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Technical Contributions

Publications

News from the Industry

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

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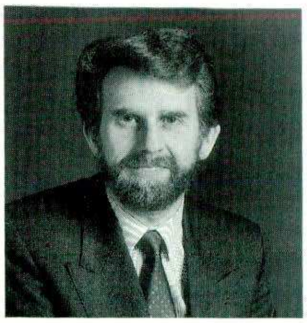


Dear Fellow Member

This specially enlarged Euronoise issue should be published in time for distribution to the delegates to that conference and it gives me an opportunity to welcome participants on the Institute's behalf.

For those who will not be there, Euronoise is a new venture that the Institute has initiated with the expectation that successive conferences in the series will be held in different European countries during the roughly alternate years that Internoise is being held away from Europe. We await the reaction to the first Euronoise from our overseas friends before judging whether we have started a process that will continue.

Having said this, I am writing at precisely the time when doubts about Maastricht are beginning to raise serious uncertainties about prospects for European cooperation; President Mitterand's television appeal is not certain to provide a positive response in the French referendum. Nevertheless we can but wait and hope that the clouds lift soon and we can see where things are going.

I wish to report to you a related matter that has come to the fore recently and that is the question of a place for a European acoustical journal which has already been given the title Acta Acoustica. Several meetings have already been held involving individual members of the major European acoustical societies to discuss the possibility of a journal of this name being sponsored collectively by all or many of the European societies. The basic idea is that the journal would have broadly the same position in European acoustical affairs that JASA has across the Atlantic with the exception that the material carried would be a particular mixture of academic, technical, professional and Institutional articles.

The thinking so far has concentrated on the question of how to guarantee a very wide initial circulation; with such a circulation, the argument runs, intending authors would be keen to publish in the journal with a consequent guarantee of quality and making it more or less self sustaining. But the question of how to achieve this has focused on the role of the collaborating societies and how many reduced rate subscriptions each would be willing to guarantee taking on behalf of their members. The societies concerned already have in place a wide variety of means by which they regularly communicate with their members; how such a proposed journal would fit in with this pattern is not immediately clear. Equally it is uncertain how such a journal would be placed in respect of the existing journals.

A sub-committee of Council has been considering the issues involved on behalf of the Institute and I shall attempt to keep you informed on the progress of the negotiations. I am certainly inclined to welcome the present proposals, as far as they go, as tangible evidence of emerging European cooperation but awkward questions on viability will have to be answered.

Finally may I add that the size of this issue should make you reach for your pens and order the copy of the Bulletin binder you have promised yourselves for so long. Price £6 including VAT and postage, cheque with order, from the Institute office!

With best wishes

Yours sincerely

Peter Wheeler.

PROTECTION AGAINST NOISE AT WORK: SITUATION IN THE EUROPEAN COMMUNITY AND VIEWS WITHIN THE COMMISSION

M van der Venne

Introduction

Noise at work has been addressed in Council Directive 86/188/EEC [1], which had to be transposed in the national legislation of the Member States on 1st January 1990 or 1991 (depending on the country) at the latest; on 1st July 1992, eleven out of twelve of them have complied with this duty. That Directive however was never intended to be the end of the road on noise control at work, and it contains a requirement for review by the end of 1993.

The Commmission of the European Communities had this in mind when it included in its Action Programme relating to the implementation of the Community Charter of the Basic Social Rights for workers [2], the presentation of a Proposal for a Council Directive on the minimum safety and health requirements regarding the exposure of workers to the risks caused by Physical Agents. That proposal is to be based on Article 118A of the EEC Treaty and established as an individual directive within the meaning of Directive 89/391/EEC, the Framework Directive regarding the improvement of health and safety at work [3].

The Problem and the Situation

There are legal, political and logical reasons for including noise in the physical agents covered by the proposed Directive which aims at harmonising minimum provisions in this field, as part of the social dimension of the internal market.

Under Directive 86/188/EEC, there is a **legal** duty, for the Commission, to submit the proposal which is requested to allow the Council to debate and review the existing provisions (specifically, lifting the exemption of sea transport and air transport must be considered, and the Directive must be re-examined with a view to reducing the risks arising from exposure to noise). The Commission cannot evade its own obligations resulting from a Directive, while checking with the utmost care that all Member States fully respect each of theirs.

On the other hand, the **political context** has been deeply modified since May 1986: the European Single Act (Article 118A) as well as Directive 89/391/EEC set up a new frame to the prevention of occupational risks, and their provisions reflect a new political understanding. Council and Parliament also insisted that the previously existing directives were to be adapted, particularly when their scheduled re-examination takes place, and the Commission took such commitments for the Noise Directive.

Finally logical arguments plead for including noise in the scope of a directive on physical agents: it is the most relevant one met at work, and it is well suited to pattern the Community regulation on other physical agents.

The timing of the proposal also appears acceptable, in so far as the deadline of 31 December 1993 for a Council decision would not be out of reach (provided everybody agrees with everything ...). It must be remembered, in order to compare like with like, that Directive 86/188 was proposed in 1982, adopted in 1986 and implemented in 1990; ten years have thus passed prior to resuming the process and starting phase two which might then be in force in Member States towards the end of the century. One can speculate that the Ministers had this in mind when they set up the time schedule in 1986.

There are thus compelling reasons for reviewing the Noise Directive; the author sees a number of merits in doing it through a proposal on Physical Agents.

A Proposal on Physical Agents

A proposal for a Directive requires formal adoption by the Commission, which has not occurred at the time of writing. The working documents which have been drafted and discussed are not binding on the Commission and what follows merely represents the author's views and opinions.

A proposal on Physical Agents is not an isolated item but it fits in a whole context; it takes into account other texts relevant to health and safety, as for example the directives adopted either under Article 118A (aimed at improving the workplace and protecting persons) or under Article 100A (dealing with free circulation of equipment). Provisions already adopted are not to be discussed again, so the proposal does not repeat them: they are referred to when it appears necessary to give additional elements or indicate ways of applying them in the case of a specific physical agent.

The proposal tries to set up objectives of protection expressed as results to be achieved; the detailed specifications or technical instructions which must be available to the practitioners in order to ensure that the goals are reached do not have to be included in a Directive: a Ministers' meeting is not the most appropriate place for discussing them and they are better developed by suitably instructed specialists. Following such a strategy ensures that the allotment of competences and responsibilities complies with our ruling texts: political decisions describe the safety level to be achieved and are taken by the public authority (solely responsible for the protection of human health), while those decisions are expressed in operational terms (which may be quite complex in the case of physical agents) by qualified experts.

Of course, the 'political' and 'technical' aspects must be interfaced; a system which is already used in the Community legislation about building materials might be very valuable if suitably adapted to this problem: what is called in Directive 89/106/EEC 'interpretative documents' can give additional specifications, ensure that all Member States apply the provisions according to a common understanding, and lead to a commonly agreed view about what is the state of the art in a given field at a certain moment.

It is the author's view that such an articulation (Directive, interpretative documents, technical specifications) soundly applies the principle of subsidiarity to the protection of occupational health.

The general approach on which the Physical Agents proposal is based defines three zones of risk:

- a black zone corresponding to an exposure involving risks which are not accepted.
- a white zone where the residual health risk does not deserve specific measures and which is a goal for long term efforts.
- in between, a grey zone where appropriate measures must gradually be implemented; those measures are ranked in order of priority (reduction at source, then collective and finally individual protection measures), and the darker the shade of grey, the swifter must be the application.

The Framework Directive already specifies a number of points which are thus already established:

- the field of application covers any activity in which workers are exposed (to harmful physical agents) except in specific public service activities (armed forces, police, civil protection etc.)
- the employer has a duty to provide a safe and healthy work environment and he must evaluate the risks which are present; when necessary this includes measurement (of the physical agent) in order to identify the relevant workers and workplaces
- the risk must be avoided or at least reduced; emergency measures must be taken in the event of serious, imminent and unavoidable danger
- information, training and balanced participation of workers must be ensured
- workers are entitled to a health surveillance where relevant.

As **equipment** is generally the source of physical agents and thus the main cause of excessive exposure, a proposal aimed at protecting people must also address the corresponding problems. Existing texts (eg the Machinery Directive 89/392/EEC) contain already safety-oriented provisions which are relevant for physical agents. However, they do not (and probably cannot) solve all problems; the supplier is not even aware of all the conditions in which his products are used or maintained and there is a limit to the duties imposed upon him by directives which ensure primarily the free circulation of goods.

This proposal thus takes the relay and contains user-oriented provisions which ensure that, like work places and work processes, equipment used at work is as safe as feasible and does not result in undue risk; pertinent equipment-specific information on the residual risk allows also the employer to face his responsibilities in protecting his employee's health.

The proposal also acknowledges that some activities may result in an increased risk of over-exposure and that they thus deserve particular attention. Other ones result in conditions which are not met in the usual work situations, and which may present abnormal risks to health and safety; adequate steps must then be taken.

Generally speaking, the proposal proceeds along the lines of the existing Noise Directive, taking however into account aspects which surfaced when that Directive had to be implemented by Member States, as well as problems which had not been addressed at the time of its adoption.

Protection Against Noise

We see no good reason to change the quantities used in Directive 86/188/EEC as predictors of hazard which thus remain the daily personal noise exposure (which has in the meantime been formally standardised in ISO 1999 - 1990) as well as the peak sound pressure, for which the C-weighting has been selected to overcome problems due to different frequency responses of available instruments.

Reviewing the Noise at Work Directive must occur with a view to reducing the risk, and Member States are committed to encouraging improvements with no reduction in levels of protection already achieved. The author therefore feels that the proposal must generalize the lowest noise levels which Member States have adopted when transposing the provisions of Directive 86/188/EEC. This seems fair towards both the workers (who then enjoy the same level of protection) and the employers (who operate on a level playing field). To summarise, the black zone would remain at an effective exposure of the ear exceeding 90 dB(A) or 200 Pa and 75 dB(A) would be the upper boundary of the white zone, with an intermediate grey zone in between.

To avoid misinterpretations, the meaning of 'threshold' and 'action' levels must be kept in mind: they are NOT Maximum Permissible Exposure levels. The threshold level of 75 dB(A) is the value aimed at by preventive measures, and efforts must continue, in order to control the risk considered, at least as long as that objective is not reached. Of course the general principle of concentrating efforts on the greatest hazards still applies, and the noisiest situations deserve most efforts. The idea is already implicit in Directive 86/188/EEC: Article 5.1 does apply below 85 dB(A) as well, as noise exposure below that figure definitely results in Noise Induced Permanent Threshold Shift (ISO 1999 allows one to make an estimation), even when it remains below a conventional definition of hearing loss or handicap. This pleads for a more explicit formulation, and expressing such a long term goal in quantitative terms is felt to be a great help for designers of equipment processes and workplaces.

'Action levels' represent conditions in which a certain risk may be found, which justifies specific actions, (at least a more thorough investigation of the situation); it may be seen as a warning signal which starts blinking.

In quantitative terms, actions levels are proposed at

- 80 dB(A) for informing workers on the existing risk, making protectors available, opening the right to health surveillance
- 85 dB(A) (and 112 Pa) for training workers, providing information on noise produced by work equipment, applying a programme of engineering/ administrative control
- 90 dB(A) (and 200 Pa) for delimiting a noisy area, and for mandatory wearing of protectors.

It is also felt that when the ambient noise (the hazard of which must be reduced by wearing hearing protectors) exceeds 105 dB(A) or 600 Pa, the significant increase of risk justifies that such cases are reported, and that equipment producing such levels is marked so that workers in its vicinity are alerted about the increased potential hazards.

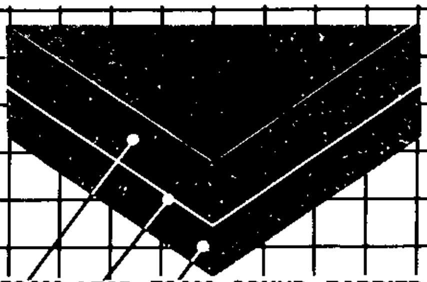
As can be seen, those provisions deal with the risk to hearing, except however that the proposal also requests that lower levels of noise must be respected in situations where other health or safety impairments would occur. An obvious example is found on board sea going ships, where the sleeping quarters of the crew must provide noise levels way below what is accepted for 'ordinary' workplaces. Non-auditory effects of noise, which range from physiological disturbances to interference with good performance when tasks require concentration, is an intricate and sensitive question. The available scientific knowledge does not readily allow one to specify quantitative limitations of the exposure, and non-auditory effects (which should however not be disregarded) are generally less socially significant than noise induced deafness. It is thus felt that the problem should be addressed elsewhere than in such a Directive, and a Recommendation appears more adequate to deal with it.

Harmful effects of noise exposure must be reduced, and this is certainly not an easy task; it requires time and imagination to improve workstations and equipment. The determined efforts, of which Directive 86/188/EEC is an example must proceed stoutly and dynamically, and the proposed Directive on Physical Agents would be a contribution to that objective.

References

[1] OJEC L 137 of 24.05.86
[2] COM(89) 568 (final)
[3] OJEC L 183 of 29.06.89

Marcel van der Venne is Principal Administrator in the Health and Safety Directorate of the Commission of the European Communities in Luxembourg. This paper forms the basis of the Opening Lecture to be given at Euronoise '92 at Imperial College, London on 15 September 1992.



STANDARDS ON MACHINERY NOISE NEEDED TO SUPPORT EUROPEAN COMMUNITY DIRECTIVES

R F Higginson

Introduction

European Community Directives intended to remove technical barriers to trade are formulated within the Commission and approved by the Council of Ministers, following which they are implemented through legislation in each of the member states. They apply to all goods marketed within the Community, no matter where in the world they are manufactured. Directives published up to around 1985 and already in operation, and a few later ones derived from them, include several specifying limits on the noise emitted by individual machine types. These earlier Directives quote maximum noise emission levels related to the size or power rating of the machines, and they contain annexes with all the details of the methods of test. Current (so called 'New Approach') Directives, produced as part of the effort to complete the Single European Market, include only a statement of essential requirements. Techniques for demonstrating compliance with these requirements are then given in European (EN) Standards, produced by the Comité Européen de Normalisation (CEN). Two such Directives [1,2] covering the safe operation of a wide range of machinery, will come into operation in 1993. These refer to risks arising from noise emission, as well as to other safety hazards, and CEN Technical Committee 211 (Acoustics), in co-operation with ISO Technical Committee 43, has established a programme of work to produce standards generic to all types of machinery, which address the noise requirements of these Directives. A large number of other CEN Committees, responsible for standards on particular machinery types, have the task of producing machinery-specific standards, taking the generic standards as a basis. This paper summarises the response of the international standards organisations to these European legislative requirements relating to noise emission.

Machinery Directives

General.

The later Directive, 91/368 [2] amends and serves primarily to extend the scope of the earlier one, 89/392 [1]. Between them they apply to most devices which can be described as machinery, both stationary and mobile in operation, and including machinery for lifting. The major exceptions are machines which would more generally be described as means of transport, though there are other special exceptions also.

The requirements of the Directives are addressed to the manufacturers of machinery, rather than to purchasers or operators. Essential Safety Requirements are given, whereby the normal use of the machinery has to be envisaged and steps taken to prevent abnormal use; risks from the use of the machinery have to be eliminated in the design, or at least reduced to the minimum; protective measures have to be taken regarding the remaining risks, and information has to be given on the need for training of operators or the provision of personal protection. Each of these factors is discussed in the Directives in relation to the different hazards which might occur in the use of machinery. When they come into operation, manufacturers will have to make a declaration of conformity with the requirements and mark permanently all machinery of the type concerned with the EC mark.

To demonstrate conformity, reference may be made to published standards indicating particular safety criteria and methods of test. These standards can be harmonised European ones or, lacking these, suitable national standards which have been declared for the purpose can be used. CEN and ISO have agreed to work closely together in production of the large number of safety standards needed to cover all the types of machinery involved.

Noise Requirements.

The stated requirement for noise is that the machinery must be designed and constructed so that risks resulting from noise emission are minimised, taking account of the availability of means of reducing noise at source. Further, it is required that the instructions for the machinery give information on the sound pressure levels at work stations, the sound power level if the sound pressure level at work stations exceeds 85 dB(A), and on the methods and operating conditions used for noise measurements.

It is interesting to note, in the context of interpreting these requirements for purposes of producing standards, that there is no indication that the Essential Safety Requirement for noise might be expressed as a noise emission limit. Also, the opinion of the Commission of the European Communities has been expressed that the information on noise given in the instructions should be representative of normal use of the machinery at a typical workplace, in a realistic acoustic environment [3].

International European Standards Under Development

Within CEN a hierarchy of standards has been established, comprising type A standards giving basic concepts and principles for design applicable to all machinery, type B standards dealing with one safety aspect (such as noise) across a wide range of machinery, and type C standards giving detailed requirements for a particular type of machinery. In view of the existence of a large body of International Standards on noise emission, CEN TC 211 sought the co-operation of ISO TC 43 in preparing type B standards needed to implement the noise requirements of the EC Directives. These will deal with low-noise design of machinery and workshops, measurement of the performance of noise-attenuating devices, measurement and determination of sound pressure levels at positions around machinery, and determination of sound power levels of machinery.

In many cases, the new standards are being developed through revisions of existing standards, but there were no standards dealing with low-noise design and TC 43 set up three new working groups to prepare these. Up to the present time, drafts have been circulated giving recommended practices for the design of low-noise machinery (the ISO 11688 series) and for the design of low-noise workplaces (the ISO 11690 series). With the long-term aim of quantifying the state of noise control technology of machinery groups, a draft standard has also been circulated describing means of systematic collection and comparison of noise emission data (ISO 11689). With regard to the determination of the acoustical performance of noise attenuating devices, drafts have so far been circulated on the sound insulation of enclosures (the ISO 11546 series), on the insertion loss of ducted silencers (ISO 11691), and on the sound insulation of cabins (ISO 11957).

ISO 6081 at present gives guidance on the measurement of sound pressure levels at the operator's position of machinery, but its scope is too limited to be useful across

a sufficiently wide range of machinery types for the purposes of the Directives. It will therefore be superseded by a new series of standards, the ISO 11200 series, in five parts, now in preparation. These will define a quantity termed the emission sound pressure level, to make it clear that they refer only to the sound emitted by the machinery under particular conditions, and not to the noise exposure of an operator. The first part will serve as a guide to the remaining four, and the latter will comprise a method of measuring emission sound pressure levels in hemi-anechoic acoustic conditions (ISO 11201); two measurement methods for use with the machinery in situ, one with a rather crude environmental correction (ISO 11202) and the other with a more involved and accurate environmental correction (ISO 11204); and two alternative methods of calculating emission sound pressure levels from the sound power level (ISO 11203).

The ISO 3740 series of standards, at present in eight parts, gives a variety of methods of determining the sound power level from measurements of sound pressure level. These standards date back to the 1970s and experience in using them has enabled a number of deficiencies to be identified. A major revision has therefore begun, concentrating first on the most widely used parts in the series. The existing ISO 3743, giving a method for use in 'special' reverberation rooms, will be re-issued unchanged as Part 2 of the same standard, and a new Part 1 will shortly be published giving a comparison method for small portable machines in hard-walled test rooms. The numbers ISO 3744 and ISO 3746 will be retained, but completely revised standards are being prepared, both employing an enveloping measurement surface, the former for use in hemi-anechoic conditions and the latter to be applied with the machinery in situ. The new draft of ISO 3744 has now been finalised, and a further draft of ISO 3746 is about to be circulated.

ISO 9614 is a new standard to be issued in two parts, giving methods for determining the sound power level from sound intensity measurements. Part 1, describing measurements made at discrete positions, has been finalised, and the first draft of Part 2, in which the sound intensity probe is scanned around the machinery, is expected to be circulated shortly.

ISO 4871 at present covers noise labelling of machinery, but it is inadequate for the circumstances that will exist under the Directives. Manufacturers will have to declare noise emission levels which might at some stage need to be verified by a user or an authority, and the levels will be subject to a degree of measurement uncertainty. The extent of the uncertainties varies with the measurement method, and some data on this are included in the standards described above. The declaration and verification of noise measurements is covered in detail in ISO 7574, but a simplified approach which should be adequate for most practical cases will be given in a completely new version of ISO 4871.

The type C standards will mostly be produced by the respective technical committees dealing with the individual machinery types. Around 30 CEN committees are known as having potentially to deal with noise, and in order to assist them in achieving conformity with one another in the hundreds of standards which will eventually be produced, CEN TC 211 and ISO TC 43 are preparing yet another type B standard giving guidance on the preparation and contents of noise test codes. This will be ISO 12001. A consequence of the production of the latter is that it brings into question the need for and the content of the existing standard acting as a guide to International Standards on measurement of airborne noise, ISO 2204, and ISO TC 43 is now looking closely at this standard before coming to a decision on its future.

Points for Discussion

In discussing type C standards on noise emission, some machinery technical committees have questioned whether or not they should include noise limits for their types of machinery, or at least some guidance on the lowest noise levels that might be achievable in the present state of technology. The argument in favour is that a statement of the noise levels to be achieved would enable machinery manufacturers to set design goals which would be regarded as satisfying the Essential Safety Requirements of the Directives. This is a complex issue, which in some quarters is regarded as unsuitable for standardisation. Authoritative opinions are awaited from the European Commission and the CEN Technical Board, but some technical committees are moving towards the position of setting 'minimum achievable noise levels' for specific types of machinery [4] as part of a long-term aim to define 'maximum permissible noise levels'.

It has also been questioned whether it is possible to establish a 'scale factor' for inclusion in the standards, by which to adjust noise emission values obtained in laboratory conditions and so to yield operator noise exposure levels approximating to real life working conditions. The European Commission has expressed a wish, as mentioned above, for measurement methods to yield noise levels representative of typical use of the machinery, in a likely work situation. Some of the standards in preparation by ISO TC 43 are intended to be applied in situ, and environmental corrections are included. However, the types of machinery to which the standards are applicable, and the conditions under which they are used in practice, are so diverse that so far it has not been thought possible to develop a scale factor of the kind envisaged.

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Permission to reproduce this paper which was presented at Internoise '92 is gratefully acknowledged.

Roger Higginson is at the National Physical Laboratory

UK ENVIRONMENTAL NOISE LEGISLATION AND THE BIRMINGHAM APPROACH

John Hinton MIOA

Introduction

In the United Kingdom most legislation concerning the control of environmental noise is enforced by local authorities. This legislation includes the control of noise at the planning stage and the concept of nuisance which is central to the abatement of existing noise problems.

An indication of the extent of noise pollution in the UK is given by annual statistics on the number of noise complaints received by local authorities. These statistics indicate that general noise complaints increased threefold from 1978 to 1988. Over the same period complaints about domestic noise increased fivefold and these now represent the most prolific form of noise complaint in the UK today.

Further evidence on the extent of national noise pollution was obtained from a survey carried out in England between 1985 and 1987 on some 14,000 households. The results of this survey indicated that around 14% of the adult population was bothered by domestic (neighbourhood) noise particularly amplified music and barking dogs with a further 11% bothered by road traffic noise and another 7% bothered by aircraft noise.

These figures suggest that a high proportion of people in the UK are adversely affected by enviromental noise. The following sections of this paper review the way that government regulations, standards and guidelines are used to reduce overall noise pollution and mitigate its effects on the population.

Noise Control at the Planning Stage

In the UK noise has formally been a matter of concern in town and country planning for nearly twenty years. This, without doubt, is the correct approach as noise is most effectively regulated and prevented at the planning stage. Responsibility for planning control is shared between central and local government. In general, central government is concerned with the legislative framework and with providing advice and guidance on the use of legislative powers. However, most responsibility for action to prevent noise problems rests with local authorities who are permitted to exercise discretion in interpreting and carrying out their duties as set out in various Acts of Parliament. Current government advice to local authorities is summarised in a circular which was published in 1973 [1]. Briefly this circular recommends that new noise sensitive developments should not normally be permitted in areas exposed to unacceptably high levels of noise. It also provides specific noise levels for road traffic and industry which constitute the limits of acceptability and gives general advice on applying conditions to planning permission to avoid problems where potentially noisy developments are authorised.

