## Headphones: Noisy Environments

Secondly there are the problems of listening on headphones when the background noise is high. The circumstances may vary, from, for example, a junior engineer 'tidying up' a track at the back of a control room while his senior colleague records the band's next number, to a commentator in the pits at the Formula One Grand Prix at Silverstone. Noise excluding headphones can help. However, in the first case the engineer also needs to know what is going on in the control room and cannot be completely isolated. In the second case even very good noise excluding headphones barely keep out enough sound to allow listening to the cue programme at a level that will not itself cause excessive exposure.

The second example is extreme, but background noise is a problem in many outside broadcasts and, if listening critically, in many other situations. Active noise cancelling headphones may provide some answers to this, by reducing break-in of low frequency sound that is most effective in causing masking, but at present they are very expensive and unsuitable for most broadcasting applications. Television camera operators have a particular problem of needing to hear the programme sound together with a continuous stream of instructions, often in very noisy circumstances such as a 'Top of the Pops' recording.

Other safety aspects must not be forgotten; a person using noise excluding headphones to work in an open-plan office must still be able to hear the fire alarm.

## Headphones: Foldback to Musicians

Thirdly, there is a specific problem associated with live music recording. Musicians in bands often require 'foldback' on headphones to enable them to play together, either with others in different parts of the studio or with prerecorded material. The band sometimes provides this foldback from their own resources, but studio equipment is very often involved. Foldback to a brass group or a drummer may have to be very loud to be audible. This is perhaps a grey area legally – the broadcasting organisation may not employ the musicians directly, but it is difficult for it to abdicate all responsibility for sound levels provided via its own equipment. In the BBC, the studios which do most of this type of work are equipped with headphones attached to boxes which carry high sound level warning lights and warning signs. It has been found that a strictly engineered limitation on level in these circumstances, results in no recordings. Of course if we implemented such a limitation, the recordings could still be made – but in non-BBC studios.

## Headphones: DJs

Fourthly there are the DJs, more formally known as self-

operating presenters on popular music programmes. These are of course performers employed for their personality and ability to project a particular image. All DJs listen on headphones much of the time, and those who deal in rock and pop music often require high sound levels. I have no doubt that DJs use these high levels to enable them to generate the required atmosphere of excitement. They are also used to hearing their own voice (which, since it is their living, is naturally of prime importance to them) in their ears at this high level, and often in headphones of their own choice which they will carry from one job to another. Any attempt to restrict the maximum sound level to less than they want will make them most upset.

I think there are two things needed to overcome this problem. Firstly, good and convincing education in the causes of hearing damage; and secondly a common approach by all who use DJs, not only broadcasters but also clubs and discos. Until this happens, any attempt to control headphone levels will lead to continued arguments that DJs are allowed what level they like in other places. BBC Network Radio is currently considering methods of giving DJs a warning light system similar to that used for loudspeakers.

### Portable cassette players

Finally on headphones, there is the problem of Walkman type portable tape cassette players. These are widely used by production staff for listening to tapes submitted by would-be performers and keeping up to date with broadcast programmes. Many of these machines are capable of providing an excessive sound level under the Regulations, although the law permits them to be sold freely for non-work uses. They are usually provided with a fig-leaf in the form of a warning about high sound level in the instruction manual. Your guess as to the chances of a professional user reading this is as good as mine.

The BBC has solved the technical problem of designing an effective limiter which will work with the low impedance, high sensitivity headphone that personal cassette players use. However the fitting of such a limiter may well quadruple or quintuple the cost, not just of the headphones but of the whole outfit. There is considerable resistance in any organisation to such a relatively expensive move, particularly when millions of the same devices are in use by the general public without protection, and one's competitors do not seem to be concerned.

### Conclusion

This survey has not been exhaustive, but shows some of the problems likely to be faced by anyone attempting to formulate and implement noise control policy in broadcasting. (I have not even touched on the noise exposure of musicians from their instruments, as in Britain the BBC is the only broadcaster that employs musicians on salary or long term contract. However any organisation that employs both orchestras and acoustic engineers cannot escape some responsibility in this field). The overall conclusion is that in many areas solutions are possible, although in some they involve considerable expense and effort. In some areas the solutions are still not clear.

Those who work at the programme production 'coal-face' of broadcasting are in general highly committed to achieving the best possible product, and believe strongly that they need to use particular working practices. If they see noise control as getting in the way of their productions, it will not be easy to introduce it effectively. In overcoming this barrier, education and persuasion is vital. Although it is civil litigation and thus not directly applicable to the Regulations, the case of *Berry v. Stone Manganese Marine Ltd* (1972) [7] may be relevant. Here the judge made the point that because noise hazard is not self-evident, mere enforcement of wearing ear protection is not enough, but it is the duty of employers to take steps by persuasion and propaganda to ensure that ear protection is used.

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The Novotel site lies just off junction 4 of the M4 motorway. Heathrow airport lies 2.5 km to the south of the site. The four-storey building forms a horseshoe shape around a 14 metre high atrium which houses the reception area, lounge, bar and restaurant. The Novotel's location makes it an ideal meeting place and this is reflected in the five conference rooms available for hire. A leisure centre consisting of heated indoor swimming pool, exercise room and changing area completes the hotel's facilities.

Accor's self imposed primary objective, however, is 'selling sleep'. Given the location of the site and the multi-function role of the building, it was obvious from the beginning that in order to achieve this objective, the acoustic design of the Novotel would be of great importance.

## Sound Insulation

Accor's own UK specification contains a very detailed section on acoustics. Ultimate criteria are set in terms of Noise Rating (NR) values for various areas within the hotel complex, see Table 1. A figure of NR 20 is quoted for bedrooms. For this particular site, however, much of the general specification was replaced by one specifically for the site.

An initial environmental noise survey by Accor's consultants on the proposed site established typical external

background noise levels of 50–55 dB  $L_{A90,T}$  falling to 45  $L_{A90,T}$  in the small hours of the morning. Corresponding values of traffic noise from the M4 and its slip road were 60–65  $L_{A10,T}$  falling to 50 dB  $L_{A10,T}$  at night. This background noise survey was used to establish guideline specifications for construction details and also break-in criteria for affected rooms, see Table 1.

The underlying structure of the building consists of a traditional in-situ concrete frame, supported on piled foundations with circular columns from ground to first floor. From the first floor to the roof, a concrete frame was constructed using a purpose made form work system to produce an egg-crate-shaped skeleton ready for external finishes to be applied. This method of building is known as a 'tunnel form' construction. The actual building incorporates three contrasting colours of terracotta, red and cream 100 mm face brick, 50 mm cavity with strip ties and insulation to the 140 mm rendered dense concrete structure.

For aesthetic reasons, secondary double glazing was not considered to be appropriate in bedrooms. Custom-made thermal type double glazed units were, therefore, specified. A configuration of 10 mm clear glass/12 mm air gap/17 mm laminated glass was fitted into an aluminium framing system. The units can pivot at the bottom for ventilation or are fully openable. Special packing wedges had to be provided, however, to prevent the sheer mass of the window causing it to drop when fully opened.

As with all glazing treatments, an area requiring particular attention was the junction between the window frame and surrounding building fabric. An expanding, dense, polystyrene foam was used between the frame and surrounding structure and this was allowed to set hard prior to plastering inside and external sealing with conventional caulking compound.

In order to check the performance of the composite facade, a mock up bedroom was constructed on site. This room was fully carpeted and furnished for the purposes of the test. The test results are given in Figure 1. The construction exceeded the theoretical prediction except for a slight deficiency at 2 kHz. The cause of this was quickly traced to a small section of missing blockwork on the returns of the window reveals which was remedied in the final construction itself. An external level of traffic noise was reduced from 68  $L_{A10,T}$  to 22 dB  $L_{A10,T}$  internally. Subjectively this transformed the roar of passing HGVs outside to no more than a gentle 'swish' inside.

