

ACOUSTICS

BULLETIN



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ACOUSTICS

BULLETIN

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Front cover photograph: The Amsterdam concert hall Muziekgebouw aan't IJ was opened in 2005 and features 'variable' acoustics, so that the hall can be adjusted to suit the particular performance requirements of the musical programme. One of the technical contributions in this issue discusses the application of the technique to various concert halls and theatres. Another looks at how a loudspeaker orchestra can be used to test a venue without the time, trouble and expense of hiring a professional symphony orchestra.

The Institute of Acoustics is the UK's professional body for those working in acoustics, noise and vibration. It was formed in 1974 from the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society.

The Institute of Acoustics is a nominated body of the Engineering Council, offering registration at Chartered and Incorporated Engineer levels.

The Institute has over 3000 members working in a diverse range of research, educational, governmental and industrial organisations. This multidisciplinary culture provides a productive environment for cross-fertilisation of ideas and initiatives. The range of interests of members within the world of acoustics is equally wide, embracing such aspects as aerodynamics, architectural acoustics, building acoustics, electroacoustics, engineering dynamics, noise and vibration, hearing, speech, physical acoustics, underwater acoustics, together with a variety of environmental aspects. The Institute is a Registered Charity no. 267026.

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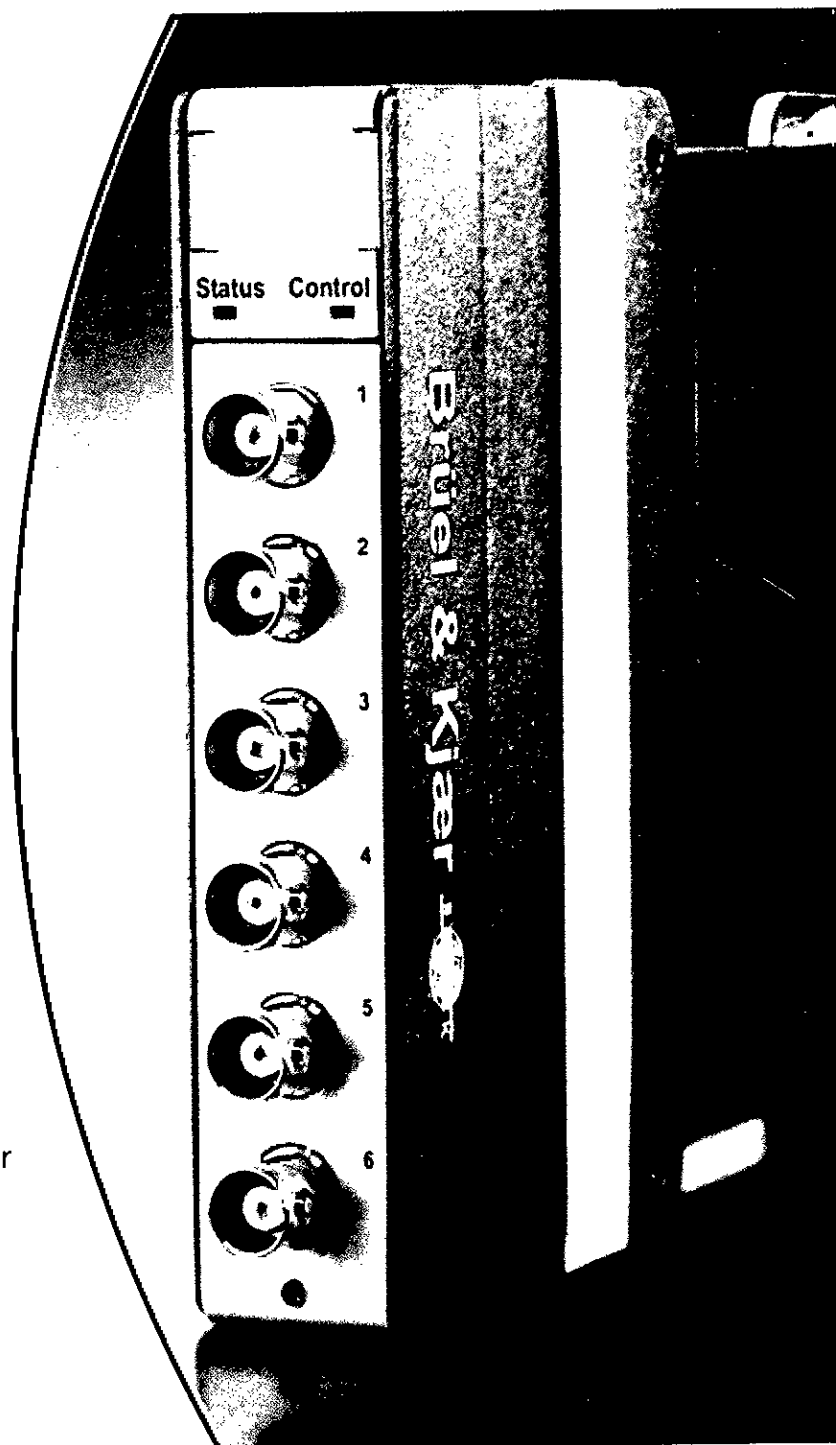
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Dear Members

As I write this letter Euronoise 2009 is only just over a week away. This is the most important IOA event that will take place during my presidency. It is apt that the conference is organised after the completion of the first round of noise mapping and the development of noise action plans required under the Environmental Noise Directive. A number of sessions at the conference will address these and related subjects. I am very excited about the conference and by the time you read this letter I am sure we will be looking back on a highly successful and enjoyable event.

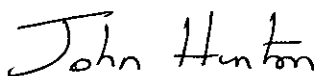
As you can imagine the Institute is extremely busy with the organisation of Euronoise. Nevertheless, preparations are already in hand for further meetings and conferences including the joint IOA and Belgian Acoustics Association conference on Noise in the Built Environment which will be held in Ghent during April 2010 (see Institute Affairs in this Bulletin for further information) and a joint conference with the International Commission on the Biological Effects of Noise that will be held in London during July 2011. We have also expressed interest in organising, the European Conference on Underwater Acoustics 2012, Inter-Noise 2013, the International Congress on Sound and Vibration 2013 and Forum Acusticum 2014.

I am pleased to inform you that the Institute has recently responded to two more public consultation documents. One was the consultation on proposed changes to Part F and Part L of the Building Regulations. Our response was prepared by the Building Acoustics group and is reproduced in this issue of Acoustics Bulletin. I give my thanks to the group and in particular to Peter Rogers. The other consultation was on proposed amendments to the Building (Scotland) Regulations 2004 and the Technical Handbooks. Our response was prepared by our Scottish branch with input from the Building Acoustics group. Many thanks to all involved and in particular to Alistair Somerville who prepared the final response, which should be available on the web site <http://www.scotland.gov.uk/consultations> from November 2009. The IOA has also received an update from the Department for Children, Families and Schools concerning further progress on the review of Building Bulletin 93, also included in this issue.

I am watching with interest the development of proposals for the formation of a Senior Members' group, not least because I may soon qualify to be a member! One of the suggested tasks for this group is to chart the early days of the Institute following its formation in 1974, before everybody has forgotten what happened! If anyone is interested in helping to shape the development of the group please contact Geoff Kerry by email: geoffkerry@tiscali.co.uk.

Some of you will have noticed recent changes in personnel at HQ. Firstly, Pat Slade has retired after four years of service. We wish her all the best for her future. Just before Pat left she told me how much she enjoyed working for the IOA. Some of the credit for this must be down to Kevin Macan-Lind and his staff at St Albans. Interviews to fill Pat's position of administration assistant have begun. The second change concerns the recent appointment of Debbie White as our new publicity officer, and we are very much looking forward to working with her.

Finally, with everything else that is going on please do not forget Reproduced Sound 25 'The audio explosion' which takes place in Brighton on 19 and 20 November 2009 and is, of course, organised by our Electroacoustics group. Further details are available on our web site.



John Hinton OBE

PRESIDENT



Response to the consultation on amendments to part L and F of Building Regulations (2010)

Peter Rogers. On behalf of The Institute of Acoustics (approved 15 September 2009)

These comments relate entirely to the proposed Appendix 5, and the principle that too much noise may cause people to reduce ventilation to keep the noise down and risk their health as a result.

The Institute of Acoustics welcomes the recognition that unwanted sound ('noise') from mechanical systems needs regulating to protect health of people in their homes. Our comments relate to the principles of controlling the ambient noise climate in the home, and with specific comments on the proposed objective levels set out in Appendix E.

Concept

The home can sometimes be quite a noisy place, whether it be noise breaking in from outside through open or closed windows, or noise from essential appliances like the refrigerator or central heating. Running some appliances such as washing machines, cooker extractors or dishwashers, generates noise, however this is within the control of the occupant in terms of timing and frequency of use. When people are sleeping or relaxing there needs to be the right environment for this to be possible, without interference from mechanical systems. The reason for Appendix E being proposed seems to be principally because of the fear of discouraging use of whole house systems, however a wider consideration of the noise in our homes is perhaps of merit to test the suitability of the approach encapsulated in the proposals.

The benchmarks for noise ingress into the home remain BS.8233:1999 and WHO guidelines currently, which work to sound pressure level values of 30dB (A-weighted over an 8-hour night period) for a 'good' standard in bedrooms, and 30dB (A-weighted over a 16-hour day period) for a 'good' standard in living rooms. This will be revisited when considering the proposed limits.

A continuously running domestic mechanical ventilation system therefore needs to be sufficiently quiet so as to not discourage the occupant from obtaining sufficient ventilation. It should also be borne in mind however, that when trying to achieve the above standards in rooms, noise from such ventilation systems should also not raise internal noise levels significantly above these targets. Conversely, the constant noise created by a ventilation system serves to remind the occupant that the system is operating, and combines with sound insulation between homes to determine the overall privacy experienced. This latter point is relevant as making such systems too quiet would not assist in this regard. This can be a problem when facades are sealed and passive systems do not provide any meaningful background noise.

Part E of the Building Regulations deals with sound insulation, and by including noise limits within Part F there is the opportunity to 'join-up' the thinking and assist the aims within Part E so as to achieve enhanced levels of privacy between dwellings, providing that the balance is considered carefully. By working to the above principle, a modicum of services noise may be useful to optimise privacy between dwellings, in conjunction with Part E and the Code for Sustainable Homes, without creating internal noise conditions which are intrusive or likely to affect the way people use the systems.

The Institute would agree that at this point in time it does seem eminently sensible to include some sort of acoustical limit where mechanical systems are used, and indeed this would equally apply to hybrid systems which will also generate internal noise levels that will affect habitable environments. The distinction between a full house mechanical system and a hybrid one that uses mechanical elements to assist passive systems seems to be almost semantic now.

There is recognition within sections 4.33, 4.34, 4.35 and 5.37 that the ingress of environmental noise through the systems themselves and the effects of noise generated by the systems upon the environment also need to be taken into account, however these are generally dealt with through the planning system.

Proposed objective limits

Considering Appendix E of the consultation proposal in detail, the following comments are put forward.

- The choice of sound power level (L_w) as a parameter is understandable, because of the need to deal with regulation off site without testing, but the figures stated would suggest that these are in fact sound pressure levels (L_p). The figures are considered to be incorrect as currently proposed and should be reviewed.
- BS EN 13141 is a perfectly reasonable standard for quantifying the L_w of a device, but this is an inherent quantity of energy of the unit rather than the behaviour in the system, which equally needs to be considered with the help of an acoustician. The merit of using L_w for a laboratory test is considered valid, and assessment in third-octave band values is welcomed as requiring manufacturers to make available data that is not currently standard practice. This information can then be used in the assessment of mechanical systems to predict the operational noise levels in the dwelling. It might be advisable to include a simple Sabine conversion calculation from L_w to L_p as part of the standard to allow comparisons with the Part F limits, or to allow consideration by assessments against standards such as WHO or BS.8233:1999.
- Field testing of the sound pressure level *in-situ* can be fraught with difficulty when the noise source levels are close to the background levels. It would therefore be useful to note this in the guidance.
- There is no mention of the reverberation conditions that should be assumed to be the benchmark, whereas Document E (via ISO 140) assumes that a typical room would have $T_{20} = 0.5$. This would assist in avoiding grey areas of assumptions to help check that any figures proposed are reasonable.
- The figures proposed in Table E1 seem to be approximately 5dB too high if they are L_p values, and too low if they are L_w figures. It is considered an appropriate aim not to raise internal levels significantly above the BS.8233:1999 standard for 'good', when the system is at full duty, and although there is no need for an explicit reference to the standard this principle should be part of the thinking behind setting the limits in part F, Appendix E. It

is considered therefore that limits 5dB below the figure (ie 25dB in bedrooms and living rooms) would only then raise the combined level to 31dB. Therefore if planning restrictions aim to keep environmental noise below 30dB in bedrooms this approach would not compromise the quality of acoustic environment and potentially add some useful masking of transportation source noise also.

- There is no clear guidance on what Standard for sound power measurement should be used when the radiated noise is tonal. This requires clarification in the guidance.

It is likely to be necessary to be spell out that advice needs to be sought to check that the acoustic performance of the domestic system design will not compromise the internal noise climate. Reference could then be made to the standards set by BS.8233 (or other relevant considerations eg a planning condition) if considered appropriate. This is particularly important where the on-site compliance route via measurement is chosen, in which case we would advise proceeding with caution.

Point 12 seems to be suggesting that where necessary to meet the values in Table E1, attenuators might need to be added to the system. This is fine, however duct-borne fan noise is simply one aspect of a ventilation scheme design. The system really needs to be checked and calculations provided to show that the targets have been achieved, and with the measures taken to do this set out (eg measures such as avoiding tortuous duct routes and excessive duct air velocities so as to control regenerative noise in the system). This is fairly standard practice for acousticians and could be dealt with by requiring that a report by a competent acoustician be provided, to supply evidence of how the performance requirements are to be achieved. This is then consistent with some aspects of Part E eg the calculations needed to support the control of reverberation in common areas.

Finally, the applicability of this section to hybrid passive systems certainly seems to be equally strong as for pure mechanical (HVAC) systems, where there is prolonged use of mechanical systems to assist the otherwise passive ventilation process.

In conclusion, the Institute of Acoustics supports the principle for this Appendix, but has concerns over the proposed application of parameters and the figures offered. We strongly advise a review of the performance criteria to make sure they are correct and achieve not only the intent to prevent people from being discouraged from using such systems, but also so that they will not compromise the quality of the internal acoustic environment for occupants. It is thought likely that the industry will not receive this Appendix at all well, as the use of L_w to assess a system is not common at present for such systems and may introduce a new field not understood by many suppliers. It is likely that this would force assessments by acousticians to produce calculations to demonstrate compliance. If this is the intention then it should be clearly stated that such assessments should be completed and submitted for approval to Building Control.

It is hoped that these initial comments are of assistance.

The Institute would welcome the opportunity to provide input more directly to this section to get the limits and parameters right. Currently it is feared that this may undermine the importance of domestic services noise at a time when where we are looking toward improving internal soundscapes to improve health and wellbeing within the sustainability remit.

Peter Rogers - Chairman, Building Acoustics Group



Institute of Acoustics Medals & Awards Programme 2010

The Institute of Acoustics annually honours people whose contributions to acoustics or to the Institute have been particularly noteworthy. The medals and awards programme has evolved over the years and is now quite wide ranging in its acknowledgment of academic achievement, practical engineering applications and innovations, student achievement and contributions to the Institute and to the world of science and technology.

The medals and awards programme is overseen on behalf of Council by the Medals and Awards Committee, which is chaired by the President. Nominations may be made at any time either on standard forms available through the Institute's office or by writing direct to the President.

For more information or to download a nomination form, please visit the IOA web site:

<http://www.ioa.org.uk/medals-and-awards/>

2010 nominations deadline is 31st January 2010

IOA certificate pass list

Certificate Name: Certificate of competence in workplace noise risk assessment
Exam Date: 6 March 2009

Colchester Institute	EEF Sheffield	Schofield W D	Hagar B	Shorcontrol Safety Ltd	Gibbons R
Judd M	Cowan L	Thain A	Mudd B C	Baker E	Mallon C
Le Brigant R	Mitton J Y		Murphy S	Bates G	McGarry S
Marshall S	Nixon P A	EEF Northern	Stoker G M	Byrne S F	McLogan D
Takacs Z	Osborne S C	Bullock T E		Donovan J	Molloy S
	Partridge J E	Forde T J			Woulfe J G

Certificate Name: Certificate in the management of occupational exposure to hand arm vibration
Exam Date: 24 April 2009

EEF Sheffield

Dent W Edwards M Evans M J Lewis C Vallely P W

Certificate Name: Certificate of competence in environmental noise management
Exam Date: 15 May 2009

Bel Educational Noise Courses	University of Birmingham	University of Derby	Liverpool University	Thomas S R	Gallagher A
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Duffy K A		Knowles A R	Hall C	Holmes S K	University of the West of England
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Little E	Chen J	Squires J P	Little D		Jarvis R
Meechan E S	Coughlin E J	Whitehead A L	Roberts R	Shorcontrol Safety Ltd	Lowry M L
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			Selwyn T		

New members

The IOA Membership Committee meeting on 7 May 2009 made the following recommendations to for new members to Council. These were ratified on 18 June 2009.

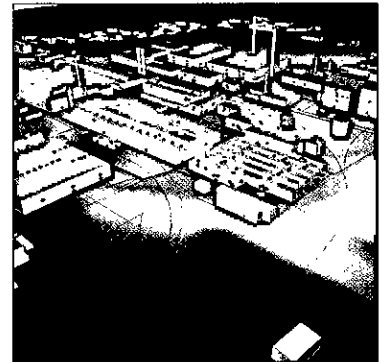
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Bristow A L	Lovell J M	Bagherpour M	Sedgman, T R	McMeel S
	MacDonald R R Member	Bhalla P	Stewart, D M	Thompson A
Member	Magloire E	Cho Y	Witty, K P	
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Cook A R	Murray P B	Edwards J T	Adegboye E A	Larrazabal I M
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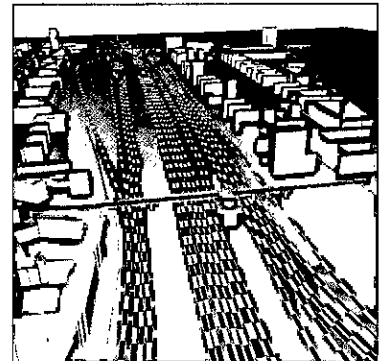
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Committee news

Peter Wheeler. Engineering Division

The numbers of Institute members gaining Engineering Council registration has continued to grow over the past twelve months, following the record year reported in the September/October and November/December 2008 issues of the Bulletin. Helen Butcher CEng (Arup Acoustics) and John Lloyd CEng (AECOM) have become members of the Engineering Division committee and they will join the team of Professional Review interviewers in due course. Kirill Horoshenkov CEng will also join the team of interviewers for 2010.

Engineering Council registration may be gained by corporate members of the Institute who can demonstrate that they have acquired the relevant engineering expertise exemplified in the publication *UK Standard for Professional Engineering Competence (UK-SPEC 2008)*. We offer candidates advice and support in the development of their portfolio of evidence for interview - just contact acousticsengineering@ioa.org.uk or contact the office by telephone or post.

In the last year, Angus Deuchars (Arup Acoustics), Richard Budd (Sound Research Laboratories), Ned Crowe (Arup Acoustics), Philip Wright (Arup Acoustics), Teli Chinelis (Hann Tucker Associates), Anthony Frost, Steven Gates (BAE Systems Submarines), Steven Swan (Arup

Acoustics), David Owen (Arup Acoustics), Yuyou Liu (Adnitt Acoustics), Andrew Monk-Steel (Mott MacDonald) and Xiaozhen Sheng (Cummins Turbo Technologies) have all been successful at Professional Review interview.

We are considering applying for a licence to register Institute members as EngTech. This category of Engineering Council registration is especially relevant to those members working in testing and instrumentation areas, including many Technician Members. More information can be found on www.engc.org.uk.

Members, or their employers, interested in this category of registration should contact the Institute at acousticsengineering@ioa.org.uk for further information.

If you are already registered with the Engineering Council, either through IOA or another institution, and would like to play a part in our committee work, interviews and support to candidates, please contact us as above.

We are also seeking to develop closer links with the many UK Universities now offering degrees in the broad area of audio engineering, whose graduates are joining acoustic consultancies, in order to promote closer collaboration in professional development. We are proposing IEng registration for young acoustics and audio engineering graduates as a valuable benchmark in their career development. If either of these initiatives interests you, just contact us, as above.

Peter Wheeler CEng HonFIOA, for the Engineering Division Committee

Meeting report

Nigel Triner. London Branch

The London branch meeting of 15 April 2009 took as its subject *Experiences of Implementing the First Round of the Environmental Noise Directive* and was presented by Nigel Jones and Matthew Burdett of Extrium Ltd. Matthew started the presentation by running through the definitions set out in the Directive, such as agglomerations, major roads or railways. These terms are not defined as precisely as might be first thought, with Member States having considerable leeway in their interpretation.

Nigel then moved onto the key implementation issues, which he listed as acoustic understanding, data, GIS, noise calculator, IT infrastructure, and project management.

Acoustic understanding included, for example, the selection of appropriate calculation methodologies, such as national or interim methods. *Data* was one of the key issues because the data are often 'second-hand' and not specifically developed for noise mapping.

The *GIS* or geographical information system is important because the Directive is a spatial policy. The *noise calculator* used obviously brought up many issues, such as whether or not the chosen software package supported the required method, and whether or not it linked into a GIS environment.

IT infrastructure could be a significant factor, as serious computing power was often required for the noise predictions, and *project management* was a critical issue when dealing with large complex projects.

Nigel then outlined the reporting mechanism to the European Commission (EC). This consisted of 11 individual reporting obligations, called 'data flows'. The process suffered from a number of problems which resulted in the development of a relational database - the Electronic Noise Data Reporting Mechanism (ENDRM).

Nigel reminded us that the noise maps were not the final output but were a stepping stone in the noise action planning process.

The presentation ended with the usual question-and-answer session with one hot topic being the issue of the merits (or not) of combining noise levels from different sources into a single value.

Call for papers

Inter-Noise 2010

Inter-Noise 2010, the 39th International Congress and Exposition on Noise Control Engineering, will be held in Lisbon, Portugal, from 13 to 16 June 2010. The congress is sponsored by the International Institute of Noise Control Engineering (I-INCE), and is co-organised by the Portuguese Acoustical Society (SPA) and the Spanish Acoustical Society (SEA). The congress venue will be the modern Lisbon Congress Centre, located on the north bank of the River Tagus in a new rehabilitated tourist waterfront area, full of amazing gardens and esplanades.

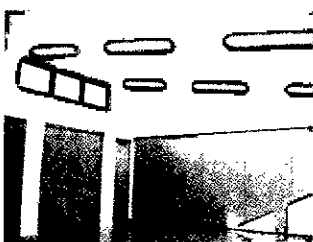
Spread over seven hills, Lisbon boasts over 2000 years of history, witnessed by many monuments and historical sites well worth exploring. From Roman town to capital of the Discoveries, evidence of this rich historical background is there to be explored. Lisbon is also an exciting cultural city, offering an array of events from museums and to theatres to music festivals catering for all tastes. With average temperatures rising well above 20°C, June is the perfect time to visit this bustling metropolis. By day or by night, there will always be monuments, historical landmarks, shopping centres, cultural sites and open-air locations to be enjoyed. Having all this potential, Lisbon is an ideal and pleasant location for the congress.

Despite the fact that the congress will be held in Lisbon, it represents the involvement of all the Iberian peninsula. The main theme is **Noise and Sustainability**. Everyone knows that the development of society creates noise as a by-product. Sustainability enforces and highlights the need to preserve the future generation's stability and existence, without compromising the global development. The junction of these aspects sets up a strong responsibility for the acoustical community as a whole.