The circular is currently being reviewed and a draft document has been recently circulated for public comment. Briefly the draft document proposes four noise exposure categories for new noise sensitive developments near a noise source:-

Category A: for proposals in this category noise need not be considered as a determining factor in granting planning permission.

Category B: for proposals in this category some noise control measures are required.

Category C: for proposals in this category there should be a strong presumption against granting planning permission. If permission is given planning conditions should be imposed to ensure an adequate level of sound insulation against external noise.

Category D: for proposals in this category planning permission should normally be refused.

The proposed noise exposure categories are shown in Figure 1.

Noise source	A	B	C	D
Road traffic (07.00-23.00)	<55	55-63	63-72	>72
Air traffic (07.00-23.00)	<57	57-66	66-72	>72
Rail traffic (07.00-23.00)	<55	55-65	65-74	>74
Mixed sources (07.00-23.00)	<55	55-63	63-72	>72
All sources (23.00-07.00)	<42	42-57	57-66	>66

Fig. 1. Consultation draft - Planning Policy Guidance. Planning and noise exposure categories for dwellings - $L_{Aeq,T}$ dB

Noise from industrial activities is not included in the new draft circular but this subject is specifically dealt with in a recently amended British Standard [2]. This standard describes methods for assessing whether an industrial noise is likely to give rise to complaint from local residents by comparing the noise level with the offending source present with the background noise level in the absence of the source. If, after correction for factors such as the character and duration of the offending noise source, the difference between the two levels is 10 dB(A) or more then the standard predicts that complaints are likely. The intention is that this standard will be complete-

ly reviewed in the mid 1990s to take into account the findings of research which is currently being undertaken into a number of related issues, such as people's response to low frequency noise and noise with a tonal quality.

The Control of Noise from Specific Sources

Road Traffic

The limitation of noise from individual road vehicles is controlled by international agreements which are incorporated in UK regulations. These regulations have resulted in a reduction in 'drive by' noise levels from motor vehicles of up to 10 dB(A) over the last 10 years. Furthermore, recent UK research work shows that it should be possible to develop heavy goods vehicles which are up to 5 dB(A) below current legislative limits.

In recent years there have been particular problems with noise from motorcycles with defective or non-standard silencers/exhaust systems.

The latter problem has been overcome with legislation which now makes it illegal to sell a non-standard motorcycle silencer or exhaust system. However, the problem of defective silencers still remains and is unlikely to be fully resolved until a quick and simple roadside vehicle noise test procedure is developed and implemented.

Noise from any vehicle on a UK highway is exempt from nuisance legislation. However, regulations concerning the insulation of residential property affected by increased levels of road traffic noise have been in force on the UK mainland since 1973 [3]. These regulations require highway authorities (normally local authorities) to offer noise insulation to the occupier of a dwelling if the facade noise levels arising from the use of a new or significantly altered road reaches or exceeds 68 dB L_{A10} (18 hour). The insulation work consists of the provision of secondary (acoustic) glazing and acoustically treated ventilation units. There is a strong body of opinion which believes that further research work is necessary to ascertain whether the current standard of 68 dB(A) is still appropriate having regard to changes in social attitudes to traffic noise which may have occurred since 1973.

Railway Noise

In the UK noise from railway operations are effectively exempt from noise nuisance legislation and there are no existing regulations to control noise from individual rail vehicles at the design and construction stage.

Furthermore, at present, there are no regulations in force which provide for the insulation of sensitive buildings against noise from new railway lines. This difference in the treatment of those affected by rail noise compared with those affected by road noise has not been a pressing issue in recent years as few, if any, new railway lines have been opened in the UK. However, this will not remain the case in the future, as the impending direct rail link with France will result in the need for new railway track on the UK mainland. In addition many UK cities now have advanced plans to introduce light rail public transport systems into urban areas.

As a result of these recent developments, it is central government's intention to introduce a noise insulation standard for new railways in the form of regulations during 1992. The indications are that any residential property subjected to facade levels of 63 dB L_{Aeq} 18 hour (0600 hours to midnight) or 63 dB L_{Aeq} 6 hour (midnight to 0600 hours) will be eligible for a grant for noise insulation.

These proposals are to be welcomed. However, there is a strong body of opinion which believes that the regulations should be extended to include dwellings affected by a significant intensification in the use of existing railway lines which could not reasonably have been foreseen. This form of intensification is almost certain to occur on many existing railway lines as a result of the opening of the Channel Tunnel.

Aircraft Noise

International rules which prescribe noise limits for each type of aircraft relative to its maximum all-up-weight have been set by the International Civil Aviation Organisation. Jet aircraft are categorised into three groups known as Chapters 1, 2 and 3. Chapter 1 aircraft are the noisiest and have been banned from UK airports since 1988 unless they are modified (hush-kitted) to bring them into the Chapter 2 group. Many Chapter 2 aircraft are still operated in the UK today although the long term intention is to gradually phase them out of use by replacing existing fleets with more modern and quieter Chapter 3 aircraft. However, the reduction in noise levels that this will achieve will undoubtedly be offset at many major UK airports by a steady increase in the total number of aircraft movements.

In the UK, aircraft in flight are exempt from noise nuisance legislation provided the rules of the Air and Air Traffic Control Regulations and normal aviation practice are observed. However all the major commercial airports in the UK operate noise insulation schemes, although not required to do so by the force of law. Most of these schemes are based on the 66 dB L_{Aeq} 16 hour noise contour which is calculated from a knowledge of the number and type of aircraft movements in and out of a particular airport. All residential properties within the area covered by this contour are normally eligible for a grant for noise insulation purposes.

Noise from Industrial and Commercial Premises

The control of noise from existing industrial and commercial premises in the UK is achieved almost entirely by the use of nuisance legislation contained formally in the Control of Pollution Act 1974 [4] and now in the Environmental Protection Act 1990 [5]. Under the terms of this legislation any individual may complain to a magistrates court about noise of an industrial or commercial origin. If the court is satisfied that a nuisance exists it has the power to prohibit the recurrence of the disturbance. In addition, under the terms of the same act, when a local authority is satisfied that noise emanating from a particular industrial or commercial undertaking constitutes a statutory nuisance, that local authority has a duty to serve a notice requiring the abatement of the noise nuisance by whatever means the authority sees fit. Failure to comply can result in a fine of up to £20,000. The terms and requirements of a notice can be contested in court and it is a legal defence for the industrial or commercial undertaking to show that they have taken best practicable means to prevent or counteract the effect of the noise. The concept of best practicable means allows a court to take into account the costs that any remedial action would incur.

The concept of nuisance, which is central to UK legislation, is a subjective criterion and many hours can be spent arguing whether a particular noise amounts to a nuisance in law. However, most industrial cases are eventually resolved by referring to the British Standard on industrial noise [2] although the document was not originally drawn up for this purpose.

The existing nuisance legislation when applied to commercial and industrial noise works reasonably well in most situations. However, it cannot prevent a general rise in industrial noise levels which can occur over a long period.

This effect is termed the creeping ambient. In order to tackle this particular problem, local authorities have the power to declare areas as Noise Abatement Zones. In such a zone the existing noise levels from all industrial sites are registered and it is then an offence punishable by fine, to exceed these levels. The powers to declare Noise Abatement Zones have been available to local authorities since 1974, but have rarely been used because the rules governing the operation of such zones are impractical. The whole subject is currently being re-examined at a government research establishment.

Domestic Noise

Domestic noise can be defined as noise which affects people in their homes or elsewhere on their property, as a direct result of the activities of their neighbours, their neighbours' guests or their animals.

The control of domestic noise in the UK, like that from industrial or commercial premises, is achieved almost exclusively through nuisance legislation which is available both to individuals and local authorities. However, in the case of domestic noise, the defence of best practicable means does not apply. The criterion used by local authorities and courts when assessing a complaint of this nature is normally whether the noise causing complaint is the result of unreasonable behaviour on the part of the neighbour. For example, constant loud music from a neighbour's house at night would amount to unreasonable behaviour and a local authority should serve an abatement notice requiring the neighbour to cease the disturbance. If the notice were to be ignored the individual could face a fine of up to £2,000. Recent developments in this field have seen local authorities confiscate music amplification equipment where disturbances have been persistent and totally unreasonable. This course of action is also available when noisy parties occur on a regular basis.

It is important to appreciate that many of the noise problems which occur between neighbours are not necessarily due to unreasonable behaviour. They can be at least partly due to a lack of sound insulation between adjoining properties. In the UK an adequate level of sound insulation between properties is deemed to have been achieved providing approved building materials and construction techniques are employed at the building stage.

These requirements are defined in the Building Regulations 1992 [6]. However, there is often a lack of adequate supervision during the construction of properties, with the result that poor workmanship results in poor sound insulation. This problem has been recognised and research is currently being undertaken in order to develop a reasonably simple and accurate test which would indicate whether a newly built dwelling achieved the required level of sound insulation. Once such a test technique has been developed, some form of random testing of new dwellings must be undertaken.

Entertainment and Sporting Noise

Responsibility for controlling noise from venues which are used for public music, dancing and similar forms of entertainment is vested in local authorities through a licensing system. Therefore the limitation of environmental noise from public entertainment may, if the local authority sees fit, be one of the terms of such a licence. Noise control conditions may also be placed on the licence required for a premises to sell alcohol.

It has to be accepted that there may be a wide variation in the approach to the control of entertainment noise between local authorities. For example, what is acceptable in a major tourist resort may not be acceptable in a mainly residential area with no tourist-based economy. Therefore local authorities should not be constrained by rigid laws and regulations in such matters. This approach seems to be accepted by central government which only offers guidance to local authorities by way of codes of practice which have no force in law. The codes currently being drawn up include:

A code on noise from pop concerts and similar events
A code on noise from clay pigeon shooting
A code on noise from oval circuit motor racing.

Construction and Demolition noise

Local authorities in the UK are empowered to control noise from construction and demolition activities under the terms of the Control of Pollution Act 1974 [1]. This Act allows local authorities to serve noise abatement notices where problems occur. Generally, such action would only be taken if the conditions and advice outlined in a British Standard on the subject [7] were being ignored.

Policies, Procedures and Initiatives Adopted by Birmingham City Council

Birmingham is a densely populated and highly industrialised city which is at the centre of the UK motorway system and on its outskirts has arguably the fastest growing airport in Europe. Every conceivable potential source of noise pollution, with the possible exception of agriculture is present in the city. As a result, Birmingham City Council have always been in the forefront in the fight against noise pollution in any form.

Therefore, Birmingham rigorously applies all regulations and guidelines on the control and prevention of noise which have been issued by central government. Where no national standards or official guidance exists the council has drawn up its own guidelines, for example to mitigate the effects of railway noise on new residential developments and to control noise from entertainment events.

The city has also embarked on a number of initiatives. For instance, it was the first local authority to use automatic noise monitoring equipment and to further develop its use by the application of computerised data processing. It has also pioneered the use of tape recording techniques for the investigation of noise complaints [8, 9]. In addition, Birmingham was very influential in the introduction of the Noise Insulation Regulations 1973/75 [5] and was the first local authority to develop realistic limits for noise at pop concerts. A recent initiative has resulted in the development of a method for predicting the noise impact of light rail vehicles [10].

A current initiative concerns the development of an overall environmental strategy for the city which encompasses noise. The prime objectives of the noise strategy will be to protect the hearing of all those who live, work and spend their leisure time in the city and to aim to provide an acceptable acoustic comfort level for all residents.

Current research work being carried out by the city includes a survey to identify the main sources of environmental noise in Birmingham, a limited survey designed to establish which sources of noise are of most concern to the citizens of the city and a survey of background noise levels.

Conclusions

In this paper I have attempted to outline the way that most potential and existing noise problems are dealt with in the UK. I have also attempted to identify what I consider to be any shortcomings in the existing legislation from the point of view of a local authority. I hope this will be of some benefit to others.

My overall conclusion is that in the UK the existing systems deal quite effectively with most noise problems and where they do not, this fact has generally been identified and appropriate research work is being carried out or is planned. (A list of current UK research work is given at the end of this paper.)

However, from my experience in Birmingham, I believe that the main noise problems that will face this city and many other major European cities in the future, have not necessarily been adequately addressed and need to be considered both at a national and international level to ensure adequate funding for research work and any remedial actions that may be required. In the main, these problems concern the control and mitigation of all forms of transportation noise to account for the increasing mobility of the European population and the increasing movement of goods across and throughout the continent.

In addition, there appears to be an escalating problem with noise from domestic neighbours which I do not believe is unique to the UK. Education can be used to overcome this to a certain degree, but we must ensure that the houses and flats we build provide enough sound insulation particularly between adjoining dwellings, to suit modern day life styles, attitudes and aspirations.

Finally, I believe that local authorities such as Birmingham have a vital role to play in the formation and implementation of new legislation to control noise both in the UK and throughout Europe. Therefore the views of these local authorities must be actively sought by national and European legislative bodies. I am pleased to say that in general this is the case in the UK.

Any views or opinions expressed in this paper are those of the author and not necessarily those of Birmingham City Council or the UK government.

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Major UK Research on Noise

1. National Noise Attitude Survey, Building Research Establishment (BRE).
2. Disturbance Caused by Industrial Noise, National Physical Laboratory (NPL) and the Institute of Sound and Vibration Research, Southampton University (ISVR).
3. Detection and Assessment of Low Frequency Noise, BRE and Salford University.
4. Unified Model for Human Response to Transportation Noise, BRE and ISVR.
5. Development of a Model to Predict Environmental Noise from a Noise Source Within a Building, BRE and Salford University.
6. Traffic Noise Modelling, Transport Research Laboratory.
7. Traffic Noise Barrier Design, Transport Research Laboratory.
8. Quiet Vehicle Development, Transport Research Laboratory.
9. Low Noise Road Surfaces, Transport Research Laboratory.

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NOISE ISSUES OF 1992

L C Fothergill FIOA, N F Spring FIOA, J E T Griffiths MIOA, P M Nelson FIOA

Four Institute members were invited to write on their own specialisations and comment on the issues that presently need attention. This article is the result.

Building Acoustics

Introduction

Building acoustics is a very broad subject, covering such diverse topics as the design of rooms for speech and music, sound reinforcement, sound insulation between rooms, protection against noise from outside (and vice versa) and criteria for control of services and plant noise.

Sound insulation between rooms and protection from noise outside are dealt with in this section. Building services noise is covered briefly below by Neil Spring.

Sound Insulation Between Rooms

Physical principles: The frequency range of most interest for building acoustics is 100 Hz to 3150 Hz, although there is increasing evidence that lower frequencies are also important now that hi-fi loudspeakers are more common. As is well known, the sound insulation of a panel is influenced mainly by its mass, stiffness, damping, and permeability. The derivation of the effects of these parameters is well documented [1] and will not be repeated here. The practical design objective is to provide sufficient mass to give the required sound insulation, and to keep resonances and other effects that reduce insulation out of the important frequency range. It is interesting to see how important these effects are.

The 'coincidence' effect reduces sound insulation at frequencies where the speed of sound in air and in the panel are equal, and it is often seen as a pronounced dip (usually in the range 1 kHz to 4 kHz) in the insulation curves of windows and plasterboard constructions. For masonry constructions coincidence usually occurs between about 100 Hz and 400 Hz. The dip is less pronounced than in light constructions, but it is still important. Figure 1 shows the insulation of two walls built from the same type of concrete blocks - one 400 mm thick and the other 100 mm thick. At low frequencies the difference in insulation is about 10 dB which is consistent with the difference in mass. However, at higher frequencies the difference is much greater because the lighter wall has a broad coincidence region which increases the frequency at which the insulation of the wall starts to improve rapidly with frequency. This is one reason why double leaf walls do not perform better than solid walls of similar mass.

At high frequencies double leaf walls behave like two single leaf walls and so insulation improves rapidly with frequency. However, at low frequencies the air and ties between the leaves behave like a spring which joins the leaves together and reduces the performance at the 'mass-air-mass' resonance frequency. The frequency of this resonance depends on the masses of the leaves and the cavity width and it is usually possible to design the

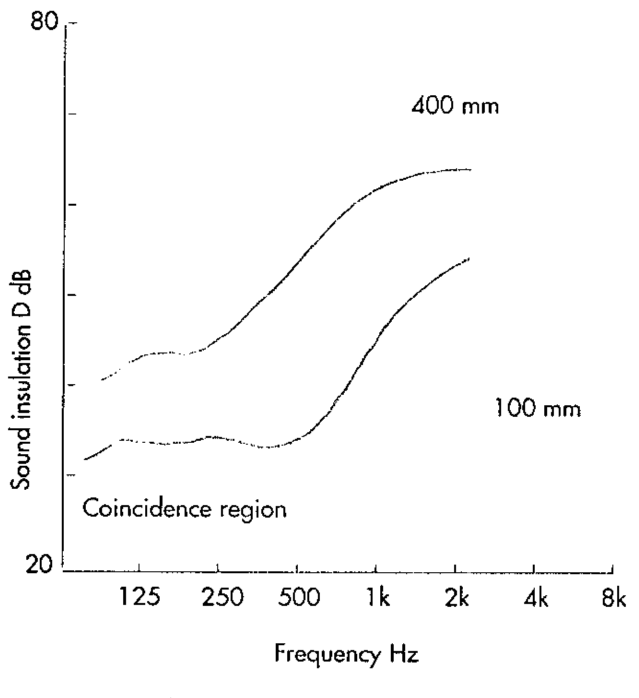


Fig. 1. The effects of mass and critical frequency on the insulation of a concrete block wall

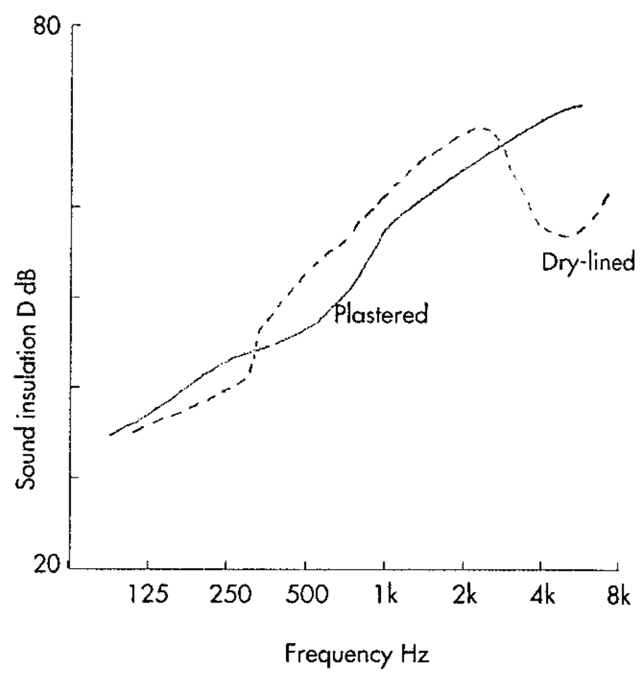


Fig. 2. Comparison of dry-lined and plastered finishes on a dense concrete wall

wall to keep it at an acceptable value. However, when a wall is drylined with a sheet of plasterboard there is little scope for design, and the resonance is likely to occur at about 200 Hz. If the wall is permeable the resonance will be well damped and the air cavity may behave as though it is wider than its physical width so the resonance has little adverse effect. If the wall is built from a material which has low permeability, such as dense concrete, the adverse effect may be more marked as shown in Figure 2. Here the beneficial effect of the lining at mid frequencies is offset by the resonance at low frequencies and by coincidence at high frequencies.

In the past most theoretical work has been concerned with the behaviour of individual elements. Attention is now being directed to the more complex transmission paths between rooms which involve several elements. Because the problem is so complex the most promising approach appears to be statistical energy analysis, rather than seeking exact solutions. The primary aim of this technique is to estimate the distribution of vibrational energy among the coupled 'subsystems' (eg walls), and for this purpose energy balance equations are set up which involve expressions for power flowing from one subsystem to another. Sophisticated measuring techniques are required to provide the necessary physical data. Using this technique computer models are being developed to allow calculation of sound insulation between rooms from the information given on architect's drawings [2]. This will be of great value to designers and building control certifiers, and will eventually reduce our dependence on field measurements as the only way to establish performance.

Regulations: Sound insulation is of great importance because people particularly dislike hearing noise from their neighbours, and it is the subject of Building Regulations in many countries. In the UK the standards for sound insulation were originally set after a social survey showed that people who had solid brick separating walls or floating concrete separating floors were generally satisfied with the sound insulation.

The requirements that appeared in the 1965 Regulations were therefore based on the typical performance achieved by constructions of these types. Studies led by Langdon [3, 4] during the 1970s confirmed that people still considered these standards to be reasonable and they have been used as the basis of the current requirements.

An interesting finding by Langdon was that when sound insulation was poor, people were concerned most about hearing airborne sounds, but as the airborne insulation improved they became aware of structure borne sounds such as doors banging, as shown in Table 1. The control of such noises is an area where more research is required.

Since June 1992 sound insulation between flats formed by conversion has been covered by Building Regulations. The standard required is slightly lower than that for new build to reflect practical constraints of conversion work, such as the need to use as much of the existing construction as possible, and reduce room sizes as little as possible. This often precludes using wall linings to reduce flanking transmission (ie sound transmission along elements other than the separating element) as shown in Figure 3 for a floor. Although the scope is limited, normally substantial improvements can be achieved.

Influence of Europe: The Construction Products Directive [5] has led to a need to produce European standards on sound insulation measurement and rating [6]. These standards will have to be adopted by all EC and EFTA members. The measurement standards will be based on ISO 140 which is already used in the UK as BS 2750. The changes will improve the accuracy of the methods, but inevitably make them more complex.

The rating methods are likely to be based on ISO 717 which is already used in the UK as BS 5821. However, the rating methods are likely to incorporate a mandatory dB(A) method as well to meet the needs of countries where the dB(A) is used.

RANK	Airborne Sound Insulation $D_{nT,w}$ dB				
	>53	53 - 51	50 - 48	47 - 45	<45
1	Footsteps on stairs ○	Record player •	Record player •	Television •	Talking •
2	Banging doors ○	Children •	Raised voices •	Talking •	Television •
3	Record player •	Television •	Television •	Record player •	Raised voices •
4	Raised voices •	Raised voices •	Talking •	Footsteps on stairs ○	Record player •
5	Television •	Footsteps on stairs ○	Electric sockets ○	Banging doors ○	Children •
6	Electric sockets ○	Talking •	Footsteps on stairs ○	Children •	Radio •
7	Children •	Electric sockets ○	Banging doors ○	Electric sockets ○	Music •

Table 1. Types of noise causing complaint for different levels of insulation against airborne noise. Note DnT,w figures converted approximately from AAD data.
○ = impact sound • = airborne sound

Protection Against External Noise
Windows: The main sources of external noise are road and air traffic. As is well known, the acoustically weakest parts of a building facade are single glazed windows - so these are the first elements to be upgraded. Good sealing is essential and small cracks have been found to behave as resonators [7].

For noises such as aircraft with strong high frequency components, secondary glazing performs better than thermal double glazing. However, for low frequency sources such as road traffic the benefit is reduced because the mass-air-mass resonance has more effect on secondary glazed systems. With high performance window systems of small area the overall performance may be limited by transmission through other parts of the facade, even if it is of traditional brick/block construction.

The acoustic characteristics of sealed window units can be changed appreciably by filling the space between the panes with a heavy gas. To some extent this allows the performance of the windows to be optimised to suit any rating system, so it is essential that rating methods correctly reflect subjective requirements. Coincidence effects can be controlled by laminating the glass with transparent plastics.