For those bedrooms overlooking the

| Area              | Accor UK Specification<br>Internal noise levels<br>(NR) | Novotel, Heathrow, Criteria<br>Internal break-in noise<br>(dBLA <sub>10,T</sub> ) |
|-------------------|---------------------------------------------------------|-----------------------------------------------------------------------------------|
| Guest bedrooms    | 20                                                      | 35 (0700–2200)<br>25 (2200–0700)                                                  |
| Conference rooms  | 25                                                      | 35                                                                                |
| Banqueting rooms  | 40                                                      | 35                                                                                |
| Public rooms      | 40                                                      | 40                                                                                |
| Circulation areas | 45                                                      | 40                                                                                |

Table 1. Extract from acoustic specifications

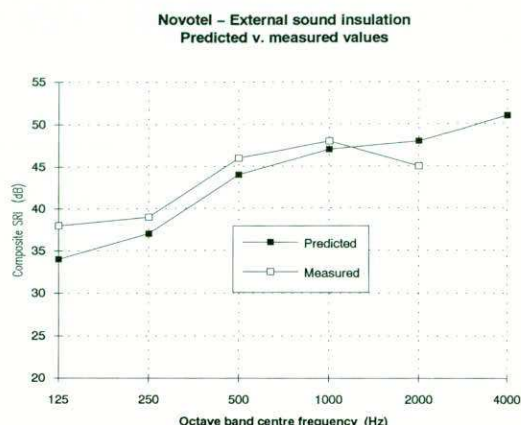


Fig. 1. Sound insulation of composite external bedroom facade

Atrium, 20 mm Pyrostop glass was used in a sealed unit. In the case of those bedrooms adjoining lift lobbies, additional insulation to the concrete structure was provided with the British Gypsum Laminated Wall Lining System. Commissioning tests recorded an A-weighted pink noise level difference of 56 dB through this construction.

The centre piece to the complex is the glazed Atrium, see Figure 2. Leading off this is the restaurant/dining area together with meeting rooms, banqueting halls and swimming pool. Given the large volume of this space, together with the multifunction adjoining areas, the client was initially concerned that reverberant noise levels within may cause problems and consequently specified space absorbers. An analysis of the Atrium acoustics by Wimpey Environmental, however, indicated a predicted mid-band reverberation time of 2.3 s. These predictions are compared with measured values in Figure 3. By not using the space absorbers, the architectural integrity of the design has been retained without compromising the intimate atmosphere of the area.

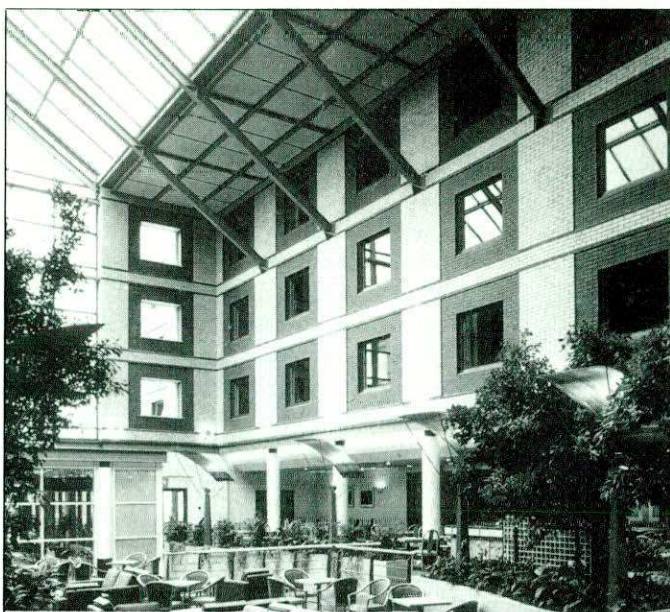


Fig. 2. Internal view of atrium

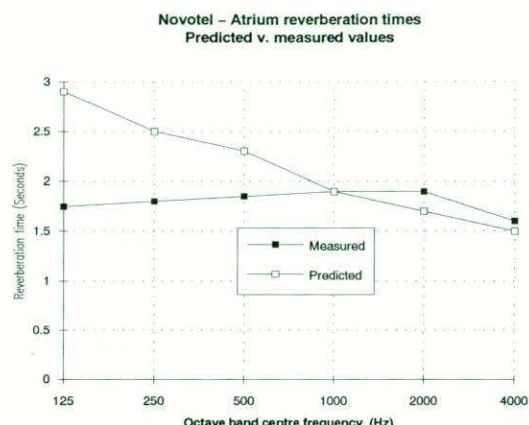


Fig. 3. Reverberation times of atrium

Particular attention to detail was also required for the meeting rooms adjoining the Atrium. Again for aesthetic reasons, a sound lobby from the Atrium to these areas was deemed unsuitable. In the actual construction, a 6/12/6 mm thermal double glazed partition incorporating 44 mm Beech-faced solid core doors was used. A target A-weighted, pink noise level difference of 34 dB had been specified for this partition. At the commissioning stage, however, only 29–31 dB was being recorded. A close inspection, however, revealed that the seals between closing surfaces of the doors were inadequate and that some of the 'blind' diffusers in the Atrium led straight into the ceiling void of adjoining meeting rooms. Treatment to these areas with proprietary seals was sufficient to achieve the specification.

Since the various rooms within the Novotel generally have a multi-purpose role, some of these areas have mobile partitions which can be drawn across. The insulation specification for these was an A-weighted pink noise level difference of 40 dB. This was based on a laboratory measurement for a specific system which had then been corrected to a field result by subtracting 5 dB. Commissioning tests, however, indicated actual results of only 30 dB. Various checks were carried out to ensure correct installation/operation, void barrier integrity etc. These were all found to be in order. Given the sound insulation difficulties which are often encountered with mobile partitioning systems, it may be better to use sound insulation data from field tests when specifying particular units rather than corrected laboratory results.

## Services Noise

Wimpey Environmental's involvement in this area came only at the commissioning stage. A certain amount of difficulty was encountered at this time since there had been no formally agreed specification for the contract and such guidance as was available came in the form of 'dB(A)' figures as opposed to the preferred NR specifications of BS5720.

The HVAC contractor had provided a commercial installation which was suitable for use in a hotel complex. Unfortunately, however, this was not compatible with the

acoustic environment required at the Novotel.

The main plant room is at the western extreme of the site behind the kitchen area. A second, smaller room was also provided at ground floor for the Atrium air handler unit (AHU). A third party was situated in the roof above the third floor bedrooms. Of particular concern was noise break in to rooms immediately below this area. The reason for this problem was immediately obvious upon a visual inspection of the plant room. During the installation, the 100 mm steel mounting channel and isolating system for the AHU had not been fitted. This meant that the AHU was resting directly on the structural concrete slab. The tunnel form construction already described, results in a very 'live' structure and to prevent problems elsewhere in the building it was, therefore, necessary to take action with the AHU.

Vibration measurements on the structural slab recorded levels of vibration of 0.06 mm/s PPV in the z-direction (= 0.012 m/s<sup>2</sup> rms acceleration) with a significant frequency component at 40 Hz. This was clearly associated with the fan motors which were running at 2400 rpm. These were, however, already vibration isolated and, when taken in the context of the recorded vibration levels, structure borne vibration was not thought to be the cause of the problem.

Since the AHU was already in-situ and operational, it was not possible to raise it through any great height without major modifications to ductwork etc. The solution, which was not Wimpey's preferred approach was carried out by HVAC consultants and involved placing 35

mm Tico pads strategic locations beneath the AHU. Subsequent vibration measurements after this treatment recorded only a minimal change in vibration level. The acoustic effect of the Tico pad in the bedroom below, however, was to re-shape the noise spectrum, giving a subjectively more acceptable sound (resulting in NR 33 to NR 30). This was presumably due to the creation of an airgap between the AHU casing and the floor.

At the same time as the Tico pad was installed, the main supply duct to the AHU was treated with Revertex barrier mat. Noise breakout from the duct was a significant contributor to the overall level in the plant room and upon treatment noise levels fell from 81 dB L<sub>Aeq,T</sub> to 79 dB L<sub>Aeq,T</sub>.

Problems in other areas were mainly due to regenerated noise from excessive air velocity. This was remedied by increasing the area of diffusers where possible.