Interested acousticians are invited to submit a paper and participate in this event. Papers related to the technical areas of building and environmental acoustics, education, psychological and physiological acoustics, speech, measurement and analysis, equipments, noise and vibration tools, material and technologies for noise and vibration solutions are especially welcome for presentation at the Inter-

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Noise 2010 Congress. The deadline for the receipt of abstracts is 15 January 2010. Notification of the paper's acceptance will be sent to authors on 1 March 2010. Manuscripts for publication in the conference proceedings are due on 1 April 2010.

Many distinguished speakers will share their knowledge and experience with the participants in ten parallel sessions.

The following plenary lectures are already scheduled:

1. *General view of road traffic noise problem* by Prof Hideki Tachibana
2. *Noise attenuation and comfort* by Prof Samir Gerges
3. *Effectiveness of noise barriers* by Prof Gilles Daigle
4. *Economics of noise* by Prof Abigail Bristow
5. *The tuning of noise pollution with respect to the expertise of people's minds* by Prof Brigitte Schulte-Fortkamp

A large number of exhibitors are expected to attend the congress showing and promoting their latest tools, equipments and recently developed materials. Three short courses on emergent and important themes are also planned.

In addition, there will also be a wide range of social activities as well as pre- and post-congress tours to wonderful and fascinating places, such as Madeira and Azores archipelagos.

Inter-Noise 2010 will be a very important and fruitful event, and a great opportunity to promote and show the scientific research and development of noise control engineering in various fields of applications, to meet old friends and make new acquaintances and partnerships.

For additional information please visit the web site:
www.internoise2010.org.

Looking forward to meeting you in Lisbon.

Jorge Patrício (SPA), Antonio Pérez-López (SEA) - Co-presidents, Inter-Noise 2010

Erratum

In the article *Prediction and assessment of wind turbine noise* which appeared in volume 34, no.2 of *Acoustics Bulletin* (March/April 2009) an error has been noticed. The text needs to be corrected, especially in view of the increasing acceptance of the subject Agreement in the wind energy field. Page 36 of the article has a bullet point which reads:

- On some sites and in some wind conditions the situation may arise that the wind speed U_1 (at the greater height H_1) is equal to or lower than the wind speed U_2 at the lower height H_2 . In this situation, the wind shear calculation specified above should not be performed and our suggestion at this time is that the hub height wind speed should be assumed to be the same as the wind speed at the upper height H_1 .

Incorrect parameters are referenced in the text which may cause confusion, therefore the bullet point should be amended to read:

- On some sites and in some wind conditions the situation may arise that the wind speed U_2 (at the greater height H_2) is equal to or lower than the wind speed U_1 at the lower height H_1 . In this situation, the wind shear calculation specified above should not be performed and our suggestion at this time is that the hub height wind speed should be assumed to be the same as the wind speed at the upper height H_2 .

In other words, the wind speeds U_1 and U_2 at heights H_1 and H_2 were accidentally transposed in this bullet point and nowhere else.

New faces at St Albans

Recent staff appointments

Debbie White has recently joined the Institute of Acoustics as its new publicity officer.

A senior journalist with newspaper experience in both New Zealand and Australia, the Antipodean is very pleased to be part of the IOA. Since moving to the UK in 2006, Debbie has gained PR experience in Hertfordshire - particularly writing for the web.

With October's international Euronoise 09 conference in Edinburgh, the Reproduced Sound 25 conference in Brighton in November and a 'motor sport noise' event at Silverstone in March 2010, Debbie will have plenty of major meetings to cover and promote to the press.

She is looking forward to meeting IOA members and publicising their work and contributions to the world of acoustics.

Please contact Debbie with anything related to acoustics requiring publicity through the Institute on debbie.white@ioa.org.uk.

Eleanor Sutton has joined the team at Head Office as a replacement for Pat Slade who retired recently. Ele has a wealth of experience having had a number of secretarial and office-based roles over the past 24 years.



Debbie White



Eleanor Sutton

'I am looking forward immensely to many years working for the IOA. I know that I have a hard act to follow', commented Ele.

'Ele is an essential addition to the staff at the IOA and I know that her enthusiasm and sense of humour will be a tremendous asset, and will be popular with the membership too', added Kevin Macan-Lind. 'Her arrival follows swiftly on from Debbie White's. The IOA's new publicity officer has already started to make an impression and her expertise and experience will be invaluable'.

Meeting report

London Branch

WHO Night Noise Guidelines for Europe – Ssh! It's oh so quiet

Sleep is an essential part of human functioning and can be adversely affected by noise. The World Health Organisation Regional Office for Europe has set up a working group to provide scientific advice to the European Commission and its Member States for the development of future legislation and policy in the area of assessment and control of night noise exposure. The working group has reviewed and reached general agreement on proposed guideline external noise levels for a final document on night noise guidelines (NNGs) for Europe as follows.

- An $L_{night,outside}$ of 30dB should be the ultimate target of the night noise guideline (NNG) to protect the public, including the most vulnerable groups such as children, the chronically ill, those with sleep problems and the elderly.
- $L_{night,outside}$ values of 55dB and 40dB are recommended as interim targets I and II for the countries where the NNG cannot be achieved in the short term for various reasons, and where policy-makers choose to adopt a stepwise approach.

In his presentation on 17 June 2009 Dani Fiumicelli, technical director of AECOM, discussed the proposed night noise guidelines for Europe, and looked at the development of the guidance and considered distribution of sound levels across the UK compared with the NNGs. He also examined the sustainability and implications of use of the proposed NNGs.

Dani explained how the proposed NNGs had been derived and that they represented noise levels above which an effect started to occur or showed itself to be dependent on the exposure level. But this was tempered by the fact that NNG threshold of observed effects do not establish the significance of effects, which may not become significant until values higher than the threshold of effect level, ie the NNGs, are exceeded. Dani also pointed out that using the NNGs as guidelines for planning control seriously risked preventing sustainable development as there were very few locations in the UK suitable for meeting the identified massive future housing needs where such noise levels existed, and that even if such locations could be found, keeping the post development noise levels as low as the ultimate NNG would not be

practicable without sacrificing other important sustainability objectives such as decreased car use, increased use of public transport, and local access to employment, leisure, education and health resources. Dani went on to point out that it may be desirable for none of the adverse effects of noise to occur. But this could only be achieved if noise impacts were considered in isolation, without contemplating the degree of impact, and the historical, planning, social, cultural, health and economic consequences of such an approach. Additionally the audience was reminded that noise is inevitable in a thriving and sustainable economy, and acceptance of a degree of noise can be necessary to achieve more desirable overall planning and health objectives. The significant drawbacks of the WHO NNGs were highlighted, including: not considering the practicability of achieving any of the recommended noise levels; the insistence on setting external exposure levels rather than internal 'doses' ie assuming low levels of building envelope insulation (open windows); and ignoring the point that high quality building design and construction could be used to achieve good internal noise levels - after all, noise levels in external amenity spaces should rarely be an issue at night! In conclusion, Dani commented that as they stood the proposed NNGs:

- Were very precautionary/risk averse
- **Did not** indicate significant impacts
- Were already widely exceeded across UK
- Could inform, but should not dictate policy
- Had an ultimate target which was unrealistically low
- May not be sustainable in many cases.

During the question and discussion period of the meeting several members of the audience reinforced the view that the proposed NNGs were unrealistically low and consequently risked being sidelined as unworkable. Additionally, the point was made that the working group that had proposed the NNGs appeared to have gone beyond their brief of providing advice to the EC and Member States, and were now looking to set policy: this should remain the responsibility of the EC and individual member states.

Conference notice

Springtime in Ghent

This is to remind members that six months after Euronoise, there is another opportunity to participate in a European conference. Next year's IOA Spring Conference is being held jointly with the Belgian Acoustical Association (ABAV) on Thursday 29 and Friday 30 April 2010. The meeting is supported by the European Acoustics Association as an EAA Symposium.

The conference is to be held in the beautiful city of Ghent in Flanders, Belgium. Ghent is a 30-minute train ride from Brussels and can be reached in around three hours by train from London St Pancras.

The conference venue will be the university conference centre, Het Pand, an ancient and beautiful former monastery in the very centre of Ghent. There are several hotels in all price ranges nearby as well as many cafes, bars and restaurants. It is planned to hold the conference dinner in the Gravensteen, the old castle in Ghent, which is a five-minute walk from the conference venue.

The theme of the conference is 'Noise in the built environment' and papers are invited on any topic within this theme, including soundscapes; tranquillity; transportation noise; classroom, hospital and entertainment noise; environmental noise measurement and policies; sound insulation; health effects of noise; noise induced hearing loss and hearing protection; noise control; industrial noise; noise mapping; and wind farm noise.

Plenary lectures will be given by Prof Keith Attenborough (*Acoustical exploitation of periodic structures in the urban environment*), Prof Massimo Garai (*Recent advances in noise barrier testing, qualifying and standardisation*), Prof Jian Kang (*Soundscapes: where are we?*), and Dr Patrick van de Ponsele (*Recent advances in sound quality*).

Further information will be published on the IOA website as it becomes available. The closing date for abstract submission, by email to Linda Cauty at linda.cauty@ioa.org.uk, is 13 December 2009: full papers are to be submitted by 1 March 2010.



Het Pand, the university conference centre



Gravensteen castle

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- The ANC guideline documents and Calibration Kit are available to Members at a discount
- Your views will be represented on BSI Committees - your voice will count
- Your organisation will have the opportunity to influence future ANC guideline documents
- ANC members are consulted on impending and draft legislation, standards, guidelines and Codes of Practice before they come into force
- The bi-monthly ANC meetings provide an opportunity to discuss areas of interest with like minded colleagues or just bounce ideas around
- Before each meeting there are regular technical presentations on the hot subjects of the day

Membership of the Association is open to all consultancy practices able to demonstrate, that the necessary professional and technical competence is available, that a satisfactory standard of continuity of service and staff is maintained and that there is no significant financial interest in acoustical products. Members are required to carry a minimum level of professional indemnity insurance, and to abide by the Association's Code of Ethics.

www.association-of-noise-consultants.co.uk

Meeting report

Martin Armstrong. Did you hear that? Concepts of audibility and inaudibility

Sh! Sh! Please keep quiet! This was the background to the Measurement and Instrumentation group's one-day meeting held on 23 June 2009 at the Royal Society, a society renowned for quiet contemplation and learning. This also applied to the delegates who enjoyed an informative day on a subject that can prove difficult to quantify.

The meeting was organised by **William Egan** of Brüel and Kjær UK, who assembled a wide range of speakers covering aspects of 'not clearly audible noise' to 'clearly audible warning signals', and many points in between.

The first paper was by **Simon Hill** and **Ben Coleman** of South Oxfordshire District Council and titled *Clearly audible licence conditions - a pragmatic approach*. Their focus for noise control from licensed premises was for the local environmental health authority to avoid the need to set a precise noise level. If a level is set too low then it may be unnecessarily onerous. The wording of the conditions applied by the Environmental Health department was for noise emanating from the premises, as a result of regulated entertainment, not to be '...clearly audible at the boundary of any adjacent residential premises'.

The approach taken following a complaint was to listen inside the complainants' property and determine if the music could be heard. If it was clearly audible then the condition had been breached at the boundary. Such an assessment is within the skill set of the Environmental Health staff. A case study was highlighted when a technical assessment showed that the noise was audible and the licensed premises were in breach of the conditions. However 3 non-technical councillors did not agree and the conditions were not enforced.

The second paper moved outdoors to look at music noise from daytime rock concerts and other smaller events at night. Many of these were one-off events where the aim was to achieve inaudibility within noise-sensitive premises. **Rob Pierce** of Vanguardia Consulting said this inaudibility target was typically with windows open for ventilation. A level of 45dB $L_{Aeq,10\ min}$ at the façade correlated well with subjective assessments. For larger events, which radiated over a greater area, the 63 and 125 Hz bands were set beside the L_{Aeq} levels. However more research was needed on subjective responses to low-frequency (LF) noise.

Andrew Monro of Monro Acoustics next considered the difficulties with LF noise and that hearing thresholds in standards were in error. Examples of sounds up to a few dBs above NR15 could remain inaudible, which showed that inaudibility was not the same as measurability. Using L_{max} over $L_{eq(20sec)}$ had been found to be clearly useful as a criterion for audibility.

The fourth paper looked at the operation of the 2003 Licensing Act. **Michael Eade** from the ENcentre listed the liberalised conditions in the Act and said that they should be phrased in simple terms, be clear and unambiguous, be easily understood by all and be able to be monitored. The main criterion should be the prevention of public nuisance, but were inaudibility conditions compatible with the Licensing Act? The regime is still relatively new and it will take time to shape the law as licensing is a permission to pollute, not a zero-tolerance approach.

Inaudibility and annoyance are not the same because a tonal noise can give rise to complaints if it is only just audible. **Dan Saunders** from Brüel and Kjær UK explained the method contained in ISO 1996-2:2007 for measuring tonal audibility and moved on from that to provide a tone-corrected rating level. Modern sound level meters now incorporated FFT analysis able to search for tonality, and having identified a tone were able to make a wave recording.

The AGM of the Measurement and Instrumentation group took place before lunch. William Egan chaired the AGM as Richard Tyler, the group chairman, was unable to attend. William read out the chairman's report on the past year's activities. The four retiring members of the committee, Martin Armstrong, Elizabeth Brueck, Ian Campbell and William Egan were re-elected. A new co-opted member, Paul Hopwood, was elected.

The afternoon sessions looked at audibility starting with **Ian Cushing** from the University of Salford. He described the near-field speech levels and frequencies around a talker. The standard reference used in telephony was at 1 metre on-axis. In many situations with hands-free headsets, lavalier microphones, and other close microphone placements, the speech spectra could be quite different. This could present difficulties in automated speech recognition systems as the quality was impaired. The results of a pilot study using phonetically balanced speech



William Egan introduces the first speaker



Excellent conference facilities at the Royal Society

materials under controlled anechoic conditions were presented.

Jacqueline Patel from the HSE Laboratory, Buxton presented a paper on *Audibility of warning signals - Learning lessons from incidents*. The problems encountered in providing effective audible warnings in the work environment were the possible masking effects of the general noise, the hearing protection worn, plus any hearing losses, and other communication systems in use. The work presented covered investigations following workplace incidents resulting in injuries or fatalities. Were warning signals loud enough or distinctive above the ambient noise at the time of the incident? BS EN ISO 7731 was mentioned: was L_{Amax} the best parameter? Jacqueline concluded that audible warnings had an important role in attracting attention.

The final paper was a wide ranging one by **Peter Mapp** of Peter Mapp Associates, on *The audibility and inaudibility of speech - privacy, distraction or nuisance?*. Public address announcements could be very intrusive as even 0dB signal-to-noise ratios could be intelligible, and even at negative S/N ratios discrete words and phrases were discernable. As speech was both tonal and impulsive in nature, then from BS.4142:1997 a penalty weighting factor of 5dB should be applied. Should metrics such as L_{10} or

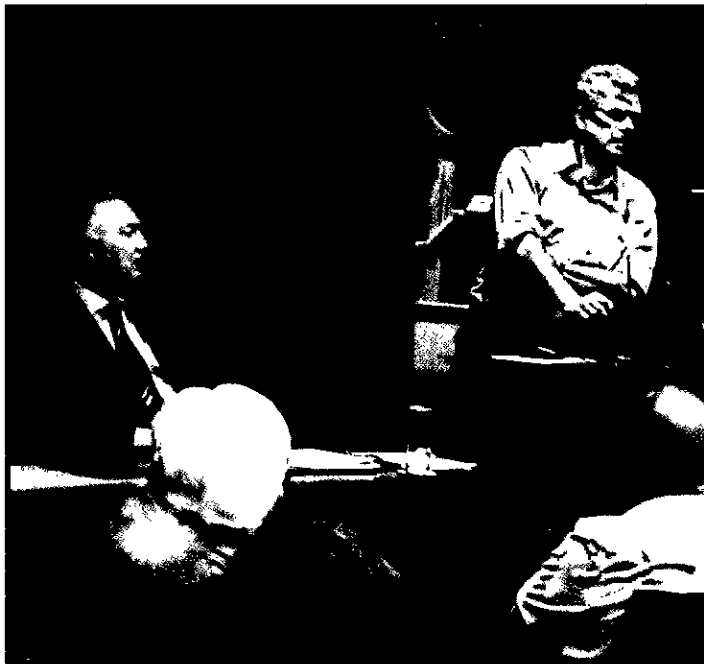
L_{01} in place of L_{eq} , whether A-weighted or otherwise, be used? Several case studies were covered where problems had arisen, for example at a speedway track where high mounted loudspeakers proved to be a disadvantage, radiating further afield than the bikes at ground level. Locating the loudspeakers nearer to the ground, to broadcast at the spectators, was the solution.



Martin Armstrong takes a question from the floor



Pleasant surroundings for 'networking'



Peter Mapp on 'inaudibility'

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Acoustics in schools

Richard Daniels. BB93 update

In late 2008 the BB93 review panel was re-convened in order to assess whether the document required updating. The unanimous decision that an update was required and a call for feedback was posted just before Christmas 2008 to the IOA and other stakeholders.

Following feedback received, including a joint IOA/ANC meeting held in February (from which the IOA formal response to the feedback request was formulated), the review panel met to work through the points raised and formulate a response to the DCSF and DCLG with the purpose of becoming the basis for the revision.

The revision project manager, Les Fothergill, subsequently prepared a revised version of BB93, taking into account the items raised and discussed as part of the review process and he submitted the finalised revision to DCSF/DCLG in March 2009. The intention was for the revised BB93 to be published within a month or so of this process being completed.

But then, silence...

After the mad rush to get the revision completed within the given timescales, the document never materialised. A formal query was put to DCSF by the Building Acoustics group in August to request an update on behalf of membership, as there was general annoyance and dissatisfaction at the lack of information regarding the status of the updated document. The following response was received from DCSF, which answers many questions from membership.

'Thank you for your e-mail on behalf of the Institute of Acoustics Building Acoustics group. We appreciate the time and help that you all gave to produce a draft revised Section 1 of BB93 as well as revised Section 6 and various consequential changes to the appendices. These will be invaluable in our ongoing revision of BB93.'

The original timescale for the review of Section 1 of BB93 was to some extent a result of DCLG funding for Les Fothergill to conduct the consultation process only being available in 2008-09.

The reason why we have taken so long to inform you of our plans is that these have been changing as a result of ongoing discussions and consideration of acoustics in schools prompted to some extent by NDCS lobbying of ministers in DCLG and DCSF.

The design team in DCSF is currently working on a project plan for acoustics in schools. An outline of the work we propose on follows. We would welcome your comments.'

DCSF Project: Acoustics in Schools

Proposed work outlined

Introduction

Good acoustic conditions are essential to good teaching and learning and a particular need for hearing impaired children who are increasingly attending mainstream schools. Providing schools that support the needs of all children and young people is in keeping with the aims of the recently published White Paper *Your child, your schools, our future: building a 21st century schools system* which calls for a system which develops every child's potential giving them the broad skills they need for the future.

BB93 needs some technical updating and most of this already exists in the draft of Section 1 which IOA and ANC helped to produce with funding from CLG. In addition we need to ensure that the guidance can be applied to 21st century methods of teaching and learning.

Current developments in teaching and learning styles are leading to more flexible - and in some cases more 'open plan' - spaces which need to be thoughtfully designed to ensure a suitable acoustical environment.

Some designers have been using alternative performance standards in order to comply with the regulations on acoustics because they have had difficulty in applying the standards in BB93 to these kinds of spaces.

Aim / vision

The aim of the project is to raise awareness of the importance of the acoustical environment for successful learning and teaching and for building professionals and their clients to have all the information and guidance they need to:

- Build schools with a good acoustic environment that suits a range of teaching and learning method, and
- Use spaces appropriately to ensure all children and young people can take part in a full range of learning and social activities.

Outcomes

In order to achieve the aims outlined above, we need to ensure that:

- Clients understand the key principles of acoustics and the implications of choosing different kinds of spaces;
- Building professionals know how to use Building Bulletin 93, Acoustic Design in Schools (BB93);
- Our design guidance is fully up to date and can be applied to 21st century methods of teaching and learning, and takes full account of people with hearing impairments.

We propose the following work:

- Produce a design practice note explaining the key principles of good acoustic design, to complement the DCSF's technical guide BB93, by the end of 2009 or early 2010 if it includes case studies.
- Evaluate up to ten primary and secondary schools, looking at the acoustic environment of key spaces in each school, in particular open plan areas, how designers met the requirements of BB93, the link between activities taking place and the acoustic requirements, and what management procedures are in place to ensure the acoustical environment meets the needs of the activities. Publish a selection of the evaluated schools as case study examples. All this is to be completed by early 2010.
- Update BB93, informed by the investigatory work above. A draft revision of Section 1 (the section referred to in Building Regulations Approved Document E) has already been carried out by DCLG and this will need to be reviewed. An updated BB93 informed by the evaluation work and other studies would then be produced. We may then need to go out to public consultation on the revised BB93 depending on the extent of the revision.

In addition, to ensure consistency across all DCSF/PfS guidance on acoustics:

- Update the acoustics section of Building Bulletin 86, Music Accommodation in Secondary Schools (BB86) as part of the revision to the whole document (already commissioned and scheduled for completion by the end of June 2010).
- Consider how to revise the Standard Specifications for Layouts and Dimensions (SSLDs) on floors and partitions, to ensure consistency with BB93.
- Update acoustical sections of other linked documents and web sites including the 'school buildings' acoustics webpage and PfS's standard contract documents.

The table on the following page gives a brief description and an outline of how the work is to be carried out.

The following are not included in the scope of the project:

- Long term detailed research into acoustics in schools;
- Acoustics in early years or FE facilities.

Project success criteria

It would be difficult to measure the effect exactly but the following would indicate success:

- Sample BSF projects scoring better on acoustics in CABE's design review panel;
- PfS post occupancy evaluations showing good quality acoustics;
- Anecdotal evidence that designers find the new regulations and guidance easy to apply;

Design practice note

Evaluation of up to [ten] primary and secondary schools and publication of a selection of the evaluated schools as case study examples

Update of BB93. Minimum update would be based on the draft revision produced by Les Fothergill and funded by DCLG ie Section 1, Section 6, and associated changes, to appendices etc

Update the acoustics section of BB86

Revise the Standard Specifications for Layouts and Dimensions (SSLDs) on floors and partitions

Update acoustical sections of other linked documents and web sites including the 'school buildings' acoustics webpage and PFS standard contract documents

Initial drafting by DCSF and seek comments from stakeholders before publication

Work to be commissioned through DCSF Lot 3 Technical Services Research Project Management Framework Contract. Funding secured from DCSF SEN Division for 2009-2010.

Extent of revision and means of publication to be established

Included in overall update of BB86. Contract has already been let with D-Squared consultants. Raf Orlowski is acoustics subcontractor for this work.

Means of revising SSLDs yet to be established

No cost (done in-house)

- NDCS being satisfied with the acoustic environment of new buildings;
- Anything else?

Project constraints

Section 1 of BB93 is referred to in Approved Document E of the Building Regulations. Any major change to section 1 could be difficult. Any new recommendations must be affordable.

(Inter)dependencies

The acoustics section of BB86 (currently being updated) must be done in conjunction with BB93. The study being carried out jointly by South Bank University, Salford University and the Institute of Education into a variety of learning settings under an EPSRC 3-year research programme which started in June 2009.

Resources

DCSF Schools Capital design team staff:

Jane Briginshaw senior reporting officer
Lucy Watson, Nick Mayer project leads
Richard Daniels technical adviser

A working group will be set up to advise on and guide the project. External consultants to carry out the work have yet to be decided.