Requirements: For noise sensitive development, sound insulation requirements are usually set by the local planning authority. Requirements are usually in terms of sound insulation or acceptable internal noise levels. Official guidance is available in Circular 10/73 'Planning and Noise', but this will be superseded by Planning Policy Guidance (PPG), currently available in draft form. This PPG introduces 'Noise Exposure Categories' which define bands of noise levels in which different noise control measures are appropriate. Such guidance can only be general because acceptable noise levels depend on local circumstances. However, the Department of the Environment is currently supporting a large research programme designed to

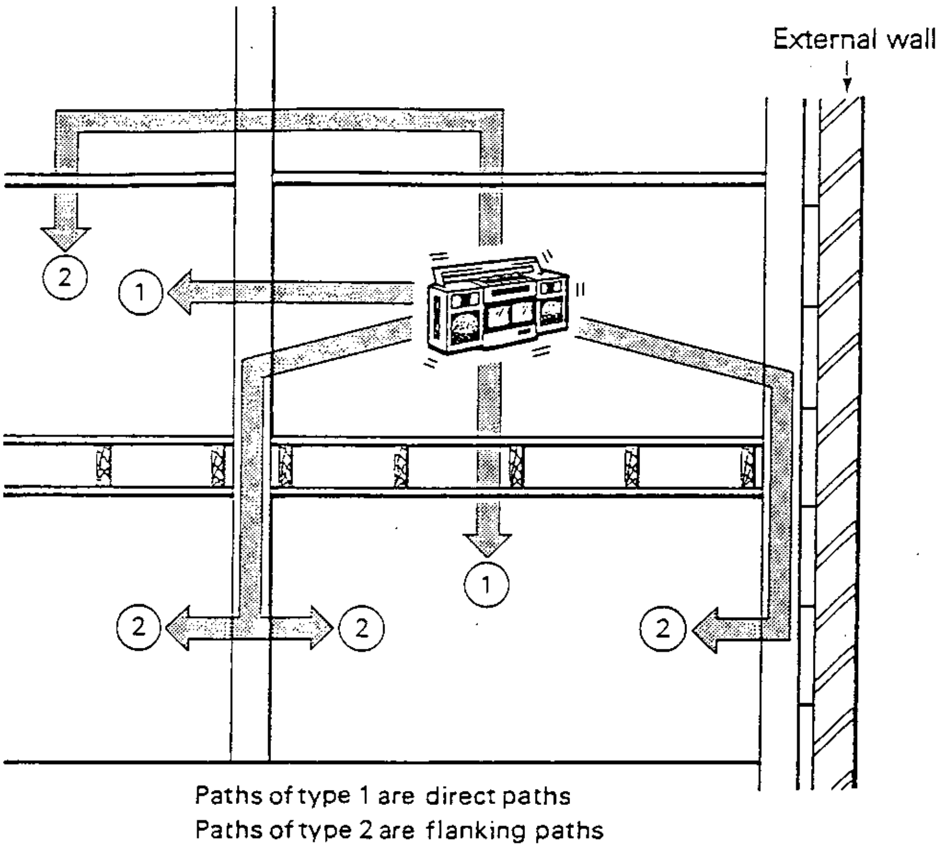


Fig. 3. Diagrammatic section through rooms in a pair of flats separated by a timber floor illustrating transmission paths for airborne sound

improve our understanding of people's response to industrial and transportation noise and this will lead to more specific guidance in the future.

Conclusions

Active research programmes on both the physics of sound insulation and assessing subjective requirements are being supported by the Department of the Environment, and the fruits of this work should be increasingly apparent over the next few years.

L C Fothergill

Building Services Noise

Building services engineering consists of all the engineering associated with a building other than civil or structural engineering. Building services noise is taken to cover all noise that arises from the mechanical and electrical equipment that forms part of the permanent installation of a building. The kinds of equipment that can be a source of noise nuisance include fans, diffusers and grilles, pumps, electric motors, transformers, compressors, cooling towers and boilers.

The accuracy of prediction and control of noise from building services equipment continues to improve. This is partly a result of better research and understanding of the underlying theory but mainly because of the improvement and growth in measurement standards and the better data provided by equipment suppliers. However, there is still plenty of room for improvement, particularly in the design of noise control for ducted ventilation systems. There is no internationally accepted standard for carrying out the calculations and although the guides produced by bodies such as AIRAH, ASHRAE and CIBSE nearly always result in sufficiently low noise levels, the fact that the guides differ implies that the safety factors are probably unnecessarily generous. The associated waste of energy is difficult to defend in these green times. One way round the problem is to design the buildings to have natural ventilation, an increasingly popular solution for the admittedly few buildings under construction in the UK at the present time.

This lack of precision in predictive methods in respect of, for example, the noise generated by large items of roof-top mounted air handling equipment can, one suspects, lead to overly cautious design of silencers for the equipment. Another aspect of essentially the same issue is the continuing uncertainty of just what it is about mechanical plant noise that gives rise to appreciable disamenity to residential neighbours. The cost implications to the client of over-specifying attenuation for whatever reason can be a major issue.

The ever increasing use of demountable light-weight partitions in modern office blocks has come to place considerable emphasis on the requirements in terms of acoustic design for preserving speech privacy; mechanical services noise is therefore playing a positive role in offering some compensation for shortfalls in the insulation performance of installed partitions.

Although methods of ventilating buildings mechanically change over the years as witness, for example, the increasing use of displacement systems and in-seat ventilation in auditoria, the basic tools and methodology of the noise control designer do not change very rapidly. This is reflected in the relatively small number of papers on this topic in Euronoise '92.

Active noise control for ducted ventilation systems is yet to make a big impact, in spite of many years of hope and expectation. However we are informed that shortly after Easter 1993 a new office block with properly designed and built active noise control will appear in Florida.

N F Spring

Live Entertainment Noise

Introduction

During this summer period, we have seen more major artistes on tour than has been the case for over a decade. In fact the concert industry has saturated the market and with the continuing recession a number of concerts have been poorly attended. This high level of touring has placed a heavy demand on the availability of venues in terms of the need to find new venues and the need to operate from a venue on more occasions than is the norm. This demand has therefore placed an even greater emphasis on the aspect of noise in terms of both environmental impact and audience/employee exposure limits. The recently published draft guidance notes from the HSE [8] covering all aspects related to pop concerts also discusses these areas of noise and has therefore further focused on the importance of these issues. This contribution for the Bulletin discusses the evolution of noise guidelines in this field along with a look at developments for the future.

The GLC Pop Code

One of the first authoritative documents dealing with noise from pop concerts was published by the GLC in June 1976 [9]. This document was revised several times with the final version in 1985 being adopted by many licensing authorities throughout the country. The guidance on noise was in the main in two parts dealing with audience noise exposure and environmental noise.

The audience noise exposure guidelines were based on an Equivalent Continuous Sound Level (L_{Aeq}) value of 93 dB(A) for an eight hour event with the equal energy principle applying for concerts of shorter or longer duration. For outdoor concerts, this guideline was assessed at a distance of 50 metres and beyond from the sound system, whereas for indoor events the assessment was made in terms of 'any member of the audience shall not exceed...' which usually implied the nearest audience position to the

concert sound system. The limiting figure of 93 dB(A) was derived from the Department of Employment's Code of Practice [10] for employees at work which recommended a maximum limit of 90 dB(A). The increased margin of 3 dB(A) was applied, given the reduced exposure time experienced by members of the audience as compared with the Department of Employment's 8-hour working day guideline.

The environmental guideline was initially based on an L_{A50} but with the advent of sound level meters measuring L_{Aeq} in the late 1970's data were obtained in terms of this index and the guidelines were changed in favour of L_{Aeq} assessed over a 15 minute period. Results from GLC studies [11] showed that for occasional concerts (ie up to three per year per venue) an increase of 10 dB(A) above the background L_{Aeq} is likely to minimise complaints. The GLC environmental guidelines were therefore based on the 10 dB(A) increase up to 20.00 hours although this was generally extended up to 23.00. For concerts held at a venue on more than three days per annum a 1 dB(A) increase was defined as an acceptable criterion. After 23.00 hours the sound from the concert was to be inaudible within a nearby receiver.

Noise Council Working Party

Some time after the demise of the GLC, the Noise Council set up an entertainment noise working party which had the initial brief of revising the GLC environmental guidelines for pop concerts. The working party consisted of members from both the public and private sectors who had particular experience in this field.

Having reviewed all relevant data, a report with suggested guidelines was issued to the Department of the Environment in March 1991 with a view for the report to be drafted as an approved Code of Practice under the Control of Pollution Act.

The Noise Council's environmental guidelines were based on the GLC's Code, but from our results obtained at venues holding just one or two events per year it was apparent that a greater increase of the background L_{Aeq} was achievable with a minimal level of complaints.

This year for example, level increases in the region of 20 dB(A) above the background L_{Aeq} were recorded at venues such as Maine Road (Guns 'N' Roses Concert), Lancashire County Cricket Ground (Simply Red Concert), with virtually no complaints of noise. My assessment of the sound levels at Wembley in conjunction with officers from Brent Council also showed that complaints could be minimised for up to twelve events per year providing the concert L_{Aeq} was no more than 10 dB(A) above background and that the concert finished by 22.30 hours. With this and other such evidence, the Noise Council's guidelines were based on these data with a venue holding more than twelve events per year being treated on the basis of the strict criteria applied to an annual music and dance licence.

The Health & Safety Executive's Guidance Notes

While the DoE were assessing the Noise Council's work, the HSE set up a working party to prepare guidance on all aspects of health, safety and welfare at pop concerts. Travers Morgan were asked by the Chairman of the Working Party to give advice on suitable guidelines to minimise audience exposure at concerts.

Following several meetings it was agreed that there was a need for information on the risks to be given to attendees. People attend concerts, and indeed pay to go to concerts, of their own free will. The audience expectation is also for reasonably high sound levels in order to provide an effective form of entertainment. In this case therefore, if information on the risks of hearing damage is provided to an audience, is there a need to stipulate a noise limit? Is this not similar to the interest risks of smoking?

Although this point was debated at length, it was agreed that there is a general duty on the promoter/licensee to provide a safe venue and hence safe event. In this case therefore it is not reasonable to expose members of the audience to very high sound levels which could cause acoustic trauma or potential long term damage.

A study [12] was undertaken to assess the audience exposure sound levels at various concerts throughout the country. The mean L_{Aeq} recorded at the front barrier position (the nearest audience position to the concert sound systems) was 104.7 dB(A). The results were surprisingly high and only one of the eighteen concerts surveyed met the original GLC guidelines for reducing the risk of hearing damage. An event L_{Aeq} of 104 dB(A) at the first barrier position has been suggested by the HSE in the present draft guidance notes. From the data obtained during the survey, the impact of this guideline would result in some 60% of concerts reducing their sound levels. The Concert Promoter Association have strongly objected to this criterion and have suggested an exposure figure of 107 dB(A) based on an individual attending some twenty five two-hour concerts per year, at worst, at the front barrier position for ten years of the individual's life. In exposure terms, this attendance pattern would have a similar NIL to that of a worker exposed to the 'first action level' for 8 hours a day for forty years. Studies into concert attendance patterns and further research on hearing damage risks from entertainment sources are required before a more definitive statement can be made.

The draft proposals published by the HSE also included advice on environmental criteria. These were, in the main, produced by the DoE and were based on the advice given by the Noise Council. The background level was however based on the L_{A90} index and as a result the difference between the Concert L_{Aeq} and background L_{A90} was increased by 5 dB(A) from the original figures given in the Noise Council report.

Further discussions have since taken place with the DoE, the Chairman of the Noise Council's Working Party and ourselves. We are at present favouring absolute levels in relation to the number of events, time of day etc. The external 15 minute L_{Aeq} music noise levels (MNL) being proposed are 75 dB(A) for one event, 70 dB(A) for two to five events and 67 dB(A) for 6 to 12 events. For more than 12 events it is proposed that the MNL should not exceed the background L_{A90} by more the 5 dB(A).

After 23.00 hours the music should be inaudible inside any noise sensitive building with windows open in a typical manner for ventilation. These criteria are still under discussion following the results from several concerts we have recently studied where it warranted an assessment against a background datum when assessed with the level of complaints.

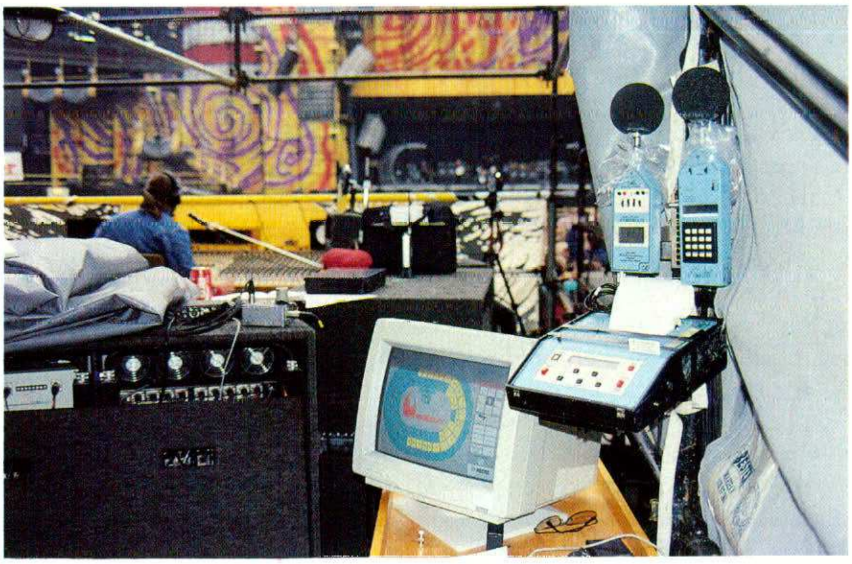
Concerts in Europe

There appears to be a growing awareness in Europe of the need to monitor and control concerts given some of the recent reports of large scale noise complaints and fines. We have monitored the noise at concerts which have not been controlled at a number of venues in large cities in Europe. For the same artistes performing at concerts in the United Kingdom, the sound levels were typically 4 dB(A) lower providing a noise control programme was in operation. Such control procedures have been documented elsewhere, but we have had considerable success in engineering a distributed sound system which we project managed for Wembley Stadium. Rather than the sound being projected from one main source at the stage end, the sound is also distributed via over one hundred loudspeakers which are angled down towards the audience. The signal to each loudspeaker is delayed in time with reference to the stage by the use of digital signal processors (DSP). The DSP's are controlled by central computers which in turn route the signals via fibre optic cables to each amplifier associated with each loudspeaker. The system has been used for over twenty concert events and provides the following advantages: the stage system does not need to produce the usual high sound power output which is an advantage on both hearing and environmental grounds, no large scale delay towers are required to be sited on the pitch which means no loss of sight lines for the audience and the risk of high exposure levels is reduced, the in-house sound system focuses the sound locally to each section of the audience which reduces the risk of sound propagation outside the venue.

Although this system is a permanent installation, temporary sound systems distributed in a similar manner have been very successful in controlling sound within venues, such as those being used for all night pay parties or 'Raves'. These types of events, which are held throughout the night, appear to be on the increase, and very stringent noise control and engineering measures are usually required in order to minimise disturbance and preserve sleep for local communities.

A set of workable and effective noise criteria are required for all types of live entertainment from pop concerts to all night pay parties. Refinements to the previously described guidelines are taking place and the HSE expect to publish their guidance by the end of 1992.

J E T Griffiths



The computer monitor and noise equipment in use during the Rolling Stones show at Wembley

Road Traffic Noise

Introduction

There can be little doubt that of the three primary transport modes, road transport produces the greatest noise intrusion. During the past twenty years, exposure to traffic noise has risen steadily as a result of the combination of growth in urbanisation and increased mobility by the population. The growth in traffic has led to traffic congestion in the cities and conurbations which has tended to encourage the motorist to spread the period devoted to commuting. The result is that traffic noise remains high for longer during the working day often affecting periods where previously some respite in traffic noise could have been expected. It is known that some 15% of the populations of OECD countries (ie > 120m people) are currently exposed to noise from road traffic which is judged, by most authorities, to be unacceptably high [13].

The methods of attacking the problem generally follow two main directions. The first approach is to attempt to reduce noise at source by limiting emission levels of new and in–service vehicles as determined by standard test procedures. The second approach involves broad scale attempts to minimise the effects of traffic stream noise in the community. The techniques used include road design, the erection of barriers, the insulation of dwellings, route and traffic flow control and land use planning. In addition, in the UK, individuals may also be compensated for depreciation in the value of their property and can, if they wish, use the compensation for further noise attenuation measures.

Vehicle Noise

The generation and propagation of noise from vehicles is governed by several different mechanisms. At low vehicle speeds the

noise from the vehicles' power unit, ie the engine and its ancilliaries, gearbox, exhaust, and cooling system etc, will often dominate over the noise generated by the tyre/surface interaction. However, as the speed of the vehicle increases, noise generated by the tyres will also increase and will eventually become the dominant noise source at high passing speeds.

A review of the methods of controlling vehicle noise is given in a separate paper by the author in this edition of the Bulletin. Briefly, the main points to note are that over the past two decades considerable progress has been made in reducing the noise produced by the power unit on vehicles. Projects such as the TRL Quiet Heavy Vehicle project were instrumental initially in demonstrating to both the industry and to the legislators that quiet vehicles were technically feasible without incurring significant cost penalties to the manufacturer [14, 15]. The result is that the European Community has been able to introduce progressively more stringent noise limits for all new vehicle types. For example, since 1982 the noise limits for some vehicles have been reduced by more than 9 dB(A) [16, 17, 18]. In addition, further significant reductions in power unit noise have recently been accepted by the European Commission which are planned to come into effect for all new vehicle types by the mid 1990s.

Tyre/surface noise

Apart from progressively reducing the noise limits for power unit noise the EC has also made recommendations that a separate test procedure and noise limits for vehicle tyre noise should be introduced. These recommendations reflect the realisation that simply limiting the noise from the power unit alone will not greatly effect the noise emitted by passing vehicles operating at both moderate and high passing speeds where tyre noise will tend to dominate. Assuming the potentially conflicting requirements of low noise and safety performance can be resolved then it is anticipated that type-approval procedures for tyres could be introduced in the latter half of the 1990s.

In addition to these recent moves towards developing regulatory controls for tyre noise, considerable research effort has been focussed on both tyre and surface design to reduce noise. The factors affecting tyre noise are mainly the speed of rotation of the tyre and the texture pattern applied to both the tyre and road surface. Generally, however, the tread pattern has a smaller influence on tyre noise than the texture variations that can occur on road surfaces. For this reason, therefore, it is generally considered that there are greater opportunities to reduce tyre/surface noise by changing the road surface texture than by re–design of the tyre. This view seems to be supported by experience which has shown that despite considerable investment in tyre noise research particularly by the tyre manufacturers, there has not been a great deal of progress in producing quieter tyres. In fact, it appears that for car tyres at least, the noise levels have increased slightly in recent years due to progressive use of low aspect ratio tyres for reasons of style.

Work on road surface design has concentrated on establishing the relationships between noise generation and propagation and the characteristics of the road surface. It has been established, for example, that there is a relationship between vehicle noise and the surface macrotexture (ie large scale asperities in the surface). Macrotexture has also been shown to be important in governing the number of accidents on a road and so there appears to be an important connection between tyre/surface noise and safety. In general surfaces which provide high noise levels are also safer and more durable surfaces.

The research has also tended to focus on attempting to discover surface designs which provide the elusive combination of good safety characteristics and low noise levels. For example, considerable interest has been centred on road surface materials which have an open or porous structure. These materials have been found to offer the advantage of significantly lowering the noise levels compared with alternative non–porous conventional road pavements. In addition, they also provide benefits in terms of the rapid removal of surface water which helps to reduce the risk of skidding accidents and reduces the incidence of ponding and spray generated by the traffic during periods of wet weather.

Mathematical models have been developed and validated for porous surfaces and are currently being used to define the road surface specifications to help reduce traffic noise further. Future developments in the field of road surface design for low noise may include new road surface materials such as porous concrete, exposed aggregate concrete and new forms of surface overlays to repair worn and damaged existing road surfaces.

Road Design and Alignment
The noise radiated by traffic streams can be influenced by both the vertical and horizontal alignment of the road. For example, the road may be placed in a cutting where the sides of the cut then act to screen a sensitive area. Where a higher degree of noise attenuation is required, the use of covers, enclosures or tunnels can be considered. However, the high cost of these constructions generally prevents their use in most situations.

A more cost effective method may be to erect a barrier or screen alongside a road. The main requirement is that the barrier should be sufficiently high and long enough to provide a reasonable vertical and horizontal overlap with the line of sight of the road from the reception point. Current research into noise barriers is attempting to establish more cost effective designs. The most promising of these new designs are being tested at the full scale noise barrier test facility at TRL and production prototypes will be installed at roadside locations, hopefully, in the near future.

Traffic management
Concentrating traffic on a few main routes, thus reducing noise levels on minor roads, can provide considerable benefits to large numbers of people. For example, halving the traffic flow on a lightly trafficked residential street may reduce noise by 3 dB(A) and yet the number of vehicles that are redirected could be quite small and easily absorbed into neighbouring roads purpose built to take higher traffic flows. Other techniques include restricting access or imposing restrictions on the use of noisy vehicles during certain times of the day. For example, night bans have been introduced on the operation of heavy vehicles in some areas. Some countries have also introduced the concept of 'low noise vehicles' which are authorised to enter a protected area covered by traffic restrictions. The use of by–passes can provide substantial benefits by taking traffic away from populated areas. Reductions in accidents and journey times are also benefits resulting from by–pass construction.

Land Use Planning
Noise impact control can be achieved by appropriate management of the land adjoining a major transport route. Appropriate techniques include:

Using the natural land form and planting to screen the road from sensitive areas.

Placing noise compatible activities such as car parks and commercial facilities between the noise source and the noise–sensitive areas.

Using cluster development concepts for housing estates rather than ribbon development where the first row of housing tend to take the full impact of the noise.

Building design and insulation
Improvements to the acoustic insulation of buildings can be considered for new buildings, where layout and insulation can be considered as part of the overall design objectives, as well as existing buildings where some form of retrofit may be needed.

Doors and windows provide the most obvious components of low sound insulation in a building. However, good quality double windows with at least 100 mm of gap between the panes can achieve a sound insulation of approximately 35 dB when fully closed which is only slighty less than that normally achieved by a solid partition wall. It should be noted, however, that tightly closed or sealed windows cannot be used for natural ventilation and a mechanical ventilation system must also be provided if the degree of sound insulation is to be effective under all conditions. It follows that all vents and inlets should be located away from noisy facades or should be fitted with baffles so that they do not provide paths for the transmission of sound.

In several countries legislation has been introduced which provide powers for the road authorities to offer sound insulation treatment to property affected by noise from road traffic. In the UK, for example, the Land Compensation Act 1973 provides powers for Highway Authorities to insulate buildings against noise caused by the construction and use of new or improved roads. The Noise Insulation Regulations, which first came into effect in 1973 (later modified in 1975 and 1988), stipulate the conditions for entitlement to the sound insulation treatment of residential property, and the method to be used to determine eligibility [19]. The method specified in the 1975 Regulations was that given by the Technical Memorandum 'Calculation of Road Traffic Noise' (CRTN). The latest edition was developed at TRL [20].

It should be noted that CRTN describes procedures for both predicting and measuring the noise from road traffic and is intended to be used as a general purpose prediction method as well as a standard for calculating entitlement as part of Regulations. It is used, for example, to assess the effect of traffic noise on properties by the Department of Transports' Manual of Environmental Appraisal (MEA). The MEA provides the assessment framework used by highway authorities to compare the environmental impact of alternative options for proposed road schemes [21].