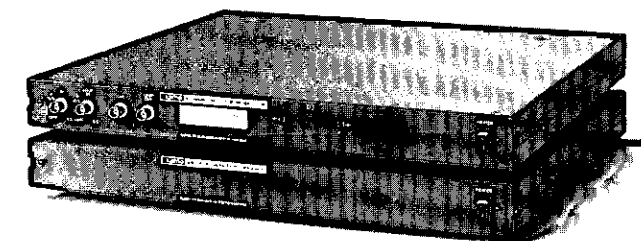
## Conclusion

The Novotel is now fully operational and enjoying heavy demand for its facilities. Close liaison with the building contractor and client throughout has produced an acoustic environment of high quality. The particular difficulties with services noise has highlighted the need for a clearly defined specification which is both workable and fully understood by the contractor at the tender stage.

J D Tate AMIOA and W Stubbs FIOA are with Wimpey Environmental, Hayes, Middlesex.

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# NOISE INSULATION REGULATIONS FOR NEW RAILWAYS AND OTHER GUIDED SYSTEMS

Report of the Institute of Acoustics Workshop, 6 December 1993

Geoff Leventhall FIOA

The development of new railway systems in the UK, ranging from town light railways (the rebirth of the tram) to the proposed light speed Channel Tunnel Rail Link has led to the requirement for Noise Insulation Regulations and a noise calculation method which parallel the well established road traffic procedures.

The first step to satisfying the requirements was in the report of the Mitchell Committee (Railway Noise and the Insulation of Dwellings, HMSO 1991). The report recommended a national noise insulation standard for new railway lines. However, the recommendations were modified before acceptance by the Minister and are currently

|                |                             |
|----------------|-----------------------------|
| 06.00 to 24.00 | 68 dB(A) $L_{eq}$ – 18 hour |
| 00.00 to 06.00 | 63 dB(A) $L_{eq}$ – 6 hour  |

in order to give equitability with road traffic levels.

The first Mitchell Committee was followed by a second Committee which delivered Noise Insulation for Railways and other Guided Transport Systems and also a calculation procedure for predicting railway noise. The documents produced by the second Mitchell Committee were issued for comment in October 1993 and the Institute's response follows:

Following publication of the Consultation Document the IOA arranged for a Discussion Workshop to be held in London to formulate an Institute response. The Workshop was attended by nearly 40 delegates. At the commencement of the Workshop, all documents in the Consultation package were reviewed in order to select topics for further, more detailed, discussion. The initial range of topics for discussion was reduced, by agreement, to the following as topics of most importance:

- Intensification
- Maximum pass-by level
- Eligibility distance
- Effect of points and crossings
- Barriers
- Propagation over ballast
- Facade correction
- Effect of rail wear
- Inclusion of generic train types
- Validation of (a) accuracy, (b) implementation
- Action levels and assessment periods.

**Intensification:** The Workshop's view was that NIR (Noise Insulation Regulations) action levels should not be exceeded by a planned increase in exposure which would occur over a defined time period, and that this can be distinguished from 'simple' intensification. Such a planned increase in exposure should be included within the Regulations.

For example it is possible to define intensification which qualifies for inclusion in the following way:

- (1) There is an increase in level of N dB(A)
  - (2) The new level exceeds the NIR trigger level
  - (3) The planned change occurs over a period of Y years.
- The values of N and Y are open to discussion, but the Workshop generally favoured N = 3 dB(A), Y = 15 years.
- Maximum Pass-by Level:** The workshop took the following views

(1) Para 2.1.6 in the Explanatory Note was not clear in its reference to small numbers of trains. Several members of the Workshop had carried out preliminary estimates which showed that 10 – 20 trains with  $L_{max}$  of 85 dB(A) could pass in the 6-hour period before the trigger level was exceeded. The actual number depends on speed and length of train. The Workshop felt very strongly that the Explanatory Note was incorrect and misleading on this point.

(2) It was felt that the protection of a maximum level should be included. However, it was accepted that measurement of a maximum level has uncertainties and may not be technically supportable, as it suppresses the time dimension. Thus the criterion might be set in terms of SEL or short  $L_{eq}$ .

An alternative which also found favour with the Workshop was to define the night-time levels as: 'The six-hour  $L_{eq}$  should not exceed 63 dB(A), whilst any one-hour  $L_{eq}$  should not exceed N dB(A).' Suitable choice of N will give the desired protection. This method is similar to that used in controlling construction noise.

**Distance over which Regulations apply:** The Workshop felt that limitation to 300 m was too restrictive because: (a) eligibility should depend on the noise from the new line and not distance from it and (b) a segment extension could give a distance greater than 300 m. This requires clarification.

**Track Types (Table 1, page 15):** The following omissions were noted:

Points and crossovers, bends and tight curves, rail wear. The Workshop noted that points and crossovers cause enhanced levels in their vicinity and that a way of including these should be found. The local level increase could be at least the same as that for jointed track.

Bends are known to cause enhanced level. These should be included, perhaps by relating speed and curvature.

The Workshop believed that track should be included in its typically worn 'average' state, not new 'ideal' state, and that an allowance for rail wear should be added at

some point in the calculation procedure, either in Table 1 or in the source levels, or as a separate addition at an appropriate stage of the calculation.

**Barriers:** The Workshop noted the differentiation between reflecting and absorptive barriers. However, this categorisation depends on the distance from the train. For example, absorptive barriers lose their benefit as the distance from the train increases and train/barrier reflection becomes less important. Can guidance be given on this?

It was also noted that the curve fitting equations for the barriers are more complex than well established equations and that the difference resulting from the two sets of equations is small. Could simpler equations be used?

**Propagation over ballast:** The 2.5 dB(A) reduction for propagation over ballast, eg from the far-side track, caused comment. Members of the Workshop were not familiar with this and requested that a physical justification, to show that the effect was applicable to all situations, should be given.

**Facade correction:** The Workshop questioned the use of a 1.5 dB(A) facade correction which is lower than that used in CRTN. Again, physical justification of the general applicability was requested.

**Source levels:** The Workshop felt that the inclusion of a large number of train types was potentially confusing, as the actual trains to be used may not be known during the prediction stage. It was suggested that:

(a) For a first look, the train/vehicle types should be simplified into four categories:

- Disc braked
- Tread braked
- Diesel Locomotive
- Electric Locomotive

(b) The fuller range of types could be used at a later stage if/when the information was known.

**Validation:** The Workshop believed that it was necessary to have a mechanism to validate both

- (a) the accuracy of the prediction and
- (b) the implementation of mitigation measures which developed from the prediction.

**Responsible Authority:** There was concern that the Responsible Authority, probably a non-public body, is to have the triple task of

- (a) producing the traffic forecasts
- (b) defining the properties to be insulated and
- (c) determining appeals

It was felt that there should be a mechanism for independent audit/enforcement.

**General matters:** The Workshop discussed the limitations under which the Mitchell Committee worked. There was a strong feeling that the restrictive brief requiring equity with 1970s road traffic criteria, was not appropriate to the 1990s and beyond.

In order to protect against noise from new railways it was necessary to look at the effects of railways themselves. In particular, reaction to existing railway noise may not be the appropriate determinant for new railways.

The time periods were discussed. It was pointed out to

the Workshop that Local Authorities in the South East and London had adopted the time periods recommended in the report of the Noise Review Working Party (Batho).

|         |               |                   |
|---------|---------------|-------------------|
| Day     | 07.00 – 19.00 | 65 dB(A) $L_{eq}$ |
| Evening | 19.00 – 23.00 | 60 dB(A) $L_{eq}$ |
| Night   | 23.00 – 07.00 | 55 dB(A) $L_{eq}$ |

This night period is the same as in the original Mitchell recommendation, but in this the level was 61 dB(A)  $L_{eq}$ . The subsequent adoption of a night period from 24.00 to 06.00 at 63 dB(A)  $L_{eq}$  has had the effect of removing the first and last night hours, when activity is likely to be greatest. For example if the hours from 23.00 to 24.00 and from 06.00 to 07.00 taken together, carry heavier traffic than the period from 24.00, this leads to the possibility of an additional elevation of level to that specified in the original Mitchell night period. Was this taken into account when the Mitchell recommendations were changed?