Stakeholders who we propose to involve in this work are school heads, Local Authorities, architects, acoustical consultants, PFS, CABE, NDCS, IOA and ANC.

Meeting report

David Watts. Central branch

The changing design of sound level meters and the benefits of digital technology was the title of the Central branch meeting held on 28 July 2009. The meeting began by welcoming the IOA President, who kindly thanked the branch for its efforts and commended the attendance of regional branch meetings as a convivial way of keeping up to date and meeting colleagues, particularly given that most branch meetings are free.

The branch members were then treated to an enjoyable talk at Casella CEL by Steve Tearle, head of technical services, who was introduced by Tim Turney, product manager. Steve's responsibilities encompass not just noise, but dust, gas and meteorological instruments and he gave a brief overview of the company's history, starting in 1799, mentioning gas lamps and Voltaire batteries along the way, and taking in noise instrumentation relatively recently in 1998, when Casella and CEL joined forces.

Noting that the real world was analogue, not digital, Steve outlines the technical challenges of designing an instrument capable of measuring the range of sound pressures detectable by the human ear, using the analogy with distance and pointing out that an equivalent range would be 1mm to ten million mm, some six miles! The traditional approach to sound level meter design was based on log/antilog techniques exploiting the logarithmic response of the bipolar junction transistor. Steve described the 'bucket loads' of AD637 logarithmic amplifiers packed into instruments with several stages being required to achieve usable dynamic ranges. Armed with an early model of noise dose-meter and a hot air gun, he ably demonstrated one of the major drawbacks of transistors: a marked change in the response with temperature caused the displayed dB value to change. The same extreme heat applied to a digital equivalent meter caused no wavering in the indicated 114dB level from the calibrator attached. It was explained that careful control in an analogue design was necessary in order to avoid the meter becoming more reliable as a thermometer than for measuring sound level.

Analogue meters also needed a lot of additional components to screen out other undesirable interference, whereas digital meters were inherently stable and largely immune to environmental effects. Once the sound level was a digital value, that number could not drift or become 'noisy'. This was illustrated by a circuit diagram for an analogue meter, extending over three sheets, whilst a digital meter required only a single sheet. Steve described how a digital signal processor (DSP) which could perform around 75 million calculations

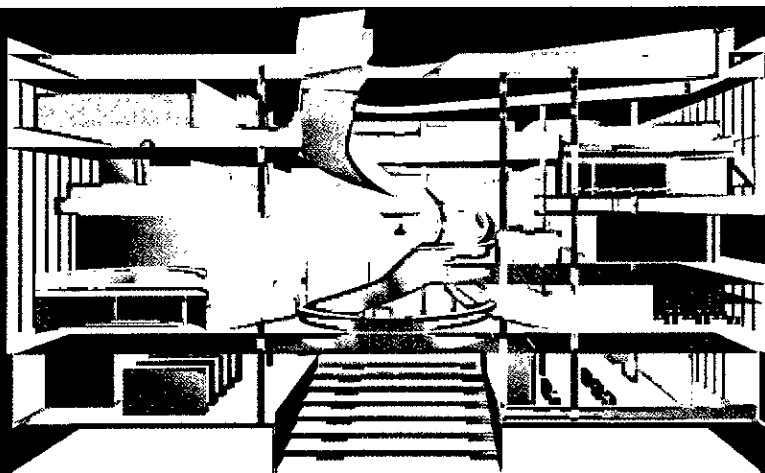
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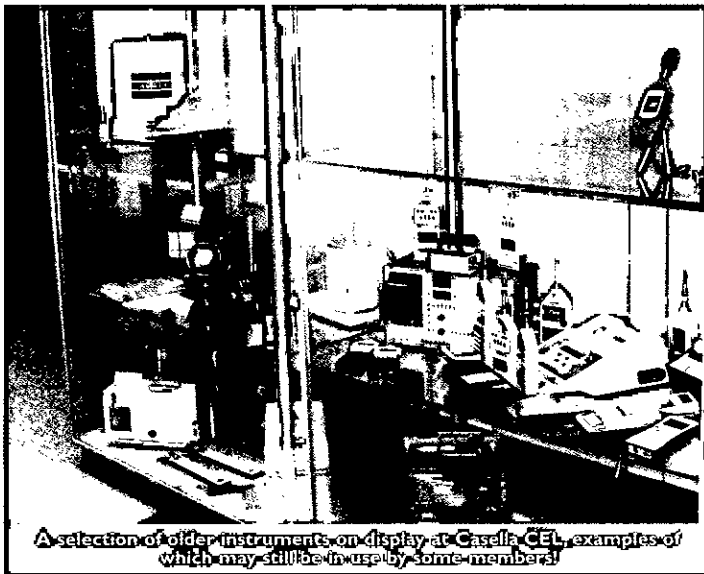


Meeting report - continued from page 17

a second was at the heart of all modern digital meters. However, issues that arose with digital meters included precise timing, anti-aliasing to mask out frequencies above the range of interest, and the complexities of digital filtering.

Nonetheless, it was no surprise to hear him roll off the benefits of digital instruments including low power consumption, stability, immunity to extraneous signals, wide dynamic range, parallel processing of multiple operations, perfect repeatability, good reliability, and future-proofing - in the sense that product development was largely a matter of changing software rather

than hardware. As he concluded, the future of digital sound level meters may only be limited by our ability to imagine new and innovative applications.



Steve Tearle takes the audience through the history of sound level meters

Instrumentation corner

John Shelton. Statistics in third octaves: La Belle L_n ?

In the May/June issue of Acoustics Bulletin, Martin Williams wrote a nice summary article on the calculation and possible pitfalls of statistical values of noise levels, otherwise known as L_n 's.

The vast majority of statistical calculations refer to the A-weighted sound pressure levels, and the use of L_{A90} as a descriptor of background noise level is almost universal and is written into several standard and codes of practice.

However, in recent years, the concept of spectral L_n 's has emerged, either through a genuine desire to calculate them, or simply because sound level meter manufacturers find a new think to calculate, hence differentiating their products from the competition — the jury is still out on which! Indeed, I remember this calculation possibility finding its way into one of our newsletters as long ago as 1994, but it is only recently that it has become a feature of modern sound analysers.

So what is a spectral L_n ? Well, it is to be hoped that we are all familiar with what is meant by L_{A90} - the A-weighted sound pressure level exceeded for 90% of the time. If we now consider our real-time spectrum analyser as a series of band-limited sound level meter (31 of them from 20Hz to 20kHz!) each calculating a value of L_n for each third-octave band, we can now think in terms of an L_n spectrum. An obvious extrapolation from equating L_{A90} with background noise level would therefore be to equate an L_{90} spectrum to the background spectrum.

So is this a reasonable assumption? After all, I have regularly seen statements to that effect in environmental noise reports. Apart from

the issues highlighted in Martin's article, which still apply to spectral data, we first have to understand what is actually being calculated.

An example of an L_n spectrum is shown in Figure 1. This is ordinary office noise, and shows a typical L_{eq} spectrum and the associated L_{90} spectrum, measured with a modern sound level meter capable of doing this kind of measurement with a couple of button pushes.

Logically, you can see that the L_{90} is lower than the L_{eq} and intuitively

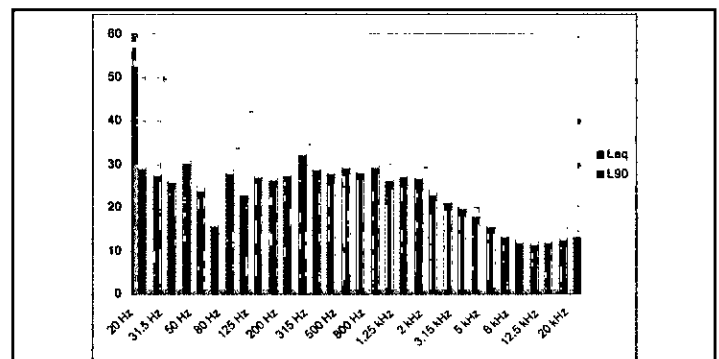


Figure 1

L_n spectrum for office noise

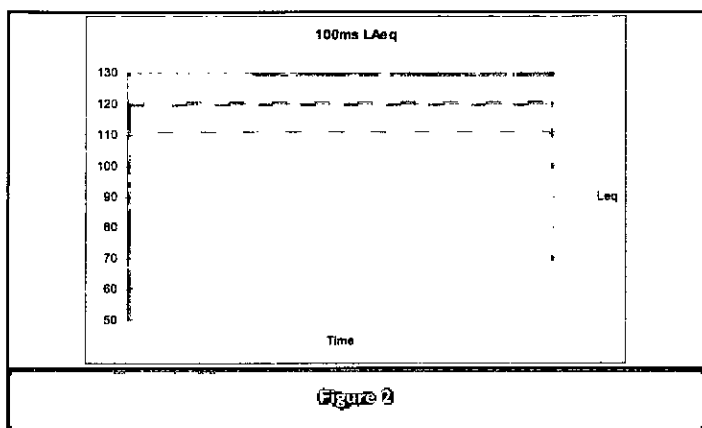


Figure 2

Three bursts of sine wave repeated over 30 minutes

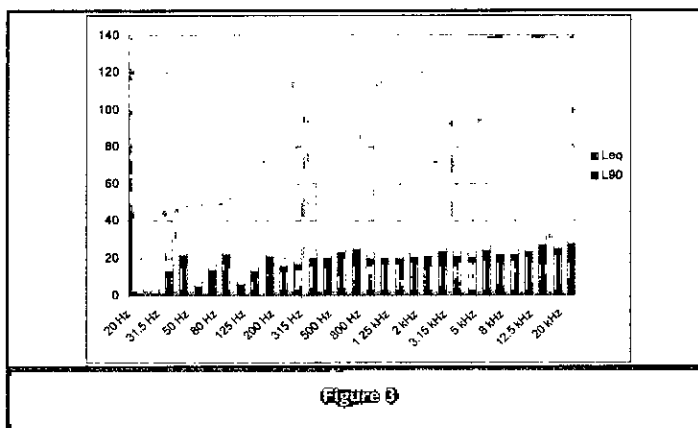


Figure 3

'Spectra' for the measurements in Figure 2

it seems reasonable to think of the L_{90} spectrum as the spectrum exceed for 90% of the time - the 'background spectrum'. So what is the problem? If we look at the true L_{A90} as displayed on the sound level meter, we see a value of 36.9dB, and if we add up the energy in the L_{90} spectrum, we get a total L_{A90} of 36.3dB, which is certainly within the realms of calculation error, and the shape of the spectrum looks credible for the type of environment.

But the interesting thing about this L_n spectrum is that it is actually a spectrum which *never* existed! The spectrum that is displayed is simply a construct from the L_n calculated in each of the 31 individual band-limited sound level meters. Each third-octave value is completely independent of the next.

To illustrate the dangers in the 'background spectrum' assumption, two

signals were constructed to see what kind of error is possible in this type of measurement. Running these signals through a sound level analyser yields some interesting results. Both signals would be extremely unpleasant to listen to, but in neither case did the 'background spectrum' express this.

The first signal was three bursts of a sine wave, at frequencies of 250Hz, 1kHz and 4kHz. Each frequency lasted one minute before switching to the next frequency, a duty cycle of 33%. The time history of $L_{Aeq,100ms}$ over a 30-minute period is shown in Figure 2. The level of each frequency changes slightly as a function of the A-weighting curve,

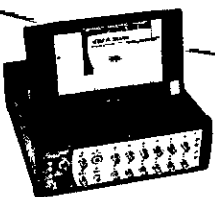
continued on page 20

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NetdB 8-Ch Environmental Noise and Vibration Analyser

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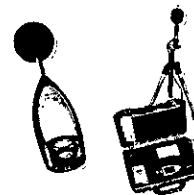
BLUE SOLO 1-Ch Environmental Noise and Vibration Analyser

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- Time domain signal recording with Advanced vibration analysis PPV, VDV, MTVV with dBFA
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Noise & Vibration Innovation

Instrumentation corner - continued from page 19

but it can be seen that the signal is present all the time.

The overall $L_{Aeq,T}$ for the measurement was 118.6dB and the overall L_{A90} for the measurement was 110.8dB, as the level varied between 119.6dB and 110.9dB over the course of the measurement. This would be an expected result for a continuous signal, present for 100% of the time.

The corresponding spectra are shown in Figure 3. In the L_{eq} spectrum, you can clearly see the three frequencies, but interestingly, the L_{90} spectrum shows nothing. Of course, it is a spectrum that never existed, as the tones were present at some point in the spectrum at all times, but there was only signal in each of the third octave bands for 33% of the time.

Although this scenario is artificial, imagine if someone was installing a fan with a strong tonal component, and a noise limit was applied in terms of an L_{90} spectrum. All they would have to do would be to make sure that the frequency of the tonal component changed regularly with time, and the tone would not show up at all!

Another example uses a broad-band noise signal consisting of two signals, both pink noise, one high-pass filtered at 1kHz, and the other low-pass filtered at 1kHz, as shown in Figure 4. A signal was present at all times, each noise with a duty cycle of 50%. The $L_{Aeq,T}$ for the measurement was 107dB and the L_{A90} was 101.1dB, again not surprising for a continuous signal. The resulting spectra for L_{eq} and L_{90} are shown in Figure 5.

As expected, the L_{eq} spectrum is flat, as it consists of an average of both the high-pass and low-pass filtered signal. The L_{90} spectrum however is completely different, even implying a tonal component in the 'background' noise with a peak at 1kHz. Again, it is a spectrum which never existed. In this case, the value of L_{A90} calculated from the spectral values is closer to reality, with a level of 92.7dB, but it is still lower than the true value.

So what are we to learn from this? By taking two different signals, we can fool our statistical spectrum analyser into giving very misleading results. Although the signals used are unlikely to be experienced in environmental noise (we hope!) they should make us think about what we are really measuring or calculating, and to treat spectral L_n values with caution.

Two simple rules of thumb emerge.

- 1 Never calculate an overall A-weighted L_n from the L_n spectrum
- 2 Never assume an L_{90} spectrum has any relation to a 'background noise' spectrum unless you know quite a bit about the type of signal you are measuring.

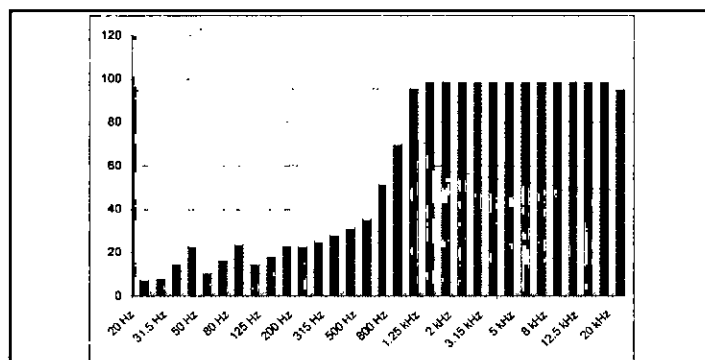


Figure 4

Two pink noise signals, 1kHz high-pass and 1kHz low-pass filtered

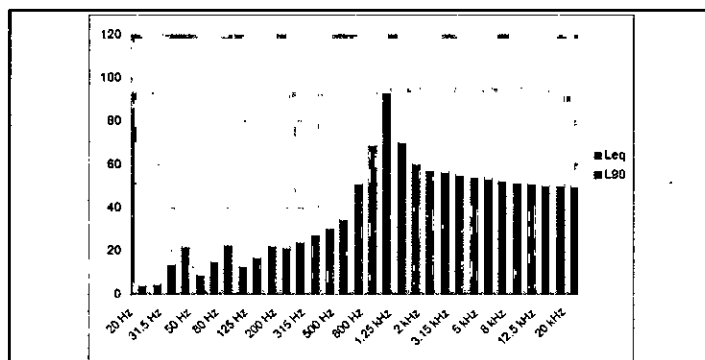


Figure 5

Figure 3: 'Spectra' for the measurements in Figure 4

It could be useful, for example, to get an idea of an underlying spectrum when your measurements are polluted by occasional noises - such as birdsong, the bane of A-weighted L_{eq} measurement.

So, next time you see a new feature in your new sound level meter, always remember the golden rule: don't measure and report a result just because you can!

These and other issues are regularly discussed in the IOA's Measurement and Instrumentation group, at our one-day meetings held over the year.

ANC consultancy spotlight

Adrian James. Acoustics in schools and other matters

Author's note: An awful lot has happened since the last issue, and what follows can only summarise some of the issues which have been keeping the ANC officers so busy over the last two months. Inevitably, given the subject matter, the following is littered with RCAs (Really Confusing Acronyms) which I have tried to explain as I go along. I have also tried to avoid the worst clichés although I can find no single-word synonym for that much overworked term 'stakeholders'. I apologise also for the grammatical inelegance caused by writing now about an event in the future which I hope will already have happened by the time you read this - I am told that the correct tense for this is future conditional optimistic. As a final stylistic note, may I point out that use of the first person plural pronoun refers variously to the ANC or to its board, rather than betraying the incipient megalomania of its chairman.

Euronoise 09

As I write this we are preparing for the intellectual extravaganza that will

be Euronoise 09 in Edinburgh. For the first time ever, the ANC has invested in an exhibition stand. This is part of our drive to raise the profile of the Association both in the UK and overseas, and to allow non-members to see a little of what we do. Thank you to all of our members who will have helped us to man the stand (see what I mean about tenses?). We will also have had a company meeting open to all members immediately after Euronoise. All of this will be written up at enormous length in the next issue of *Acoustics Bulletin*.

Acoustic commissioning in schools

At the time of writing, much frantic activity has been caused by an announcement from Delyth Morgan, the Children's Minister (that's not

continued on page 22

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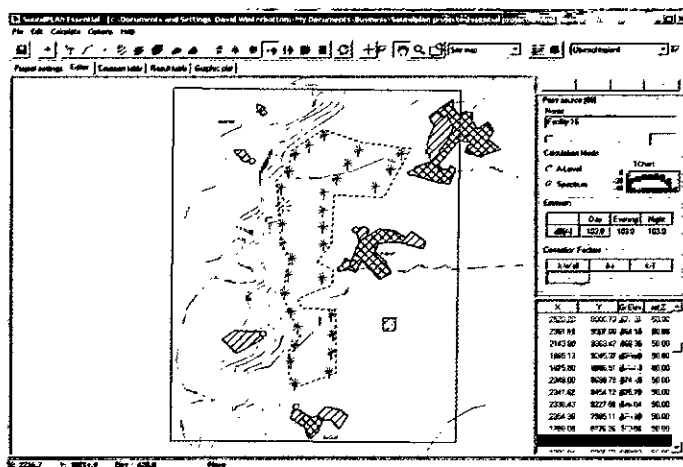
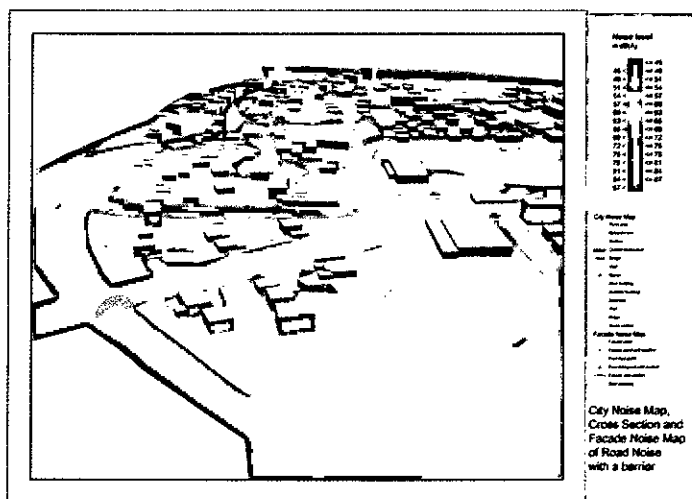
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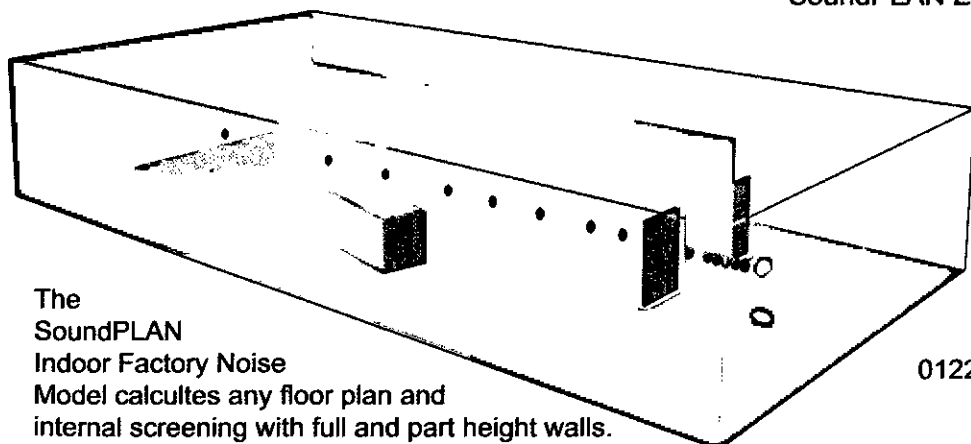
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ANC consultancy spotlight - continued from page 20

a clergyman on CBBC, but a minister from the Department for Children, Schools and Families or DCSF) . She has announced that 'acoustic testing' will be a contractual requirement for all secondary schools funded under the Building Schools for the Future (BSF) projects in England. And no, acoustic testing is not a new type of aural SAT test - it is the acoustic commissioning of school buildings.

This is good news, if perhaps a little later than many of us would have liked. In 2003 the consultation on what was then the shiny new draft of BB93 strongly supported compulsory commissioning in schools as well as dwellings. At the joint IOA/ANC workshop on school acoustics in February this year, there was an overwhelming consensus that good school designs were being let down by the lack of acoustic commissioning. In March the DCSF's own 'BB93 review panel' unanimously voted in favour of compulsory commissioning. This unanimity was the more remarkable because the acoustics consultants on the panel were asked not to vote: the decision was made by the teachers, educationalists, architects and other stakeholders on the panel.

In view of this it might be thought that compulsory commissioning was bound to follow. In fact the DCSF, having appointed Les Fothergill to oversee a very efficient consultation exercise and a complete review of BB93 within an improbably compressed timescale, then announced that it would keep his report and draft somewhere safe for a year while it commissioned some more research, and that it would go out to consultation again in 2010. The text of the letter from DCSF, the research proposal, and some very pertinent comments are set out in the report of the Building Acoustics group (BAG).

It is widely believed that one reason for this change of heart was the report's robust recommendations on open-plan teaching spaces and the obvious acoustical limitations thereof. Having spent, with the IOA, a great deal of time and money assisting in the consultation process, we contacted DCSF expressing our disappointment and hoping that at least some movement on the issue of commissioning might be forthcoming in the short term. The reply was that compulsory commissioning would require a change not just to BB93, but to the underlying Building Regulations, and therefore would have to be referred to the Department of Communities and Local Government (DCLG). This was of course correct, but we felt that it was always open to DCSF to encourage or even require commissioning without having to rely on changes to building regulations, for example through the Education Premises Act.

So what prompted the sudden announcement? It seems to have been the embarrassing revelation that the Hearing Impaired Unit at a high-profile BSF project in London had been built without adequate sound insulation. Or, as more succinctly reported by the Times Educational Supplement (TES), *'Acoustics gaffe at hi-tech deaf facility: a new £39 million school in south London boasting a state-of-the-art "soundproof" room ... has no soundproofing'*. At present it is not clear who the Acoustics Gaffer might be; it seems unlikely that even the most inventive interpretation of the BB93 alternative performance standards could have omitted the sound insulation from a hearing impaired unit. The press reports suggest that the fault lay in implementation rather than design - in other words, what was designed was not built. Hence the DCSF press release on 16 October *'No funding will be signed off for a BSF secondary school building project without a commitment to having the £6000 acoustic test'*.