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P M Nelson

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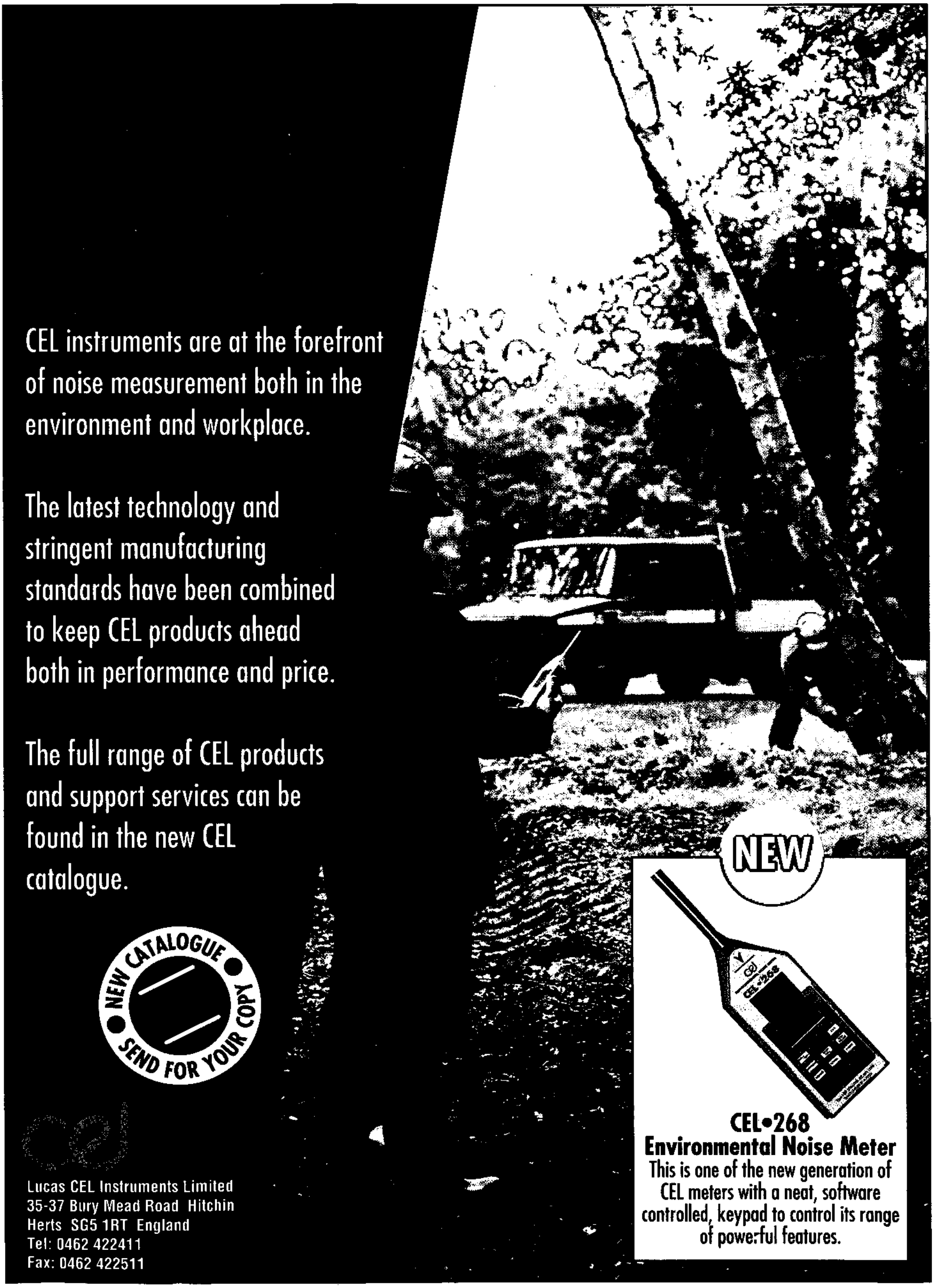
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This year has seen a number of important additions to the Bruel and Kjær product range and some of the most recent of these new instruments and transducers will be on display.

The range of portable frequency analysers which started with the 2143 now consists of nine different analysers including the new **2148 Dual Channel FFT analyser** and the **2140 Industrial Analyser** which will both be on the stand.

The **Deltatron** accelerometer range was introduced in July and at present comprises a range of three accelerometers each with integral electronics. These accelerometers incorporate Bruel & Kjær's accelerometer experience in an industry standard format and at an extremely competitive price.

This summer also saw the release of the extended software for the **3550 Multi-channel Analyser System** which was released last year. This software extends the already comprehensive range of processing capabilities in the 3550 and includes time history and time capture functions amongst others.

A key to Bruel & Kjær's success has been the customer services provided to back up the range of instrumentation, services which become more important every year. These services have been further enhanced this year in a number of key areas. In July the calibration laboratory at the Harrow office was awarded NAMAS accreditation for microphones and calibrators. Accreditation for more instruments is expected soon. Full details are available on the Bruel and Kjær stand.

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Cirrus Research plc, winners of the Queen's Award for Export in 1991, will exhibit a diverse range of noise measuring instruments whose applications range from the simple to the highly sophisticated.

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October / November 1992

AUTUMN CONFERENCE 1992 - Speech and Hearing

Formal Presentations

Adaptation and Normalisation

PERCEPTUAL COMPENSATION FOR THE EFFECTS OF REVERBERATION ON AMPLITUDE-ENVELOPE CUES TO THE 'SLAY'-'SPLAY' DISTINCTION • *A J Watkins.* TWO-STAGE UNSUPERVISED MODEL ADAPTATION TO IMPROVE THE PERFORMANCE OF CONNECTED-WORD RECOGNITION • *J N Holmes.* SPEECH RECOGNITION IN NOISE USING MODEL BASED ADAPTATION STRATEGIES • *M Kadirkmanathan.* SPEAKER ADAPTATION FOR CONTINUOUS DENSITY HMMs BASED ON KALMAN FILTERING ANALYSIS • *C Chan, J E M Tyler, I G MacKenzie & S J Cox.* NOISE ADAPTIVE HIDDEN MARKOV MODELS • *S V Vaseghi & B P Milner.*

Auditory Modelling

INVESTIGATION OF PHONETIC CLASSIFICATION USING A COMPUTATIONAL MODEL OF AUDITORY PROCESSING • *A Darling, A Faulkner, M Huckvale & S Rosen.* ASSESSMENT OF RELATIVE SYLLABLE STRENGTH VIA AN AUDITORY MODEL • *R Patterson, A Cutler, S Butterfield & M Allerhand.* OUTER HAIR CELL ACTIVE NON-LINEARITIES IN A COMPUTATIONAL MODEL OF THE AUDITORY PERIPHERY • *C Giguere & P C Woodland.* SPEECH RECOGNITION IN NOISE: COMPARING AN AUDITORY MODEL WITH HUMAN PERFORMANCE • *W A Ainsworth & G F Meyer.* INTERFACING AN AUDITORY MODEL TO A PARAMETRIC SPEECH RECOGNISER • *S W Beet & I R Gransden.*

Speech Synthesis

PROSODIC ASSIGNMENT IN SPRUCE TEXT-TO-SPEECH SYNTHESIS • *M A A Tatham & E Lewis.* ARTICULATORY COPY SYNTHESIS USING MULTIPLE CODEBOOKS • *A R Greenwood & C C Goodyear.* PHYSIOLOGICALLY CONTROLLED VOICE SOURCE MODELS FOR DIFFERENT SPEAKERS • *C Scully.* ON THE PHONETIC INTERPRETATION OF RHYTHM IN NON-SEGMENTAL SPEECH SYNTHESIS • *J Local.* A TONAL ATTRACTOR MODEL OF ENGLISH INTONATION PHONOLOGY AND ITS IMPLICATIONS FOR F0 IN SYNTHETIC SPEECH • *T Gillott.* METHODOLOGICAL ASPECTS OF THE IMPLEMENTATION OF EMOTIONAL CHARACTERISTICS IN SYNTHESISED SPEECH • *E Abadjieva, I R Murray & J L Arnott.*

Spoken Language and Dialogue

RESULTS OF AN EXERCISE TO COLLECT 'GENUINE' SPOKEN ENQUIRIES USING WOZ TECHNIQUES • *R Moore & S Browning.* THE PHONOLOGICAL ANALYSIS OF SPEECH STYLE • *S M Williams, L A Boucher & S P Whiteside.* THE DESIGN AND EVALUATION OF DIALOGUES FOR AUTOMATED TELEPHONE SERVICES • *J C Foster, R Dutton, M A Jack, S Love, I A Nairn, N Vergeynst.* BYPASSING COMMUNICATIONAL DIFFICULTIES TO ALLOW SATISFYING CONVERSATIONAL PARTICIPATION BY A NON-SPEAKING PERSON • *N Alm, J L Arnott & I R Murray.* FUNDAMENTAL RESEARCH UNDERLYING THE DESIGN OF AN AUTOMATED DICTATION SYSTEM • *J Monaghan.*

Poster Presentations

UNIT INVENTORY AND MODEL STRUCTURE FOR VOCABULARY-INDEPENDENT HMM RECOGNITION • *W Holmes, L Wood & D Pearce.* SUBSCRIBER- A PHONETICALLY ANNOTATED TELEPHONY DATABASE • *A Simons & K Edwards.* THE DEVELOPMENT OF THE SPEAKER INDEPENDENT ARM CONTINUOUS SPEECH RECOGNITION SYSTEM • *M J Russell.* EXPERIMENTS WITH THE SYLK SPEECH RECOGNITION SYSTEM • *P D Green, L A Boucher & N R Kew.* A COMPARISON OF HIDDEN CONTROL NEURAL NETWORKS AND HIDDEN MARKOV MODELS • *G D Tattersall,G E Lee & S G Smyth.* WELSH LETTER-TO-SOUND RULES FOR TEXT-TO-SPEECH SYNTHESIS • *B Williams.* REAL TIME PITCH EXTRACTION WITH REAL WORLD CONSTRAINTS • *C M Barnes & J A S Angus.* INTELLIGIBILITY TESTS ON DEREVERBERATED BINAURAL SPEECH • *P D Stringer & A I Trew.* ON THE FUNCTION OF INTONATION IN DISCOURSE: INTONATION WITHIN THE FRAMEWORK OF CONVERSATIONAL GAMES • *J Kowtko.* PITCH SYNCHRONISATION FOR FREQUENCY-DOMAIN ANALYSIS • *A J H Simons.* THE SPEECH FILING SYSTEM: A TOOL FOR COOPERATIVE SPEECH RESEARCH • *M D Edgington, C M Barnes, J A S Angus and D M Howard.* EVALUATION OF SPEECH RECOGNITION BY SYNTHESIS IN COMPARISON WITH CONVENTIONAL HMM RECOGNITION • *L Moye.* SPEAKER VERIFICATION USING CONNECTED WORDS • *M J Carey & E S Parris.* THE SPEECH ACTIVITY CENTRE: A SPEECH TRAINING AID FOR PRE-LINGUAL CHILDREN • *J A S Angus & M Bennet.* EVALUATION AND OPTIMISATION OF A SEGMENTER FOR A PC-BASED PRONUNCIATION TEACHING SYSTEM • *F R McInnes, F Carraro,S M Hiller & E J Rooney.* AN IMPROVED COMPUTER MODEL OF AFFERENT NEURAL PROCESSING FROM THE COCHLEA TO DORSAL ACOUSTIC STRIA • *M J Pont & S J Mashari.* MAXIMUM LIKELIHOOD AND MAXIMUM MUTUAL INFORMATION TRAINING OF CONTINUOUS DENSITY HIDDEN MARKOV MODELS - EXPERIMENTS ON THE E-SET • *S Kapadia, V Valtchev & S J Young.* A COMPARISON OF NEURAL-NETWORK AND HIDDEN MARKOV MODEL APPROACHES TO THE TIERED SEGMENTATION OF CONTINUOUS SPEECH • *M Huckvale.* PHONETIC LABELLING STANDARDS FOR SEGMENTATION AND LABELLING OF TELEPHONE QUALITY SPEECH • *C Scott, R Lickley, K Edwards, A Simons.* A DECISION TREE APPROACH TO TASK-INDEPENDENT SPEECH RECOGNITION • *S N Downey & M J Russell.* PALM: PSYCHO ACOUSTIC SPOKEN LANGUAGE MODELLING • *K Morton.* THE DESIGN AND PERFORMANCE OF TWO ACCENT DIAGNOSTIC 'SHIBBOLETH' SENTENCES • *E Edwards, J Laver, M Jack & A Simons.* STATISTICAL RELATIONSHIPS BETWEEN AUDITORY AND ACOUSTIC RECORDS OF INTONATION • *N Ghali & P Roach.* THE ROLE OF HARD-WIRING IN THE PERCEPTION OF SPEECH • *S J Mashari & M J Pont.* A LARYNGOGRAPHIC STUDY OF THE SPEAKING AND SINGING VOICES OF YOUNG CHILDREN • *P White & G F Welch.* THE DESIGN OF A SPEECH DATABASE FOR WELSH DIPHONE EXTRACTION • *B Williams.* CYBERSPACE IN REAL TIME VISUAL DISPLAYS • *D Rossiter & D M Howard.* ACOUSTIC CUES TO BREATHINESS: A TRUE MARKER OF SPEAKER GENDER • *G Dempster.* AN INFORMATION-THEORETIC METHODOLOGY FOR SPEECH RECOGNITION ASSESSMENT, WITH APPLICATION TO THE SYLK SYSTEM • *K R Kew, L A Boucher & P D Green.* A COMPUTER CONTROLLED SYSTEM FOR ASSESSING AND CLASSIFYING NOISE INDUCED HEARING LOSS • *D Brown & T Goodrich.* SPEECH AIDS FOR THE HANDICAPPED: DESIGN AND DEVELOPMENTS AT THE UNIVERSITY OF HERTFORDSHIRE • *C Cheepen.* CORRELOGRAMS AND AUDITORY IMAGES • *M Allerhand & R Patterson.* A HYBRID GRAMMER-BIGRAM LANGUAGE MODEL WITH DECODING OF MULTIPLE (N-BEST) HYPOTHESES FOR SPEECH RECOGNITION • *C J F Jones, J H Wright & E N Wrigley.* FINDING THE N-BEST PHRASES IN A CONTINUOUS SPEECH RECOGNITION SYSTEM WITH PARTIAL TRACE-BACK • *M Kadirkamanathan.* APPLICATION OF AN ARCHITECTURALLY DYNAMIC NETWORK FOR SPEECH PATTERN CLASSIFICATION • *V Kadirkamanathan & M Niranjan.* IMPROVEMENTS TO A KEYWORD RECOGNITION ALGORITHM • *E S Parris & M J Carey.* NOISE MASKING IN THE MFCC DOMAIN FOR THE RECOGNITION OF SPEECH IN BACKGROUND NOISE • *A P Varga & B A Mellor.* CONTROL OF SPEECH SYNTHESIS USING PHONETIC FEATURES • *J Iles.* DSP-56000 BASED REAL-TIME ELECTRO-LARYNGOGRAPHICALLY-DERIVED CLOSED QUOTIENT • *D M Howard & P E Garner.* LEXICAL EFFECTS ON PHONEME PERCEPTION IN SPOKEN JAPANESE WORDS • *S Amano.* FEATURE HISTOGRAMS AS A MODEL OF SPEECH PERCEPTION • *R Linggard, P Linford & J Oglesby.* DEVELOPMENT OF A MULTILINGUAL SPEECH INTERFACE FOR A CAR PHONE • *W A Ainsworth & S R Pratt.* TWO DIMENSIONAL REPRESENTATION OF PHONEMES OF THE ENGLISH LANGUAGE • *E M Ellis & A J Robinson.* USE OF PALATE SHAPE DATA IN AN ENHANCED ELECTROPALATOGRAPHY SYSTEM • *W S C Chiu & C H Shadle.* THE ASSESSMENT OF SPEAKER VERIFICATION SYSTEMS • *W Millar, J Oglesby, M Pawlewski & J Tang.* SPEECH AIDS FOR THE HANDICAPPED • *C Bootle & A King.* THE COMPUTER AIDED LEARNING ENHANCEMENT PROJECT (CALE) • *C Cheepen & J Monaghan.* MODELLING AUDITORY SCENE ANALYSIS: A REPRESENTATIONAL APPROACH • *G J Brown & M Cooke.* A MULTIPLE SPEAKER PHONEME DURATIONAL MODEL • *C M Tuerk & A J Robinson.* A SEGMENTAL STATISTICAL MODEL FOR SPEECH PATTERN PROCESSING • *M J Russell.* ANALYSIS-RESYNTHESIS: MODELLING SELECTED PHONETIC SEGMENTS OF A WOMAN SPEAKER WITH A GENERAL NORTHERN ACCENT • *S P Whiteside.* INFERENCE OF LETTER PHONEME CORRESPONDENCES USING GENERALISED STOCHASTIC TRANSDUCERS • *R W P Luk & R I Damper.* AN ALPHANET APPROACH TO CONTINUOUS SPEECH RECOGNITION • *J S Bridle, L Dodd & P Nowell.* RESULTS FROM A PILOT LONGITUDINAL STUDY OF ELECTRO-LARYNGOGRAPHICALLY DERIVED CLOSED QUOTIENT FOR ADULTS SINGERS IN TRAINING • *D M Howard & D Rossiter.* THE ACOUSTICS ENVIRONMENT IN HIGHER EDUCATION CLASSROOMS. DO OVERSEAS STUDENTS FACE GREATER DIFFICULTIES DISCRIMINATING SPEECH THAN HOME STUDENTS • *D Canning.* A LOW COMPLEXITY, VARIABLE RATE SPEECH CODER FOR DIGITAL TELEPHONE ANSWERING MACHINES • *C I Parris & D Y K Wong.* TOWARDS A USABILITY MEASURE FOR AUTOMATED TELEPHONE SERVICES • *S Love, R Dutton, J C Foster, M A Jack, I A Nairn, N Vergeynst & F W M Stentiford.* A DYNAMIC LEVEL BUILDING ALGORITHM FOR LARGE VOCABULARY LEXICAL ACCESS • *P Nowell.* A TRANSFORM METHOD FOR GENERATING PERCEPTUALLY BIASED SPECTROGRAMS • *M D Edgington & J A S Angus.* A NEW ANALYSIS TECHNIQUE FOR FRICATIVE CONSONANTS • *C H Shadle, A Moulinier, C Dobelke.* SPEAKER VERIFICATION USING ORTHOGONAL LINEAR PREDICTION • *E Abadjieva.* RESURRECTION OF SPEECH INTELLIGIBILITY TESTS IN AUDIOLOGY • *R D Wright.* MAPPING THE AUDITORY SCENE: INVESTIGATING TEMPORAL PROXIMITY • *S M Williams, K L Baker & R I Nicolson.* AN EXAMINATION OF THE POTENTIAL OF CROSS-MODAL ENHANCEMENT TO IMPROVE SPEECH-LEARNING IN THE DEAF / HEARING IMPAIRED CHILD • *S Benton.*

CALL FOR PAPERS

Underwater Acoustics Group

International Conference

ACOUSTIC CLASSIFICATION AND MAPPING OF THE SEABED

University of Bath, 14 - 16 April 1993

Classification of the seabed and understanding the physical processes operating at the benthic boundary layer is fundamental to many civil and defence requirements.
Since the Institute of Acoustics conference entitled Acoustics and the Seabed held nearly 10 years ago, significant progress has been made both in innovative concepts and implementations using advanced technologies. This conference has been conceived as a forum for the presentation and discussion of the major advances in the acoustical study and characterisation of the seabed. The status of the conference is underwritten by the international experts who have agreed to present keynote papers and to set the scene for supporting contributed papers. All papers will be published in a special volume of the Proceedings of the Institute of Acoustics (1993), which will be available at the conference.

The Keynote Speakers and the provisional titles of their presentations are

Denzil Taylor-Smith, University of North Wales, UK, *Geophysical-Geotechnical Predictions*

Larry Mayer, University of New Brunswick, Canada, *A Multi-Faceted Acoustic Ground Truthing Experiment in the Bay of Fundy*

Christian de Moustier, Scripps Institute of Oceanography, *Swath Mapping of the Seabed*

Jacque Guigne, Guigne International, Newfoundland, *High Resolution and Broadband Processing of Benthic Seabed Acoustic Images*

Laurie Linnett, Heriot Watt University, UK, *Remote Sensing of the Seabed Using Fractal Techniques*

Bob Chivers, University of Surrey, UK, *Real Time Acoustic Surveying of the Seabed*

Lloyd Huff, Nautical Charting NOAA, USA, *High Resolution Multi-beam Focussed Sidescan Sonar*

Prospective authors are invited to submit abstracts as soon as possible but before 19 October 1992. Guidance on acceptable subject matter may be had both from the range of topics addressed by the keynote speakers and from the following non-exclusive list:

Advanced sidescan sonars systems: Side scan processing for seabed classification: Swathe sounding systems (interferometric and multibeam): Data presentation including correlation of bathymetric and sidescan images: High resolution sub-bottom profiling including parametric and chirp techniques: Normal incidence seabed classification: Techniques for measuring acoustic and engineering properties of the seabed: Acoustic backscatter from the seabed.

Successful authors will be notified by 16 November 1992. Full length manuscripts will be due by the end of January 1993. The Conference Notice will be issued at the end of November 1992 and will contain the Provisional Programme and the Registration Form.

For further information please contact the Conference Convenors:

N G Pace, School of Physics, University of Bath, Claverton Down, Bath, Avon BA2 7AY.
Tel: 0225 826826 Ext 5274 Fax: 0225 826110
D N Langhorne, Defence Research Agency, Bincleaves, Weymouth, Dorset.
Tel: 0305 823883 Ext 492 Fax: 0305 766114

CALLS FOR PAPERS

ACOUSTICS '93

a joint conference of

THE INSTITUTE OF ACOUSTICS (IOA)

and

LA SOCIETE FRANCAISE D'ACOUSTIQUE (SFA)

University of Southampton - England

21 - 23 April 1993

The IOA is pleased to announce that the Council of SFA has accepted an invitation to take part in the annual spring conference of the IOA to be held at the University of Southampton in April 1993, the year of the thirtieth anniversary of the founding of the Institute of Sound and Vibration Research.

A joint scientific committee will plan the technical programme. The joint chairmen are Frank Fahy of IOA and Emile Luzzato of SFA. Papers and abstracts may be written in English or French, but all oral presentations will be made in English.

Abstracts, of 200 words in length, are invited for the following topics, which have been agreed by the two societies as constituting areas of substantial common interest to their respective members, and which will form the principal structured sessions of the conference:

> ***machinery noise - prediction, measurement and control • environmental noise - prediction, rating and control • transportation vehicles - exterior and interior noise prediction and control • factory noise - prediction and control by design • active vibration control • non-linear sound and vibration • audio-frequency vibration analysis, measurement and control • pipe noise and vibration • musical acoustics • underwater acoustics • noise and vibration in aerospace technology • student paper session***

Abstracts may also be submitted on other topics for consideration by the scientific committee; they are also required for papers submitted by bona-fide undergraduate or graduate students for the student paper sessions, but full written papers will not be needed.

The abstracts should arrive before 31 October 1992 at the latest. Submissions are unlikely to be accepted after this closing date. Full papers, which will be published in Proceedings of the Institute of Acoustics, Volume 15 (1993), will be required for printing by 31 January 1993. Camera ready paper based on a normal length of 8 pages will be supplied, along with word-processor formatting instructions.

This conference will be the occasion of the presentation of the Institute's 1993 Rayleigh Medal and the 1992 Tyndall Medal, and plenary lectures will be presented by the medallists. Guest lecturers from SFA will review recent progress made in France in three major areas of acoustics. There will also be a special award for the best student presentation.

There will be a Civic Reception at Southampton Art Gallery, the Conference Dinner will be in the Great Hall of the city of Winchester and a visit is being arranged to a National Trust house and garden for accompanying persons.

The Registration Fee for IOA and SFA members will be £165 + VAT and £195 + VAT for non-members; this covers lunches and refreshments. Accommodation will be available in the University Hall of Residence at £20 + VAT per night and local hotel accommodation can be arranged. Daily registration will also be available.