There was also some concern that the DoE and DTp appear to be dealing with noise in different ways. For example compare the draft PPG on Planning and Noise.

The Workshop discussed the derivation of the 'relevant noise levels'. There was concern that these were not based primarily on railway noise research, but on a transmutation of, possibly unsatisfactory, road traffic levels via uncertain relationships.

In the change from Mitchell recommendations to DTp regulation levels, the daytime change was fairly clear, but the nighttime was not and it was suspected that there had been an element of 'fudge' in this.

It was noted that further guidance on the noise from stationary trains in depots/sidings etc was required.

**Percentage of people annoyed:** It is known that, in the past, criterion levels have been set in the knowledge that a significant number of people (20 – 50%) would still be annoyed at those levels. The Workshop believed that future criterion levels should aim to protect a greater proportion of the population.

**Future research:** The Workshop noted the following areas in which additional information was required in order to specify criteria with confidence.

- SEL as an index of community response
- Method of specifying a maximum noise level
- Combined exposure to road and rail noise
- The development of a 'Design Manual' for new railways, similar to that which is used for new roads.

**Editorial points and related matters:** The following were noted:

- Prevailing noise level – there was a difference in wording between page 5 of the Regulations and page 5 of the Technical Memorandum.
- Advice on measuring prevailing noise level and its relationship to ambient noise level should be given.
- Wind – Para 41 of the Technical Memorandum should be modified as, at present, it could include a negative vector.

*The relevant consultative document can be obtained from the DTp at 2 Marsham Street, London SW1P 3EB*

**Geoff Leventhall FIOA is with Digisonix at Southbank Technopark and is a former Institute President.** ♦

# THE NOISE COUNCIL – A BRIEF HISTORY

Bob Peters FIOA

Many readers may remember the series of reports, with chocolate brown or white covers issued in the 1970s by the Noise Advisory Council. They dealt with a wide variety of noise-related issues, including for example neighbourhood noise, helicopter noise and a guide to the measurement and prediction of  $L_{eq}$ . These reports were generally authoritative and well respected, and therefore the abolition of the Noise Advisory Council in the early 1980s, as part of the UK Government's great quango hunt was regretted by many workers in the field of noise control.

Discussions between members of the Institute and other professional bodies concerned with the problems of noise in the community and workplace led to the formation of the Noise Council in 1986, aimed at filling the gap left by the demise of the Noise Advisory Council. The participating bodies which founded the Noise Council were the Institute of Acoustics (IOA), the Institution of Environmental Health Officers (IEHO), the Royal Environmental Health Institute of Scotland (REHIS) and the Institute of Occupational Safety and Health (IOSH). The aims of the Council were to promote and respond to issues relating to noise and vibration and to make independent technical and scientific expertise available to international and national agencies, central and local government, commerce and industry. Lord Elliott of Morpeth was appointed Chairman with Roy Emerson (IEHO) and Geoff Leventhall (IOA) as Deputy Chairmen.

The Noise Council's first publication, entitled 'Noise Legislation – its effectiveness for noise control' was issued at its launch, on 13 March 1986, at the House of Lords. The 16-page document reviewed the effectiveness of legislation in the following areas: construction noise, noise abatement zones, sound insulation between dwellings, road traffic noise, and occupational noise exposure. In January 1987 the Noise Council organised its first one day conference, jointly with IOSH, on the theme of 'Noise at Work – what kind of law do we want?' In retrospect both of these Noise Council initiatives can be seen to have presaged changes which were to take place within a few years.

The Noise Council now meets formally four times each year, with additional meetings of various working groups; items received between meetings and requiring prompt comment are dealt with by post. The members of the Noise Council, apart from Lord Elliott, are all appointed representatives of the four constituent founder Institutions. The secretarial duties have been shared between the IOA and the IEHO with Graham Jukes of IEHO currently acting as Noise Council secretary, assisted where necessary by Cathy Mackenzie. Noise Council meetings are normally held at the premises of IEHO, who also provide administrative support and arrange auditing facilities.

The Noise Council became a private company with limited liability in February 1988.

The work of the Noise Council has been funded jointly by the Department of the Environment (DOE) and the four constituent organisations. Representatives of the Noise Council meet regularly, at least once a year, with DOE representatives, to report progress and to identify targets for future Noise Council projects. In addition to the ongoing work of the various working parties producing reports, guides and Codes of Practice, the Noise Council also receives reports requiring comment, queries and requests for information from various organisations as well as from DOE; this sometimes includes letters from members of the public. Examples of issues that have been considered and commented on by the Noise Council include the Draft PPG on Planning and Noise, the Noise and Statutory Nuisance Bill, and its implementation, proposed BRE methods for assessing noise caused by amplified music, DOE Noise Awareness months and an EC Commission proposal on Noise Legislation.

As the problem of noise in our society increases there has been a proliferation of organisations and groups providing advice, producing reports and codes and seeking to exert influence and promote particular viewpoints on noise issues. In respect of its relationship with other organisations, the Noise Council has always sought to highlight its independent position when called upon to provide professional advice and comment on scientific and technical matters. For its part, the DOE has expressed its appreciation of this independence. As well as holding discussions with DOE, the Noise Council has participated in a Noise Forum discussion between the DOE and representatives of bodies such as the Noise Abatement Society, The Right to Peace and Quiet Campaign, the UK Environmental Law Association and the National Society for Clean Air and Environmental Protection (NSCA). The Noise Council also exchanges minutes with the NSCA National Noise Committee.

The work of the Noise Council has not been entirely without problems in recent years. The funding arrangements of the DOE have required the participating bodies to match, collectively, the DOE funding in cash terms each year. This has been a source of some difficulty, even though the value of services provided, in terms of accommodation for meetings, secretarial support and members' time at meetings and in working groups can be held to exceed the DOE contribution. To the frustration of members, time diverted to overcoming these difficulties has necessarily been at the expense of the real work of the Council. Income has been generated from the sale of publications and from meetings, such as the very successful meeting on Noise and Planning in 1991, jointly organised with the London Branch of the IOA and IEHO.

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Another source of frustration has been the slow rate of progress in producing some of the reports, arising from existing pressures on the time of the members of the Council. The possibility of employing a professionally qualified part time technical secretary to answer day to day enquiries and to progress ongoing work on publications has been investigated, but the idea has been shelved at the moment for financial reasons. By contrast, the Council's predecessor was favoured with extensive support from scientists and administration in the Civil Service.

Recent developments have however raised a feeling of optimism. The DOE has announced new funding arrangements for bodies such as the Noise Council whereby contributions 'in-kind' can be allowed as part of the matching of DOE funding and the Noise Council is therefore now working urgently on a new funding application.

Given the difficulties, it is encouraging to report that the Noise Council Code of Practice on Off-road Motor Cycle Noise has just been issued and is for sale at £5 per copy. The Code of Practice on Entertainment Noise (Pop

Concerts) is scheduled for early publication, after modifications have been incorporated following a period for public comment.

A Code of Practice on Noise Units is very close to completion and should be issued by the middle of 1994. Additionally a questionnaire designed to enable the Noise Council to advise the DOE on the usefulness and effectiveness of existing Codes of Practice has been prepared and is about to be circulated.

A working party is considering the feasibility of issuing an annual digest of noise related information and statistics. It is proposed to hold a Noise Council Conference later this year to publicise reports published during the year.

Over the years the membership of the Noise Council has changed. The current IOA representatives are Geoff Leventhall (founder member and Vice Chairman), Stephen Turner, Ian Flindell, Dudley Wallis and Bob Peters.

**Bob Peters FIOA is at NESCOL at Ewell.**

## **Noise Council Code of Practice on Noise from Organised Off-road Motor Cycle Sport 1994**

### **Introduction**

Codes of practice do not in themselves have the force of law; their principal aim is to give advice to noise makers on appropriate methods of minimising noise so that annoyance to the public is reduced. They are also intended to be of assistance to Local Authorities and Magistrates Courts (or the Sheriff in Scotland) when considering whether the 'best practicable means' have been used for preventing or counteracting the effect of the noise.