The announcement was, however, not just a knee-jerk political reaction to some embarrassing publicity on a single project. Ever since the BB93 review panel's meeting in March, the National Deaf Children's Society has been campaigning very effectively for compulsory acoustic commissioning, with technical assistance from some members of the IOA and ANC. I have been asked why the ANC did not support this campaign more publicly, and the fact is that as a professional representative organisation rather than a pressure group, we did not feel that we could do so. None the less, I hope that we can congratulate the NDCS on the success of its campaign, and welcome the improvement in acoustic standards that will surely follow.

Other welcome news is that DCSF and CLG will write jointly to

every building control body in England and Wales, reminding them of the following:

- Acoustics are important in all schools including primary schools, especially for pupils with impaired hearing;
- Where acoustical testing is carried out they should use this data to assess compliance with the regulations;
- Building control bodies should not approve alternative acoustic performance standards *unless a full and proper case has been made in accordance with Building Bulletin 93.*

Of course, a few questions remain. What will happen to schools which are not secondary school BSF projects? And exactly what is meant by 'The £6000 acoustic test'? We hope that by the time you read this, these issues will have been resolved at a meeting between representatives from the ANC, IOA, DCSF and - positively the last acronym in this section - Partnerships for Schools (PFS).

Test certificates for schools

Always quick on the draw, the ANC registration committee has already considered a scheme for certification of BB93 sound insulation tests, should this be required. Well, actually, this was done in February when we thought that the revision to BB93 was imminent. The main subject for debate is, surprisingly, not the choice of background colour for the certificates (a rather fetching buttercup yellow) but how such a scheme would cope with the complications of testing in schools, with such a complexity of room types and criteria - and indeed whether such certification will be required. Watch this space.

Association of Noise Consultants Registration Scheme (2008)

Certificate of Measured Sound Insulation of a Wall or Floor under B893 (Schools)

This certificate is based on measurements made by an ANC Registered Test Organisation in accordance with the relevant Part of International Standard EN ISO 140:1998

Site Acoustic School Form/Type New Program Building/Workshop Vale Park Builders Threat Wall Wall Aluminium Impact Aluminium Support Beams Concrete - Lab 1 Receiving Beams Reinforcement - Kitchen	Registered Organisation Testis Builders Test Reference Number ICP 21261-9 Date of Test 21/07/09 Certificate Date 14/08/10 Test Engineer James O'Connell Signature 
--	--

Calculated Rating Value: 46 dB(DnT) (test max)
Declared Rating (Schools) = 48 dB

LABC

We have had several comments on the paragraph in the last issue about what we consider to be the inappropriate advertising of a noise consultancy by LABC. Our problem is not with the noise consultancy in question as much as with the whole principle of LABC apparently advertising the services of individual companies.

For those people not familiar with LABC, it is the member organisation representing Local Authority Building Control departments in England and Wales. LABC's members are therefore those local authority building control officers who, if approached by members of the public, are not allowed to recommend specific architects or builders. The FAQ page of the LABC website states:

'The Council is not permitted to give you any names of architects or builders. Your building control officer is required to be completely impartial in his or her dealings with any architect, builder or client, and this would obviously not be possible if he or she were in the position of recommending one builder ahead of another.'

This impartiality seems not to extend to other professions. Anyone wanting to see what worries us has only to do what a building control officer, contractor or householder might do to find out about sound tests - try a Google search for 'local authority building control' which will take you to the LABC website, and in that website search for 'noise'.

'acoustic' or 'sound test'. You will be directed to pages on the LABC web site which advertise, variously, an acoustics consultancy (noise.co.uk) and a supplier of sound insulating materials. Noise.co.uk appears along with an energy rating consultancy and two LABC building warranty schemes.

It seems obvious that householders, contractors and indeed local authority officers may be led by this web site to believe that these companies are 'approved' by local authorities. Indeed noise.co.uk's website states 'We are the only sound test company who are officially "endorsed" and "preferred" by local authority building control. As business partners with LABC you can be assured of the level of service we provide to you our clients'.

Several of our members have contacted LABC to ask how one becomes a preferred business partner for LABC. A typical reply was: 'LABC currently has a partnership with noise.co.uk and therefore is not looking into additional partnerships with any other "acoustic providers". LABC's business partners enter into contracts with LABC, which usually include fees, providing training, attending seminars, etc. These partnerships are agreed by our technical team and our commercial partnerships working group'.

We have written to LABC and their reply states that 'LABC is a private company and not a public body. LABC does not want multiple "partner" relationships. Nor do we want a multiplicity of trade organisations using LABC as a channel to market or bullying us into adding more and more marketing content. We have only a handful of relationships and how and when we decide on these is our business ... noise.co.uk is LABC's (not local authorities') preferred partner'.

We consider the last statement a very fine distinction - too fine for most visitors to the LABC web site, who will reasonably assume that any preferred partner of LABC is also preferred by the local authority building control bodies which are LABC's members. Indeed the distinction seems to be too fine for a number of local authority building control officers, who have told us that their local authorities have a business partnership with noise.co.uk and do not need to talk to any other acoustics consultants. If you don't believe this, do a Google search using 'LABC sound testing' and you will find a number of local authority web sites which advertise noise.co.uk either indirectly through LABC or, astonishingly, actually on their own web site.

We raised this with the Building Control section of the Department for Communities and Local Government and were rather surprised to be told that they can do nothing about this as LABC is a private company. We are therefore pursuing this through other channels. In the meantime if you come across a local authority which is directly or indirectly advertising or recommending any consultancy or test house, please email the details to us at anc@kingstonsmith.co.uk.

ANC PCT scheme

It is a pleasant change for this section not to be the longest part of an ANC article. The good news is that the ADVANCE system of online certification is working very well. This is the first stage towards phasing out the paper certificates which are currently sent out by post, and ADVANCE now allows building control officers to receive and check test results during postal strikes. Even better news for testers is that when paper certificates are phased out, the savings in printing and postage will result in a substantial reduction in the cost per test.

UKAS

Less good news is that it is now a year since we submitted the paperwork (and the initial payment) to UKAS for accreditation of the administration of the ANC scheme, as requested by CLG and BRE. The only progress that we have had since then is to be told that the (very helpful) assessor who advised us on the application has now been moved elsewhere. In spite of our best efforts we still await the allocation of an assessor - a process which, according to UKAS' own procedures, should have happened nine months ago. Of course the scheme does not depend on UKAS accreditation - which under the circumstances is just as well.

A few months ago one of our members received a report by a test company which was not UKAS accredited for such tests (although it has since achieved UKAS accreditation). The report contained a number of serious errors — not least use of the criteria for dwellings, rather than

schools. These errors were pointed out and the test company replied by publishing some extraordinary accusations about the ANC registration scheme, including that the scheme merely requires testers to pay a fee to the ANC without being subject to any form of assessment or auditing. Anyone who is familiar with the ANC scheme will know that this is a slur not only on the ANC but also on staff at the Department of Communities and Local Government and at BRE, who have assessed the ANC scheme and declared it to be equivalent to UKAS accreditation for the purposes of Approved Document E, Ecohomes, the Code for Sustainable Homes and BREEAM.

This sort of event is in danger of polarising opinion between those of our members who are UKAS accredited for pre-completion testing and those who are members of the registration scheme. We make a conscious effort to avoid this. The sound insulation section of our web site lists all members who are either UKAS accredited or members of the registration scheme (several companies have the benefit of both). In setting up the scheme we invited input from our UKAS-accredited members, one of whom remains an observer on the registration committee. In fact to protect the standing of our members with UKAS accreditation, we would like to see some differentiation between UKAS-accredited test companies which have no other acoustical expertise, and those which are genuine acoustic consultancies (many of which, of course, are members of the ANC). A useful guide to this is whether a company's staff includes members of the IOA. Several UKAS-accredited test houses advertise acoustical consultancy services yet appear to have no MIOAs or FIOAs on their staff. That is, perhaps, something that should cause concern within the IOA as well as in the ANC.

We all know that there is no such thing as UKAS accreditation for consultancy. Members of the public, however, do not generally know this, and on seeing the UKAS symbol on a website they may assume that the UKAS accreditation applies to all of the company's activities, including consultancy. If this seems far-fetched, consider the recent case of a door manufacturer who had his acoustic doors rated by a UKAS-accredited laboratory, and on that basis had his doors selected for installation in a new school. Fortunately, one of our members examined the test reports very carefully and found an error in the calculations which resulted in the claimed rating of the doors being 6dB too high. It transpired that the test laboratory's UKAS accreditation did not include sound insulation testing.

Schools research

Consultants benefit greatly from university research, and we encourage our members to assist such research where possible. Often we will have access to vast amounts of useful data. A new research project is being carried out to investigate the acoustical environment in secondary schools to determine whether noise and poor acoustics affect children of secondary school age and their teachers. The researchers are Bridget Shield (London South Bank University), Julie Dockrell (Institute of Education) and Trevor Cox (University of Salford). As part of the project they wish to create a database of acoustical data in secondary schools including external and internal noise levels and room acoustics measurements, especially in post-BB93 schools. If any consultants are willing to share their data the research team would be very grateful. The schools and consultants would be kept anonymous in any publications. If you are willing to provide any data please contact Robert Conetta, the acoustics research fellow working on the project, on 020 7815 7563 or at conettar@lsbu.ac.uk.

The Art of Being a Consultant

This excellent and popular one-day conference is having another outing, this time in Manchester, on 9 December. The subjects range from the practicalities of contracts and report writing to the more subtle issues of ethics and of what, exactly, consultancy really is, all delivered by senior and respected members of the IOA and ANC. Details can be found elsewhere in *Acoustics Bulletin* or on the IOA website.

Acoustic design of theatres for natural speech and/or variable acoustics

M Luykx, M Vercammen, R Metkemeijer. How much reverberation is 'right'?

Introduction

Basically there are two types of acoustics: the acoustics of the open air and the acoustics of closed spaces. The first type has minimal reflections, the sound that travels in a straight line between the speaker and the listener (direct sound) is dominant over the sound reflected by nearby objects. This type of acoustics is especially suitable for transferring information, like speech, and to determine the direction of a sound source. It is the acoustics for the consonants and has high definition.

In the second type the direct sound is of little significance. Almost all energy reaches the listener in an indirect manner, by many reflections originating from the boundaries of the closed space. This type of acoustics is generally felt to be most suitable for musical sounds and vowels, and has low definition.

The open-air and the speech-theatre are characterised by short and/or very weak reverberation, and the concert hall by long and/or strong reverberation: this makes a variation in acoustical properties desirable when a hall is used for both types of performances. One of the challenges in designing halls with variable acoustics is not to compromise the strength of sound in the theatre mode. Specific acoustical requirements, as well as experience of developments over the last 30–40 years with the design of theatres with natural variable acoustics are illustrated in this article, which goes on to describe an almost uncompromised theatre with variable acoustics in Zwolle (NL).

Acoustic factors

Reverberation

Generally speaking, reverberation is considered an important parameter for describing room acoustics. The reverberation time (RT60) is the time needed for the sound pressure level to decrease by 60dB after the sound has stopped.

In concert halls, reverberation is an important parameter, although it is understood nowadays that many others are also involved¹. In the concert hall for classical symphonic music, a reverberation time of approximately 2 seconds is ideal. This follows from the way the music was composed and orchestrated, but also from the way our hearing mechanism integrates sounds. In addition, the way the 19th and 20th century musical compositions and orchestra sizes developed to the taste of the audiences must have played a role in reaching consensus regarding the 'ideal' reverberation time all over the world.

The larger the hall, the longer the 'optimal' reverberation time will be. A reverberation time of 2s would sound too dry in a very large hall such as the Royal Albert Hall (volume 80,000m³) but too live in a small recital hall such as the glass Amvest Hall (2000m³).

In addition, the 'optimal' reverberation time also depends on the type of music. More reverberation gives a 'fuller' sound, whereas less reverberation enables the details in the music to be heard, which is especially important for chamber music or modern 'classical' music. For example, the *Muziekgebouw aan 't IJ* in Amsterdam (opened in 2005) has variable acoustics to adjust the reverberation time and the acoustical volume. The concept of a 'reverberation chamber' or reverberation gallery is present in the Royal Albert Hall and is successfully applied in *De Spiegel* in Zwolle, in the latter case enabling variation of reverberation time. This variability introduces new challenges for the user of the facility: what mode is the right one for a given situation? Who decides, and based on what? It is especially challenging given that there is no such thing as an 'ideal' acoustic: tastes differ.

Too much reverberation, in principle, has a degrading effect on the intelligibility of speech. In theatres for natural speech, the reverberation

time needs to be sufficiently short. Nevertheless a certain level of reverberant sound is necessary to gain sufficient loudness above the background noise level, because of the limitations in the sound power of the human voice. This is important for the intelligibility of speech, especially for those seated at large distances from the actors. This combination of demands requires a sufficiently small room volume for the theatre. When a hall has to be used for both kinds of performance, symphonic music as well as spoken word, a variation in acoustical properties such as reverberation time will be necessary.

Definition and intelligibility

Definition or clarity is the counterpart of reverberation: it concerns the distinction between single notes or words. Chamber music with fast melodies and quickly changing harmonies will sound blurred in a large concert hall with long reverberation. But even with the same reverberation time there can be differences in definition between halls. Definition can be improved by adding early reflections or by reducing reverberation. Definition is better at positions closer to the stage. For concert halls, the clarity required is often specified using the parameter value C80 (the ratio between early energy, from zero to 80ms, and late energy, from 80ms to 800ms) which should be less than 0dB.

Whereas for concert halls a form of sound blending is needed, in theatres this would be detrimental to the main acoustical requirement of transferring speech. Here we need high definition and clarity, and usually values of C80 above +4dB are required. This can be achieved by a proper design giving many beneficial early reflections and a low reverberation.

A true measure for the speech intelligibility is the parameter AL_{cons} (articulation loss of consonants). This is really the percentage of wrongly understood consonants which means that test persons have to be used since they are the ones that understand. Not only the transmission channel, but also speaker-listener effects (proficiency of speaker, complexity of message, familiarity with content etc) determine the speech intelligibility. The speech intelligibility can be regarded as 'good' if the AL_{cons} value is below 10%, 'reasonable' if it falls between 10% and 15%, and 'bad' above 15%. Peutz has defined a way to predict the AL_{cons} of the transmission channel based on distance, source directivity, room volume, reverberation time and the noise⁵. Another method is to calculate the AL_{cons} based on the direct-to-reverberant ratio, reverberation time and the signal-to-noise (s/n) ratio⁶. There are also other prediction algorithms for AL_{cons} that distinguish between early and late sound, based on information indices^{4,7}. These can be used when measuring impulse responses, from which the parameter STI (speech transmission index⁸) is often deduced also, as a prediction of speech intelligibility. Peutz stated that without direct sound AL_{cons} will be limited to 9 times RT60 [%] for situations without noise. Based on statistical relations in the reverberation field without direct sound, it was shown that a good intelligibility can be realized with RT60 values between 0.8 and 0.9 seconds. In that case at least 55% to 60% of the sound energy will arrive at the listener within 50ms¹¹. This part belongs to the 'early' sound and it means that provided sufficient sound energy is supplied by early reflections, there is no need for a direct sound to achieve good intelligibility¹¹.

Loudness and noise

In concert halls generally the walls and ceiling are made of acoustically reflective materials. The public and their seats provide the sound

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absorbers, and the loudness is directly dependent on the number of seats. This loudness is usually indicated by the factor $G^{(3)}$, which is defined as the sound level difference at positions in the hall beyond 10m from an omnidirectional source on stage, and the sound level 10m from the same source in a free field. Assuming a diffuse sound field in a single room volume an estimate for G can be deduced, based on

$$G[\text{dB}] = 31 - 10 \log(S\alpha_r/4) - 10 \log(1-\alpha_s)$$

where S is the total surface, α_r the average absorption coefficient of the room (determining $RT60$), and α_s the average absorption coefficient as 'seen' by the source. Note that α_r and α_s may be different, except for an omnidirectional source. Additionally a decrease of the reverberant field with distance should also be implemented¹⁰.

In the concert hall for classical music loudness should have a defined value, determined by the size of a symphonic orchestra and the number of seats. Values of G to achieve in symphonic concert halls are from 2 to 5 dB, and for chamber music from 6 to 9 dB. Very large concert halls generally have a loudness level that is too low. For that reason it is important to limit the size of concert halls, but the effectiveness of the absorption can also influence the loudness of a hall. Rigid criteria for the dimensions of concert halls are hard to give. For symphonic music goals are a depth of 40 to 45 metres, a width less than 25m, and a maximum height of 15 to 20 m. Figures 1 and 2 give schematic examples of a thousand-seat concert hall (*Muziekcentrum Enschede* (NL)) and a small theatre.

For theatres in which the spoken word is natural, an acoustic must be created that is as loud as possible, because of the limitations in the sound power of the human voice. But the acoustic should also have as much as possible direct (and early) sound and minimal (late) reverberation, because sound which is too reverberant may degrade speech intelligibility. The reverberation time should generally be limited to less than 1 second. In that case, provided there is sufficient loudness of the hall, the intelligibility of the reverberant (speech) sound will still be good, even at the furthest distances where direct sound is not relevant. According to the basic statistical laws of room acoustics the best space for speech therefore is as small as possible, with reflective walls and ceiling, the only sound absorbing area being the audience. Additional absorption should be limited as much as possible, to maintain loudness and strength of early reflections. RT values above 1.0s are undesirable because then AL_{cons} increases above 9% to 10% at the greatest distances. Although rigid criteria are hard to give, because a certain adaptation of the voice is well possible, the best theatres for classical plays are all smaller than 4000 - 5000 m³, with a reverberation time of 1 second or less. Related demands for their dimensions are a depth of the hall less than 23m, a width less than 20m, a height under 13m, a width of stage opening less than 14m and a maximum room volume of 5m³ per person. Amongst these theatres, those with $RT60$ values of 0.8 to 0.9 seconds have a noticeably better intelligibility ($AL_{\text{cons}} < 7\%$), as is illustrated in the example of the *Stadsschouwburg* in The Hague. In this theatre AL_{cons} values between 3% and 5% were measured, as a result of added early reflections. The dimensions of this intimate theatre are schematically drawn in Figures 1 and 2 (green lines), together with those of a concert hall (red lines). The comparison between the two halls illustrates the contradictory requirements and the challenges when these two different uses have to be combined in one multi-purpose hall.

Besides reverberation, the strength of sound (loudness) is another determining factor. Since our ears need a certain sound level to hear properly and there is always a certain amount of background noise, the acoustical signal has to be loud enough. Degradation of speech intelligibility by background noise in a theatre may be significant. Usually ventilation noise (air conditioning) should be below 25dB(A), as should fan noise from lighting etc. However, lowest background noise levels due to the audience of at least 30 to 35 dB(A) may occur in the auditorium during theatre performances. In very quiet concert halls, with ventilation noise below 15dB(A), it appears that the audience adapts to this silence during performances and can be very quiet too, which is favourable for the dynamics of the music and to hear the softest *pianissimo* of the orchestra or solo instruments. To make

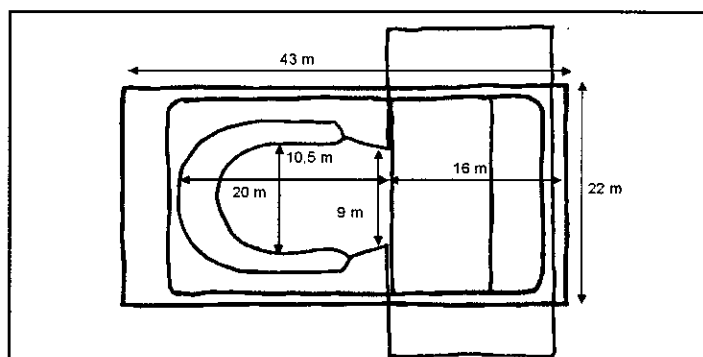


Figure 1

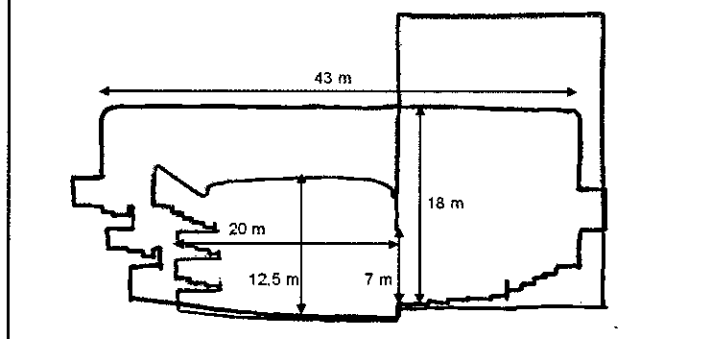


Figure 2

Schematic plans and cross-sections of a typical intimate small theatre for natural speech (*Stadsschouwburg The Hague*, 2800m³) and a regular shoebox concert hall (*Muziekcentrum Enschede* 16000m³).

the most of the natural dynamics of actors' speech this would be beneficial in theatres too: more detailed research will be performed in due course.

As an example for the influence of noise let us assume a theatre of 5000m³ and an $RT60$ of 1 second, with an average absorption factor (α_r and α_s) of 25%. The strength or gain G for an omnidirectional source in the middle of the stage opening is then +2dB. Suppose an actor is talking (for which $Q = 2$) with a sound power level L_w of 70dB (at 1 - 2 kHz) on stage. Using algorithms for the decrease of sound level with distance¹, the calculated speech levels 15m distant are about 45dB (direct sound 38dB, reverberant sound 44dB). With noise levels below 20dB, the signal-to-noise ratio will be at least 25dB, and a value for AL_{cons} of 6% is predicted, which would provide 'good' speech intelligibility. When higher noise levels of 25, 30 or 35 dB are expected from the audience, the s/n ratio reduces from 20dB or 15dB down to 10dB, and subsequently higher AL_{cons} values are predicted from 7% or 8% up to 10%. At a greater distance of 20m these values would be 8%, 9% and 12%, and speech intelligibility becomes only 'fair'. If the actor were to turn away from the audience and speak to the side, the direct sound as well as the reverberant sound reduces and the s/n ration becomes smaller, with values of 16, 11 and 5 dB. Related AL_{cons} values increase to 9%, 11% and 15%, and speech intelligibility becomes worse.

These examples indicate that if there is noise it will have a significant influence on speech intelligibility, and that every dB increase of strength that can be achieved is worthwhile. In contrast to the criteria of 4000 to 5000 m³ and 1 second reverberation time mentioned before, it can only be achieved with smaller volumes of 3000m³.