Abstracts, in English or French, should be sent to either:-

Professor F J Fahy FIOA
ISVR
University of Southampton
Southampton SO9 5NH
UK
Tel: +44 (0)703 592291
Fax: +44 (0)703 593033

Dr E Luzzato
EDF/DER-
Department Acoustique
1, avenue du General de Gaulle
92141 Clamart CEDEX
France
Tel: +33 (1) 47 65 37 06
Fax: +33 (1) 47 65 39 78

WINDERMERE CONFERENCES

REPRODUCED SOUND 8

Provisional Programme

Prediction and Simulation

PREDICTIVE REALITY - IS IT SCIENCE OR FALLACY? *F Ampel, Technology Visions* • SPECIFICATION AND AUTHENTICATION OF AUDIBLE SIMULATION (AURALISATION) SYSTEMS *K D Jacob, M Jorgensen & C B Ickler, Bose Corporation* •

Multi-channel Radio Microphone Systems

AIRSPACE MANAGEMENT - AN OVERVIEW *B Copsy, ASP Frequency Management* • MEETING THE CRITERIA - A MANUFACTURER'S VIEWPOINT *J Wykes, Micron Ltd* • MULTI-CHANNEL RADIO MICROPHONE SYSTEMS *J Haug, Beyer Dynamic* • COMPUTER SUPPORT IN MULTI-CHANNEL RADIO MICROPHONE APPLICATIONS *H Kuehn, Sennheiser Electronics* •

BS7443 and Speech Intelligibility

BS7443 AND SPEECH INTELLIGIBILITY IMPLICATIONS - AN OVERVIEW *P Barnett, AMS Acoustics* • A COMPUTER-BASED SYSTEM FOR ASSESSING SPEECH INTELLIGIBILITY *D Brown, Cirrus Research* • STI MEASUREMENTS IN STADIA *P Mapp, Peter Mapp Associates* • SPEECH TRANSMISSION INDEX - PRACTICAL INTERPRETATION AND LIMITATIONS *P W Barnett & R D Knight, AMS Acoustics* •

Loudspeaker Systems and Array Characteristics

BASICS OF LOUDSPEAKER INTERFERENCE EFFECTS *K D Jacob, Bose Corporation* • VIRTUAL ARRAY LOUDSPEAKER SYSTEMS *K Forsythe, EAW* • A LOUDSPEAKER SYSTEM WITH ACTIVE TRANSMISSION LINE LOADING *P Darlington (1), K P Roungkvist (2), M S Neilsen (2) & G C Nicholson (1), (1) University of Salford (2) Odense Teknikum* • SOUND REINFORCEMENT DESIGN FOR INDOOR ARENAS *C Janssen, Acoustic Dimensions* • CLUSTER TECHNOLOGY AT LONDON OLYMPIA *P W Barnett, AMS Acoustics* •

Music Induced Hearing Loss

HEARING LOSS AND MUSIC - A STUDY OF THE AVAILABLE LITERATURE *K Dibble, Ken Dibble Acoustics* • AUDIENCE AND EMPLOYEE NOISE EXPOSURE IN THE NEW HEALTH & SAFETY EXECUTIVE POP CODE *A Dove, Health & Safety Executive* • COCHLEAR MECHANICS - THE WORKINGS OF THE EAR *C Kross, University of Sussex* • PREVALENCE OF MUSIC-INDUCED HEARING LOSS *J J Knight, Consultant* • DISCO DEAFNESS - EVIDENCE FROM YOUNG PEOPLE *E F Evans, University of Keele* • MUSIC-INDUCED HEARING LOSS IN MUSICIANS PLAYING DIFFERENT MUSICAL INSTRUMENTS *C H Mawhinny & G C McCullagh, University of Ulster* •

Environmental Noise Control at Outdoor Events

THE HISTORY OF CONTROLS OVER OUTDOOR CONCERT NOISE - OR HOW WE GOT TO WHERE WE ARE *D Trevor-Jones, Rendel Science & Environment* • PROPAGATION FROM HIGH-POWERED SOURCES OUT OF DOORS *G Kerry, University of Salford* • ENVIRONMENTAL NOISE CONTROL IN THE NEW HEALTH & SAFETY EXECUTIVE POP CODE *A Dove, Health & Safety Executive* • NOISE CONTROL AT GLASTONBURY FESTIVAL *S Anderson, Mendip DC* • ROCK MUSIC AT MAINE ROAD, MANCHESTER - A NOISE TOLERANT ZONE? *S Gregory, Manchester City Council* • NOISE CONTROL AT ALL NIGHT ACID HOUSE RAVES *K Dibble, Ken Dibble Acoustics* •

STI Measurement Workshop

STI MEASUREMENT USING TEF *P Christensen, Techron Inc* • STI MEASUREMENT USING MLSSA *D Rice, MLSSA Corp* • STI MEASUREMENT USING THE B&K TYPE 4225 *M Armstrong, Bruel & Kjær* •

Recording Studio Design

AIR STUDIOS CONSTRUCTION PROJECT: OVERVIEW *D Harris, Air Studios* • AIR STUDIOS CONSTRUCTION PROJECT: ACOUSTICS AND NOISE CONTROL *R Galbraith, Sandy Brown Associates* • AIR STUDIOS CONSTRUCTION PROJECT: ROOM PERFORMANCE *A Munro, Munro Associates* • THE ABBATOIR, BIRMINGHAM - UB40'S NEW STUDIO COMPLEX *K Dibble (1), D Snead (2) & K Green (3), (1) Ken Dibble Acoustics, (2) UB40/DEP International, (3) Tiflex* • ALTERNATIVE DIFFUSER SEQUENCES *J A S Angus, University of York* •

Ambisonics

AMBISONIC SURROUND SOUND - AN OVERVIEW *S Garman, Nimbus Records* • IMAGE PRESERVATION IN STEREO SOUND REINFORCEMENT SYSTEMS *N Sobol, AKG* • EXPERIENCE WITH A LARGE AREA 3D AMBISONIC SOUND SYSTEM *D G Malham, University of York* • MULTI-CHANNEL AMPLIFICATION SYSTEM FOR THEATRE AND CONFERENCE AUDIO SYSTEMS *C Riethof, Keienberweg, Netherlands* • A PUBLIC ADDRESS TIME ALIGNMENT INSTRUMENT *J A S Angus & R M Claxton, University of York* • THE USE OF BINAURAL TECHNIQUES IN THE EVALUATION OF CONCERT HALL ACOUSTICS *P H Scarborough,*

Engineering Presentation

THE BOSE **PANARAY** SYSTEM WILL BE DEMONSTRATED PRIOR TO THE EUROPEAN LAUNCH IN SPRING 1993 *K Jacob & D Bell, Bose Corporation* •

Reproduced Sound 8

Organised in collaboration with AES, APRS, ABTT, SCIF.

Programme Committee Chairman: Ken Dibble

Venue: Hydro Hotel, Bowness on Windermere
Dates: 29 October - 1 November 1992
Registration: from 4pm on 29 October
Conference Fee: includes all conference papers, entry to all sessions, workshops and demonstrations, Saturday lake trip, social programme including the Institute and Exhibitors' receptions. £175 + VAT for contributors, members of the Institute or any collaborating organisation: £220 + VAT for non-members. A limited number of one-day registrations will be available
Residence Fee: Delegate £140 + VAT (single room occupancy in the hotel, all meals including the Conference Banquet with wine as served). Accompanying Non-delegate sharing room with delegate £115 + VAT, meals as for Delegate
Manufacturers' Exhibition
Social and Accompanying Non-delegates programme
Trains: main ones from Euston will be met at Oxenholme
Proceedings of the Conference: available at registration; £40 (members) including postage for those not attending

Autumn Conference 1992: Speech and Hearing

Organised by the Speech Group

Programme Committee Chairman: Dr W A Ainsworth FIOA

Venue: Hydro Hotel, Bowness on Windermere
Dates: 19 - 22 November 1992
Registration: from 4pm on 19 November
Conference Fee: includes all conference papers, Saturday lake trip, social programme including the Institute and Exhibitors' receptions. £155 + VAT for contributors and members of the Institute: £205 + VAT for non-members. There is a special rate of £95 + VAT for a limited number of bona-fide full-time research students
Residence Fee: Delegate £140 + VAT (single room occupancy in the hotel, all meals including the Conference Banquet with wine as served). Accompanying Non-delegate sharing room with delegate, £115 + VAT; meals etc are as for the Delegate
Manufacturers' Exhibition
Social and Accompanying Non-delegates programme
Trains: main ones from Euston will be met at Oxenholme
Proceedings of the Conference: available at registration; £50 (members) including postage for those not attending

Fax the Institute on +44 (0)727 50553 for a registration form and further details. Indicate which conference.

met by few materials where moisture and soil as well as earth pressure, which means high static load, can cause problems.

Examples of such constructions are illustrated in Getzner's technical literature. Their service does not stop here however. The company offers an extensive technical back up service using modern equipment to simulate conditions and provide solutions. This is precisely why they have made their name over the last 15 years.

Supply and technical back up is provided through Getzner's UK distributors:
Croxton & Garry Ltd, Curtis Road, Dorking, Surrey RH4 1XA, Tel: 0306 886688 Fax: 0306 887780..

Ecophon Pilkington

Ecophon Pilkington offer a range of ceiling systems and wall panels specifically designed to control acoustics in a wide range of different applications.

The high density, resin bonded glass wool tiles provide a unique combination of total moisture resistance with high sound absorption coefficients. They are also robust, easy to install and maintain and will not sag, warp or deteriorate even in the most extreme conditions.

A wide range of products is available, from the cost-effective **Apollo** range suitable for general use to specialist systems, such as **Hygiene**, which is designed to withstand regular washing with detergent and presure washing. Ecophon's curved **'S' Line** and flexible tiles give the scope for effective interior design effects; **System Entre** gives easy access to services in the ceiling void; and **Super G** panels are ideal for areas such as sports halls where high impact is likely.

Whatever the application - factory, hotel, hospital, leisure complex, school or office - Ecophon's comprehensive and versatile range of high performance, top quality ceiling tiles and wall panels can help to ensure an attractive, peaceful, comfortable environment.
Ecophon International, Ramsdell, Basingstoke RG26 5PP, Tel: 0256 850977 Fax: 0256 850600.

Ferguson & Timpson

Ferguson and Timpson Ltd provides a comprehensive service to industry in the field of noise control.

Extensive stocks of noise control material are held which can be supplied in sheet or roll form. The material range covers a wide variety of specifications and is able to meet most customers requirements. A first class selection of adhesives and self-adhesive is available which can operate under the most demanding conditions. The Glasgow-based manufacturing division is registered with BSI Quality Assurance to BS5750 Part 2: 1987 (ISO 9002:1987) and is fully equipped to laminate and die-cut the range of noise control materials and to supply finished parts ready for application to customers equipment.

The company's Glasgow based Rubber Moulding Division has developed special techniques for the successful moulding of polynorbornene compounds that provide excellent vibration damping characteristics.

A sheet metal fabricating subsidiary company based in Bromborough provides a design, manufacturing and installation service for custom-built acoustic enclosures. These enclosures are used successfully thoughout industry for both 'in-plant' applications and to enable original equipment maufacturers to achieve their customers' noise level specifications.

Service is available throughout the UK from branch offices located in London, Birmingham, Hull and Liverpool.
Ferguson & Timpson Ltd, 5 Atholl Avenue, Hillington, Glasgow G52 4UA, Tel: 041 882 4691 Fax: 041 810 3402, Telex: 77108 FTHO G.
Ferguson & Timpson are Sponsor Members of the Institute.

Hewlett-Packard

At **euro•noise '92** Hewlett-Packard will be displaying a selection of instrumentation from their Dynamic Signal Analyser range spanning portable to multichannel FFT and real time acoustic solutions. In particular the recently released **HP3569A** portable low cost frequency analyser will be available demonstrating real time octave analysis, sound pressure, sound power, sound intensity and reverberation measurements. Incorporating the latest DSP technologies full time octave measurements are performed for analysing rapidly changing signals or for compliance testing. In addition a variety of solutions using synthesised octave displays from narrow band FFT data will be shown.

Details of HP's range of transducers for noise, vibration and structural measurements will also be available including accelerometers, microphones, power supplies, calibrators and sound intensity probe.

Hewlett-Packard Ltd, Cain Road, Bracknell. Berkshire RG12 1HN, Tel: 0344 362346 Fax: 0344 362905.

KEMO Ltd

Kemo specialises in the design and production of electronic filters of all kinds. These filters, and the many specialised systems which incorporate them, find numerous applications not only in the measurement and evaluation of noise, but also its control and modification.

The range extends from simple filter modules (including digitally programmable ones with up to 16 bit performance) for use at the component level, through versatile laboratory filter instruments, to high density multichannel systems with transducer and computer interfaces.

At **euro•noise '92**, KEMO will be showing a diverse selection from its product range, including one of the new **VSS Spectrum Shapers**. This is a high performance adjustable filter bank which allows very precise control over the frequency response of an input spectrum. Many other similar products are in the design stage, and our engineers will be available to discuss such systems as programmable multichannel graphic equalisers, and wide frequency range, wide dynamic range real-time spectrum analysers and monitors.

The latest in laboratory filter instrumentation will also be on show, demonstrating the ergonomic benefits which microcontroller techniques can bring to these traditional workhorses.

Kemo Ltd, 12 Goodwood Parade, Upper Elmers End Road, Elmers End, Beckenham, Kent BR3 3QZ, Tel: 081 658 3038 Fax: 081 658 4084, Telex: 8953189 KEMO G.

Larson*Davis Laboratories

LARSON*DAVIS are manufacturers of superior noise and vibration monitoring and analysis instrumentation.

The product line includes:

- Environmental noise analysers (for long and short term applications)
- Personal noise exposure meters
- Integrating sound level meters
- 1/1 and 1/3 octave band analysers
- Precision integrating portable real time, FFT and sound intensity analysers
- Microphones and accessories
- Computer programs or direct printer output for data retrieval

Flexibility is a key concept in the design of L*D instruments allowing the customer to build a package which ideally suits his application but more importantly, affording him the capability to expand his system through growth and change in requirements

New instruments on display at the exhibition include:

The **Model 2800/2900** single and dual channel precision realtime sound level meters with digital fractional octave and FFT facilities as standard. The Model 2900 can be used with the intensity probe **Model 2250**. Both instruments are battery or mains operated and are truly portable.

The **Model 820** is a hybrid of the extremely popular **Model 870** and is used as a precision integrating sound level meter and environmental noise analyser for short and long term applications. The instrument is compact in size without restrictions in capability.

The **Model 705 Noise Badge™** is the most advanced personal noise dosimeter currently available. The Noise Badge™ weights less than three ounces and measures 3 x 2.2 inches. The instrument is managed from a simple to operate computer program which enables the instrument to be set up and subsequently downloaded, showing time history data, Leq, C and linear weighted Peak data as well as statistical distribution and Lns etc.

There are established agents throughout Europe and details of these are available from the exhibition stand. Demonstration will continue throughout the exhibition and the UK agents Industrial and Marine Acoustics Ltd will be in attendance.

*LARSON*DAVIS Laboratories, 1681W, 820N, Provo, Utah 8461, USA, Tel: 801 375 0177 Fax: 801 375 0182.*

Lucas CEL

Lucas CEL Instruments, who have recently received BS5750 approval for their quality assurance management system, will be introducing a new environmental noise meter at **euro•noise '92**. A software driven keypad has replaced conventional switching in the new Type 1 **CEL-268** providing the operator with finger-tip access to a powerful array of features including a 60,000 value non-volatile memory.

The Type 1 instrument offers a 10-140 dB measurement range in three overlapping sub-ranges which enable the instrument to be used for measurements ranging from the asessment of noise in residential areas, at construction sites and for the noisiest activities such as shooting and motor sports.

The processing power of this compact hand-held instrument can be used to measure, evaluate, store and post process the information to resolve complex enviromental problems on site.

A variety of menus can be scrolled through the **CEL-268's** liquid crystal display from which the operator selects measurement criteria and duration (using the instrument's real time clock) and measurement results can be presented in a number of ways including period Leq and Lns, Short Leqs, Event Profile and Accumulative Results.

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CONTROLLING VEHICLE NOISE - A GENERAL REVIEW

Paul Nelson FIOA

Introduction

Of all the disadvantages associated with road traffic, noise is the most commonly cited. The reasons are obvious; it is ubiquitous and it influences many aspects of our daily lives, affecting our ability to concentrate at work and to relax at home. It causes annoyance when it disturbs an activity, interferes with communication and affects sleeping patterns. Stress may be introduced by the presence of noise, and stress may then induce physiological changes in the body and a general decline in health and wellbeing.

In the last twenty years, exposure to traffic noise has risen steadily as a result of the combination of growth in urbanisation and increased mobility by the population. Changes in travel patterns and behaviour of drivers have also helped to spread the intrusion of noise. The growth in traffic has led to traffic congestion in the cities and conurbations which has tended to encourage the motorist to spread the period devoted to commuting. The result is that traffic noise remains high for longer during the working day often affecting early morning and late evening where, previously, some respite in traffic noise could have been expected.

The reduction of traffic noise exposure by controlling the sources of noise is an obvious starting point, because the need to control noise by secondary measures such as road design or land use clearly depends on how successful controlling noise at source has been. However, a more important consideration is that the secondary forms of noise control tend to be expensive, with the costs loaded on society rather than onto the user or producer of vehicles.

There is, clearly, more than one approach to source control. The most obvious is to quieten the vehicles themselves through technical improvements to the noise producing components. However, it is clear that as advances are made to reduce the component sources of vehicle noise it is also necessary to consider the road surface on which the vehicles run. The surface design can greatly influence the overall levels emitted, particularly for vehicles travelling at moderate and high speed. In addition, source control can be extended to the drivers as driving style can influence the noise emitted and in some cases there may even be deliberate modification of the vehicle's exhaust.

The achievement of significant reductions in the noise emitted by vehicles requires both ingenuity and substantial investment in research. Since the benefits provided by such investment are intended primarily for society at large rather than the individual producers and users of polluting products, there is often little prospect of significant commercial gain. It is not surprising, therefore, that manufacturers, particularly of commercial vehicles, have in the past been reluctant to pioneer the research needed to develop quiet vehicles.

It is necessary, therefore, for incentives to be established to encourage appropriate technological innovation. Legislative action may be required to limit noise and test conditions have been prescribed for both new and in-service vehicles. However, other forms of incentive can be contemplated such as licence fees or taxation dependent on noise output in an attempt to create a market sensitive to vehicle noise. Such a market will encourage consumers to buy quiet vehicles which, in turn, will encourage manufacturers to develop the products required.

It is clear from the above that a successful vehicle noise control strategy requires a balanced approach involving both an understanding of the technological advances that can be made coupled with the sensitive application of political, economic and social incentives. This paper is concerned with examining these various issues.

The Sources and Control of Vehicle Noise

General Characteristics of Vehicle Noise

Traffic noise results from the collective contribution of the noise produced by individual motor vehicles. These vehicles vary enormously in terms of their type and noise emission characteristics. Private motor cars form the largest group, the great majority of which are powered by 4 cylinder, in - line, water cooled diesel or petrol engines with a capacity of between 1 and 2 litres and engine powers typically ranging between 20 and 100 kW. Heavy commercial vehicles are generally powered by diesel engines with engine powers in the range 150 - 250 kW. Between these two groups, there exists a less well defined range of vehicles which is mainly composed of light commercial vehicles in which petrol and diesel power units are equally common. Motorcycles form the smallest of the main groups.

The relative contribution or ranking of different vehicle types can be examined by comparing the peak noise levels of passing vehicles in traffic. An example of vehicle noise data collected at the roadside is shown in Figure 1. The Figure gives cumulative distributions of noise levels generated by various categories of vehicles operating in a wide range of urban traffic conditions. The distributions were compiled from over 22,000 vehicle pass-by events [1].

The Figure shows clearly that there is a very wide range of noise emitted by vehicles in urban traffic; in this

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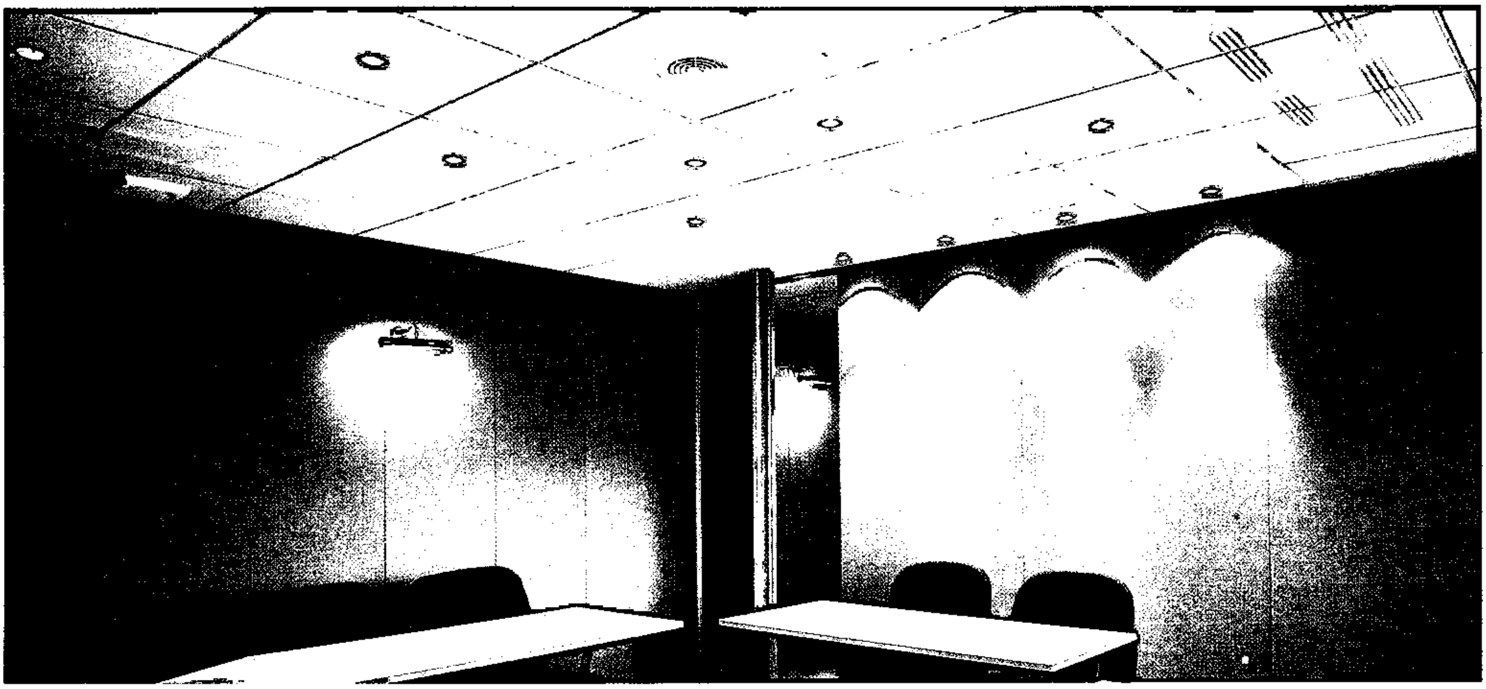

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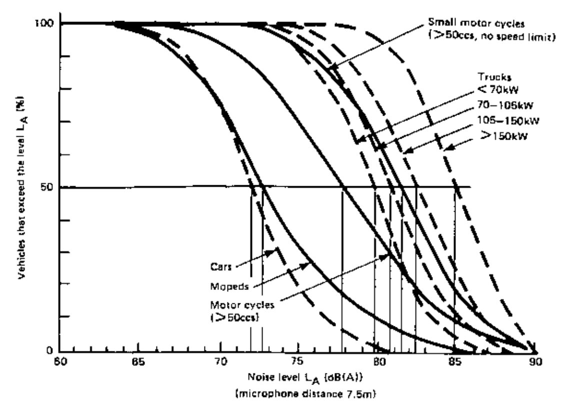

Fig. 1. Distribution of peak noise levels of various groups of vehicles taken from vehicles operating in urban traffic conditions. Source ref [1]

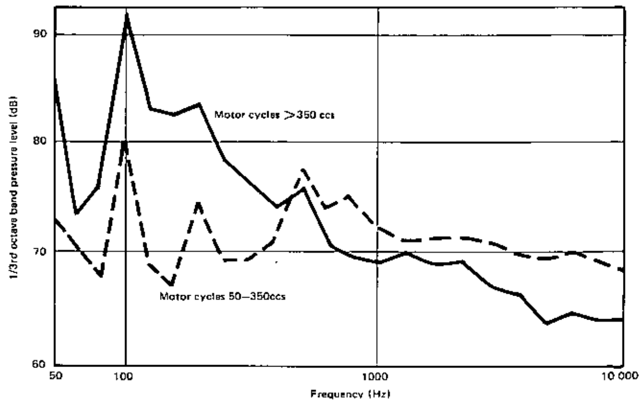

Fig. 2. Comparison of average frequency spectra for motorcycles of different engine capacities. Source ref [2].

example the range is from 57-92 dB(A). The quietest vehicles were petrol cars and the noisiest were heavy trucks with engine powers exceeding 150 kW. The differences between the two groups average 12 dB(A).

It is interesting to note that small motorcycles with engine powers in the region of 10 - 20 kW tend to produce more noise than some medium powered commercial vehicles with engine powers in the region of 100 kW.