This Code of Practice (COP) has been produced by the Noise Council in conjunction with motor cycle sporting bodies, the motor cycle industry and environmental organisations. The members of the Working Group who produced the document were J D Clegg (Chairman), A F Baker and A J Gilbert.

The following is an attempt to summarise the contents of this COP so that interested or concerned people can choose to acquire the full document for perusal. In the case of organisers of events who have already applied the principles of the Code, it is hoped that they will feed back to the Noise Council Working Group their comments and suggestions for future revisions.

The COP applies to the use of motor cycles for all organised competitive off-road events and is aimed at establishing guidelines to ensure that 'suitable and reasonable actions have been taken to minimise the impact on neighbourhood noise from organised off-road motor cycling events'.

The COP is a comprehensive document dealing with critical noise considerations involved in off-road events such as Enduro, Grass Track Racing, Moto-Cross, Rally

Cross, Sand Track, Trials, Trail Cross and Beach Cross.

It includes discussions on the legal aspects, reducing noise emission, reducing the reception of noise at sensitive premises and public relations. There are annexes defining the different types of motor cycle sport, describing the test procedure for measuring the noise output of individual machines and advising on the screening of noise sources.

### **Legal controls over motor cycle events**

The use of land for motorcycling may be subject to various legal controls which the code recommends should be carefully observed at all times.

These include:

- (a) the possible requirement for specific planning permission, for example if land is used for more than 14 days in a year for the purposes of racing and/or permanent structures are erected on site;
- (b) Section 33 of the Road Traffic Act 1988 requires Local Authority authorisation for a motor cycle trial of any description on a footpath or bridleway and
- (c) As long as the event is 'authorised' according to the Motor Vehicle (off Road Events) Regulations 1992, the offences described in the Road Traffic Act 1991, ie dangerous, careless and inconsiderate driving, do not apply. There is also reference to Section 80 of the Environment Protection Act 1990 in relation to Abatement Notices in respect of statutory noise nuisance arising at events. In Scotland, the Control of Pollution Act 1974 provides similar noise nuisance abatement powers, while in Northern Ireland, the Pollution Control and Local Government (Northern Ireland) Order 1978 applies.

### Reducing noise emission

This section deals with testing the noise produced by individual motorcycles to ensure that they do not exceed the noise levels recommended by the various regulating bodies. The stationary noise test procedure laid down by the International Federation of Motor Cyclists is described and an annexe to the code contains a table of maximum noise levels allowed according to the type of event and machine.

The levels range from 87 dB(A) for a 2-stroke trials machine to 102 dB(A) for 4-stroke grass track, trail cross or beach cross motorcycles.

### Reducing the reception of noise at sensitive premises

This concerns measures to be taken by organisers to minimise the noise heard by neighbours. There are technical limitations in controlling noise emitted by individual machines and so other methods have to be used. To reduce the reception of noise at sensitive premises the code recommends the consideration of the following factors; access/egress for cars and the location of car parking, location of start line, paddock and noise test area, times and duration of events, numbers of machines in operation simultaneously, public address systems and the provision of physical barriers to reduce sound propagation. In a final section of the code some general points are made about the importance of good public relations.

(Editor) ♦

## Group & Branch News

The South-west Branch has come to life again with an evening meeting organised by Norman Pittams of the University of the West of England on 23 March. The title was Noisy Neighbours and over seventy attended, mainly Environmental Health Officers from the region. A report on this meeting will appear in the next issue of the Bulletin.

*Les Fothergill (Chairman of the Building Acoustics Group) writes –* 'For many years the Building Acoustics Group and Industrial Noise Groups have included environmental noise in their remit. The success of recent Autumn conferences has highlighted the importance of the subject and the logic of treating environmental noise as a subject in its own right. The BAG committee therefore welcome the establishment of the new Environmental Noise Group. The three groups will work closely together to ensure all members interests are fully covered. The formation of the new group will enable the BAG to concentrate on its traditional subject areas. These include: control of noise from all sources in buildings; criteria for noise levels in different situations; sound insulation (including measurement methods, prediction and criteria); and acoustics of spaces (all aspects). The changes will provide members with a greater range of meetings and improve the service provided by the Institute.'

As always the BAG committee will welcome suggestions for future meetings from members.' ♦



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## Contributions

### Greenline Carriers Ltd Objective Basis For Nuisance?

The Greenline Carriers (Tayside) Ltd v City of Dundee District Council [1] case provides interesting reading on the subject of whether a test of existence of nuisance should be based on a subjective or objective assessment.

A notice was served by a local authority under s.58 (1) of the Control of Pollution Act 1974 (which has not been replaced by the Environmental Protection Act in Scotland) asserting that a nuisance, namely noise, existed at specified premises, requiring its discontinuance and ordering to that end that the movement, loading and unloading of lorries should cease during certain hours. An appeal was taken to the sheriff who, after proof, upheld the notice subject to deletion of reference to the movement of lorries, and issued an interlocutor and accompanying note. The pursuers appealed. Although the defenders did not accept the narrative of the evidence contained in the grounds of appeal, they did not lodge answers since they had found that the Rules of Court made no provision for answers to be lodged in such a case. The sheriff having retired, the defenders proposed that the court should order production of the sheriff's notes of evidence in order to ascertain the evidence led at the proof.

It was held (1) that the merits of the appeal fell to be determined by reference to the sheriff's interlocutor and note, not by ordering production of the sheriff's notes; (2) that an objective standard should be applied to the issuing of a notice under s.58 of the 1974 Act and it was vital that the local authority in issuing a notice, and the sheriff in determining an appeal, should apply such a standard and that the sheriff should openly and soundly direct himself; (3) that in a case such as the present, the sheriff had to disclose what evidence he had accepted and why, explain what primary facts he had determined

upon the basis of that evidence, and explain and justify the inferences of fact made from the primary facts, and then demonstrate that in the light of a proper understanding of what the law required, he had found whether the primary and inferred facts did or did not establish a nuisance in fact and in law which the sheriff had failed to do here and (4) that where the form of the sheriff's decision was not prescribed by statute he should, in order to comply with the rules of natural justice, not only issue an interlocutor stating his decision in precise legal terms but should give adequate reasons and not merely state whether or not he found the case established; (5) that no proper basis for the sheriff's decision having been shown, his interlocutor could not stand and appeal allowed and interlocutor and notice recalled.

#### Comment on the above

For the purposes of determining whether or not a nuisance exists EHO's normally look for guidance to the principles established in Common Law. One of the strengths of s.58 is that EHO's are able to issue a nuisance notice if in they are satisfied that nuisance conditions exist. Given this decision, it is not unreasonable to anticipate a scenario whereby local authorities will not issue a s.58 notice on the basis of one or a combination of the following points;

(i) A lack of confidence in the technical requirements of quantifying what is in the opinion of the local authority a nuisance. Quantification of nuisance when dealing with steady state broad band intrusive noise and steady state broad band background noise is relatively straightforward if assuming that any increase in background noise can in certain circumstances constitute a nuisance. The introduction of variables such as low intermittent background noise, low frequency and/or intermittent intrusive noise make the task of defining a set 'nuisance' standard well nigh impossible.

(ii) A lack of suitable instrumentation for spectral analysis and continuous monitoring which could be required for characterisation of non-steady

state intermittent noise, and (iii) Insufficient manpower to devote to the time required to gather sufficient data for the determination of the actual 'nuisance level'.

Ricky Burnett hopes to explore this subject further at the forthcoming 'Noise Nuisance and the Law' meeting being organised by the Environmental Noise Group and London Branch on 18 May 1994. Meanwhile the Group Committee would be interested in receiving comments via the Institute office from anyone having experience of application of well defined objective nuisance standards or from EHO's who feel that the Greenline Carriers case will deter them from issuing s.58 notices based on the strict wording of the 1974 Act.

[1] The Scots Law Times: Issue 31 10-91

### Safety at Pop Concerts Guide to Health Safety and Welfare at Pop Concerts and Similar Events

In December 1993 the HSE, in conjunction with the Home Office and the Scottish Office, published the above guide. It covers numerous aspects in relation to the subject matter including a chapter entitled Sound and Noise. The chapter concentrates on the question of noise levels within the venue and how it affects employees and the audience. It makes mention of external environmental noise levels outside the venue which is presently the subject of a draft code being produced by the Noise Council.