Energy loss and parameter Q_{room}

Contrary to the case with concert halls, churches or other rooms with single volumes, in a theatre a certain part of the (direct) sound energy of a sound source on stage is lost into the stage environment (the stage tower or the like), being (mostly) absorbed by curtains and similar surfaces. This part of the source energy does therefore not contribute

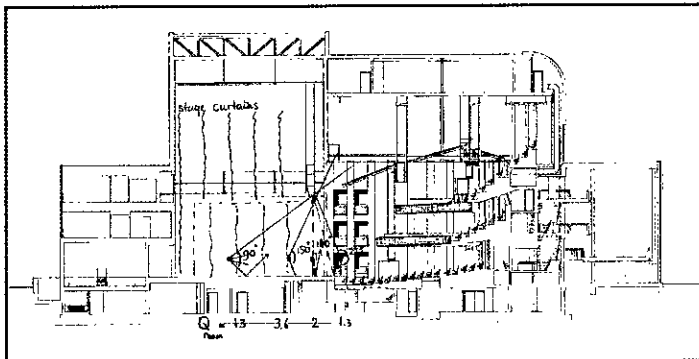


Figure 3

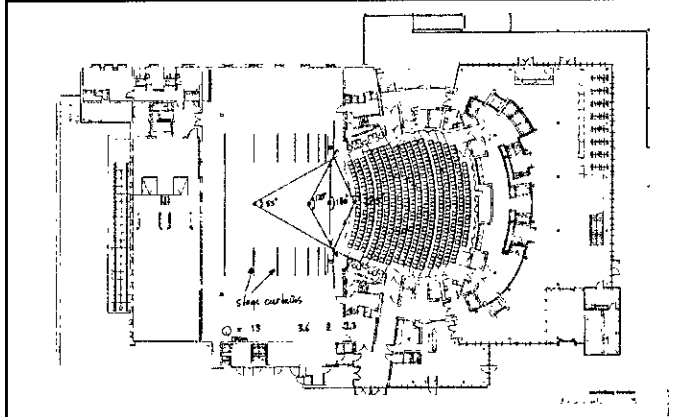


Figure 4

Plan and cross-section of a theatre with variable acoustics in Zwolle (NL). Source angles determining factor Q_{room} for different source positions are indicated.

to the reverberant sound level in the audience, or at least, not fully. This can be accounted for in the calculations of reverberation level and loudness G) introducing a factor which we will call Q_{room} . This is the inverse of that part of the source energy being projected into the hall. For instance, if $Q_{room} = 5$ then one fifth of the source's energy is projected into the hall.

The factor Q_{room} depends on several parameters:

- The source position relative to the stage opening (Figures 7 and 8);
- The size of the stage opening;
- The directivity factor and directivity pattern of the source (omnidirectional for G);
- The orientation of the source, if not omnidirectional. In practice, actors' voices may have some other directivity factor depending on the facing direction ($Q = 2$ to 2.5 if speaking towards the audience, $Q = 1$ if speaking sideways, $Q = 0.3$ if speaking with their back to the audience). $Q = 1$ can be considered a reasonable value to maintain for a worst-case situation with natural speech on stage.
- The average absorption coefficient of the stage environment (side walls, back wall, ceiling) stage curtains, and stage scenery (which may have reflective and absorptive elements). For reasons of simplicity it may be assumed that all the sound projected directly from the source into the stage area will be fully absorbed on its first reflection (100% absorption). In reality there will be also intermediate cases, for instance with a reflective back wall or reflective parts of the stage scenery.

The factor Q_{room} can then be calculated from $Q_{room} = (180/\beta) \times (360/\zeta)$ where β is the vertical opening angle towards the hall and ζ the horizontal opening angle towards the hall. In Figures 3 and 4 a plan and a cross-section of a theatre are presented, in which the relevant angles towards the room are indicated for three different source positions on stage, and related values for Q_{room} are given. For an omnidirectional source in the middle of the stage opening, 2m upstage and 10m upstage, the corresponding values for Q_{room} are respectively

2, 3.6 and 13. The related loss of reverberant source energy into the stage tower corresponds to $10 \log Q_{room}$, which gives values of 3, 5.5 and 11 dB respectively.

Because the factor Q_{room} is highly dependent on the source position, this is also the case for the value of G in a theatre. It follows that G values measured in theatres should always state the source position, to avoid misunderstandings.

With more directional sources such the human voice, with actors speaking towards the audience, these reductions will be less in practice. For instance for an actor in the middle of the stage opening ($Q = 2.5$), Q_{room} will be about 1.1 because just a small part of the energy (say 20%) is being radiated backwards from the speaker into the stage tower. When speaking to the side (at an angle of 90° with the room axis) Q_{room} will be 2, because 50% of the source energy is directed into the stage area. In fact, with a non-omnidirectional source Q_{room} has to be determined by integrating the directivity pattern of the source over a solid 3D angle into the hall, with its boundaries at the sides of the stage opening in the horizontal and vertical plane. Part of the direct sound radiated to the stage floor can be assumed to reflect directly into the hall, so this part of the solid 3D angle should be implemented in determining Q_{room} .

For omnidirectional sources, often used in room acoustics measurements, the expected value of Q_{room} can be deduced using a computer model, or by using this factor as a curve-fitting parameter to fit the measured decay with distance to the theoretical decay. Another method to determine Q_{room} in theatres with variable acoustics is to compare the measured sound levels in the reverberant field with and without an orchestra shell.

With a maximum room volume of 5000 m^3 and a reverberation time preferably between 0.8 and 0.9 s (with average absorption α_r and α_s < 20%) it can be calculated that the average value of G is 4 to 5 dB if the source is in the middle of the room. However, owing to energy loss of the source into the stage tower, in most theatres smaller values will result in practice. For an omni-directional source position in the middle of the stage opening (usually indicated in the Peutz measurement layout as position 4) the corresponding values of G in the auditorium with the above room characteristics are about 2 to 3 dB lower. This means that if the theatre volume is 4000 to 5000 m^3 , a value of G of at least 2 to 3 dB should be attainable (source in middle of the stage opening). If higher values are reached an even more efficient room design is realised, which is beneficial for the strength and intelligibility of natural speech.

However, there also seems to be a tendency to make theatre hall volumes larger, partly because of technical demands such as lighting bridges over the audience. With room volumes up to 7000 or 8000 m^3 , corresponding absorption values α_r and α_s values will be higher (up to 60% or 70%) to keep the reverberation time sufficiently low. It follows that low G -values down to 0 dB or below are to be expected in many relatively flat, rectangular-floor theatres, which compromises the strength for speech.

Effectiveness of absorption

For an audience in a concert halls, it is obviously preferable to have a good view of the performers, but it is not absolutely necessary to enjoy the music. Giving everyone a good view means steep floor rakes. From his perspective the performer will see a lot of the audience, which in turn means a lot of absorption. An important part of the music will be absorbed directly by the public and will not contribute to the reverberant sound field. In general, good concert halls such as (in Netherlands) the *Concertgebouw Amsterdam*, *Dr Anton Philipszaal The Hague*, *Muziekcentrum Enschede* and *Concert Hall Tilburg* have marginal lines of sight.

Other considerations are important for theatres. Good sight lines are needed to see the entire stage floor and scenery, and distances should preferably be no more than 25m in order to see enough of the facial

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expressions of the actors. Floor rakes that are too steep should be prevented (alternating rows are a help) because this reduces the strength of the reverberant speech, caused by increased effectiveness of the audience absorption which increases the average absorption α_s (as seen by the source) within the room. To maintain high G values the absorption α_r and α_s should be no more than 20% to 30% in theatres, which can be achieved keeping walls and ceilings reflective.

Compact theatre design

To fulfil the demands of loudness, reverberation and sight lines, a compact theatre design is necessary for good acoustics for natural speech. The theatre in The Hague is a good example of such a small, intimate theatre. It has a very efficient theatre design (volume 2800m³, 675 seats, three balconies) with average dimensions 20 × 11 × 13 (d × w × h in metres) and a stage opening of 9 × 7 metres. Some of its characteristics are illustrated in Figures 5 to 8, based on measurements.

Figure 5 gives an impression of the interior of this theatre, and Figure 6 gives a plan in which the measuring positions according a standardised scheme used for impulse response measurements by Peutz are indicated.

In Figure 7 an example of such a measurement is shown between source position 1 and microphone position 7 at 16m distance in the stalls. The graph of the arrival of the cumulative energy (lowest graph on Figure 7) shows that 50ms after the direct sound 80% of the energy has already arrived, which is owing to the large number of early reflections. This determines the very good intelligibility ($AL_{cons} = 3\%$). The clarity value $C80$ is also high (+8dB). Compared with larger theatres of around 5000m³ its strength is greater, with a value of $G = +5dB$ (source at position 4). The decrease with distance measured in this theatre in the 1kHz octave band is presented in Figure 8, together with the theoretical lines used to fit the acoustical room parameters. This results in an acoustical volume of 2800m³, a reverberation time $RT60$ of 0.95s and an average value for absorption coefficients (α_r and α_s) of 15%. The latter is partly because of the efficient audience arrangement and effective sight lines, with rather flat floors and balconies that are not raked too steeply.

Some recommendations can now be given for the design of theatres for natural speech.

- Keep the effective acoustical room volume below 4000 or 5000 m³.
- Keep the number of seats below 850 to 900. Use a regular seat width (530 to 550 mm) and as narrow a row separation as possible (900 to 950 mm) to keep the amount of audience absorption limited.
- Keep the background noise levels from ventilation systems etc below 25dB(A) for theatre uses and preferably 15 or 20 dB(A) if the venue is to be used as a concert hall too. Strict noise limits for theatre lighting and the cooling fans of computers and power equipment should also be set.
- Keep the walls and ceilings inside the hall as sound reflective as possible. This is necessary to get sufficient early sound energy to the audience, not only when the actor faces the audience, but also when he or she turns sideways away from the audience, as the voice has some directivity. The possible focusing effects of curved (rear) walls have to be accounted for. When using balconies, the rear walls will often be (mostly) shielded by the audience.
- Make the sides of the stage opening as reflective as possible, for instance by using diffusive side-boxes with seats, and by making the underside of the first stage-bridge reflective. Such reflective elements around the stage opening are also beneficial in giving support to an opera orchestra when playing in an orchestra pit. Early reflections also help to give a higher clarity value ($C80$) which is useful for speech intelligibility.
- Apply a well-designed first sound reflector in the front part of the hall, to smoothen the acoustical transition between the limited height of the stage opening and the height of the hall. Such a sound reflector will enhance the directivity and actual sound level of an

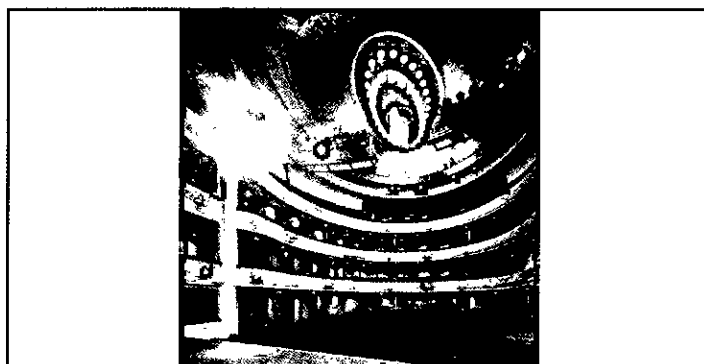


Figure 5

Interior of the intimate theatre Stadsschouwburg The Hague

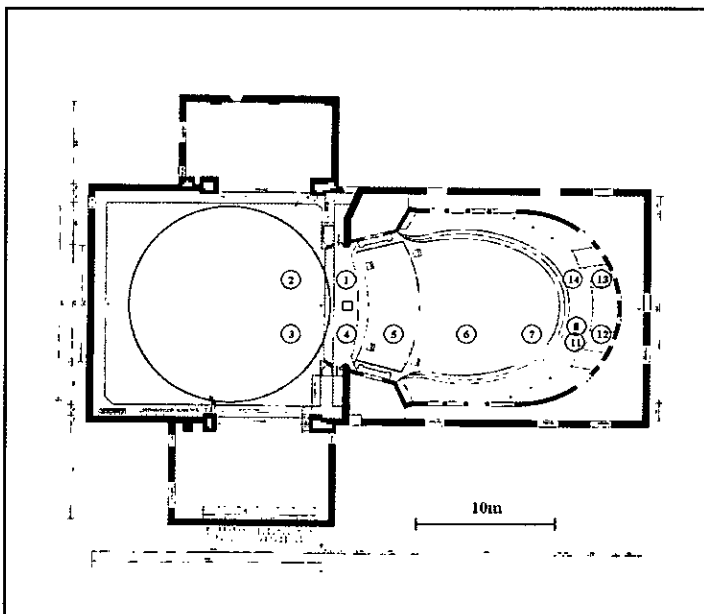


Figure 6

Plan of the theatre Stadsschouwburg The Hague, with an indication of standard (Peutz) measuring positions for impulse responses

actor and will be beneficial for the rearmost rows on the balconies. This reflector should be movable if the hall has variable acoustics or is also being used for operatic performances.

- Make (or keep) certain parts of the stage reflective, especially in smaller stage environments. This might be beneficial for the sound level of the actor in the hall, and can be done without introducing too much risk of echoes. However, the reverberation time of the stage area may not influence the reverberation time of the hall, so generally it should be lower: this might be difficult for the low frequencies in case of a very large stage. In the theatre *De Spiegel* in Zwolle the reverberation time of the stage tower is lower than the reverberation of the hall. In order to achieve this, more than 80% of the walls inside the stage house were clad with 80mm thick sound absorptive material.
- Preferably include two or three balconies to minimise the maximum distance to the stage: this maintains a good natural view of the facial expressions of the actors. The furthest audience rows should be within 25 metres of the stage, for the same reason.
- Include a proscenium stage to allow players to approach the audience, so that their voices are projected directly in the hall's volume without losing too much vocal energy into the stage house.
- Aim for a reverberation time of maximum 1 second, but preferably 0.8 to 0.9 seconds. Without having to add absorption (which would

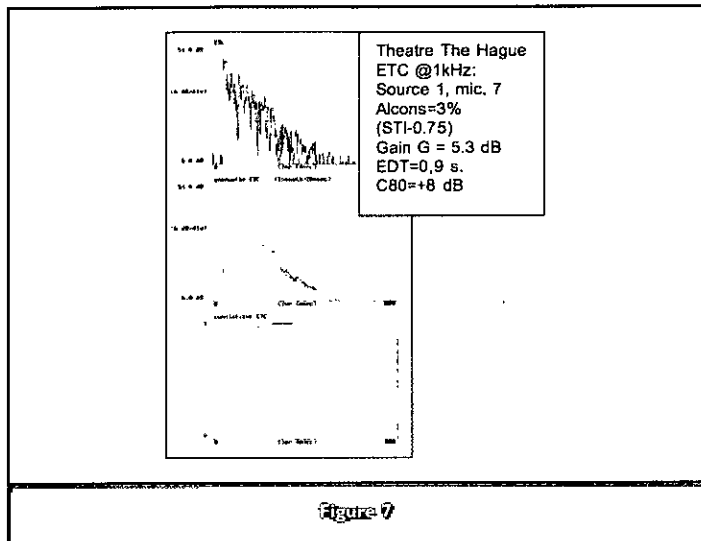


Figure 7

Energy time curve (ETC) of impulse response in The Hague theatre: source 1, microphone 7 (16m)

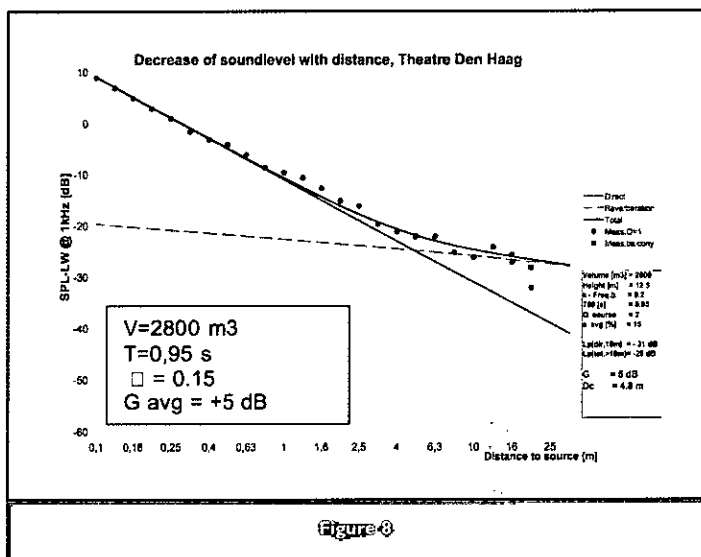


Figure 8

Decrease with distance curve (1kHz) in The Hague theatre along a straight line from source position 4 into the hall. Average value for G is 6dB

reduce the resultant sound levels) this can only be done by making the room volume even smaller than 5000m³, which would make a very room-efficient design necessary. In *De Spiegel* in Zwolle the room volume for speech is about 3800m³. In theatres with variable acoustics that have also to be suitable for symphonic music, a delicate balance will be necessary. The reverberation needs to be long for symphonic music (1.9 to 2.0 seconds) requiring a large volume, but sufficiently short for drama (< 0.9 to 1.0 s).

Developments in variable acoustics

Because of the different acoustical requirements for symphonic music and theatre use, a significant variation in properties will be necessary. This revolves mainly around reverberation time and volume, as can be seen in Figures 1 and 2, as well as related factors such as definition and clarity.

In many places theatre buildings have to be built that have to accommodate a wide variety of performances. If for reasons of building budget or running costs only one main hall can be built, it is possible to create a compromise in its acoustics that will work more or less for all performances. Halls that are designed this way usually have a bad reputation for acoustics (multi-purpose is no purpose) when they accommodate more than 500 or 600 seats. For smaller halls a compromise is possible, if properly designed.

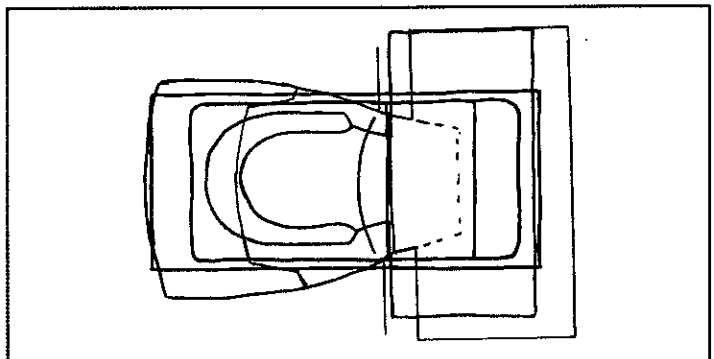


Figure 9

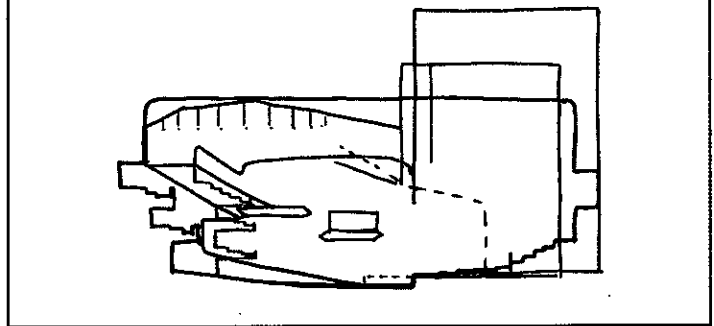


Figure 10

Schematic plan and cross-section of Theater aan de Parade (black lines) together with the previous example of an intimate theatre and concert hall.

In the 1970s variable acoustics began to be applied in this typical 'receiving' type of city theatre. With the acoustical requirements in mind, Peutz's acoustic design philosophy began with the hall size necessary for symphonic music. This was initially implemented in the *Stadsschouwburg Heerlen* (1962, 4200 to 5000 m³), but was seen more clearly in the *Theater aan de Parade* (1976, 4500 to 5000 m³). A schematic plan and cross-section of this theatre is given in Figures 9 and 10 (black lines), together with the previous example of an intimate theatre (in The Hague) and concert hall. This theatre was designed with a relatively large volume and stage opening. The stage was equipped with a movable orchestra shell. This would give a moderately long reverberation time of 1.5 to 1.7 s. To adapt the hall for classical plays the stage opening could be reduced by movable manteaux. A large quantity of vertical curtains can be unrolled from the ceiling to add absorption, in order to reduce the reverberation time: the effective acoustical volume is reduced at the same time. On the other hand a hall is created with a strongly sound absorbent ceiling, a clear concession to the optimal conditions for natural speech.

This concept of hall with variable acoustics was further developed in *De Lawei* in Drachten (1988), and the *Theater aan het Vrijthof* in Maastricht (1991), the *Stadstheater Zoetermeer* (1992) and in the *Zaantheater* (1998). A schematic plan and cross-section of *De Lawei* are presented in Figures 11 and 12 (black lines), together with the previous intimate theatre and concert hall. The basic shape of these halls is a rectangular box with sufficient volume for symphonic use. They have a stage opening approximately 20m wide and 12m high, a single main balcony and a maximum height of 16 to 18 metres (reduced by vertical curtains to 12 to 13 metres, with a total area of curtains 1000 m² or more). The total room volume including orchestra shell is 9000 to 11000 m³. The (effective) volume in the theatre mode is approximately 5000 to 6000 m³. The reverberation time ranges usually from 0.9 to 1.1 seconds in theatre mode to 1.6 to 2.0 seconds in concert mode. This concept for variable acoustics works technically quite well. The only

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drawbacks are the extra sound absorption in the theatre mode, where strength of sound is lost, and a slightly less full reverberant sound, due to the absorption of the seating because of the good sight lines. Another disadvantage may be a certain loss in architectural freedom for the hall design: these halls are not really intimate.

A next step in the development could therefore be to create a more effective volume variation, so that in the theatre mode no increase in total sound absorption would be necessary. A step in this direction was made in the main hall of *De Harmonie* in Leeuwarden (1994) where approximately 60 % of the ceiling consists of large panels that can be lowered to vary the height of the hall. On top of these elements and exactly in the same position under the roof of the hall, strongly absorbent material is applied to make the space above the lowered ceiling as 'dead' as possible. The 40% area between the ceiling panels acts almost as a 100% absorptive area. In the concert mode, with the ceiling in its highest position, all this absorption is disconnected from the hall by closing it off. The advantage of this solution is that less energy is lost in the theatre mode, but the range in reverberation time is somewhat reduced.

The final step in development was made in *De Spiegel* in Zwolle (2006). Based on the experience with good and intimate theatres for natural speech the hall was designed to be as compact as possible. Unlike the previous halls, the starting point for the design was not the concert hall, but a small theatre with 850 seats of approximately 3500m³. It has two horseshoe shaped balconies, an average room depth of 18m and a maximum room width of 20m. Although the seating capacity (850) is greater than the theatre in The Hague (675), *De Spiegel* can still be considered an intimate theatre, as is illustrated in Figures 13 and 14.

In these figures the plan and cross-section of *De Spiegel* are drawn, together with the schematic plan and cross-section of the theatre in The Hague. The ceiling in theatre mode is as low as possible: approximately 12m, mainly determined by the position of the light bridges. The width of the stage opening can be adapted from 18 to 14 m using rotatable side-boxes that also reduce the width of the stage opening. In Figures 15 and 16 the effective acoustical volume of the theatre in the theatre mode is illustrated (red area).

To provide a hall for symphonic music this ceiling can be set at 20 metres and an 4000 m³ of volume is thus added, as a kind of gallery with an additional 150 seats. This was based on experience of the Royal Albert Hall project. In Figures 17 and 18 a plan of the gallery level and a cross-section of the hall in the concert mode are presented, together with several dimensions and the acoustical volume (red area).

Including the installation of an orchestra shell a total volume of 11000m³ was created in this theatre in Zwolle, three time greater than the theatre mode. This concept was extensively tested in the design phase using scale model research¹. Measurement results reveal its interesting properties, fulfilling the design objectives. The range of reverberation time is from just under 1 second to 2 seconds without compromise to the strength of the sound in the theatre mode. G values are +6dB in concert mode, and +3 to +4 dB in theatre mode. Average clarity C₈₀ values range from 0dB for concert use to +7dB for theatre.

The design process and concept of this new theatre in Zwolle are described in English in the book '*De Spiegel: Theatre architecture as a mirror of experience*'. Since its opening this new concept for variable acoustics has inspired others to undertake similar projects abroad.

We feel that the development towards the creation of multi-purpose theatres with acceptable acoustics for a wide range of performances, which began some 30 years ago, has reached its fruition in Zwolle. These days, virtually no concessions are made to acoustical quality for natural speech or for symphonic music. In the past it was often said that a multi-purpose theatre was a no-purpose theatre. But with good variable acoustics it has proved possible to create multi-purpose theatres without compromises.

The authors are with **Peutz BV, Mook**, Netherlands. This article is closely based on their presentation at Auditorium Acoustics, Oslo in 2008.