The frequency spectra of vehicles can differ appreciably depending upon the type of vehicle and its mode of operation. Most vehicles generate a significant frequency peak associated with the firing frequency of the engine. For heavy diesel powered trucks, this will generally be in the 50-100 Hz region, whereas for cars the firing frequencies are higher at typically 150 Hz. In general, mid frequencies are affected by a wide range of both mechanical and combustion related sources and the spectrum has, as a result, a broad band nature in this region which is not generally characterised by significant frequency peaks. At frequencies above about 3 kHz most vehicle spectra exhibit a decay of about 20 dB per ten fold increase in frequency.

Motorcycles exhibit different spectra depending upon the capacity of the motorcycle and upon whether its engine is 2-stroke or 4-stroke. Some of these differences are illustrated in Figure 2 which compares average frequency spectra for large and medium capacity motorcycles. The frequency spectra of the large capacity machines shows a marked fall off with frequency whereas the smaller capacity motorcycles have a much flatter shape with a higher ratio of high to low frequency content. It has been reported that the noise signified by the flatter spectrum is judged to be harsher and subjectively more annoying than that produced by the large capacity machines [2].

A similar result was reported by Zwicker when comparing the noise from two motorcycles of similar make and engine power [3]. One of the motorcycles had been quietened by several dB(A) but, as a result of the engineering changes made to the vehicle, the resulting noise had a much flatter frequency spectra than the unmodified motorcycle. When loudness levels were calculated for the two motorcycles it was found that the quietened motorcycle gave a much higher loudness level suggesting that the vehicle with the lower dB(A) level would be judged to be subjectively much noisier.

Individual Sources of Vehicle Noise

(i) Power train noise and rolling noise

The sources of vehicle noise have been identified as the power unit (i.e. engine, air inlet, exhaust and cooling system), transmission, rolling noise (i.e. aerodynamic and tyre/ road surface), brakes, body rattles and load. For the purpose of this paper all sources related to the power unit and transmission will be regarded as power train noise and all others will be termed rolling noise.

The relative importance of these sources depends upon the type of vehicle and the operating conditions. A comparison between power train noise and rolling noise at various speeds for typical light vehicles (< 1.5 tonnes) and heavy vehicles is shown in Table 1.

It can be seen that rolling noise has a negligible effect on the noise from heavy vehicles for low vehicle operating speeds but at speeds above about 20 km/h for cars and 80 km/h for heavy vehicles, rolling noise contributes

Road Speed (km/h)	Vehicle class	Rolling noise dB(A)	Power train noise dB(A)	Total noise dB(A)
20	heavy*	61	78	78
	light	58	64	65
80	heavy	79	85	86
	light	76	74	78

Table1. Comparison of rolling and power train noise levels
* Heavy vehicles are > 1525 kg unladen weight

significantly to the overall noise level. At a speed of 60 km/h for cars, rolling noise is the dominant noise source.

These results illustrate that rolling noise can influence, to the extent of dominating, the overall noise emitted by vehicles operating at moderate and high speeds. A further point to note is that while significant reductions in the noise produced by the power train are feasible, these effects will not be fully realised, for a substantial range of vehicle operating conditions, unless the rolling noise components are also reduced.

(ii) Engine Noise

From a noise and vibration viewpoint, automotive engines are highly complex systems involving interacting dynamic forces operating upon a complicated structure of varying stiffness, damping and response characteristics. For convenience engine noise sources may be broadly classified as either 'combustion', 'mechanical' or 'gas flow' in origin. Gas flow noise is that associated primarily with the exhaust and cooling fan.

The problems associated with combustion are primarily the concern of diesel engines. Gasoline engines only produce significant combustion noise when the combustion is abnormal due, say, to some fault in the ignition system. The diesel engine operates at high thermal efficiencies, lean unthrottled mixture strengths and relatively high cylinder pressures. These conditions lead to rapid rates of pressure rise and gas load in the cylinders which, in turn, causes both structure radiated noise, exhaust noise and the characteristic diesel combustion 'knock'.

The rate of rise in cylinder pressure is of fundamental importance in noise control for diesel engines. Rapid pressure rise rates are responsible for high noise levels particularly in the mid to high frequency range (1 - 4 kHz). The characteristics for a direct injection (DI) diesel differ substantially, in this respect, from an indirect injection diesel (IDI). The rate of cylinder pressure rise for a DI engine is typically twice that of an IDI and the noise levels are, as a result, significantly higher for a DI engine. Turbo charging a DI engine is the usual way of smoothing the pressure rise to reduce noise levels.

Mechanical noise may originate from many different sources on an engine. The most common and significant mechanical sources are piston slap, bearing noise, gear and timing drive noise, valve train impact noise, and fuel injection pump and injector noise. In many instances, the sum total of these sources may exceed the combustion noise particularly at high speeds and high piston loads.

The surface of an engine is usually a significant radiator of noise. The crankcase, cylinder head, sump and rocker cover are the main components. The noise generated depends largely upon their stiffness and mass, and upon the radiation efficiency of the surface.

Idle noise is a particular characteristic of diesel engines and does give rise to problems particularly in the case of diesel passenger cars. Gasoline cars do not generally give rise to noise problems at idle because the engine is heavily throttled under these conditions. The diesel engine, however, is unthrottled at idle and this, together with the high compression ratio, (typically 2.5 times that of a gasoline engine) causes very high piston loading resulting in piston slap. These effects not only create high sound pressure levels but also, because of the rapid cylinder pressure rise, give a marked impression of impulsive noise, which is regarded by most people to be subjectively objectionable.

In summary, the main methods of controlling engine noise include:

1. Controlling combustion noise by smoothing the pressure rise in the cylinders. This can be achieved by controlling more closely the injection of the fuel into the cylinders either by staging the injection, retarding the ignition or by turbocharging.
2. Reducing mechanical noise by refinements to piston design to reduce piston slap, attention to gear profiles to reduce mesh impacts and 'chatter', smoothing the drive of timing gears by repositioning and closer attention to alignment.
3. Reducing structure radiated noise by stiffening panels to change the natural frequency. Using damped panels or laminated panels to reduce surface vibration, and the isolation of engine structures using resilient mounts and gaskets.
4. Use of covers and shields fitted over the engine compartment.

(iii) Exhaust noise

Exhaust pulse noise can be reduced through the use of chambered silencers which can consist of either resistive or reactive elements. Silencers which rely on resistive or absorptive chambers are generally good at reducing the high frequencies in the exhaust spectrum. However, their low frequency performance is generally poor unless the silencer can be made very large. This type of silencer is also less durable than the reactive type because of the effects of high temperatures and corrosive products in the exhaust on the absorptive materials used. Reacting or reflecting silencers attempt to reflect sound back to the engine usually by introducing changes in cross-section of the piping or, more commonly, by connecting the main gas flow pipe to large chambers. These silencers offer the advantage of low back pressure and can also be effective at low frequencies provided the outflow chambers can be made large enough. Unfortunately in the case of large diesel powered vehicles, constraints of space, weight and engine performance often make adequate silencer design difficult.

In general, improvements in exhaust noise can be obtained by careful consideration of the chamber volumes and their positioning along the main gas flow pipe.

Considerable improvements have been made in recent years in the modelling of exhaust silencers such that it is now possible to design silencers mathematically given the insertion loss requirements and the gas flow and engine characteristics [4].

Additionally exhaust noise may be controlled by attention to the control of cylinder pressure at the point where the exhaust valve opens. This can be achieved through modifications to the valve geometry and to the lift and closing characteristics as determined by the cam profile.

(iv) Fan noise
Noise from the cooling fan can be an important noise source particularly on large commercial vehicles where large airflows are required in order to stabilize engine temperatures. The main noise arises from a combination of the airstream, the rotation of the fans' blades past fixed objects, and mechanical noise caused by vibration of the fan and cowling. Fan noise increases with both fan power and blade tip speed and so methods of noise control involve techniques to reduce the speed of the fan whilst maintaining sufficient airflow to cool the engine. The symmetry of the blade layout can introduce tonal characteristics to fan noise which can raise noise levels and cause annoyance and so attention is also given to the layout of the blades.

Additionally, the fan can be driven through a thermally actuated clutch. In many cases the ram airflow is of sufficient volume to satisfy medium to high vehicle speed cooling requirements and the fan will, therefore, be automatically declutched for much of its operation. Tests carried out in the US, for example, showed that the 'fan on' time could be as low as 1% for heavy trucks [5].

(v) Transmission noise.
There is little evidence of noise problems created by transmission noise to date although it is likely that this source of noise will need to be treated in the future as other major sources are reduced. The main sources of noise are related to the meshing of gear teeth which translate vibrations to the housing or mountings. Improvements can be made by improving gear tooth profiles and drive shaft alignment.

(vi) Tyre and road surface noise
It has already been stated that rolling noise can have a considerable influence on the total noise emitted by moving vehicles. By far the most important component of rolling noise is that generated by the action of the vehicles tyres rolling over the road surface. The mechanism of noise generation is, however, complex and at present not fully understood.

The main factors affecting tyre noise are the speed of rotation of the tyre, the type of tread pattern and material, and the texture applied to the road surface. It is interesting to note that changes to the tread pattern and tyre construction generally have a much smaller effect on tyre noise than changes made to the road surface material and texture pattern. For this reason it is generally considered that there are greater prospects for controlling this form of noise by changing the road surface design rather than by changing the tyre design.

This view has been underlined, in recent years, by the development of open textured road surfaces which offer the dual advantages of good skidding resistance qualities in wet weather and high acoustical absorption characteristics. As a result, these surface types provide both a good standard of safety for the motorist and substantial reductions of both tyre noise and power train noise from vehicles.

In broad terms open textured porous road surfaces can reduce the total noise emitted by vehicles by, typically 3–4 dB(A) and, with suitable optimisation, greater reductions are technically possible. This result would appear to apply to all vehicle operating conditions and not just to conditions existing on motorways and high speed roads. At present, considerable research effort is being devoted to improving the durability of this type of road surface and, in some countries, versions of this material are already being laid as standard on a large proportion of the major road network.

(vii) Other sources of noise
Aerodynamic noise generated by the air flow over the surface of the vehicle is not a significant source of external noise at normal road speeds. Low frequency wind flutter can be especially troublesome due to resonance of the air space inside the cab or saloon of a vehicle as air streams past an open or semi-open window. Generally the frequencies are in the 10-20 Hz range. The remedy is to improve the aerodynamics of the vehicle so that the air flow is deflected past the window.

Brake squeal can be a significant source of noise. Vibration of the brake drum or disc would appear to be the likely cause although little has been done to study this particular source of noise.

Noise from compressed air braking systems on commercial vehicles can also give rise to high noise levels during braking. A possible remedy is to include some form of air brake silencer at the venting points.

Noise arising from the vehicle's body including noise generated by the load carried by the vehicle does give rise to complaints from the public. Although this is not a question which could be dealt with by purely design considerations, it follows that good body design and road maintenance would help to reduce both load and body noise.

Quiet Vehicle Development

(i) Engineering projects
Since the early 1970's several countries have initiated research and development projects aimed at producing vehicles with substantially reduced noise levels.

A review of these projects was carried out in 1983 for the European Commission as part of the considerations given to the establishment of new type approval limits for the European Community [6]. Some details of the results obtained are given in Table 2 together with data obtained more recently from other sources. The data have been arranged according to vehicle type and discriminates between vehicles which have been constructed to production standards, ie designed for in-service operation, and those which were developed as research vehicles. In each case the noise levels quoted were obtained according to the procedure detailed in ISO R 362 [7].

Passenger Cars: The data on passenger cars show that, generally, experimental prototypes developed over a decade ago were capable of meeting the noise limit of 77 dB(A) specified in the current European Directive and some of these vehicles were capable of meeting the more stringent target of 74 dB(A) which is the limit proposed by the EC for the car group for the mid 1990s. Most of the reductions reported were achieved through refinements to the engine and by attention to exhaust noise. Engine and transmission encapsulation had not been

Vehicle type	Description	Engine Power (kW)	Vehicle Status	Noise level dB(A) Before	After	Date of completion
Passenger cars	Diesel (F)	36	P	77	75	1983
	Diesel (F)	36	E	81	77	1975
	Petrol (G)	36	E	78	73	1981
	Petrol (G)	36	E	77	73	1981
	Petrol (G)	48	E	81	77	1981
	Diesel (G)	51	E	80	74	1981
	Diesel (G)	64	E	81	77	1975
	Petrol (air cooled) (G)	147	E	82	73	1977
	Petrol (water ") (G)	147	E	82	78	1977
Trucks and Buses (Europe & Japan)	5 delivery lorries (G)	48-95	P	83-90	76-81	1983
		65	P	86	80	1988
	Delivery lorry (G)	66	P	88	80	1984
	Delivery lorry (G)	95	E	89	84	1976
	Delivery lorry (F)	95	P	90	74	1981
	Delivery lorry (G)	187	E	92	80	1979
	Tractor (UK)	207	E	88	85	1978
	Tractor (J)	216	E	89	85	1978
	Construction site truck (F)	223	E	89	85	1978
	Tractor (J)	228	P	-	80	-
	Tractor (F)	255	P	92	81	1981
	Tractor (UK)	256	P	88	80	1978
	Tractor (UK)	260	E	91-94	81-87	1982
	Tractor (F)	132	E	89	84	1976
	Urban bus (F)	195	E	88	85	1978
	Urban bus (F)	-	P	89	78-82	1979
	Urban bus (J)	-	P	87-90	80-84	1980
Trucks & Buses (USA)	Tractor	173	E	92	82	1976
	Tractor	176	P	88	82	1982
	Tractor	200	P	88	77	1981
	Tractor	212	P	88	79	1981
	Tractor	235	E	94	83-87	1976
	Tractor	255	P	94	78	1976
2-wheeled vehicles	Moped (G)	6	P	80	73	1981
	M/cycle (G & N)	19.8	P	86	80	1984
		32.8	P	90	79	1984
		37.3	P	85	79	1984
		37.3	P	86	77	1984
		48.5	P	86	78	1984
		60.4	P	83	77	1984
		-	E	98	86	1973

Table 2. Quiet vehicle development projects.
E= Experimental vehicles: P= Production prototype.
F= France, G= Germany, N =Netherlands, J= Japan, UK= United Kingdom.

established significantly in the passenger car sector. However, in West Germany a fleet of diesel taxis had been fitted with encapsulated engines to reduce noise and these were run normally in service. The treated vehicles were reduced from 80 dB(A) to 74 dB(A) and, subjectively, are reported to be very acceptable, comparing favourably with equivalent gasoline powered vehicles.

Trucks and buses: The most substantial vehicle quietening programmes have been on trucks and buses. The most difficult type of truck to quieten is the heavy articulated tractor. Commercial interests require these vehicles to maximise both the engine power and the carriage space while both national and international regulations impose restrictions on the length and width of the total vehicle. These two constraints interact to minimise the tractive unit space such that there is often little spare room for adequate exhaust silencing and for acoustic insulation which will not affect engine cooling.

The data given in the Table show that several development programmes have resulted in the production of commercial vehicles with substantially reduced noise. Many programmes have favoured engine encapsulation to achieve the degree of quietening desired. Encapsulation has the advantage that it can be introduced relatively quickly and can, in some cases, be retrofitted to existing models, but has potential disadvantages in terms of weight and servicing penalties. Examples of successful engine encapsulation treatments are mainly to be found in Germany, the UK and the USA.

In Germany 130 air cooled delivery lorries with engine compartment encapsulation have been put into service by the Federal Post Office. In addition the rated speed of the engines was reduced and turbocharging was introduced to both compensate for the slight loss of power and to reduce combustion noise by smoothing the pressure rise in the cylinders. The overall noise levels were reduced by, on average, 14 dB(A) giving 77 dB(A) under the standard test.

An example of a low noise water cooled heavy tractor unit quietened to 80 dB(A) is the British Quiet Heavy Vehicle (QHV) which was developed to production standards in the late 1970s. This vehicle incorporated a tunnel enclosure over the engine and gearbox and also included a large mixed flow fan to ensure adequate cooling. Substantial modifications were made to the exhaust system which was designed to meet fairly stringent engine back pressure constraints and low frequency noise emission targets. This latter feature was considered to be an important consideration regarding the subjective impression of the noise produced by the vehicle.

Several countries set up publicly funded development programmes in the late 70s and early 80s in order to assist industry to develop quietened trucks which would meet the limits introduced by European Directives in the late 1980s. The British QHV 90 programme is an example but other programmes have existed in Germany, France, and The Netherlands [8, 9,10,11].

Data on buses tends to be fairly limited, but complete

engine encapsulation for rear engine urban buses is now quite common. In Germany, for example, 90 percent of new buses registered have encapsulated engines. In broad terms buses with encapsulated engines marketed in Europe have noise levels in the range 77-82 dB(A). Coaches can also be considered as candidates for engine encapsulation, but due to the generally higher engine power, cooling is more difficult and design considerations generally restrict the space available for higher duty fans.

Two wheeled vehicles: The principal noise sources on a motorcycle are the exhaust, induction and mechanical noise, with induction noise usually being more important than on other types of vehicle. In general, improvements to intake and exhaust silencing can lead to improvements of 3-7 dB(A), whilst additional treatments to the fairing around the engine can give further reductions with 6-10 dB(A) attenuation technically possible. The programmes carried out in Germany for the Federal Environmental Agency show that motorcycle noise can be reduced to below 80 dB(A) for a broad range of production vehicles without significant loss of power [12].

Future Development of Quiet Vehicles.

Most of the successes so far in quietening vehicles have relied upon relatively minor modifications to existing engines and components coupled with the use of enclosures or shields over the engine and/or gearbox. The presence of shields or enclosure panels on vehicles is not generally liked by the vehicle designer because they bring with them the attendant problems of engine cooling and increased weight, maintenance problems and costs.

Since the development and testing of the early quiet vehicle prototypes, substantial gains have been made in both the understanding of the nature of the problem of vehicle noise quietening and in the development of sophisticated signal processing techniques for both source identification and analysis. Dynamic finite element analysis, a daunting and questionable approach for engines 15 years ago, is almost accepted as a routine today and will continue to improve, enabling the designer to predict engine noise at the earliest possible design stage. Vehicle and component manufacturers are, therefore, now armed with a formidable battery of analysis equipment which can greatly simplify a complex noise generation problem and make designing a quiet engine from scratch a realistic possibility.

High on the list of priorities for the design of low noise engines must be a good structure design. Future designs will undoubtedly incorporate some form of stiffening to introduce greater rigidity of the engine structure in the region of the crankshaft. This need not necessarily increase the mass of the engine. In fact the techniques of structural optimisation often lead to a reduction in both weight and noise. For example, the British QHV engine was 50 kg lighter and 10 dB(A) quieter following structural changes made to the baseline engine.

Other important structural components include the sump and the valve and timing covers. Future designs of these components will tend to reduce the use of aluminium and pressed steel with resulting increased use of highly damped materials such as laminated steel or plastic. Additionally, greater use will be made of isolation techniques to decouple a potentially noisy component from a radiating surface. The use of new materials such as NIM's (new inorganic materials) potentially offers exciting prospects for the designer. Such materials, consisting of ordinary cement and a small proportion of bonding polymer, have excellent low noise properties and above all are extremely cheap. Tests on these materials have shown that prototype cam covers can reduce cam noise by 5-7 dB(A) compared with a conventional stamped steel cover [13].

Perhaps surprisingly, car engines present some of the greatest challenges for the future. Market forces dictate that future generation car designs will need to put more emphasis on fuel economy with the result that gasoline engines are being developed with leaner fuel mixtures and faster burn combustion characteristics leading, potentially, to problems with higher combustion noise levels. Other reasons for noisy spark ignition engines are the use of lighter structures, again for increased economy, and the increasing use of lightweight engine covers and sumps.

For small diesel engines, turbocharging will generally benefit noise, fuel economy and emissions and, although traditionally it has mainly been used to improve engine power on DI diesels for commercial vehicles, it is likely that turbocharging will also be used in the future for noise control on light duty diesel engines. Combustion excitation control at idle is of great importance, especially for passenger car applications. Great improvements are being made with IDI engines but the small DI still has some way to go to match the performance of gasoline engines.

A great deal of attention is now being placed on 'noise quality'. Hitherto, much of the emphasis in reducing vehicle noise has been directed towards the control of noise as determined by reductions on the dB(A) scale. Noise quality considerations are primarily concerned with how the sound of the engine or vehicle is perceived by the listener. For the car manufacturer 'noise quality' means that the vehicle should not only have a low noise level but should also sound 'good'. There is a market for better sounding cars and much work is being done to understand and engineer improvements in this respect [14, 15, 16].

These considerations are not limited, however, to the car group manufacturers as noise quality also has an important role to play for the legislator. Ultimately the success of any noise control policy is judged by the improvements in the impact of noise on people. 'Noise quality' considerations are, therefore, also concerned with ensuring that vehicle noise quietening policies not only produce lower numbers on some physical scale but also lead to products which are perceived to be correspondingly better.

In this respect, it has already been suggested that the quality of noise of motorcycles can be greatly affected by the ratio of high to low frequencies in the vehicle's noise spectrum [2, 3] and the scale of loudness suggested by

Zwicker [3] has been suggested as offering a much better degree of correlation with the perception of motorcycle noise than a simple scale such as dB(A). More recently, work carried out on assessing the noisiness of cars and trucks has confirmed that the scale of loudness is more closely correlated with peoples' subjective perception of vehicle noise than more conventional measures such as dB(A) [17,18]. The results of these studies would appear to suggest that it may be necessary in the future to change the way in which vehicle noise is measured if significant improvements are to be achieved in reducing the perceived noisiness of vehicles.

It should also be noted that the low frequencies emitted by some vehicles can give rise to environmental problems involving both vibration and noise effects in buildings. These effects can cause severe disturbance, particularly for people living close to roads, and are not, at present, considered in any noise control policy. Consequently, there is a case to be considered whereby future generation vehicles are required to satisfy more than one criterion associated with noise emission performance.

Finally, it is important to reiterate the importance of tyre/road surface noise on vehicle noise generation. As the noise from the power units of vehicles is reduced then the noise from the tyre/road surface interaction will begin to dominate over an increasingly wider range of vehicle operating speeds. This has already reached the stage where it influences the noise levels generated by vehicles undergoing type approval testing. This means that without some improvements in this source of noise, further reductions in total vehicle noise will be limited and eventually will reach the point where no further improvements can be made as judged by the current methods of testing. Since the road surface design is not within the control of the vehicle manufacturer, this is clearly a question which must be taken into account in setting future vehicle noise limits.

Vehicle Noise Legislation

Test Methods and Limit Values.

(i) Type approval regulations:

Various regulations and test methods apply to noise emissions from road vehicles. For simplicity, world-wide vehicle noise legislation can be split into three major regions: Europe (EEC), the USA and Japan. However, it should be recognised that other countries also have vehicle noise controls. For example, Switzerland which currently imposes the most stringent noise limits of any country.

The test method used in the EEC is based upon the 'full acceleration' test specified in the International Standard, ISO R362 [7]. Full details of this test are given in the Standard and in appropriate Directives, but briefly, the test requires the vehicle to be driven through a test site at full acceleration from a steady speed in low gear. The gear selected depends upon the vehicle type and upon the transmission system used. The peak noise level, measured on the dB(A) scale at a distance of 7.5 metres from the centre of the test track, determines the test level.

Table 3 summarises and compares the noise limits in force in different countries as measured according to the ISO R362 test procedure. In the US the test method used [19] employs the same full acceleration as the EEC test but the measurement distance is different (50 feet). In the Table, therefore, 6 dB(A) has been added to the US limits to make them correspond to European levels. Included in the table are the limit values applied in Switzerland and the limits for different vehicle categories recommended by the OECD Conference on Noise Abatement Policies which was held in 1980 [20]. The current EEC limit values given in the Table came into effect in October 1988 or October 1989, depending upon the vehicle category.