The chapter refers to the provisions of the Noise at Work Regulations 1989 and includes sections relating to controlling and monitoring of sound levels. In addition it makes recommendations to offer some protection to the audience. This includes the establishment of a maximum event equivalent continuous sound level (Event  $L_{eq}$ ) of 107 dB(A), the peak level not to exceed 140 dB and restricting the audience to locations of at least 3 m from any loudspeaker. Details of how to acquire this document are given here in the Publications pages.

Contributors Dr Bernadette McKell MIOA, R Burnett. ♦

## News from BSI

### New and Revised British Standards

**BS 7703:** Acoustics – Determination of sound power levels of noise sources using sound intensity.

Part 1: 1993 Measurement at discrete points. This is equivalent to ISO 9614-1. No current standard is superseded.

### Amendments

**BS 3638:** 1987 Method for measurement of sound absorption in a reverberation room [ISO 354]. This amendment implements EN 20354: 1993 as a British Standard and rennumbers BS 3638: 1987 as BS EN 20354: 1993.

### BS EN Publications

The following are British Standard implementations of the English language versions of European Standards (ENs).

**BS EN 22922:** 1993 Acoustics – Measurement of noise emitted by vessels on inland waterways and harbours. This is equivalent to ISO 2922. No current standard is superseded.

### BS ENs implemented by amendment

The following BS ENs are implemented by amendment to existing documents:

**BS EN 20354:** 1993 Acoustics – Measurement of sound absorption in a reverberation room. This is implemented as a European Standard by amendment to BS 3638: 1987. It is equivalent to ISO 354.

### DD ENV Publications

The following standard is a British Standard implementation of the English language versions of European Pre-Standards ENVs). It is issued as a Draft for Development (DD).

**DD ENV 28041:** 1993 Human response to vibration – Measuring instrumentation.

It is equivalent to ISO 8041. No current standard is superseded.

### British Standards Reviewed and Confirmed

**BS 6686:** Methods for determination of airborne acoustical noise emitted by household and similar electrical appliances. Part 1: 1986 General requirements for testing.

### British Standards Withdrawn

**BS 4891:** 1972 A guide to quality assurance. This is partially superseded by BS 5750: Parts 0, 8 and 13; and also conflicts with BS 6143 and BS 7850: Part 2.

### European New Work Started

**EN 1030:** Hand-arm vibration – Guidelines for vibration hazards reduction – Part 2: Management measures at the work place (EN 1030-2).

## Draft British Standards for Public Comment

**93/408738 DC BS ISO 10014** Guide to the economic effects of total quality management. This is equivalent to ISO 10014.

**93/506284 DC** Revision of BS 5821 Methods for rating the sound insulation in buildings and of building elements. Part 1: Airborne sound insulation [ISO/DIS 717-1 and prEN 20717-1].

**93/506262 DC ISO/DIS 362** Acoustics – Measurement of noise emitted by accelerating road vehicles – Engineering method – Amendment 2.

**93/506263 DC ISO/DIS 7188** Acoustics – Measurement of noise emitted by passenger cars under conditions representative of urban driving – Amendment 1.

## IEC Publications

**IEC 1252:** June 1993 Electroacoustics – Specifications for personal sound exposure meters.

## ISO Standards

**ISO 10494:** 1993 Gas turbines and gas turbine sets – Measurement of emitted airborne noise – Engineering/survey method. Implementation as a dual-numbered British Standard is under consideration.

## BSI Information Services Technical Publications

BSI Information Services produces a range of publications covering the technical requirements for various industrial products and services in markets worldwide. These documents are available from BSI Publications at Milton Keynes.

**TH 42059:** 1992 Personal Protective Equipment. A bibliography. This lists current European and national standards in 17 European countries. It covers breathing apparatus; respiratory protection; head, ear and eye protection; protective clothing; buoyancy devices; fall arresters and safety belts. It also includes EC Directive, and DTI notes relating to the UK.

**TH 42060:** 1993 Quality systems. A list of national and international standards.

*It has only been possible to include information from September and October 1993 editions of BSI News in this issue of the Bulletin. In the next issue information will be supplied from November 1993 editions of BSI News to date.*

This information was provided by Miss Nicole Porter MIOA of NPL

## HSE Publications

The following publications recently issued by the Health and Safety Executive on noise related subjects are available from Dillons or from any branch of Ryman the Stationer or a Ryman Computer Store. Alternatively all priced and free publications are available by mail order from HSE Books, PO Box 1999, Sudbury, Suffolk, CO10 6FS. Tel: 0787 881165 Fax: 0787 313995.

## Attitudes Towards Noise As An Occupational Hazard

This HSE contract research report was carried out by Thomson-MTS and Building Use Studies into the attitudes of the workforce and management towards noise in a variety of industries. It involved a national survey of 48 organisations and a more detailed examination of ten of these as a case study.

The findings are published in three volumes. Volume one: 'Summary reports of the study', and Volume two: 'Detailed reports of the study', are available as a combined publication at a cost of £60.00 (ISBN 0 11 882128 8). Volume three, 'Literature survey and review of public awareness campaigns', at a cost of £30.00 (ISBN 0 11 882133 4).

## Guide to Health Safety and Welfare at Pop Concerts and Similar Events

This joint HSE, Home Office and Scottish Office publication deals with all aspects of planning and operating pop concerts and other related events. There are specific chapters which deal with Communication including Radio and Public address systems, Sound and Noise which looks at exposure levels of both the workforce and the audience including the monitoring of sound levels and also a chapter on the Means of giving warning in case of fire. Available at a cost of £10.00 (ISBN 0 11 341072 7)

## Control of Noise in Quarries (HS (G) 109)

Part of a series produced on various hazards associated with the quarries industry. It is produced for employers and those managing quarries to make them aware of

their obligations to The Noise at Work Regulations 1989. It covers noise measurements, assessments of exposure and has extensive coverage of prevention and control to items of plant and machinery used in the industry. Further sections deal with hearing protection and instruction and training and the duties of designers, manufacturers, importers and suppliers of plant and machinery. Available at a cost of £4.50 (ISBN 0 7176 0648 1)

Keith A Broughton MIOA

## Book Reviews

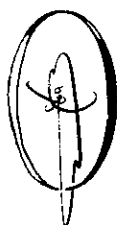
### The IRS Guide to the Noise At Work Regulations

Frank B Wright & James A Powell

Industrial Relations Services, 18 Highbury Place, London N5 1QP (1993) ISBN: 1 870771 10 9 Price £40.00

This is a useful work of reference for those who are concerned mainly with the legal aspects of the Noise at Work regulations. It does provide some guidance to their implementation, but this is mostly considered from the aspect of legal requirements. The authors are a Law lecturer and a Professor of Design Systems; they have been assisted by Ian Acton, a noise specialist. There are a few lacunae of the 'dB(A)' variety, but the flavour is essentially a management guide rather than a technical interpretation; it achieves a balance that will be useful to many companies.

An A4 format booklet of 78 pages, it covers in an effective style the essential issues and responsibilities of companies – together with the self-employed. The choice



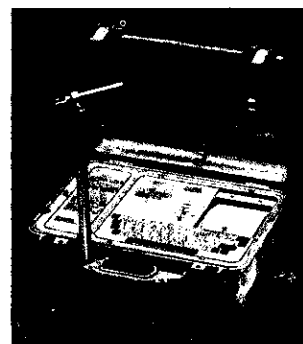
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### NOMIS

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of a small font was unfortunate; affected as I am nowadays by both middle-aged ears and eyes, the layout of the text – arranged as a single column with long paragraphs – I rated the booklet's physical readability score as 'below average'.

The content embraces everything that one would expect from the title – the Regulations themselves are reproduced in an Appendix, together with elementary but sufficient material on noise measurement, human hearing and hearing damage. It would have been a significant improvement if the booklet included an index. Since this is readily achieved with current publishing systems, it seems strange not to find one in a reference work such as this.