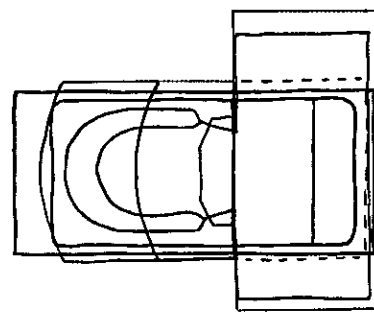


Figure 11

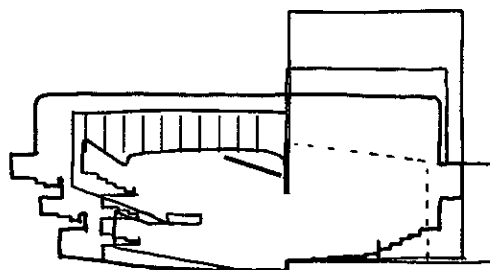


Figure 12

Schematic plan and cross-section of Theater de Lawei in Drachten (black lines), together with schematic lines of the previous example of an intimate theatre and a concert hall.

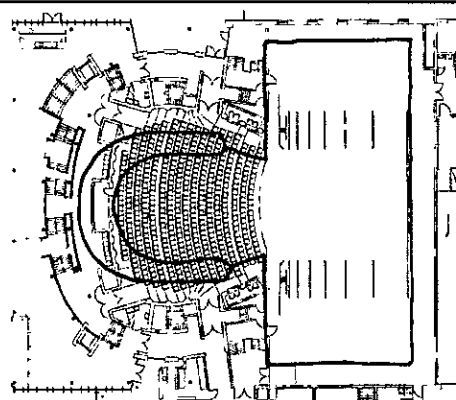


Figure 13

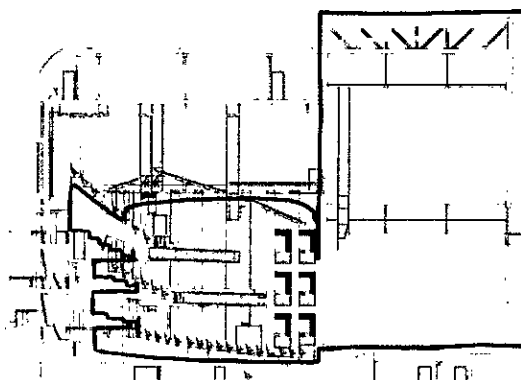


Figure 14

Ground floor plan and cross-section of theatre De Spiegel in Zwolle in theatre mode, with schematic lines (green) of plan and cross-section of the theatre in The Hague.

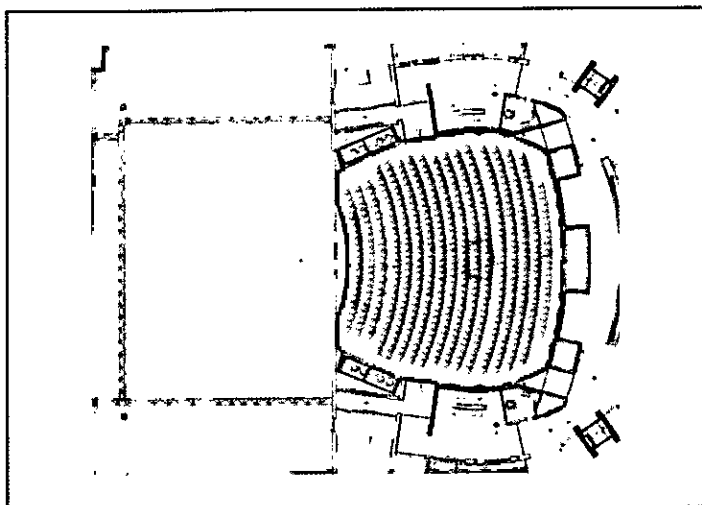


Figure 15

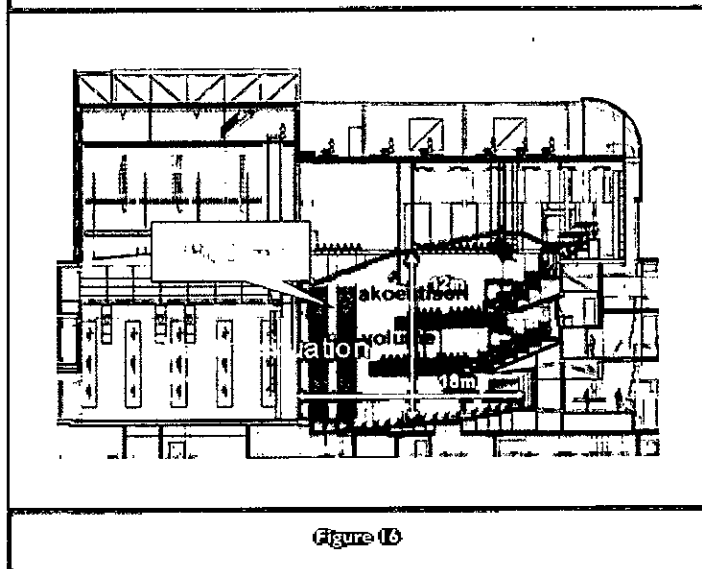


Figure 16

Plan and cross-section of intimate theatre for natural speech De Spiegel in Zwolle in theatre mode.

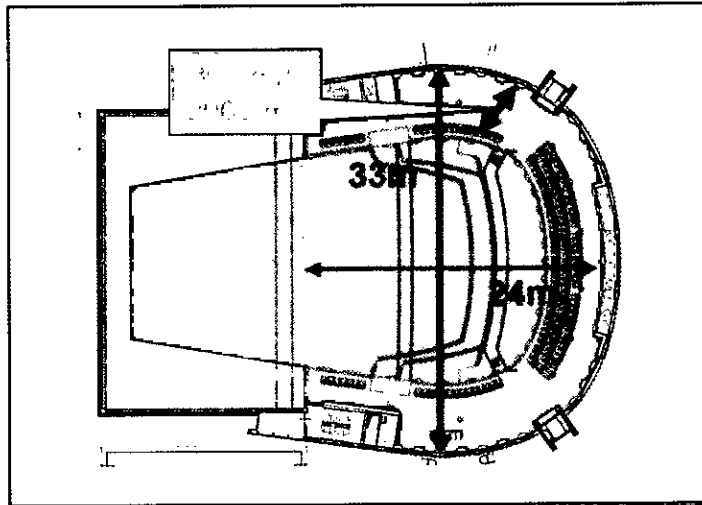


Figure 17

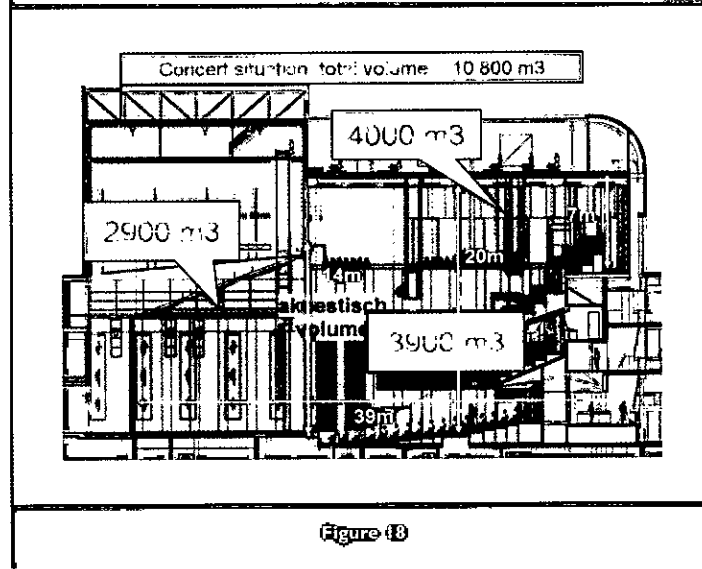


Figure 18

Plan at gallery-level and cross-section of theatre De Spiegel in Zwolle in concert mode

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A loudspeaker orchestra for concert hall studies

J Pätynen, S. Tervo, T. Lokki. The impression of a symphony orchestra

Introduction

Concert halls are commonly compared with each other with the help of some acoustical parameters such as reverberation time or clarity¹⁻⁴. These parameters, however, each provide only a single value computed from an impulse response. In concert halls, the impulse responses are often measured with an omnidirectional sound source and microphone. However, such a single source is far from a typical sound source - an orchestra. Therefore, a wide sound source would intuitively be preferable for studying concert hall acoustics. This article describes a proposal for a loudspeaker setup that mimics a symphony orchestra. Several loudspeakers are installed on a concert hall stage as a loudspeaker orchestra. Individually recorded anechoic instrument tracks of orchestral works are then played through the loudspeakers as an ensemble in order to produce an impression of a symphony orchestra. The authors are not aware that a loudspeaker orchestra of this scale has been used in acoustical music reproduction, but large loudspeaker setups for electro-acoustic music performances have been described⁵⁻⁷. In this article the loudspeaker setup is demonstrated in a single concert hall, although the system is particularly designed to be repeatable in other halls as well.

This article is organised as follows. First, the loudspeaker setup and the concert hall are described. Then, subjective opinions gathered with *in-situ* listening to the loudspeaker orchestra are presented. Finally, possible error sources are discussed and future enhancements of the system are proposed.

Loudspeaker setup

The loudspeaker orchestra was installed in a chamber music hall. The hall has approximately 400 seats and the general shape of the hall is a shoebox⁸. In addition, the audience area rises moderately. The area of the stage is 17 by 10.5 metres while the total length of the hall is 29m. The total height to the ceiling at the stage is approximately 12.3m. Acoustically reflective panels are suspended above the stage at a height of 8.2m.

The setup consisted of 24 loudspeakers of the following types: Genelec 1029A loudspeakers were used in 17 positions, Genelec 8030A in five, and Genelec model 1032A in two positions. The plan of the loudspeakers was designed roughly to represent a typical symphony orchestra with the American seating arrangement⁹. The overall positioning is shown in Figure 1 with the corresponding notation for the loudspeakers. In the layout, loudspeaker nos 11-13, 14-16, 17-19 and 20-22 stand for the first and second violins, violas and cellos, correspondingly. In addition, loudspeaker nos 23 and 24 are positioned to represent the contrabass players. A complete list of loudspeakers in different positions is given in Table 1. It should be noted that loudspeaker no.9 appears twice, as it was used for percussion and second timpani tracks as well as for the soprano soloist (see Table 2). The thick bars in Figure 1 each represent one metre. Thus, the maximum width and depth of the loudspeaker layout was 13m and 7m. The arrangement was devised for repeatability of the experiment in other halls in the future.

Loudspeakers were calibrated at their final positions one at a

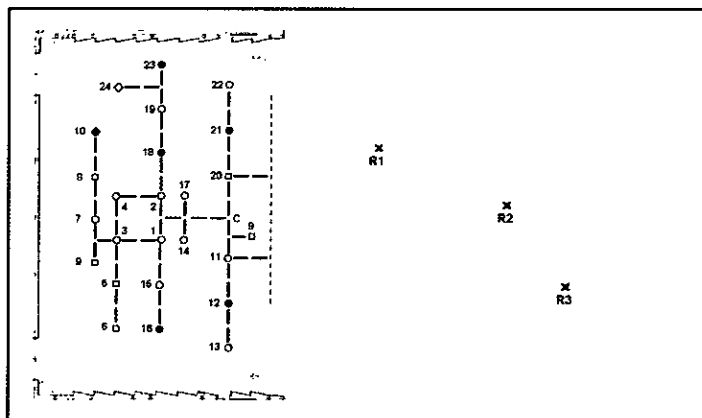


Figure 1

Plan of the loudspeaker arrangement and recording positions R1-R3. The hall is 29m long and 17m wide. Model 1029A loudspeakers are shown as circles. Model 8030A are shown as rectangles and model 1032A as diamonds. A black symbol indicates a tilted loudspeaker. The conductor's podiums located between loudspeakers 11 and 20, is marked with a letter C.

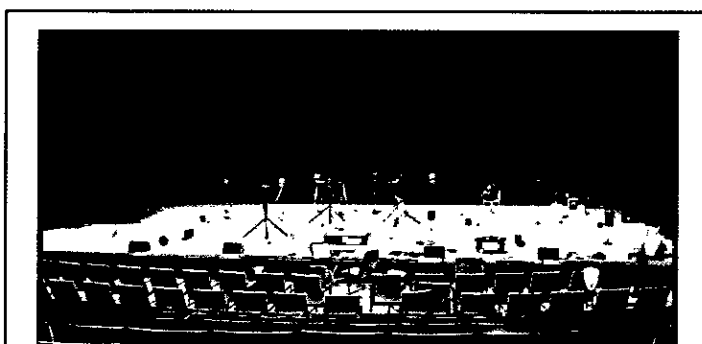


Figure 2

The stage with loudspeaker orchestra seen from recording position R2

position(s)	model	orientation	h_{centre}
1, 2, 3, 4, 7, 11, 13, 14, 15, 17, 19	1029A	forward	1.25m
22	1029A	forward	0.70m
12, 16, 18, 21, 23	1029A	upward, on floor	-
5, 6	8030A	135° clockwise	1.15m
8, 9	8030A	forward	1.25m
20	8030A	forward	0.70m
10	1032A	45° upwards, 45° clockwise	0.75m
24	1032A	45° clockwise	0.70m

Table 1

Loudspeaker models in different positions, where h_{centre} indicates the height of the acoustical axis of the loudspeaker from the floor

time by using 100 - 5000 Hz band-limited white noise. The sensitivity of each loudspeaker was adjusted so that the calibration signal produced $L_{p,A} = 87 \pm 1$ dB at one metre distance on the acoustical axis. Loudspeaker nos 12, 16, 18, 21, and 23 were calibrated in upright position. The reason for their final positioning on the floor was to direct more high frequencies towards the ceiling and to counteract the relatively high

position	assigned part(s)	Mozart	Beethoven	Bruckner	Mahler
1	flutes	1	2	3	3
2	oboes	-	2	3	3
3	clarinets	1	2	3	4
4	bassoons	1	2	3	3
5	French horns	I	I	I-IV	I-IV
6	French horns	II	II	V-VIII	V-VII
7	trumpets	-	2	3	4
8	trombones	-	-	3	3
9	soprano / percussion / timpani II	1/-	-	-	-/1/1
10	timpani I / tuba	-	1/-	1/1	1/1
11-24	The division of string parts is explained in more detail in Table 4.				

Table 2

Anechoic instrument tracks in the loudspeakers and the number of parts in each recording.

Instrument	Main direction used
flute, percussion, violin, viola	front, slightly above player's head level
soprano	front, at singer's head level
oboe, clarinet, trumpet, trombone	downwards, in direction of bell
bassoon, tuba	high left, in direction of bell
French horn	rear right, in direction of bell
timpani	front
cello, contrabass	front, below floor level

Table 3

Selected signal directions for the recorded instruments. The directions are indicated as seen by the musician.

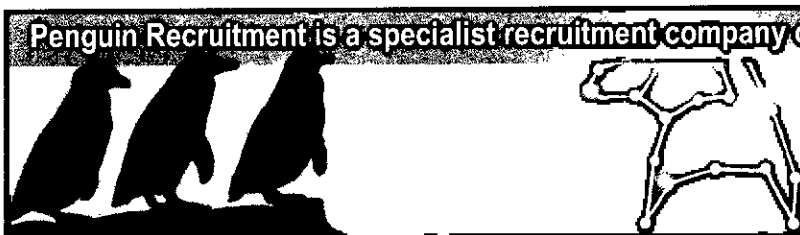
directivity of the loudspeakers. This is discussed below.

In our recent work we recorded all the instruments of a symphony orchestra in an anechoic chamber¹⁰. Each instrument part was individually recorded with 20 high-quality condenser microphones positioned evenly around the instrument with an average radius of 2.13m. Thus, the sound of each instrument was captured simultaneously in multiple directions. The recording programme consisted of four excerpts from orchestral works: Mozart's *Aria of Donna Elvira* from *Don Giovanni*; Beethoven's *Symphony no7*, first movement; Bruckner's *Symphony no8*, second movement; and Mahler's *Symphony no1*, fourth movement.

In the loudspeaker orchestra, the anechoic recordings were used so that out of the 20 recorded signals only one was selected for each instrument. Therefore, the most representative direction for each instrument had to be chosen, despite the variation in sound radiation characteristics. This was accomplished subjectively by listening to the signals in different directions and comparing the spectrum of the recordings. The 'main' directions were eventually selected by the strongest sound and the highest level at mid- and high frequencies, and also by the facing

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A loudspeaker orchestra... - continued from page 33

direction of the musician, unless some other alternative was clearly feasible. The recording directions used for each instrument are presented in Table 3.

Each instrument part except for the strings was recorded once, which corresponds with the correct number of players in an authentic orchestra. Since a symphony orchestra has as many as 16 first violinists alone, a large number of recordings of single parts would be needed for the string instruments. However, only single 'takes', of one of each string instrument, were recorded in most cases. Therefore, in the loudspeaker orchestra the strings were amplified by stacking the identical tracks in order to gain an acceptable balance between instrument groups. Additionally, the sound levels of the recorded musicians were slightly different. This was compensated by manually calibrating the instrument levels. The final composition and adjustments of the loudspeaker channels are presented in Table 4. The notation 'div I,II' means that at least two parts were recorded. For the Bruckner symphony, multiple takes were combined in string instrument parts. The notation '2x' or '3x' indicates that combined but identical recordings were stacked in one loudspeaker track, thus adding 6 or 10 dB to the channel sound level. The need of multiplication was estimated subjectively before conducting the experiment. The increase or decrease in sound level indicated in the table refers to the adjustments performed based on the *in-situ* listening in the hall. Since the first and second flute parts were exactly the same in Bruckner and Mahler, the second flute was substituted by increasing the level of the first flute by 3dB in order to avoid tuning issues. The same procedure was used for piccolo part in Mahler's symphony. This is indicated in the first row in Table 4.

Multiplying correlated signals increases the sound level by 6dB, while fully uncorrelated signals result in a 3dB increase. With recorded signals such as two consecutive takes of the same instrument part, the increase is close to 3dB. It is noticeable that the stacking performed to the string parts results in a high number of players than the typical number in a symphony orchestra. For instance, the multiplication of first violins in the Mahler equates to ten mixed uncorrelated signals (representing violinists) for both *divisi* in each loudspeaker channel.

In-situ listening

A small number of experienced acousticians participated in evaluating the loudspeaker orchestra *in-situ* in the otherwise empty hall, by listening to the recorded works in several positions in the auditorium. The setup was adjusted to the final configuration partly according to their suggestions. Their comments and impressions are described and discussed here.

The first observations on the setup were related to the positioning and orientation of the loudspeakers. Two modifications to the original plan were performed according to the *in-situ* listening. First, in spite of the multiplication of the string instrument parts discussed earlier, the strings sounded somewhat dull. Originally the 'strings' loudspeakers were directed towards the conductor's podium. After the remark we ended up pointing them directly at the audience. This procedure seemed to improve the brightness of the strings noticeably. Second, the sound field was characterised to be too horizontal, there not having been sufficient reflections from the ceiling and the panels above the stage. For this reason one loudspeaker for each strings group (nos 12, 16, 18, 21, and 23) were laid on the floor facing upwards. As the directivity of the loudspeakers was

positions	assigned part(s)	Mozart	Beethoven	Bruckner	Mahler
1	flutes			I +3dB	I +3dB
2	clarinets	+2dB			
3...8					
9	soprano	+2dB			
10	timpani / tuba				
11	first violins	2x	div I,II; 2x	div I,II; 3x, +4dB	div I,II; 3x
12	first violins		div I,II; 2x, +2dB	div I,II; 3x, +7dB	div I,II; 3x
13	first violins		div I,II; 2x	div I,II; 2x, +4dB	div I,II; 3x
14	second violins		div I,II; 2x	div I,II; 2x, +4dB	div I,II; 2x
15	second violins		div I,II; 2x	div I,II; 2x, +4dB	div I,II; 2x
16	second violins		div I,II; +2dB	div I,II; 2x, +7dB	div I,II; 3x
17	violas		div I,II; 2x	div I,II; 3x	div I,II; 2x, +3dB
18	violas		div I,II; 2x	div I,II; 3x, +3dB	div I,II; 2x, +3dB
19	violas		div I,II	div I,II; 3x	div I,II; 2x, +3dB
20	cellos	-3dB	+3dB	div I,II; 2x	2x, +3dB
21	cellos	+5dB	div I,II; 2x, +3dB	2x, +3dB	2x, +3dB
22	cellos	-3dB	+3dB	div I,II; 2x	2x, +3dB
23	contrabasses	-3dB	div I,II; -3dB	div I,II; 2x	2x, +3dB
24	contrabasses	-3dB	div I,II; -3dB	div I,II; 2x	2x, +3dB

* two recordings for each part

Table 4

Final multiplication and amplification of instrument tracks for the loudspeaker channels.
Div stands for *divisi*, meaning that an instrument group has more than one part.

stronger at higher frequencies, this was expected to increase the vertical impression of the hall for the strings. The loudspeakers on their backs are visible in Figure 2. To increase the effect further, the output level of the corresponding loudspeakers were increased for Beethoven and Bruckner (see Table 4).

Another comment about the strings was that the number of loudspeakers appeared to be too few, since the strings did not have the authentic feel of blending the sound of multiple players. The strings were also localised too accurately to the loudspeakers. This was apparent especially in front rows of the audience area: at the back of the hall the blending was much better. However, this was thought to be difficult to characterise explicitly. Besides the relatively small number of loudspeakers, a possible reason could be the limited number of recorded takes for the string parts. Also the small quantity of diffusing elements on the stage could be a partial cause, since the only significant objects were the stands and the loudspeakers themselves.

The overall impression was of a sound too 'thin' for an authentic orchestra. For this reason, the overall sound level of the instrument tracks was increased. The levels were increased by 3dB for the Mozart aria and Beethoven symphony, and by 6dB for the Bruckner and Mahler symphonies.

According to the linearity assumption in acoustics, the increase of sound level should not have any effect. Still, the impression was improved quite considerably by the sound level increase, which suggests a psychological aspect in *in-situ* listening. In position R2, the maximum sound pressure level $L_{p,A}$ of 87dB was measured during the Mahler, with the final adjustments.

The wind instruments were considered more convincing than the strings as the recorded tracks are not multiplied. Also, the number of loudspeakers was slightly closer to the number of musicians in authentic symphony orchestras. Especially in *tutti* passages, the wind instruments did not particularly stand out unnaturally, and the overall sound in orchestral *tutti* was more highly regarded than in more delicate passages.

In the Mozart aria, some comments were made that the soprano sounded too damped or restricted, but this opinion was not unanimous. In the opinion of the authors the soprano was convincing and natural.