(ii) In-use controls

The test methods and limit values given in the previous section provide a means of controlling and monitoring the noise emission performance of new vehicle types prior to their registration and entry into service. Once these vehicles are registered the question arises as to whether further checks are needed during the lifetime of the vehicles to ensure that they continue to conform to the standards achieved at type approval. Such in-use tests have been introduced in many countries but there is, as yet, no international agreement as to the preferred method of testing or to the limit values that would be applied to different vehicle categories. At present roadside checks have been large-

Country	Pass'ger car	Small van <3.5t	Small bus <3.5t	Heavy lorry <150kW	Bus <150kW	Heavy lorry ≥150kW	Bus ≥150 kW	M/cycle >500 cc
EEC[b]	77	78-79	78-79	83	80	84	83	86
Switzerland	75	77	77	82	80	84	82	80
Japan	78	78	78	83	83	83	83	75
USA	-	-	-	86	83	86	83	83
OECD[c]	75	75	75	80	80	80	80	75

Table 3. Motor vehicle noise limits in different countries[a] - values are in dB(A)

[a] based on (ISO R 362) procedure: [b] EEC Member Countries are: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom: [c] proposals for 1990.

	Close proximity stationary noise level	Date of implementation
Two-wheeled motor vehicles (> 125 cc)	99	June1986
Motor driven cycles (≤ 125 cc)	95	June1986
Passenger cars	103	June 1988
Small-sized trucks and buses (GVW ≤ 3.5t)	103	June 1989
Medium-sized trucks and buses (GVW > 3.5t PS ≤ 200)	105	June 1989
Large-sized trucks and buses (GVW > 3.5t PS > 200)	107	June 1989
Large-sized and small-sized special motor vehicles	110	June 1989

Table 4. In-use limits for motor vehicle noise (Japan)

ly limited to visual or aural inspections of exhaust systems for mechanical defects.

There are, however, a few exceptions where measurements have been employed to determine offending vehicles. In Australia, for example, some states have introduced roadside noise checking with on the spot fines for offending owners. Most of the testing has been on cars and motorcycles using the ISO R362 test method. In some other states in Australia, likely offending vehicles are 'spotted' by central state agency officers and the owners are then sent a notice requiring them to present the vehicle for test at a registered test station. In this case the owner has the opportunity to rectify the vehicle before it is tested.

In Japan close proximity noise measurements are carried out on vehicles in-use. The current test is similar to that specified for exhaust noise testing in the international standard ISO 5130 [21]. In this test the measurement microphone is positioned close to the exhaust outlet and, with the vehicle stationary, the vehicle engine is decelerated either from 1/2 or 3/4 rated speed depending upon the maximum rated speed of the engine. This form of close proximity testing was introduced in Japan in 1986 for motorcycles, in 1988 for cars, and in 1989 for lorries. Table 4 lists the close proximity noise limits applied to different vehicle categories in Japan. Vehicles failing the roadside test are instructed to have the problem rectified by a garage. If this is not done then the owner may be liable for prosecution.

Although the methods of checking in-use noise levels are primarily aimed at identifying vehicles that are producing excessive noise usually as a result of some fault with the vehicle, some countries have also introduced measures which are not specifically related to vehicle faults but which are directed at the manner of use of the vehicle. For example, the British Construction and Use Regulations restrict the use of car horns at night and for stationary vehicles. There are also measures which stipulate that the vehicle should not be driven in such a way as to cause excessive noise.

Another form of in-use control is to ensure that vehicles are fitted with appropriate silencers by prohibiting both the sale and use of motorcycle exhaust systems which do not conform to the original equipment performance specification. The UK is in the process of making regulations to prohibit the sale of non-approved systems. A British Standard [22] has been developed with the manufacturers and user organisations to allow conformity to be determined. Similarly, in France there has been a ban on the importation of non-approved motorcycle replacement silencers since 1981.

Future Developments of Vehicle Noise Regulations in the EEC

(i) Type approval testing and limit values

Before discussing the future development of the EEC vehicle noise Directive it is worth examining the changes that have been achieved to date.

The first EEC Directive relating to the permissible noise from vehicles was issued in 1970 [23], and has since been amended several times [24–26] with the current regulatory levels decided in 1984 [27]. Table 5 shows the timetable of Directives issued by the EEC, the dates of implementation and the limit values for different vehicle categories. It can be seen that although there was no apparent activity during the 1970's, there have been considerable developments during the 1980's with three major changes to the regulations implemented since 1982. It is important to note that, apart from the reductions in the limit values that can be seen in the Table, the introduction of Directive 81/334/EEC in 1985 also signified a change in the test procedure which effectively meant that the noise regulations were more stringent even though the limit values were unchanged at that time. This change affected passenger cars and vans with a gear box of more than 4 forward gears, and trucks and buses. The changes meant that for many trucks the noise limits were effectively lowered by, typically, 2-3 dB(A).

Taking this change into account, it can be seen that in less than ten years there was a considerable tightening of the vehicle type approval noise regulations in Europe and for some vehicle types this meant a reduction of more than 9 dB(A) in the level of permissible noise.

Since the introduction of the current limits in October 1988, a European Commission working Group known as ERGA–Noise has considered further changes to the motor vehicle noise Directive and has made recommendations to the Commission for a further reduction in the limit values. It is intended the new limits will take effect from the 1st October 1996 for new type approvals. The proposed limits are included in the final column of Table 5.

It can be seen that the reductions proposed also mark a substantial reduction in vehicle noise with cars reduced by a further 3 dB(A) and heavy trucks by 4 dB(A) from the current limits. The proposed limits will also achieve the long term objective of reducing the noise from all vehicles undergoing type testing to 80 dB(A) or below.

Vehicle category	Motor vehicle noise limits in dB(A)				Proposed limits 1995/96
	70/157/EEC 1970	77/212/EEC 1982	81/334/EEC 1985	84/424/EEC 1989	
Passenger car	82	80	80	77	74
Small van <3.5t	84	81	81	78-79	76-77
Bus <150kW	89	82	82	80	78
Bus >150kW	91	85	85	83	80
Lorry <175kW	89	86	86	81	77
Lorry 75-150kW	89	86	86	83	79
Lorry >150kW	91	88	88	84	80

Table 5. Schedule of Directives for vehicle noise limits in the EEC (Motorcycle limits are currently specified in Directive 87/56/EEC)

(ii) Influence of tyre/surface noise
Consideration was given by the ERGA–noise Working Group to the problem of accounting for the influence of tyre noise generated during the vehicle type approval test. Recent research has shown that tyre/surface noise is increased when the tyre is accelerated due to the increased tyre deformations that occur in the contact patch under conditions of high drive axle torque [28]. This additional source of noise can influence the total noise generated by vehicles undergoing type approval testing and could prevent, in some cases, the limit values being achieved. For example it has been estimated that, typically, cars generate about 70-73 dB(A) during the type approval test from the tyre/surface interaction alone. The proposal therefore contains suggestions for amending the test procedure so that the levels of tyre noise are reduced. Briefly the amendment specifies a lower entry speed for vehicles being tested and, for certain heavy vehicles, a lower gear ratio would be selected than is required for the current method of test. Research carried out primarily in Germany has established that these modifications to the test procedure achieve a significant lowering in the noise from the tyres due to the lower approach speed specified and the lower gear ratios, but do not affect the total noise generated by the power unit [29].

Another problem associated with tyre/surface noise is that since its contribution does affect the level of noise emitted under type approval conditions, the certification level actually achieved for a given vehicle does depend upon the test track where the test was carried out. The variations between tracks due to the surface alone can be 3-4 dB(A). Clearly, this is undesirable, particularly, as the noise regulations are international with type approval testing stations in different countries, and it is necessary to remove this particular inadequacy in the method of test as soon as possible.

An ISO Working Group has prepared a Draft International Standard (DIS) which specifies more closely the design and construction of the track surface for vehicle noise testing [30]. Although the recommendations made by the ERGA Working Group did not refer to this Draft Standard, it is understood that the Commission will incorporate this specification in the Directive when the ISO Standard is finally adopted. It is anticipated that provided the DIS is accepted by member countries the Standard will be ratified by ISO by the end of 1992.

(iii) Type approval testing for tyres
Apart from modifications to the test procedure to minimise the influence of tyre/surface noise in the type approval test, the ERGA group also proposed that type testing for tyres should be introduced when the new limits for vehicle type approvals take effect. The EC has accepted these proposals and has commissioned research to develop an appropriate test procedure. It is anticipated that the results of this study will be available to the Commission during 1993.

(iv) Type approval testing for compressed air braking systems
The ERGA proposals also contain suggestions for testing the noise produced by compressed air braking systems on road vehicles. It details a method of testing the service brake, parking brake and pressure regulator compressed air noise and specifies the maximum permitted sound level from these sources. Concern has been expressed by some member countries, however, that the proposed test is not sufficiently representative of normal braking conditions and that the limit values proposed are not achievable without the use of air brake silencers. There was also a concern that the use of air brake silencers could, in certain cases, compromise the operation of anti–lock braking systems. It appears, therefore, that further consideration of both the test method and the limit values are needed before firm proposals can be made for the type testing of noise from air brake systems.

(v) Longer term considerations
While the agenda for the future development of the EEC motor vehicle noise Directive would appear to be settled for the next few years, at least in outline, it is useful to consider now how further changes might be introduced at a later stage as this will help to give direction to the establishment of any further research which may be needed.

The most fundamental question which would need to be addressed in any further consideration of reducing the noise limits from vehicles, is whether the most beneficial route is to continue to reduce noise emission in terms of a single number on the dB(A) scale or whether some additional form of control is needed. A possible additional measure is to impose a dB(C) limit for certain categories of vehicles to control the emission of low frequency noise.

It is known that the low frequencies in the vehicle's emission spectrum can cause buildings to vibrate causing concern and annoyance to the occupants and can influence the overall perception of the quality of noise emitted by the vehicle.

Alternatively consideration should be given to the use of more sophisticated physical scales of measurement. There is a growing awareness that the dB(A) scale, which has proved to be of considerable value for a wide range of noise control applications, does not necessarily offer the best correlation with the perceived noisiness of vehicles particularly as vehicles become quieter. It is quite possible, therefore, that by progressively reducing noise by imposing more stringent limits on the levels of dB(A), the resulting vehicles will not necessarily sound less noisy. Conversely, it is also possible that substantial improvements in the quality of the noise can be achieved without affecting the levels of dB(A) generated by the vehicle. Clearly there is little merit in imposing further reductions in the limit values and thereby imposing further technological constraints on the vehicle industry if the resulting noise benefits are not clearly perceived by communities exposed to the noise.

The scale of loudness would appear to offer distinct advantages over the dB(A) in this respect. The measure itself is much more sensitive to the response of the human hearing system since it takes into account the varying nature of the sensitivity of hearing to both frequency and intensity of the sound as well as taking account of the selective masking of sounds of different frequencies in the sound spectrum. It is a well established fact that a sound which has its component frequencies well separated in different critical frequency bands in the audible range will sound louder than a sound of equal acoustic energy but where the spectral components overlap and are contained within fewer critical bands.

Loudness measures have not, so far, received any serious attention by the legislators primarily because the equipment needed to measure sound on this scale has been both expensive and cumbersome. This situation is changing so that it is now possible to measure a form of loudness using hand–held instrumentation and it is likely that further advances will be made as the market for loudness measurement instrumentation expands.

(vi) In–use testing

It was pointed out previously that there was no internationally accepted method of controlling noise from vehicles in-use although several countries were using some form of in-use checking and enforcement. In the future there may be an increasing need to be able to monitor vehicles once they have been registered because of the greater possibility that quiet vehicles can become noisy due to poor maintenance or tampering. The main problems that have to be faced in developing in-use regulations are to ensure that any test method which is adopted clearly and unequivocally identifies vehicles producing excessive noise and is also simple to carry out and is cheap to administer. In particular future developments of an in-use test method would need to :–

(i) Allow roadside checks to be carried out in a variety of ambient noise conditions. This would probably necessitate the use of a close proximity test on a stationary vehicle.

(ii) Require the measurement microphone to be placed so that it is sensitive to exhaust system failures as well as faults with the power unit.

(iii) Ensure that the vehicle is operated such that the noise produced during the test was reasonably correlated with the noise it would produce during a type approval test.

Although some attempts have been made to provide a method of general application for in-use testing [31], there still remain some difficulties in dealing with gasoline powered vehicles. At present, there are no indications that in-use testing will be introduced on an international basis in the near future.

Economic Instruments for Vehicle Noise Abatement

Although the imposition of vehicle noise limits provides a convenient means of enforcing the adoption of new technologies, the method does have its limitations. Principally, the process tends to be rather slow to react to changing technologies and, therefore, it is not a particularly good instrument to encourage innovation. Indeed, it has been necessary, in some cases, for Government to initially finance the development work needed to prove the technical and economic feasibility of quiet vehicles before appropriate and more stringent regulations can be introduced. This, of course, reflects the natural reticence by the manufacturer to provide new technology without there being an obvious market for change with resulting economic benefits to the industry.

An alternative and also complementary approach is to attempt to create a market for quiet vehicles by the use of economic incentives. Some economic instruments are intended to encourage the users and manufacturers to realise, in monetary terms, the costs imposed on society by the noise that is created. This 'polluter pays' concept imposes some charge or tax related to the noise produced, thus encouraging the producer to abate the noise in order to reduce the costs and, therefore, increasing the demand for quieter vehicles; at the same time the revenues raised from the charge compensate society for the nuisance caused. The process of charging the polluter therefore has both an incentive and a redistributive or financing role.

Additionally, economic incentives can take the form of a tax concession, grant or subsidy to industry or to research organisations to promote the development and use of quiet vehicles and low noise vehicle components.

Motor Vehicle Noise Charges

For many years, noise charges have been applied successfully to civil aircraft operations whereby a noise tax is incorporated into the landing fee. The intention is to encourage operators to reduce operational costs by using quieter aircraft and to provide a source of financing to pay for alternative noise abatement measures such as sound insulation of buildings. The imposition of a similar system for road vehicles has, however, met with consid-

erable opposition and, as yet, no country has put into practice a charging system for road vehicle noise.

One of the reasons for this opposition is related to the considerable difficulty in establishing a direct link between a scale of taxation and the noise impact produced. This arises because although the noise potential of a vehicle can be established by, say, a type approval test, the noise impact subsequently produced when the vehicle enters into service depends greatly upon the driving style adopted and the usage made of the vehicle by the owner. Furthermore, unlike the aircraft operator, the driver of a motor vehicle is not a 'stationary transactor' who can be easily identified and controlled. Consequently, the view has been taken that an impact related tax imposed on the user will not provide the benefits desired.

Additionally, noise charges are seen by some commentators as providing a way of paying for the right to pollute and that excessive noise should be prohibited instead of compensated. Such arguments are valid provided the charge is set at too low a level so that the noise producer finds it cheaper to pay the charge rather than to abate the noise. If the price is high enough to act as an incentive for the reduction of noise then the argument disappears. Nevertheless, the difficulty in finding the 'right price' to charge for noise continues to generate both controversy and indecision and this has undoubtedly contributed to the lack of progress to date in developing vehicle noise charging policies.

Type of vehicle	Tax deduction	
	3%	7.5%
Heavy trucks >3.5t	≤83	≤77
Heavy trucks >3.5t & >147 kW	≤85	≤79
Buses >3.5t	≤79	≤76
Buses >147 kW	≤82	≤79

Table 6. Qualifying vehicle noise levels for tax relief in the Netherlands in dB(A)

Grants and Subsidies

(i) Grants

As a complement to regulations, some countries have provided research and development grants to both manufacturers and research organisations to help finance the development of low noise vehicles and components.

In Germany, a research programme was launched in 1978, sponsored by the Environment Agency (UBA) which was aimed at producing production prototype vehicles with low noise emission characteristics [9]. Government sponsorship amounted to approximately Dm 8 million spread over a five year period.

In France, research on quietening vehicles was carried out through the Programme Thematic Actions (ATP) which was active between 1971 and 1982. Public funding was administered through the INRETS (formally IRT) organisation with government sponsorship in the region of FF20 million [10].

In the United Kingdom a programme known as the QHV90 was initiated. This programme was managed by the Transport Research Laboratory and the Department of Trade and Industry and provided support to develop a range of production prototype quieter vehicles. The QHV90 programme was funded half by industry and half by Government and cost approximately 10 million over a period of 6 years [8].

(ii) Subsidies

Another type of incentive is the granting of subsidies or tax relief to stimulate investment in quiet vehicle development. In the Netherlands a tax relief scheme has been in operation since 1980 which provides financial incentives to private sector companies investing in low noise vehicles. The amount of relief is in the range 3.0-7.5% of the price of the vehicle depending upon the weight, power and noise level of the vehicle. It is estimated that, currently, 70% of trucks and buses registered since 1980 have benefitted from this policy measure. In the first six years of operating the scheme a total of 36 million guilders have been saved by private sector companies in terms of reduced taxes. The tax bands and noise level requirements for different vehicle categories are summarised in Table 6. The potential disadvantages of such schemes are that there is an additional cost in implementing and administering what is essentially a complex taxation system, and that there is no certainty that the quieter vehicles, which attract the lower tax when the vehicles are first registered, remain quiet in service.

Another form of subsidy involves allocating grants to operators to purchase soundproofing kits for in-service vehicles. In France, for example, the government gives a 50% subsidy on the extra cost of purchasing retrofitted 'hush kits' for urban buses.

Other Forms of Economic Incentive

A form of noise charge has been introduced in the Netherlands for mainly financing purposes. The tax is levied as an additional charge on fuel and the revenues gathered are used to finance the Dutch noise abatement programme [3]. This form of taxation represents a charge on the actual use of the vehicle and is not really linked to the intrinsic noise output of each vehicle type. Consequently, a driver of a car with high fuel consumption producing low noise emission will pay more tax than a driver of a car with good fuel economy producing higher noise levels. The noise tax does, however, relate to the total mileage travelled which implicitly places a higher burden on the users of vehicles which impact, environmentally, most people. The tax is approximately 0.9% of the cost of gasoline and 1.2% of the cost of diesel fuel indicating that there is also some discrimination against noisier diesel powered vehicles.

Restrictions on the use of noisy vehicles at certain times of the day and area have been put into operation in many countries. Although this can be regarded as mainly a traffic control measure it does also provide an economic incentive because it promotes the production and purchase of quiet vehicles.

Germany has introduced the concept of 'low noise vehicles' which are authorised to enter a protected area

Vehicle type	Engine power (kW)	Driving style	Time taken to drive 10 km, urban traffic(min)	Mean engine speed rpm	Noise level Leq dB(A)	Fuel saving % (H-L)
Cars	53	H	39	2150	72.6	29.8
		L	40	1550	67.8	
	95	H	39	2100	69.8	21.6
		L	44	1450	64.9	
	55	H	34	2400	68.2	19.1
		L	36	1500	62.8	
	37	H	33	2750	68.6	31.5
		L	33	1850	64.9	
	51	H	34	2350	67.0	27.8
		L	35	1500	62.0	
M/cycles	13(250)	H	34	4600	76.1	
		L	35	2830	68.8	
	34(350)	H	28	3750	79.0	
		L	30	2800	73.0	
	44(570)	H	29	3350	72.6	
		L	30	2100	64.5	
	66(1000)	H	31	2750	76.2	
		L	34	1650	68.2	

H denotes driver instructed to drive aggressively with high engine speeds
L denotes driver instructed to drive passively with low engine speeds
Numbers in brackets are the cubic capacities in cc

Table 7. Influence of driving style on noise, fuel consumption and journey time.

covered by traffic restrictions. Vehicles qualify as 'quiet vehicles' if they comply with the following sound levels.

Engine power	< 75 kW	77 dB(A)
"	76-150 kW	78 dB(A)
"	> 150 kW	80 dB(A)

Driver Behaviour

Apart from vehicle class or category the noise generated by an individual vehicle depends upon the mode of operation. In particular, the noise depends upon the operating speed of the vehicle, the gear selected and whether the vehicle is accelerating or decelerating. These features are a constantly varying feature of traffic as drivers attempt to cope with the traffic and road conditions encountered as part of normal driving. However, no two drivers will react in exactly the same way to a given condition as driving styles are known to differ substantially. Consequently, some drivers will drive less aggressively than others, in a given situation, resulting in a potential saving in fuel and a reduction in the noise produced. The question is whether driver behaviour variations produce a potentially useful means of controlling noise and whether, in fact, behaviour can be influenced to a significant degree.

Effect of Driving Style

A comprehensive study of the influence of driving style has been carried out in West Germany [33]. Table 7 summarises some of the results. Different passenger cars and motorcycles were driven along a 10 km route in city traffic. The vehicles' engine speed, noise and exhaust noise were continuously monitored. From these measurements the total noise at a 7.5 metre distance was calculated. These values are listed in the Table. In this case the L_{Aeq} is the energy level averaged over the driving period. Drivers were instructed to either drive aggressively or to drive passively.

It can be seen that the passive drivers gained considerably in terms of fuel saving with only small increases in journey time and the noise levels were substantially reduced. The average noise reduction for cars was, approximately, 5 dB(A) and for motorcycles was 7 dB(A).

Similarly, it has been suggested that driving style can influence the noise levels produced by commercial vehicles [34]. The German Federal Environment Agency (FIGE) have measured the noise levels from commercial vehicles before and after the drivers had attended a training course in economical driving. It was found that after taking the course the fuel consumption of their vehicles was reduced by, on average, 14% and the noise levels by about 5 dB(A).

Restraint Measures.

The imposition of speed limits in urban streets is an often used traffic restraint measure generally introduced for reasons of safety. Although the reduction in speed expected from such a restraint will generally lead to reductions in noise, this is not specifically a question which should be dealt with in this paper on source control. However, the imposition of speed limits can also influence driving style and behaviour. For example, in a study carried out in Aachen in West Germany it was found that after the speed limit on several city roads was changed from 50 km/h to 30 km/h the noise levels were reduced partly, as expected, from the reduced speeds of the traffic but also because of changes to the driving style adopted [35]. It appeared that drivers who were restricted to 30 km/h would accelerate and decelerate less aggressively than when driving in a street with a higher speed limit. It is estimated that the noise reduction attributable to driver behaviour changes were between 2-4 dB(A) depending upon the speed actually achieved.

The effect of driving style on fuel economy can be considered as a useful proxy for noise control. Consequently if measures can be introduced to influence behaviour to reduce fuel consumption then some noise benefits should also accrue. For example, the use of cruise control and speed limiting devices fitted to vehicles could be expected to produce some benefits. Similarly, instrumentation which provides the driver with a regular update on fuel consumption performance could result in

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more economical driving with associated noise benefits.

Tampering

Another form of driver behaviour that can cause noise levels to increase is tampering with the vehicle. This is mainly a problem associated with small 2-stroke motorcycles where it is relatively easy to remove the exhaust baffles from the silencer. It is possible that this form of tampering results in a small, but probably unnoticeable, increase in power for some motorcycles. However, when this is coupled with the noise increase, which can be as much as 20 dB(A), this can give the impression of a more significant increase in power. Additionally, some owners of motorcycles deliberately fit replacement silencers which give a notional increase in power coupled with an increase in noise over the original equipment silencer. Such actions are difficult to control via in-use enforcement because of the high costs involved. A more appropriate method is to introduce regulations which ban the sale of poor quality silencers as has been introduced in France (see the section above on Future Developments of Vehicle Noise Regulations in the EEC).

Summary and Conclusions

This paper has attempted to draw together some of the more important issues regarding the control of vehicle noise. While a great deal of the emphasis has been directed towards the prospects for reducing noise from vehicles through technological development of the vehicle and its components, it is clear that a successful outcome requires a balanced approach involving both progress in the physical reduction of noise and sensitive application of political, economic and social incentives. In addition, this paper should not be viewed in isolation from other methods of controlling noise from traffic. Indeed, some of the issues discussed, such as road surface design and vehicle speed restrictions, are also topics which have application in other areas of noise control. The paper has also indicated that different methods of control through regulation and other forms of incentive are in place in different countries. It is useful, therefore, to compare experiences and ideas in order to generate better control methods for the future.

Any attempt to control noise must start from an understanding of the sources of that noise. Undoubtedly, during the past decade considerable advances have been made in this respect and, as a result, the design engineer is now much better placed to incorporate low noise concepts at an early stage in the design of new vehicle types. The result is that most vehicles from the smallest motorcycle to the most powerful truck can be quietened to the extent that it is now possible to think in terms of all production vehicles achieving the much publicised target of 80 dB(A) or below under the standard test. This particular target has been a long term objective of several governments and, in 1977, was declared as a target for all vehicle categories by the European Council of Ministers. It was undoubtedly partly the reason why the ERGA–noise Working Group recommended lowering the vehicle noise limits to 80 dB(A) or below by the mid 1990s.