One section of the booklet is devoted to employers' liability and compensation and contains a very readable and salutary summary of the current position based on common law and statutory duty. This is accompanied by a listing of some examples of compensation awards, under both common law and union agreements, charting our progress in the £/dB hearing loss stakes.

I was especially pleased to see the relevance of Quality Assurance schemes recognised together with the real benefits which a good ISO 9000 (BS 5750) system can bring. It would perhaps be excessively optimistic of me to expect more than the two pages (albeit of small type). Given that the only reason for introducing such a system into a company is to improve efficiency and to be able to measure the benefits achieved, the stress might be more on the overall benefits rather than the improved book-keeping!

In a disappointingly brief reference to training, the Institute's Competent Person course is mentioned.

*Bernard J Challen MIOA*

## Hansard

2 November 1993

### Aircraft Noise

**Mr Uwyd:** To ask the Secretary of State for Defence if he will make a statement on the progress of his Department's research and development programmes in the areas listed in appendix II to the annex to the summary of the final report of the NATO CCMS pilot study on aircraft noise in a modern society.

**Mr Hanley:** My Department is involved in several studies to further the understanding of noise associated with military aircraft. In parallel, we continue to develop noise modelling and prediction capabilities. In collaboration with authorities in the United States and Canada we have completed initial work into the feasibility of a study to investigate the possible effects on health of noise from low-flying aircraft, and a report is being prepared. In the case of airspace management, a contract has been let to develop an automated low flying flight planning enquiry and notification system – ALFENS.

**Mr Uwyd:** To ask the Secretary of State for Defence if he will make a statement on progress in implementing the recommendations of the final report of the NATO CCMS

pilot study of aircraft noise in a modern society.

**Mr Hanley:** The NATO CCMS pilot study on aircraft noise was completed in 1989. A follow-up group was created the following year to implement its technical recommendations. This group exchanges information between participating countries and encourages individual or multinational studies. The United Kingdom contributed to a major symposium on helicopter noise, sponsored by NATO CCMS and held in the USA, and is currently participating in collaborative working parties engaged in noise modelling around airports and in the investigation and modelling of helicopter noise.

### Aircraft Noise

**Mr Uwyd:** To ask the Secretary of State for Defence if he will make a statement on the progress of the joint United Kingdom – United States – Canadian study on the long-term effects on human health of exposure to aircraft noise; and if he will list any publications by participants in this study.

**Mr Hanley:** Initial work on the feasibility of a study to investigate the possible effects on health of noise from low-flying aircraft has been completed and a report is being prepared. My Department is not aware of any publications by participants in relation to the study.

### Noise Abatement Zones

**Mr Pike:** To ask the Secretary of State for the Environment what conclusions he has reached on consideration of the Building Research Establishment's report in relation to noise abatement zones; and if he will make a statement.

**Mr Yeo:** My Department is considering the effectiveness of noise abatement zones in the light of the findings of the Building Research Establishment's 'Review of Noise Abatement Zones in England and Wales 1976–1992'. The review showed that the procedure for establishing and monitoring NAZs was complex and resource intensive for all the parties involved. In reaching conclusions, we must balance the need to limit the regulatory burden on businesses with the continuing need to deal effectively with noise pollution.

### Noise

**Mr Pike:** To ask the Secretary of State for the Environment how many complaints relating to noise have been (a) reported to local authorities and (b) investigated by local authorities under the Environmental Protection Act 1990.

**Mr Yeo:** The Department of the Environment 'Digest of Environmental Protection and Water Statistics', HMSO 1992 indicates that during 1990/91, 136,609 complaints about noise were received by local authorities, relating to the Control of Pollution Act 1974 and the Environmental Protection Act 1990.

Of these, 31,721 were considered to be justified as statutory nuisances and in 6,113 cases abatement notices were served.

The 1990 Act came into operation on 1 January 1991 and separate figures for the number of complaints investigated under that Act in 1990–91 are not available.

Extracts provided by Rupert Taylor FIOA.



## New Products

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#### ARIA

A new modular acoustic measurement system from AcSoft is the first PC-based sound level meter to be type-approved by the German authority PTB for Type 1 acoustic measurements.

ARIA, from the French company 01dB, is based on plug-in cards for a PC plus a full suite of application software covering measurements of environmental noise, occupational noise, sound intensity and building acoustics.

The main benefit of ARIA is that the systems are built exactly to customers' needs, and the architecture takes a free ride on the back of developments in the PC industry, which have given huge advances in processing speed, graphics capability, and cost-effectiveness over the last few years.

The heart of the system is a dedicated card, which can be installed in any PC 16 bit full length expansion slot. Powering and conditioning is provided on the inputs for microphone preamplifiers, which can be connected without the need of external boxes. All the user interface, data post-processing and displays are handled by software running on the PC.

For further information contact John Shelton, AcSoft Ltd, 6 Church Lane, Cheddington, Leighton Buzzard LU7 0RU. Tel: 0296 662852. Fax: 0296 661400.

### NOISE CONTROL CENTRE

#### Melatech Foam

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design detail and resilient enough to take compression without losing form.

Further details are available from The Noise Control Centre, Charles House, Toutley Road, Wokingham, Berkshire, RG11 5QN. Tel 0734 774212. Fax 0734 772536.

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After many years of loyal, trouble free service in the field the Rion LR-04 chart recorder has been replaced. The newcomer, LR-06, is about the same size as its predecessor and just bristling with micro-processor technology.

For many applications it is no longer necessary to take the chart recorder on site as data can now be stored on a 'smart' memory card, using a hand held meter such as the NL-14 with an optional memory card unit. The smart card can then be read by the recorder and a hard copy printout produced. A threshold can be set in order to plot only values above a certain level at a higher paper speed. This saves paper and gives increased resolution only where necessary.

The data card can also download into a personal computer. The LR-06 will accept input from a variety of data loggers and noise and vibration meters and has many timing and recording options.

Further details from Quantitech Ltd, Unit 3, Old Wolverton Road, Old Wolverton, Milton Keynes MK12 5NP. Tel 0908 227722 Fax: 0908 227733.

### ACIAL

#### Acoustic barriers from old tyres

The French company ACIAL has developed a new design of acoustic barrier constructed from used tyres as shown in the photograph. It is highly effective in operation and environmentally friendly.

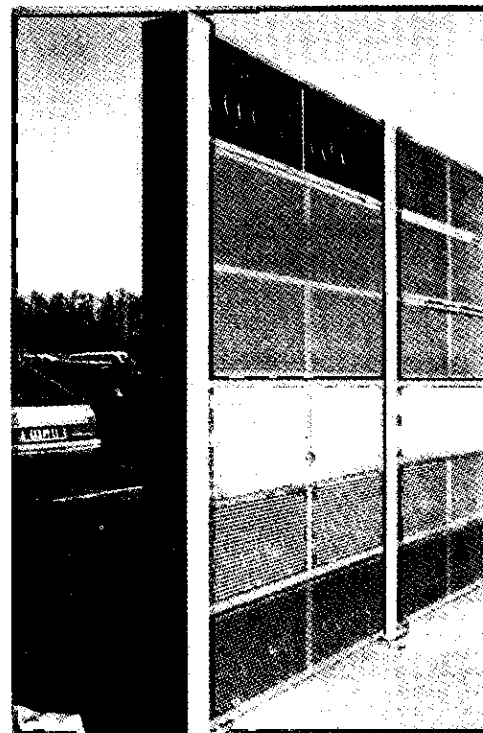
The barrier consists of a metal casing inside which are stacked tyres cut in half along their diameter. The side of the casing facing the noise is made from perforated sheet metal. The coefficient of absorption is 85% for frequencies between 250 and 2000 Hertz.

The casings are galvanised and strongly corrosion resistant. They are non-inflammable and are thick enough to withstand strong winds. The tyres themselves do not deteriorate with age. The barriers are modular, and can be positioned to produce the required heights and lengths. They are available in practically any colour, and also in aluminium or with anti-graffiti treatment.

Installation is easy. Poles welded onto plates rest on bearing plates or piles and form the supporting framework for the casings. The tyres are stacked on site. The barriers are self-cleaning or a high pressure water jet can be used.