Otherwise the loudspeaker orchestra was said to sound surprisingly good, in particular in the back of the hall and when signals were played quite loudly. Naturally, some defects were

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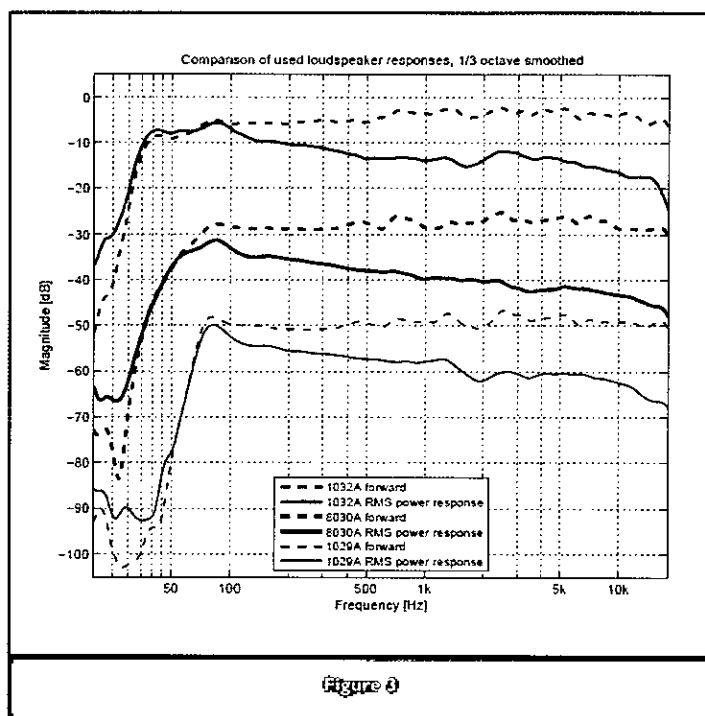
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A loudspeaker orchestra... - continued from page 34



Comparison of loudspeaker magnitude and power responses

also noticed, such as that the system seemed to have slightly a characteristic sound or timbre of the loudspeakers used, and the strings had the feel of a recording with close microphones (partially true!). In addition, the amount of low frequency sound was unnaturally high compared with a real concert, so integrated bass tilt or roll-off adjustment at the loudspeaker control was suggested to flattening the power response: this was not implemented in the study. All four musical passages were also recorded for future use in positions R1 to R3, with a Soundfield microphone, an artificial binaural head and a 3D microphone array¹¹.

Loudspeaker power response measurement

One major challenge in implementing the loudspeaker orchestra was related to the differences in the radiation characteristics between loudspeakers and musical instruments. These differences were also seen as a major source of errors between authentic and loudspeaker orchestras. Multiple studies have been using a directional loudspeaker with adjustable directivity^{12,13}. On the other hand, the use of a loudspeaker as an instrument has been discussed elsewhere^{14,15}. The effect of loudspeaker directivity on the subjective impression of sound quality in small spaces has also been studied¹⁶. However, the perceivable directivity with multiple sources in concert halls is not known to be reported.

While the directivity of a loudspeaker has a considerable function in successfully standing-in for a musical instrument, actual directivities of the loudspeakers were expected to be different from those of the real instruments, so the radiation pattern of the instruments could not be correctly reproduced. To assessing the radiated sound energy from the loudspeakers, the magnitude and power responses were measured from the loudspeaker models used.

Power response measurements were conducted by measuring

the magnitude response in an anechoic chamber with 20 microphones evenly spaced around the loudspeaker to approximate to a spherical surface. The *rms* averaged magnitude response from all microphones then provides a relative power response in the frequency domain.

A comparison of the loudspeaker power responses is presented in Figure 3. Each line pair shows the difference between the overall sound radiation and the forward direction for each loudspeaker model, Genelec 1032A, 8030A, and 1029A. A typical behaviour of declining power response is visible in all curves¹⁵. At the same time, the response in the forward direction is relatively flat. With the 1029A and 1032A slight fluctuations near the crossover frequencies were measured. However, the manufacturer's measurement shows fluctuations of the same kind¹⁷. Relative power responses are comparable with the values reported in the specifications. Note that the overall level of the curves has been adjusted to give a clearer illustration.

It is plausible to assume that the declining power response of the loudspeakers is an important reason for the comments about the dull-sounding strings received during *in-situ* listening. Originally the corresponding loudspeakers were pointing towards the podium, which resulted in a certain lack of brightness in the timbre. According to Meyer, the violin sound is radiated to a half-space pattern at highest frequencies⁹. As the loudspeaker power responses are considerably lower above 1 kHz, suggesting a narrowing directivity, turning the loudspeakers to the audience improved matters. Loudspeakers featuring ordinary directivity characteristics still present a problem with reflected sound. As the strings are assumed to be more omnidirectional than the other instruments, the loudspeakers cannot provide sufficient sound energy in arbitrary directions, which results in lower excitation in the hall acoustic than with authentic instruments. This could be improved by turning more loudspeakers with string instrument tracks to point in various directions, or by using more omnidirectional loudspeakers.

As the wind instruments sounded like their authentic counterparts, it is feasible that the directivity of the loudspeaker was closer to the radiation pattern of these instruments. The flute, however, has differing radiation pattern as the instrument has several radiation sources. While the other woodwind instruments have been reported to present an alternating directivity, the radiation is more concentrated in the forward directions⁹. According to Meyer, the brass instrument directivities have a narrowing radiation pattern which resembles the directivity of the loudspeaker, and thus a declining power response. Maybe this was the reason why the brass instruments had no noticeable deficiencies.

Future work

The experiment on the loudspeaker orchestra suggested a number of areas for future research. To obtain more comprehensive evaluation of the sound quality of the loudspeaker orchestra, a listening test is planned. The music passages recorded with the loudspeakers should be assessed against an authentic symphony orchestra recording. In addition, the power responses of the instrument recordings provide more information on the differences between the authentic instruments and the loudspeakers.

Referring to the research on the required number of recorded instruments in auralisation¹⁸, the impression of an authentic string sections can be enhanced by modulating the recorded signals and altering the instrument channels in the loudspeaker

setup. In addition, the directivities of the loudspeakers could be physically modified in order to break up the high directivity at high frequencies.

With the current design of the loudspeaker orchestra it is possible to perform the same measurements in multiple halls. The recordings from various halls provide material for comparison between performance spaces while the excitation signal remains exactly the same in all halls. Besides real halls, the acoustics of an existing space and a virtual model of the space can be compared. As a side product of the loudspeaker orchestra, the measurement of impulse responses from each loudspeaker channel is easily conducted with the setup.

Conclusion

The experience from the project was encouraging, and the comments received during the in-situ performance suggested that the loudspeaker orchestra left possibilities for further improvements. The experiment opened avenues for future work and development.

Acknowledgments

The research leading to these results received funding from the Academy of Finland and the European Research Council under the European Community's Seventh Framework Programme.

J Pätynen, S Tervo and T Lokki are with Helsinki University of Technology, Department of Media Technology, Finland. This article is closely based on their presentation at Auditorium Acoustics, Oslo in 2008.

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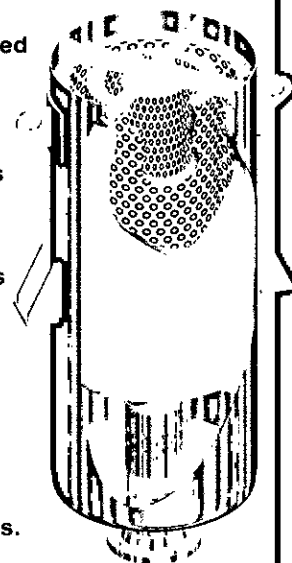
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How to control the bass coming out the back of your outdoor music rig

Keith Holland, Ian Flindell and Ian McDonald. The sub-bass directivity control system – 'SuBDiC'

The problem of bass

Many readers will be well aware of the often severe community noise problems caused by uncontrolled bass coming out of the back of small and medium scale outdoor music rigs. Most systems these days are capable of achieving high quality sound over the audience area out in front of the stage, with the only constraints being the amount of kit required for the size of the audience area and achieving sufficient height if the loudspeakers need to be 'flown'. The directivity of most mid-frequency and high-frequency loudspeakers can be optimised to achieve coverage over the audience area with control over spill off to either side and around the back. However, standard sub-bass bins (subs), which are often used to supplement the low end and provide a bit of 'kick' to the sound, radiate low-frequency sound in all directions. This means that nearby residents round the back of the stage area will hear a lot of bass and not much else.

The problem of being able to hear just the bass thump and rumble of someone else's uninvited music and not much else is well known to local government Environmental Health Officers and is one of the main reasons for outdoor music events being strictly controlled these days. It should be noted that, in this context, low-frequency is often more important than might be assumed based on community noise sound level measurements using the standard A-frequency weighting. A-weighted sound levels are relatively insensitive to the lower audio frequencies. Typical houses do not attenuate bass coming in from outside to the same extent as mid- and high-frequencies, which means that closing the windows might not help and can even exacerbate subjective problems.

The solution

In general, there are three possible solutions:

- a) Turn the bass right down; or
- b) Use specialist directional sub-bass systems; or
- c) Construct a sub-bass directivity control (SuBDiC) line-array system out of standard sub-bass bins with a standard digital delay.

Option (a), which is effectively the same as not using the subs at all, will generally be perfectly acceptable to local government Environmental Health Officers, but will probably emasculate the sound quality out at the front and might not be quite so effective in giving the audience what they want. Bands which use powerful backline bass amplifiers which are equally omni-directional at low frequencies will need to have these turned right down as well, and this may be difficult to achieve.

Option (b) can be very effective, but it is complicated and expensive and will not be commercially viable for many small and medium-sized outdoor music events which are often run on very tight budgets. Directional sub-bass systems either need to be comparable in size to the lowest audio wavelengths they are required to control, and this generally means either big or very big, or, in the case of cardioid-type systems, horribly inefficient. All specialist directional sub-bass systems are likely to be expensive.

Option (c) is simple, efficient and effective and most hire

companies will already have all the necessary components in stock. In fact, we are not really sure why the sub-bass directivity control (SuBDiC) technique is not used a lot more often, so the purpose of this article is to make it more widely known by describing a recent application.

The system used at the annual Firsdown Music Festival

There is an increasing number of small to medium-sized outdoor music events being organised by local councils and community groups all over the country. At events like this we can achieve excellent coverage over a crowd of up to around 1000 people using a standard front-of-house (FOH) system of around 10kW max power, but not without a lot of bass leakage out the back. Fortunately for this particular venue, there are no houses around the back of the stage area, but this is not the case for many other venues where bass leakage out the back can be a serious community issue. The SuBDiC system only needs two or three additional pairs of standard sub-bass bins, with suitable power amplifiers, set up in line with the master FOH system (see Figure 1), and a standard digital delay, to control the low-frequency audio feeds. For this application, we used Iyvsound's heritage EM Acoustics EBW-5 'Beamwidth' FOH concert system including horn loaded subs, with two additional pairs of Celestion CX1811 horn loaded subs and one additional pair of Tannoy B400 horn loaded subs out in front. For the delay lines, we used a 20-year-old Yamaha DDL-3. These components effectively represent bog-standard pieces of kit, the types of which many contractors may have lying unused in the warehouse, or perhaps available from friends or acquaintances.

For this application, we set up the additional subs in front of the main FOH speakers to avoid interfering with the stage area. However, and notwithstanding the usual advice to avoid putting any microphones in front of the FOH loudspeakers, there are additional benefits (see below) if the line array can be set up behind the main FOH loudspeaker stacks. The digital delays were set up to match the spacing between the additional subs, so that forward-going waves would be reinforced in-phase. The operating principle is effectively the same as that used in a shotgun microphone, but operating in reverse, and is technically known as an end-fire line array. The unavoidable wavelength-dependent interference patterns caused by interactions between the separate line arrays set up on either side of the stage area did not cause any problems in this application.

A simple tape measure is perfectly adequate for measuring sub spacing. For subs with internal horns, they should either all be approximately the same design, or some allowance may need to be made for any differences in acoustic propagation delay from the internal loudspeaker driver positions to the sound exit points. The signal level balance between the four separate sub pairs only needed to be set up by ear to achieve what turned out to be an impressive degree of directional control.

Measurements

Figures 2 and 3 show measured frequency spectra at 25m radius

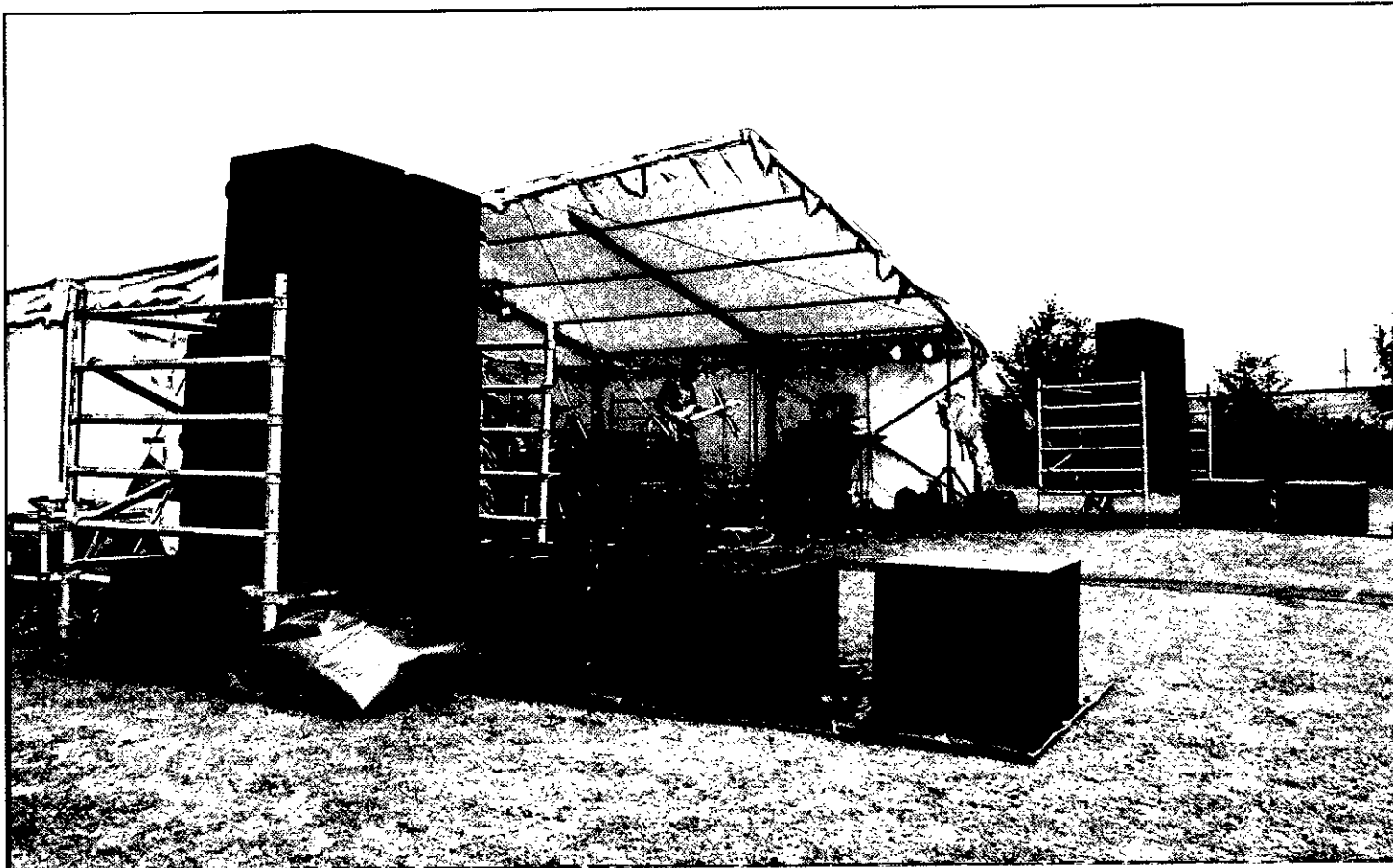


Figure 1

Deployment of additional sub-bass pairs in-line in front of the stage area at Firsdawn Music Festival 2009

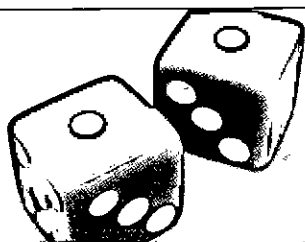
directly in front, at 90 degrees off to one side, and at 180 degrees around the back for a folk band and a rock band respectively. The subjective performance was very impressive and even more convincing than might be implied by the 10 to 20 dB differences in low-frequency content between the front and the back measurement positions. The system worked so well that it was easily possible to tune acoustic guitars by ear in the open area immediately behind the tented stage area, and the family of one of the authors was able to camp out approximately 25m behind the stage area without being very much disturbed.

Out in front of the stage and after appropriate equalisation for the enhanced low-frequency acoustic efficiency at the front, there were no obvious effects on subjective sound quality, although careful listening revealed possibly rather more low-frequency lobing off to each side than might have been expected. It is well known that wave interference patterns between the main left and right FOH stacks cause significant low frequency lobing effects anyway, and it was not possible to measure any additional low-frequency lobing caused by the line arrays under the circumstances of a live performance trial. Selective

reinforcement and cancellation in different directions around the array is caused by wavelength dependent interference patterns, with unavoidable but probably not subjectively noticeable wavelength-dependant lobing patterns out to each side. The human auditory system appears to be well adapted to tuning out these kinds of narrow band interference effects, which are much more prevalent in indoor listening spaces than many people realise. It is unlikely that the low-frequency lobing would have been noticeable to anyone not specifically listening for it.

Sophisticated computer based systems with digital phase compensation in addition to overall time delay might be capable of reducing wavelength-dependent lobing to some extent, but it is not clear that it is a problem that needs to be controlled anyway. Any technical solution would require significant investment in additional kit and additional setting up time, which does not appear to be necessary for outdoor applications. Users are reminded that any attempt to use sub-bass directivity

continued on page 40



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How to control the bass coming out... - continued from page 39

control indoors could have more noticeable effects due to interference patterns of reflected waves from nearby walls and other reflecting surfaces.

One of the practical problems encountered, and which only became a problem because the directivity control was so effective, was that because the additional line array had been deployed in front of the stage area, low-frequency spill from the FOH loudspeakers back onto the stage area was considerably reduced. In many outdoor live sound applications most of the low frequencies on stage come from backline amps or from backwards spill from the main FOH loudspeakers, not from floor wedges or side-fill stage monitor loudspeakers which are not usually designed (or even required) to radiate low frequencies effectively. To compensate for this, we found that we had to feed more bass to the stage monitor loudspeakers. This compromised the overall backwards directivity control to some extent. The obvious solution is to deploy the additional subs in line behind the main FOH stacks rather than out in front, but for most practical applications, this would need to be planned in advance. There are other possible arrangements all of which might have a range of advantages and disadvantages depending on the circumstances at the time.

Conclusions

Of the three technical solutions to the widely recognised problem of excess bass 'leaking out' from the back of small to medium-sized outdoor live music events, the sub-bass directivity control (SuBDiC) end-fire line array system was found to offer many advantages. Sub-bass directivity control is achieved by setting up additional sub-bass bin pairs in line with the main FOH loudspeaker stacks with standard digital delays to provide reinforcement in the forward direction and cancellation out to the sides and rear. When tested at the annual Firsdown Music Festival, the difference between the forward and backward low-frequency radiation was subjectively very impressive and would certainly have been enough to significantly reduce the likelihood of noise complaints from people resident behind the main stage area - had there been any such residents.

Keith Holland and **Ian Flindell** are with the University of Southampton.
Ian McDonald is with Iyysound Ltd

Acknowledgements

The authors are grateful to the organisers of the annual Firsdown Music Festival for allowing us to demonstrate the sub-bass directivity control system; to the audience who probably had not noticed anything unusual until the workings of the system were explained to them during a band change-over lull; to Thomas Holland for help with the measurements; and to the cows in the field behind the stage area who all expressed their great satisfaction with the degree of sub-bass directivity control by completely ignoring the entire proceedings.

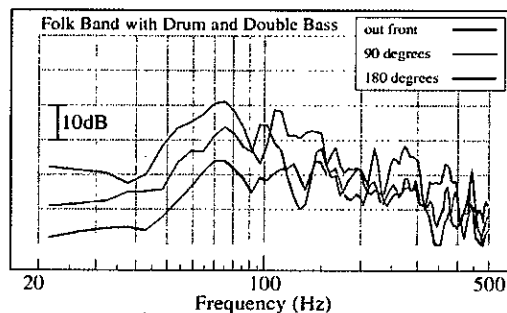


Figure 2

Frequency plots showing differences in bass around front, off to side, and around back: folk music

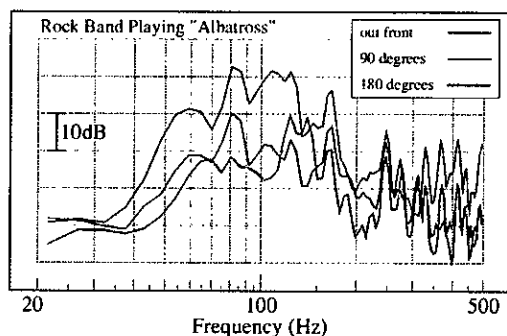


Figure 3

Frequency plots showing differences in bass around front, off to side, and around back: rock music

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Case study

Mike Rickerby, Road resurfacing using low-noise material

London Borough of Hillingdon has carried out a study of road traffic noise reduction provided by replacing a worn hot rolled asphalt (HRA) road surface. The northbound carriageway of Oxford Road, Uxbridge (on the left in the photo) was resurfaced with a textured thin asphalt material designed to minimise tyre-road interface noise. The material has a Highways Authorities Product Approval Scheme certificate 'high speed' road surface index (relative to HRA) of -5.5dB(A).

A residents' perception questionnaire was sent to 60 neighbouring properties situated at distances up to 70m from the road. Of the 25 replies received, 18 reported reduced road traffic noise levels following road resurfacing, and seven reported no change.

Period noise levels were measured with a sound level meter mounted on a tripod on the pavement, just visible on the photograph near the second roundabout sign. Measurements were made from 11:00h to 14:00h on two days before the resurfacing work, and on two days after the resurfacing had been completed. Traffic counts, HGV percentages and weather observations were recorded. The roads were dry, and traffic free-flowing. The measured $L_{Aeq,3h}$ and $L_{A10,1h}$ values averaged 76.9dB and 81.0 dB before resurfacing, and 70.4dB and 73.4 dB after resurfacing, giving reductions of 6.5 and 7.5 dB respectively (to nearest half decibel).

The quoted noise reduction of 5.5dB might not necessarily be expected at the resurfaced road which has a 30mph speed limit. This is because engine noise is conventionally thought to be more dominant than tyre noise at such low speeds. The measured noise reductions were therefore quite considerable.

The noise measurements before resurfacing were accompanied by slight easterly winds, and the winds after resurfacing were south-westerly, but no wind speeds were no more than 1.5ms⁻¹ average at 1.8m height. Supplementary noise monitoring was carried out on a day with a slight south-easterly wind, and on another day with a slight south-westerly wind. No evidence was found that wind conditions were responsible for the apparent noise reductions.

Differences in the traffic counts and HGV percentages before and after resurfacing did not explain the measured noise reductions. Resurfacing with low noise material is known to give large noise reductions if the surface replaced was rough and irregular, as were parts of this section of Oxford Road. We therefore asked ourselves if there were other contributory factors. For example, perhaps the traffic slowed down on the new road surface? This seemed an unlikely explanation because similar noise levels were measured in the supplementary monitoring carried out several months after the main post-surfacing monitoring. This may suggest that tyre noise has become more important than engine noise even at low speeds. No explanation has been found for the very large noise reductions other than the benefits, by whatever mechanism, of the low-noise material compared with the worn out HRA surface it replaced. The study seems to show that it can be possible to obtain very large reductions in road traffic noise by resurfacing with a low-noise material even on roads subject to a 30mph speed limit.

The resurfacing was paid for by Transport for London. Resurfacing with low-noise material is often difficult to justify on noise grounds alone,

because resurfacing is so expensive, but the measurements suggest that the use of low-noise material should be considered when roads are being resurfaced because they have worn out.