Apart from recommending lower noise limits for the 1990's, the ERGA group has identified the need to establish separate test procedures for the vehicle power train and rolling noise sources (tyres). With the quieter vehicles envisaged for the 1990's, the contribution from the vehicles tyres will become progressively more important often dominating the total noise from the vehicle at moderate passing speeds. Research is presently underway to establish appropriate test procedures for tyres with the objective of introducing type approval in an EC Directive by the mid 1990s.

In the longer term it has been argued that future considerations concerning the setting of vehicle noise limits should consider the most cost effective means of reducing the impact of vehicle noise. Although this may mean lowering the noise limits according to the technological possibilities for each vehicle group, this process, taken in isolation, may not be the most effective solution. Considerable attention has been centred recently upon the concept of noise quality and, in particular, the use of loudness measures as a means of establishing more accurately the perceived noisiness of vehicles. In future, therefore, regulatory authorities will need to consider the possibility that the continuing use of the scale of dB(A) alone is insufficient to ensure that future generation vehicles will be perceived to be satisfactorily quiet across the broad range of listening conditions relevant for traffic noise nuisance.

The use of economic incentives to encourage the development and use of quiet vehicles is largely an untapped form of control. Vehicle noise charging remains a possibility although no country has introduced this form of incentive to date. The use of subsidies or tax concessions in association with regulations are seen by some regulatory authorities as offering promising approaches to encourage innovation. Others are, however, less supportive and point to the disadvantages of additional costs of implementation and market place distortions which might arise from different noise taxation policies adopted in different countries. The concept of quiet zones with access limited to 'low noise vehicles' can, in principle, provide both incentive to the manufacturers and the users and offers an attractive solution to control noise impact on a limited scale. However, this again raises potential implementation problems if standards are not harmonised between regulatory authorities who may wish to operate in these areas. The concept of harmonisation of standards is similarly important on an international scale as different requirements between countries can impose difficulties both for operators of vehicles and manufacturers who, in the absence of harmonisation, are faced with an array of noise limits for their products depending upon their export markets.

The influence of the driver on the generation of noise from vehicles can be considerable and this can be influenced particularly when coupled with traffic restraint measures such as speed limits. Educating drivers to be more aware of the possibility of conserving fuel can have a benefit in terms of noise control and generally there is no conflict between adopting a driving style which improves fuel efficiency and one which reduces noise emission.

In conclusion, it is clear that today there is a much greater awareness of the quality of the environment and, with the increased affluence enjoyed by industrialised societies, there is also a greater willingness to pay to improve it. As traffic volumes grow the conflict between demands for mobility and efficiency and environmental quality will intensify. Hence the question of controlling noise to acceptable levels is likely to be of growing importance.

Acknowledgements

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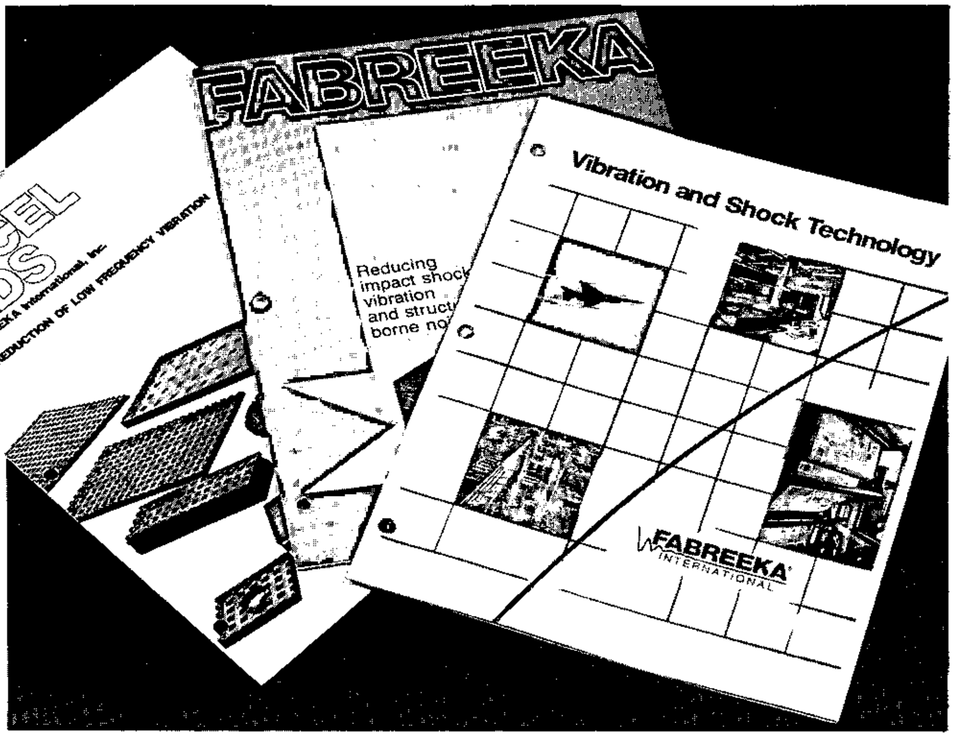
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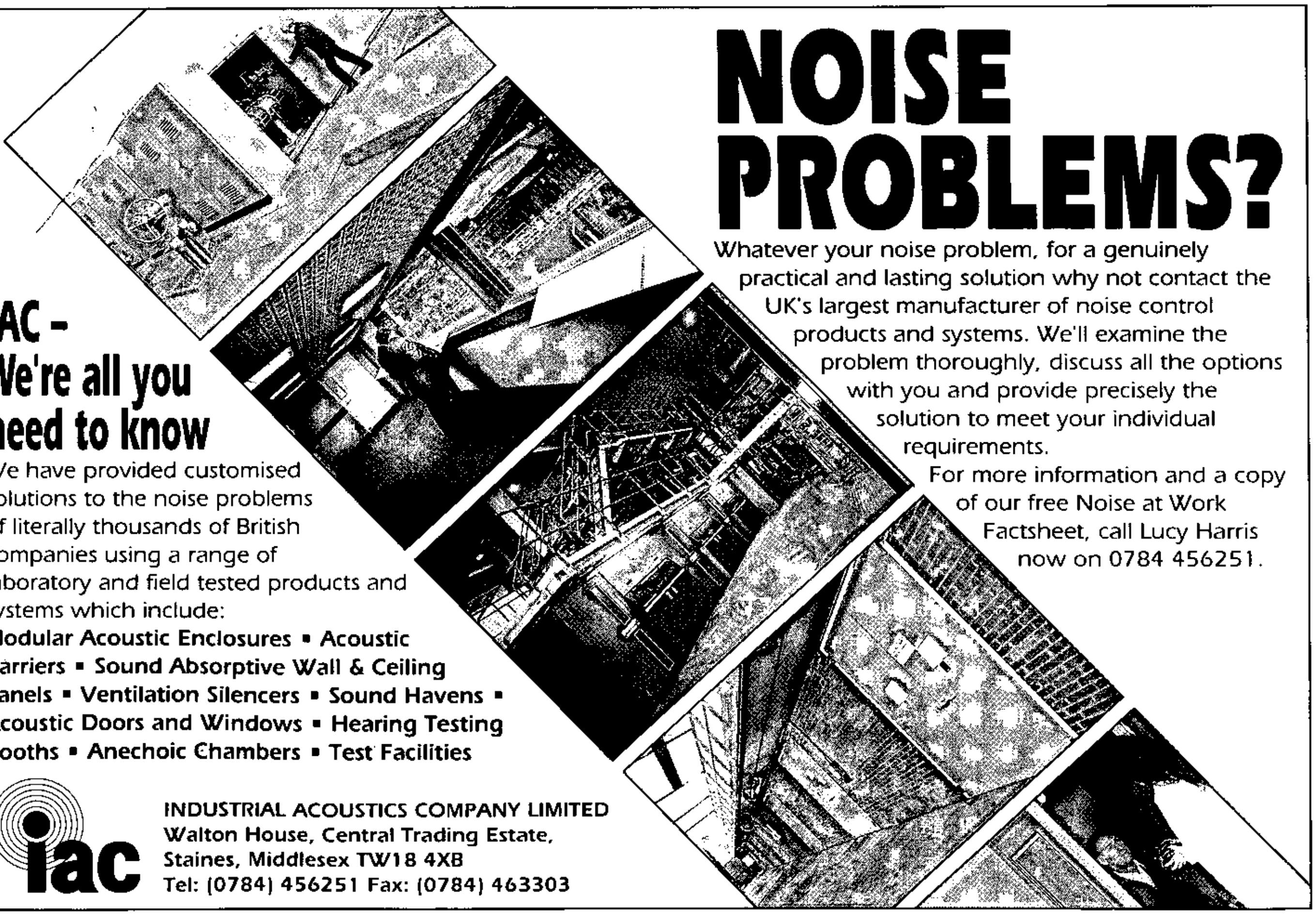

Book Review

Active Noise Control
M O Tokhi and R R Leitch
Oxford Engineering Science Series No.29,
Clarendon Press 1992, 206 pages, £35.00

To be able to publish a book primarily devoted to ones own work is an unusual privilege which has fallen upon the authors. They have carried out very specific work in active control, primarily in the area of free field systems and describe this with useful background and back-up material. The authors are control engineers and the book is written from this perspective, rather than that of an acoustical engineer, enabling acousticians to gain a different, possibly wider, view of the topic.

Following a short introductory chapter, Chapter 2 gives an account of the development of active noise cancellation from Lueg in the 1930s to Olsen and others in the 1950s, following through Jessel and Kido in the 1960s to the explosion of interest which occurred in the 1970s and 1980s and is still continuing. This chapter concludes with a review of the current technology of active control and is particularly well referenced, with about 250 listings. The process of field cancellation is considered in Chapter 3. General theoretical conditions for noise cancellations are developed, leading to a three dimensional description of cancellation in the medium and quantitative measures of this.

Chapters 4 and 5 cover controller design and system stability. Feedback and feedforward control systems are defined and developed as block diagrams, leading to general analytical expressions for the required controller transfer functions. Stability criteria, based on Nyquist, are developed for the feedback loop. These are then applied to the three dimensional spatial systems, which the authors have developed in considerable detail in their journal publications.

The following two chapters describe active noise control systems with fixed and adaptive controllers. The transfer functions are developed and measurement methods described. Digital implementation is referred to and an overall description given, but without design detail. System identification in adaptive control is discussed in some depth, leading to algorithm design.

Cbapter 8 concentrates on self-tuning active control systems and their implementation on a digital processor through correct input signal conditioning, design of a robust algorithm, self tuning, data quantisation format.

The final chapter reviews prospects for active control and concludes that 'much remains to be done, particularly in realistic industrial approaches.' This book is a useful compilation of the authors' work which, because of its individual, free space approach stands separately from much other work on the subject. The reviewer also feels that there have been sufficient industrial applications, particularly in the USA, to prove active attenuation as a valid and practical technique.

H G Leventhall

Hansard

15 July 1992

Mr Henderson: To ask the Secretary of State for Employment: (1) what was the implementation date of the Noise at Work Regulations 1989; what action is taken by the Health and Safety Executive to ensure that employers comply with them; how many employers have been prosecuted under the regulations for each year since they came into force; and if she will specify the regulations involved in each case; (2) what groups are exempt from the requirements of the Noise at Work Regulations 1989; (3) how many employees are estimated by the Health and Safety Executive to be exposed to noise at or above 85 dB(A).

Mr McLoughlin: The Noise at Work Regulations 1989 came into force on 1 January 1990. Since their introduction, health and safety inspectors have promoted awareness of and compliance with the regulations through widespread advisory and enforcement action. Wide publicity has been achieved through a series of free leaflets and extensive guidance. One employer has been prosecuted for breach of regulations 4, 8, 9 and 11. In addition, 948 improvement notices and 54 prohibition notices have been issued. The Health and Safety Executive estimates that about 1.7 million workers are exposed to noise levels above 85 dB(A).

The regulations apply to all workers covered by the Health and Safety at Work etc, Act 1974, except the crews of sea-going ships and aircraft or hovercrafts moving under their own power. They do not apply to workers in the offshore industry.

Mr Henderson: To ask the Secretary of State for Employment how many Health & Safety Executive inspectors are specialists in noise control.

Mr McLoughlin: The Health & Safety Executive has 12 specialist noise inspectors. They are supported by administrative & research staff with specific qualifications in noise. All general Health & Safety Executive inspectors have received training in noise control.

Mr Henderson: To ask the Secretary of State for Employment how much revenue has been received from the sale of literature and videos published by the Health & Safety Executive related to the Noise at Work Regulations 1989.

Mr McLoughlin: Revenue received by the Health and Safety Executive from the sale of publications related to the Noise at Work Regulations 1989 up to 1 July 1992 amounts to approximately £68,000. No videos have been produced by the HSE relating to these regulations.

Mr Henderson: To ask the Secretary of State for Employment (1) how the requirements in the noise directive on audiometry are being implemented in the United Kingdom; (2) what measures the Health & Safety Executive has taken to ensure that employees exposed to noise at or above 85 dB(A) know they are entitled to a free hearing test through the national health service.

Mr McLoughlin: EC directive 86/188/EC on the

protection of workers from noise at work requires that workers exposed to 85 dB(A) or more should have access to hearing check by a doctor. Anyone who is worried about any aspect of their health, including their hearing, already has access to the full range of NHS services.

The Health and Safety Executive has published a free leaflet for employees outlining the main requirements of the regulations and advising them about the risks to hearing of noise at work. The leaflet contains advice to workers to consult their doctor if they think there is something wrong with their hearing. The HSE's noise guide No.1 also draws attention to employers responsibilities to provide information and advice to employees.

Mr Henderson: To ask the Secretary of State for Employment what plans exist in the Health and Safety Executive or European Commission to reduce the first action level of the Noise at Work Regulations 1989; and what level is proposed.

Mr McLoughling: The European Directive on which the Noise at Work Regulations are based is to be reviewed by 1994. The European Commission is considering a proposal for a directive on the protection of workers from physical agents. This would replace the directive on noise and require a revision of the Noise at Work Regulations.

Mr Henderson: To ask the Secretary of State for Employment if the Health and Safety Executive will update its publication, '100 Practical Solutions of Noise Control at Source'.

Mr McLoughlin: The Health and Safety Executive is currently examining whether a second edition of its publication titled '100 Practical Applications of Noise Reduction Methods' would be useful.

Mr Henderson: To ask the Secretary of State for Employment what noise surveys have been carried out in her Department's buildings, since the enactment of the Noise at Work Regulations 1989.

Mr McLoughlin: There are nearly 2,000 buildings in the Employment Department group. The information requested is not held centrally and could be provided only at disproportionate cost.

16 July 1992

Mr Mallon: To ask the Secretary of State for Transport what legislation, regulations or guidelines exist to limit the impact of (a) aircraft noise (b) vehicle noise or (c) other noise pollution.

Mr Norris: I will write to the hon. Member.

Mr Mallon: To ask the Secretary of State for Transport (1) what plans he has to introduce regulations to control aircraft noise; (2) what responses he has received from N. Ireland based individuals or organisations in response to the consultation paper, 'Control of Aircraft Noise'.

Mr Norris: The consultation paper 'Control of Aircraft Noise' was published last August. More than 550 responses have been received including one from Northern Ireland. The responses are being carefully considered and an announcement of conclusions will be made in due course.

The United Kingdom has supported international agreements to phase out of operation older, noisier subsonic civil jet aircraft certified to 'Chapter 2' standards. These aircraft will be phased out between 1995 and 2002 and regulations to that effect will be introduced in due course.

Motorway Sound Barriers

Sir Michael Grylis: To ask the Secretary of State for Transport what plans he has to provide effective modern sound barriers to reduce the noise of the new feeder roads off the M25 between the M3 and M4 junctions.

Mr Kenneth Carlisle: Noise barriers are proposed at a number of locations adjacent to the proposed new link roads between junctions 12 and 15 of the M25. The type of barrier to be used has not yet been decided. A number of possible options are being considered.

Aircraft Noise

Mr Mallon: To ask the Secretary of State for Northern Ireland what plans he has to introduce regulations to control aircraft noise.

Mr Atkins: Aircraft noise at airports is subject to control under the provision of section 12 of the Aerodromes Act (Northern Ireland) 1971. There are no present plans to invoke these provisions.

Mr Mallon: To ask the Secretary of State for Northern Ireland if he will undertake a review of the mechanisms for controlling aircraft noise.

Mr Atkins: I have plans to do so as part of a general review of current airport legislation.

Noise at Work Regulations 1989

Mr Henderson: To ask the Secretary of State for Employment what estimate has been made of the cost to employers of complying with the Noise at Work Regulations 1989 in 1990 and 1991.

Mr McLoughlin: The Health and Safety Commission published a consultative document in 1987 on the draft Noise at Work Regulations. This included an assessment of the costs and benefits of the proposed regulations, which estimated their total cost to be between £240 million and £320 million, spread over a working lifetime. The main costs were likely to arise from the requirement for noise assessment, £20 million, personal protection programmes for those exposed to noise above 85 dB(A), £127 million, and those for noise reduction measures for exposures above 90 dB(A), £85 million to £175 million.

Noise

Mr Adley: To ask the Secretary of State for the Environment if he will include rights, within the citizen's charter, for those living alongside, or underneath, the creators of environmentally damaging noise.

Mr McClean: (holding answer 13 July 1992): I refer the hon Member to the answer I gave to the hon. Member for Devizes (Mr Ancram) on 7 July, Official Report, column 154, on the proposed charter for local authority environmental services. We would expect such a charter to include rights for people who are disturbed by certain noisy activities.

Extracts provided by Rupert Taylor FIOA. ❖

New Products

FABRITRAK

HDS Panel

FABRITRAK, to compliment their in-situ fabric covering system, have introduced a high performance custom made acoustic panel.

The HDS acoustic panel is a lightweight uPvc framed panel for use in acoustically sensitive areas, for example, music rooms, auditoria, school halls and offices.

The HDS Acoustic panel comprises a uPvc frame, a high specification mineral fibre core and a fabric covering. The core is constructed of compressed lamellas encapsulated in a covering of acoustically transparent glass tissue. The fabric covering is of an acoustically transparent flame-proofed fabric.

Individually made to acoustician and architect specification the HDS panel has many features not previously available on the market.

Further details in the form of a data sheet, fabric colour cards and test reports are available from Fabritrak, Fabritrak House, 21 High Street, Redbourn, Herts AL3 7LE. Tel 0582 794626, Fax 0582 794645.

LUCAS CEL INSTRUMENTS

Environmental Noise Meter

A software driven keypad has replaced conventional switching in the new CEL 268 Environmental Noise Meter.

This gives the operator finger-tip access to the meter's powerful array of features including its 60,000 value, non-volatile memory.

The Type 1 instrument uses microprocessor technology to provide a 10 - 140 dB measurement range in three overlapping sub-ranges. The processing power of this compact, hand-held instrument can be used to measure, evaluate, store and post process the information necessary to resolve complex environmental problems on site.

A variety of menus can be scrolled through the CEL 268's liquid crystal display from which the operator selects measurement criteria and duration (using the instrument's real time clock). Measurement results can be presented in a number of ways including Period Leq, Lns, Short Leqs, Event Profile and Accumulative Results.

These can be output to the screen and stored in the non-volatile memory. The storage capacity (up to 60,000 values) means that intensive monitoring sequences can be undertaken to provide complete noise histories and the data is held in the memory even if the instrument is switched off. Post measurement processing is then made possible by connecting the CEL 268, via its serial interface, to any industry standard PC. Results can also be output directly to a Centronics printer.

The CEL 268 complies with IEC651, IEC804 and ANSI S1.4.

A data sheet on the CEL 268 can be obtained from Lucas CEL Instruments Ltd, 35-37 Bury Mead Road, Hitchin, Herts, SG5 1RT. Telephone 0462 422411.

LUCAS CEL is a Key Sponsor of the Institute.

SALEX ACOUSTIC MATERIALS

__Illbruck Range__

Having recently been appointed UK distributors for German noise control materials manufacturers Illbruck GmbH, Colchester based Salex Materials Ltd (SAM) now have a product range incorporating the very latest in foam technology which complements perfectly their own extensive range of fibre based products.

The Illbruck range offered by Salex includes :

- Suspended absorbers - flat and tubular
- Profiled foams - pyramid and waffle
- Low frequency absorbers
- Waterproof absorbers
- Ceiling tiles
- Mobile screens
- Wall panels
- Studio absorbers

Further details can be obtained from: Alan Franks, Salex Acoustic Materials Ltd, Crown Gate, Wyncolls Road, Severalls Industrial Park, Colchester C04 4HT. Tel: 0206 852525, Fax: 0206 854445.

SALEX GROUP is a Sponsor Member of the Institute.

ICATS

__Portable Structural Testing and Analysis System__

ICATS, the Imperial College based Engineering Software company, announces the availability of its portable modal testing and structural system which will initially be priced at £9,950.

The system is stated to be both one hundred percent portable and self-contained for a complete modal survey of small and medium size structures.

It presents an excellent opportunity for newcomers to the subject of modal analysis and it also caters for the needs of vibration engineers who need to acquire and analyse data on site.

The portable system is also very useful as a means of checking/ validating results from much larger laboratory-bound workstation-based systems.

The portable structural testing and analysis system consists of:

- Diagnostic Instruments PL202 FFT analyser for frequency response function (FRF) measurements;
- Laptop 386SX computer with 4Mb RAM and 40Mb hard disk;
- PCB hammer kit and accelerometer;
- MODENT suite of programs for data transfer and integrated structural analysis;
- Documentation, tutorials and the most authoritative textbook on the subject - 'Modal Testing: Theory and Applications'.

Further details may be obtained by contacting David Robb, ICATS, Imperial College of Science, Technology and Medicine, Mechanical Engineering Department, Exhibition Road, London SW7 2BX.
Tel: 071 225 8973 Fax: 071 584 1560

Material for inclusion in this section should be sent to John Sargent MIOA at the Building Research Establishment, Garston, Watford, Herts WD2 7JR

News Items

AGIV Acquires Bruel & Kjær

A press release states that Bruel & Kjær has been acquired by giant German holding company AGIV which last year turned over DM 8.1 billion (£2.8 billion).

AGIV's intended strategy is stated to be to secure the future of a unique family business, which for 50 years has enjoyed a formidable reputation for the technological quality of its products, through a capital injection of D KR 350 million (over £30 million).

Bruel & Kjær's expertise is to be found today in numerous measurement systems in health and safety and environmental monitoring, design verification, production test, process control, machine condition monitoring, structural trouble shooting, and medical diagnosis.

Acquisition by AGIV will not significantly affect the applications areas in which Bruel & Kjær is active, but rather will allow the company to accelerate the development of its product portfolio.

Bruel & Kjær's UK managing director Mark Appleyard states that he is able to reassure customers that Bruel & Kjær will not only continue to support existing products but will increase condition monitoring systems, high-performance portable digital signal analysers, and products for environmental markets.

The transfer of the entire family shareholding to AGIV took place on August 15th, 1992.

Bruel & Kjær's 2300 employees, 1600 of whom are based at the company's headquarters in Nærum, Denmark, joined the 37,000 AGIV employees in three hundred enterprises in the mechanical engineering, electrical engineering, electronics, power generation, building and haulage industries.

BRUEL & KJÆR is a Key Sponsor of the Institute.

DIGISONICS

New European Office

Professor Geoff Leventhall will head the company's new European office in the South Bank Technopark, 90 London Road, London.

Dr Leventhall will work with European firms interested in developing applications of Digisonix' proprietary active sound and vibration control technology. Digisonix, a division of Nelson Industries, Inc., is known for its expertise in applying the best of both active and passive technology to solving sound and vibration problems.

Dr Leventhall is a past president of the Institute, Deputy Chairman of the UK Noise Council and a former director of the International Institute of Noise Control Engineering.

Digisonix is the leading supplier of active sound and vibration control systems for industrial fan and commercial heating, ventilating and air conditioning applications in the United States. ❖