The tyres are fitted at an angle inside the casings to drain away rain water. Each element is easily interchangeable in the event of accidental damage.

The ACIAL barriers are designed for shielding noise alongside motorways, other busy roads and rail-



ways. They can also be used in industrial settings.

Highly competitive on cost, the barriers combine efficient noise reduction with a solution to the problem of disposing of the growing number of used tyres.

M.P. Verrelle, Director, Acial, Acoustics Division, 57 rue des Saules, 75018 Paris, France. Tel: (010 33 1) 44 92 18 37/44 92 18 18, Fax: (010 33 1) 42 23 93 84 Enquiries should be made through Charlotte Barracough at the French Technology Press Bureau. Tel: 071 235 5330.

## LMS INTERNATIONAL

### LMS CADA-X Exterior Pass-By Noise

LMS CADA-X Exterior Pass By Noise measures the noise emissions of vehicles on a test track during an accelerated pass-by according to the ISO or SAE standards. The measurement starts when the vehicle passes a first light barrier. During the pass-by, the vehicle position and the engine rpm are measured by

radar and telemetry, along with the A-weighted time histories of both microphones. Immediately after the acquisition, the weighted overall levels as function of position are calculated and displayed together with the entrance and end speed, and the maximum overall levels and their locations. Pass-By quality parameters such as kick-down error, vehicle entry speed, bad calibration of radar signals and throttle release error cause an automatic rejection of the measurement.

During a typical pass-by noise test program a massive amount of data is gathered. Therefore, a powerful and flexible data management/annotation system has been integrated into the system.

LMS In-Room Pass-By Noise LMS CADA-X In-Room Pass-By Noise simulates pass-by tests in a semi-anechoic room. A roller bench is used to simulate the road loads on the vehicle and the simulated pass-by is measured by an array of microphones on either side of the room: the results being recombined

and processed against the vehicles virtual position by the software. If an existing semi-anechoic room does not meet the dimensions specified in ISO 362, the results can still be re-scaled by the software, if the free-field acoustical behaviour can still be assumed. The immediate benefits of the new approach are the accurate and reproducible pass-by noise measurements; the elimination of measurement variations caused by adverse weather or external noise sources; and accurate start conditions for the run. The system not only produces pass-by measurements but more importantly, provides extensive database facilities and a troubleshooting/refinement toolbox with comprehensive diagnostic capabilities.

For further details contact LMS UK Ltd, Cheddar Industrial Park, Wedmore Road, Cheddar, Somerset BS27 3EB. tel:0934 744222 Fax: 0934 744461.

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*Items tested receive a NAMAS Calibration Certificate defining the absolute accuracy with reference to UK National Standards.*

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# Mandoval



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## News Items

### Livingstone Hire 1994 Catalogue

Livingstone Hire's new rental catalogue is now available, providing a comprehensive guide to rental and highlighting important additions to the company's equipment range.

New capabilities include a NAMAS accredited calibration service and a machine health monitoring service. The concern of industry with the protection of the environment and the workforce are catered for with a wide range of monitoring equipment available for rental, now covering the measurement of sound and vibration, ambient air quality, stack emissions, landfill emissions, leachates, water quality, effluents and health and safety parameters.

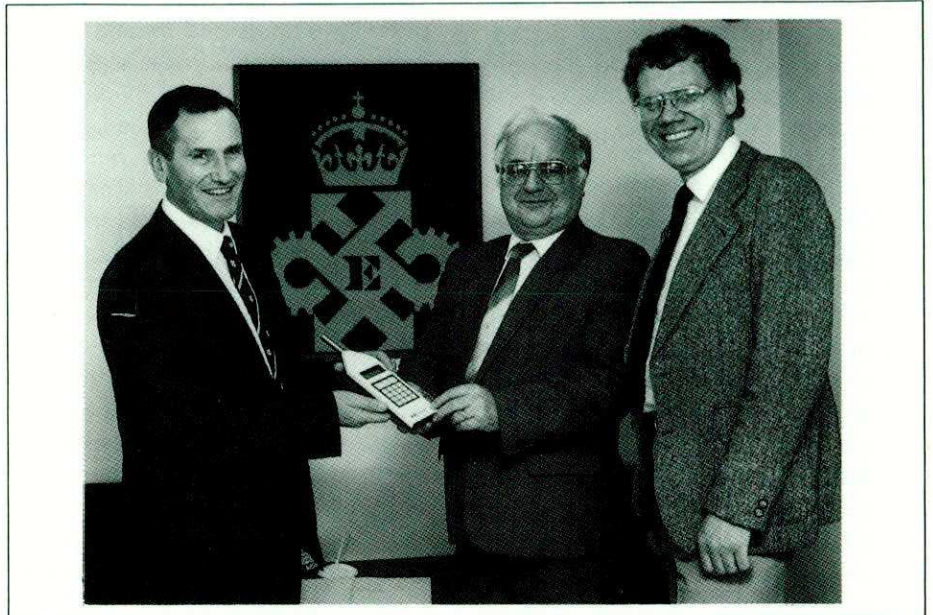
The 1994 catalogue is available free of charge from Livingstone Hire Ltd, Livingstone House, Queens Road, Teddington, Middlesex, TW11 0LB. Tel: 081 943 5151, fax: 081 977 6431.

### Cirrus Research plc Management changes

The Directors of Cirrus Research announced in February the appointment of Ian Campbell as managing director. A reassignment of responsibilities among the other directors resulted in Karl Frankish continuing as Chairman of the Board concentrating on Production and Logistics

whilst Dudley Wallis takes an Advanced Engineering portfolio. Before coming to Cirrus, Ian Campbell spent 20 years with CEL. Pictured below are, left to right, Ian Campbell, Dudley Wallis and Karl Frankish.

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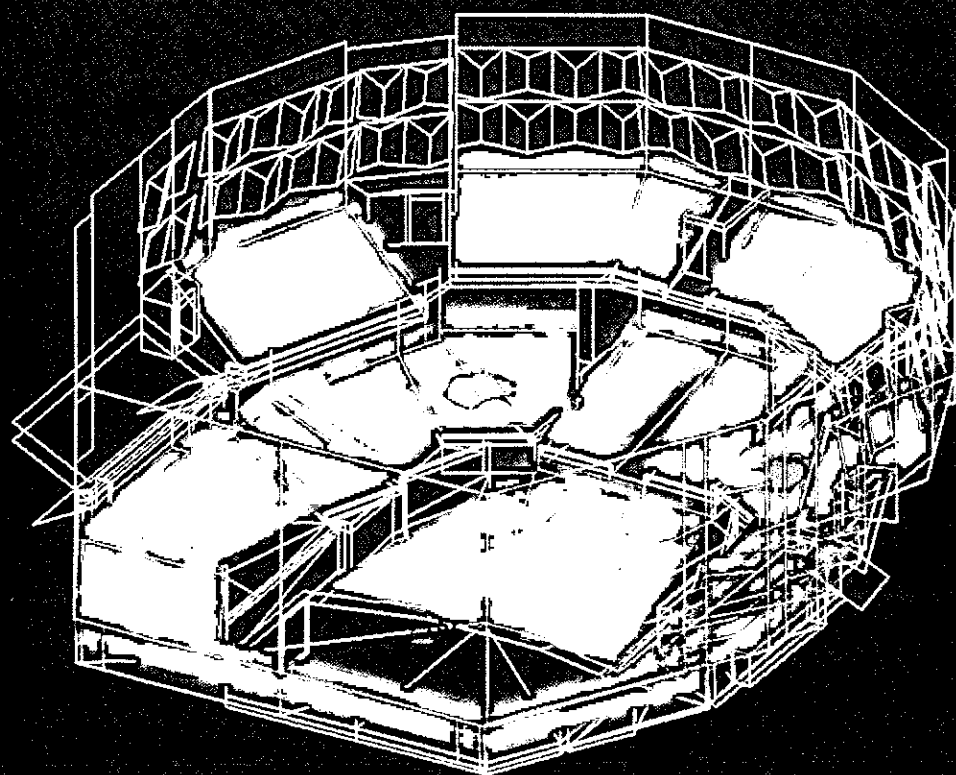


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