Mike Rickaby is an Environmental Protection Officer with the London Borough of Hillingdon

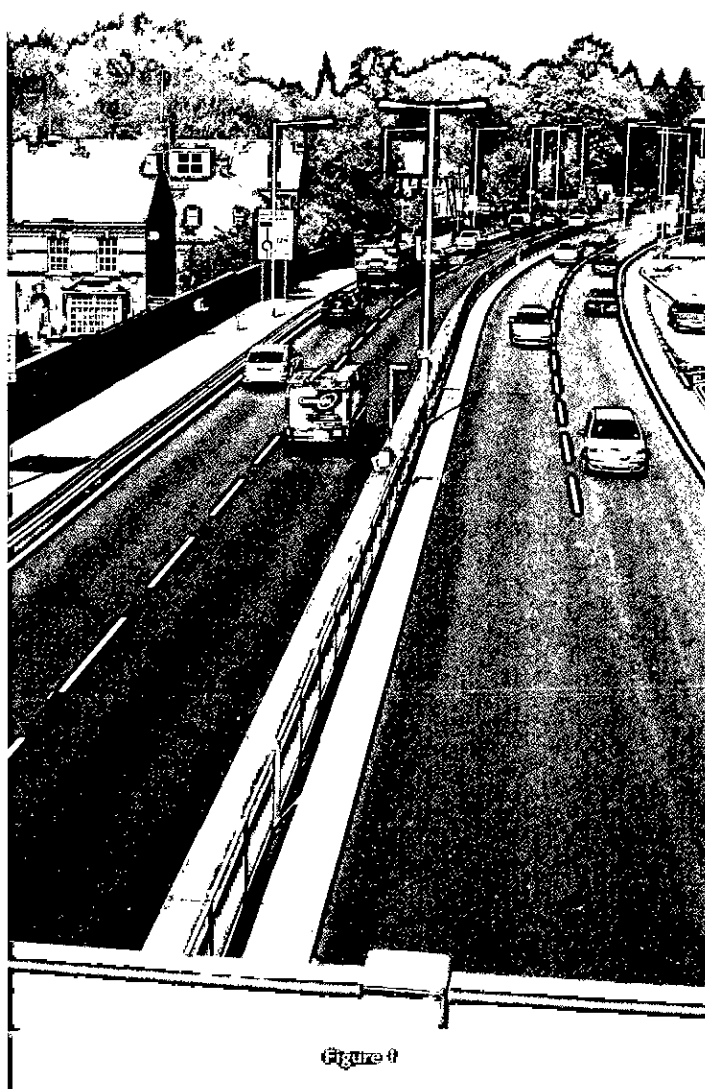


Figure 1

Good results obtained from a new low-noise surface on a busy urban thoroughway

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Hearing hazards on the road

Convertibles shown to be risky

Drivers of convertible cars could be risking permanent hearing damage from wind and road noise, a study claims. In the study, noise levels immediately to the left and right of the driver were measured while travelling at different speeds.

At 50, 60 and 70 miles per hour, the noise reached between 88 and 90 dB(A), well above the generally agreed threshold level at which permanent hearing damage becomes a risk. Road surface, traffic congestion and the wind combined to produce excessive noise.

The researchers repeated the test with a range of convertibles, on the same stretch of motorway outside rush hour, and generally found similar noise levels, but the loudest was 99dB(A).

Surgeon Phillip Michael, an ENT specialist at Worcester Royal Infirmary, carried out the research and reported that motorists did not appreciate the risk. He said that these noise levels over a period of time and given repeated exposure had the potential to cause permanent threshold shift. Mr Michael is a soft-top enthusiast himself, and presented his findings to the American Academy of Otolaryngology Head and Neck Foundation's annual meeting in San Diego, USA. He said that drivers of convertibles should consider wearing some form of ear protection, as motorcyclists do. However, keeping the windows raised cuts down the noise level to around 82dB(A) at 70mph even with the top down.

ICSV17 announced

Nonlinear acoustics

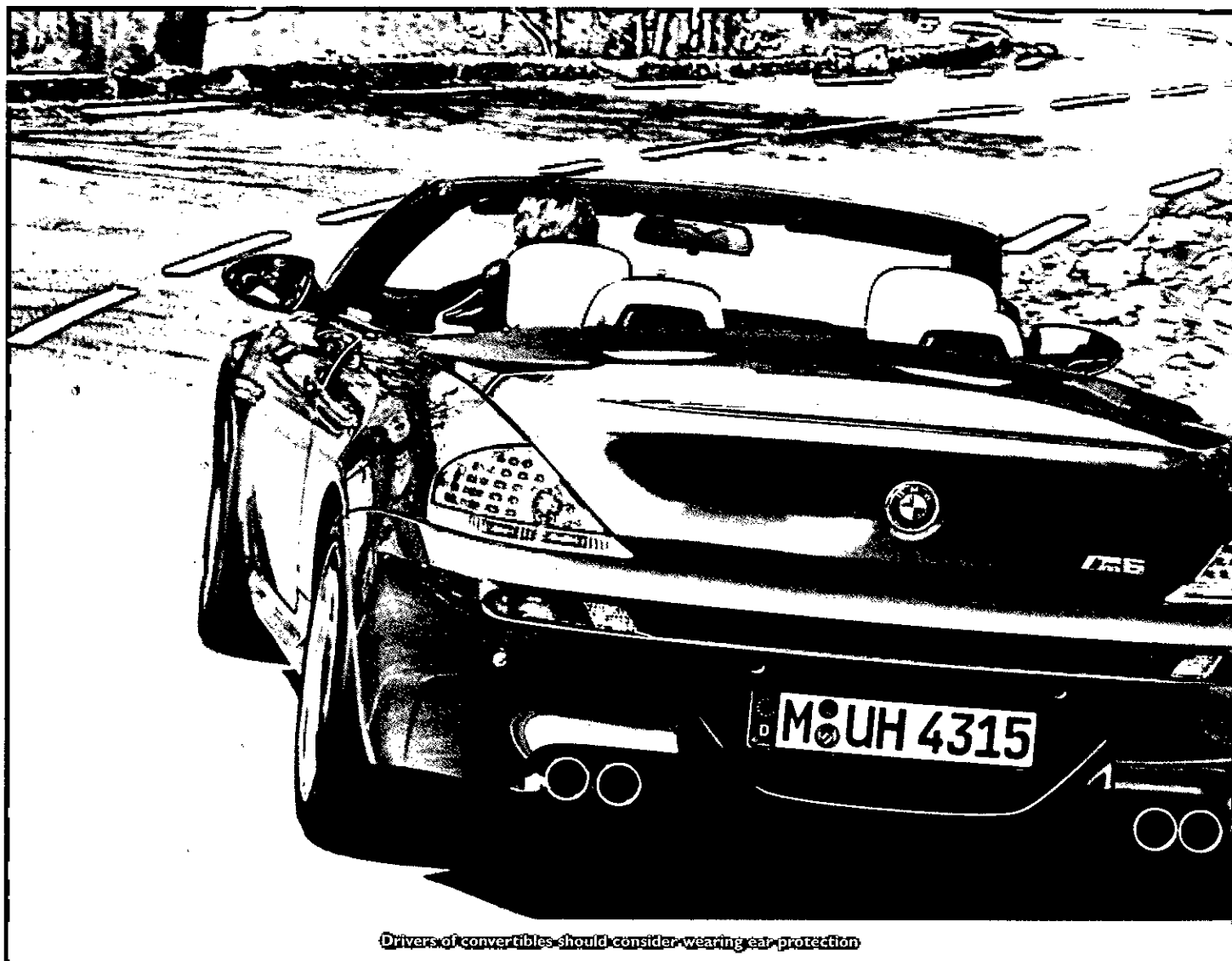
The structured session on nonlinear acoustics and vibration at ICSV17 is being organised by Dr W S Gan. He invites abstracts by 1 December 2009 for the nonlinear acoustics and vibration session at the 17th International Congress on Sound and Vibration to be held in Cairo, Egypt between 18 and 22 July 2010.

Successful authors of abstracts will be notified by 28 February 2010, and the deadline for full-length papers eight pages in length will be 31 March 2010.

The deadline for early registration is also 31 March 2010.

Please email or fax the 300-word abstracts to Dr W S Gan at wsgan@acousticaltechnologies.com. His fax number is +65 6791 3665.

For further information and online registration please go to the web site at www.icsv17.org



Drivers of convertibles should consider wearing ear protection

British Tinnitus Association

Supports EU clampdown on hearing safety regulations

The British Tinnitus Association (BTA), the only UK charity solely dedicated to supporting those with tinnitus, is urging music listeners to heed warnings about the risk of permanent hearing damage and to tune into the new hearing safety regulations set out by the European Commission regarding volume levels of personal music players, such as MP3 players and iPods.

The new legislation dictates that all personal music players sold in the EU will require a default setting where volume will be limited to 80dB(A) – a level at which exposure is recommended to be restricted to a maximum of 40 hours per week. Although listeners will still have the option to override this default setting, manufacturers will be required to display clear warnings or provide on-screen alerts of the

long-term detrimental effects that loud music can have on hearing. It is hoped that this will increase awareness of the risks of exposure to loud music and help to prevent permanent hearing damage and symptoms such as tinnitus.

The new EU hearing safety regulations have come into force following research carried out last year which highlighted the need for MP3 players and other personal music systems to control prolonged exposure to loud music.

The BTA believes this legislation is a huge step in the right direction and that it will help to educate millions of music listeners, and particularly young people. According to a 2008 British study an astounding 58% 16 to 30 year olds were completely unaware of any risk to their hearing when using personal music players.

Roy Bratby, chairman of the BTA, says that the new EU regulations emphasise the importance of reducing prolonged exposure to loud noise, and highlight the urgency of the situation. This was becoming ever more apparent as more and more people contacted the BTA reporting tinnitus as a result of exposure to loud noise in their everyday lives.

As a world leader in providing support and advice about tinnitus, the BTA has a trained team of friendly and experienced advisors for anyone who is experiencing tinnitus or is simply seeking guidance or information about the condition.

Between 50 and 100 million people use personal music players every day and an estimated 10 million people in the EU could be left with hearing damage later in life as a result of listening to music at loud volumes and for prolonged periods of time, according to an EU scientific committee.

For advice, support and information about tinnitus call the BTA freephone helpline on **0800 018 0527** or visit the BTA online at www.tinnitus.org.uk

PLASA and ESTA announce intention to merge

Agreement will strengthen both organisations and create new opportunities

PLASA (headquartered in the UK) and ESTA (headquartered in North America), two of the leading bodies worldwide for those working in the live events, entertainment and communications industries, have signed a letter of intent to merge.

The announcement comes on the back of long-term strategic reviews conducted by both associations who believe that uniting as one body will lead to a stronger voice for members, the enhancement of existing initiatives and an expansion of the range of benefits and services.

The proposed merger has the full backing of both the ESTA board of directors and the PLASA executive committee who voted on the proposal this summer and who will formally recommend the move to their respective memberships, subject to due diligence investigations being completed successfully, during the spring or summer of 2010. If both memberships vote to go ahead, the first stage of the merger will be completed by December 2010 effectively creating an industry-wide membership network of over 1100 dealers, manufacturers, installers, service providers and consultants operating under the PLASA name. This will also include members of PERA - the Production Equipment Rental Association - whose members work across the film, video and broadcast industries and which recently merged with ESTA.

In reality, any merger will simply be a continuation of an already established relationship between the two organisations who have worked together on a range of initiatives for many years and who share the same aims and objectives. The planned merger will not lead to any immediate changes and the direct priority

for the ESTA and PLASA teams will be to continue to serve the joint membership in the strongest, most relevant way possible.

To reinforce this aim, the proposal outlining the merger recommends that leadership groups be established initially in North America and Europe elected by their respective members to represent their interests and to shape the organisation to meet their specific needs. Each of these elected leadership groups will provide representatives who will sit on an executive committee charged with overall responsibility for governance, strategic planning and financial direction. Joining these representatives will be members-at-large elected from the membership worldwide.

Work on key initiatives will continue as before and in many cases will be considerably strengthened by the projected merger. ESTA's industry-leading technical standards programme has always received active participation from PLASA and its members and the planned merger envisions a further development of this essential project.

The commitment to furthering industry skills will also remain a key priority and while the methods of implementation differ, the goals of increasing the level of knowledge and skills in the industry and creating a safer working environment are jointly shared and will be fully implemented. Other initiatives such as market research will be strengthened with current research exercises expanded and opportunities for additional research explored.

ESTA President Bill Groener and PLASA Chairman Rob Lingfield view the proposed merger as a significant and essential move for members of both organisations, who they believe



will benefit from having a much strengthened representative body safeguarding their interests and developing their commercial advantages.

In a joint statement, PLASA CEO Matthew Griffiths and ESTA executive director Lori Rubinstein said that the merger was essentially about doing what was best for their members. The proposed merger would radically enhance what could be achieved on behalf of the companies and individuals represented, making the new body a more effective and informed advocate for the industry. The industry needed an organisation that was responsive to its members' needs and one where they felt fully connected and involved. They shared common goals and objectives and a united approach to the issues and challenges of our market would provide major long-term benefits and greatly broaden the role of the organisation.

www.esta.org www.plasa.org

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Obituary

Mack Breazeale

It is with sadness that the ICA advises member societies of the loss of Dr Mack Breazeale who will be remembered for his great contribution to acoustics.

Dr Breazeale died on 14 September at the age of 78. He had been a distinguished research professor of physics at the National Center for Physical Acoustics at the University of Mississippi since 1994, where he continued to be an active member of the research team. Born in Leona Mines, Virginia, USA he grew up near Crossville, Tennessee. Educated at Berea College, the Missouri School of Mines, and the Michigan State University, he was a tireless researcher and trained many others in the field of physics. Before his appointment at the National Center for Physical Acoustics, he was professor of physics at the University of Tennessee (1962-1995) and at Michigan State University (1957-1962). An editor of the Journal of the Acoustical Society of America for many years, he was a fellow of the Society and received its silver medal in 1989. He was a fellow of the Institute of Electrical and Electronics Engineers and the UK Institute of Acoustics, and had been a Fulbright Research Fellow in Stuttgart early in his career.

Dr Breazeale received his PhD from Michigan State University in 1957. He spent one year as

assistant research professor at Michigan State, then went to the University of Stuttgart as a Fulbright Fellow. Upon his return to the United States, he spent two years as assistant research professor at Michigan State University, then was appointed associate professor of physics at the University of Tennessee, and a consultant at Oak Ridge National Laboratory. He was made professor of physics at UT in 1967. At both Tennessee and Oak Ridge he interacted with graduate students served as major professor for 31 students. In 1987 he gave the president's lecture and was named distinguished lecturer by the IEEE UFFC Society: he gave a total of 39 lectures in the USA, China, Japan, Italy and Denmark. Dr Breazeale was at the University of Mississippi National Center for Physical Acoustics from 1988. His specialities were nonlinear acoustics, acoustical parametric interactions, and acousto-optic interactions. He also served as consultant to the Naval Research Laboratory, Northrop, McDonnell-Douglas, Applications Research and Alcon, and his most recent research involved these subjects applied to condensed matter physics.

A close colleague says that apart from being an excellent scientist, a distinguished professor, and a well-respected member of the community, Dr



Breazeale would above all remain an example to many of us of how a person could be so great and be so good. Anyone who ever had the privilege to know him personally would remember him as a brilliant individual, a gentleman, and a scientific father to every scientist working with him.

He is survived by his wife, a daughter and two sons, two stepsons, five grandchildren and one great-grandchild.

Obituary

David Hopkins OBE AMIOA 1936 - 2009

The Institute is sad to report that David Hopkins, a leading player in the audio supply business, has died of cancer at the age of 73. He leaves a wife Tess and two sons. David was the founder and CEO of ADS Worldwide, a Stockport based company which supplies PA system components for a number of prestigious contracts.

He became an Associate Member of the

Institute of Acoustics in December 1993. He was the longest serving member of the executive committee of PLASA, the Professional Light and Sound Association, which he joined in 1995. He held several posts on the executive and was its chairman in 2003: he was still active in the executive up until the time of his death.

Born in Cardiff, David moved to Stockport in

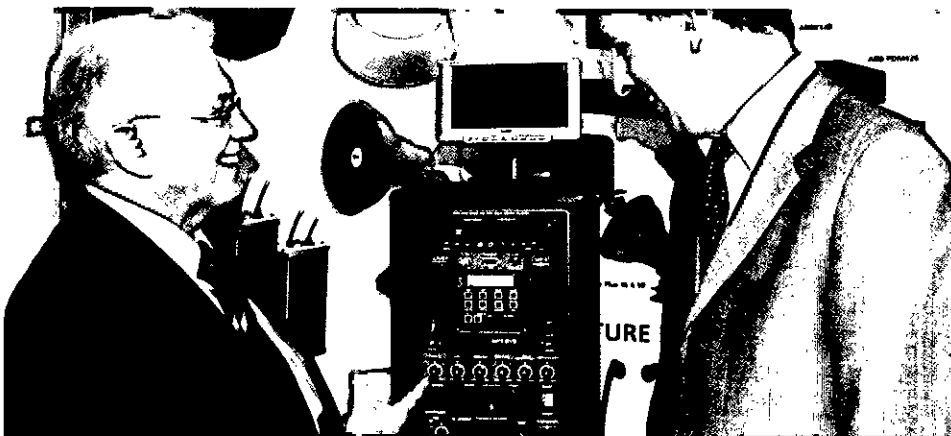
the early 1970s to take up a post as regional manager for Pye Phillips. He set up Delta Sound a decade later and Audio Design Services in 1990.

Joining Bramhall Round Table shortly after his move to the north-west, he went on to be the founder chairman and President of Poynton Round Table and founder chairman of Poynton 41 Club. He later became President of Poynton Rotary Club. Actively involved in local matters he served on Macclesfield Borough Council and Cheshire County Council during the 1980s and was awarded the OBE in 1988 for his innovative 'adopt a school' programme. He also served as President of Stockport Chamber of Commerce and as a director of Greater Manchester Chamber of Commerce.

Leading a very active life, he was always a cheery person especially when helping others, and never seemed downhearted, as was witnessed when he learned of his, sadly, terminal condition. He promptly directed his organisational skills to raising awareness of bowel cancer through the Stockport-based Beechwood Cancer Care.

He will be remembered by the many local, regional and national organisations that he started, joined or assisted. Some would not exist at all but for his foresight, and all have benefited from his enthusiasm. The IOA extends its sympathy to his family.

Geoff Kerry



David Hopkins (left) and Kevin McIndoe (right) at ICA 2007

Robin Hall joins Scott Wilson

Principal consultant in acoustics

Robin Hall has joined Scott Wilson as a principal consultant in its acoustics and vibration team. Robin has more than 15 years' experience of research, consultancy and product development which began with his research into lightweight floating floors. After completing his experimental work, he joined the team at the newly privatised BRE that wrote the current version of Approved Document E. Robin led acoustics at BRE for the last three years of his time there. His involvement in developing their commercial acoustical testing capability and associated UKAS-accredited measurement procedures led to his membership of the CEN and BSI committees currently involved with reviewing and reorganising the ISO 140 series of measurement standards.

Paul Shields, head of Scott Wilson's acoustics and vibration team said that

Robin's appointment strengthened the firm's building acoustics capability. His being based in London was an important part of Scott Wilson's strategy for improving its delivery of high quality service to existing internal and external clients and developing the noise and vibration business in the south of England.

The Scott Wilson acoustics and vibration team now has 15 members and provides a dedicated service not only to external clients but also to the whole of the Scott Wilson group worldwide. The team has considerable experience in urban regeneration, environmental impact assessments, commercial and residential developments, occupational noise and vibration, complaint investigation, architectural acoustics and expert witness work.



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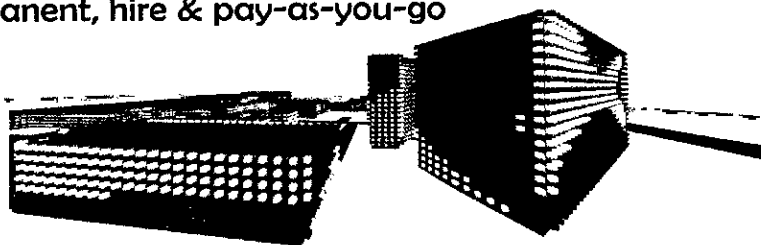
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Introducing Ramboll Acoustics

New division formed in holistic engineering consultancy

In 2007, the innovative UK engineering firm Whitbybird joined forces with the 8000 strong Ramboll group. Ramboll is known for its holistic approach to engineering consultancy with offices in Northern Europe, Russia, the Middle East and India.

The Ramboll group already included 40 acousticians based in Northern Europe and the recent introduction of a dedicated team in Cambridge extended acoustics capability to the UK.

The UK Team

Raf Orlowski, Director

Raf, a fellow of the Institute and a former honorary secretary, heads Ramboll's acoustic team in the UK. As a researcher at the universities of Cambridge and Salford, he gained extensive experience in architectural acoustics, building acoustics and noise control. Working as a consultant, his specialisations include the design of performance spaces, educational facilities and public buildings.

He is a champion of sound quality in educational buildings and acts as an advisor to the UK's Department for Children, Schools and Families, contributing to the development of regulations and working with design teams and contractors on standards and compliance.

Convinced of the part that sound has to play in shaping better environments, Raf is linking Ramboll's initiatives for innovation with research into architectural acoustics at the University of Cambridge and investigations into soundscaping at the University of Sheffield, where he has been appointed Visiting Professor in the School of Architecture.

Raf has a longstanding interest in acoustic modelling and auralisation and is keen on enabling clients to experience the acoustics of their projects using aural demonstrations.

Adrian Popplewell, Associate Director

Adrian has been working as an acoustician since graduating from the Institute of Sound and Vibration Research at the University of Southampton, in 1995, with over 12 years experience at Arup Acoustics

Adrian was the Acoustician for The Bridge Arts Centre, which won the RIBA Award 2007 – Scotland, and two Scottish Design Awards. He was also the site wide Acoustic Consultant for the 2008 RIBA Sterling Prize winning Accordia residential project in Cambridge.

He has a wide range of project experience on both multi-disciplinary and specialist projects covering many areas of acoustics, and noise and vibration control. Adrian's current areas of interest include educational buildings and healthcare facilities.

Katrina Scherebnyj, Assistant Consultant

Following research in to aircraft run-up noise, Katrina has specialised in noise modelling and mapping in a wide range of environmental project from railways to schools. She also has experience modelling the acoustics of internal spaces from performance spaces to airport terminals. Katrina has a passion for designing schools and has extensive understanding of regulatory requirements and users needs.

Phil Mudge, Senior Technician

Phil has extensive experience of measurement techniques and practical application. His specialist skills in both noise and vibration measurement have seen him lead teams on major large-scale surveys. He is keen to promote the efficient application of best practise towards measurements while avoiding the potential pitfalls.



Raf Orlowski, Director



Adrian Popplewell, Associate Director



Katrina Scherebnyj, Assistant Consultant



Phil Mudge, Senior Technician

AECOM acoustics engineer

wins prestigious Newman Award

Gil van Buuren, regional director in AECOM's acoustics group, has been awarded the prestigious Newman Award for 2009.

The Robert Bradford Newman Medal is awarded annually for excellence in the study of acoustics and its application to architecture, and is bestowed by the Acoustical Society of America. Gil won his award for his Masters' dissertation project on 'Parametric studies on the low-frequency acoustics of listening rooms using a numerical wave model'.

Gil commented that the late Bob Newman had been a major figure in architectural acoustics, and every year, the Acoustical Society of America awarded a number of Newman medals for exceptional contributions in architectural acoustics which were made as part of degree courses. Naturally, he was delighted that his work had been recognised in this way and was proud to be associated with this award.

Bernadette McKell, head of acoustics at AECOM added that they were all very proud of Gil's achievement. It was a very prestigious award and he was a very deserving winner.



Gil van Buuren

National Highway Sector Scheme 4

Certification for Jacksons Jakoustic highway environmental noise barriers

Jakoustic Highway and Jakoustic Highway Plus environmental noise barriers have now been certified to National Highway Sector Scheme 4 (for the preservative treatment of timber) having met with the requirements of the standard. This recent achievement follows certification of the Jakoustic Highway reflective barrier to

- BS EN 1793 Part 2 (Category B3)

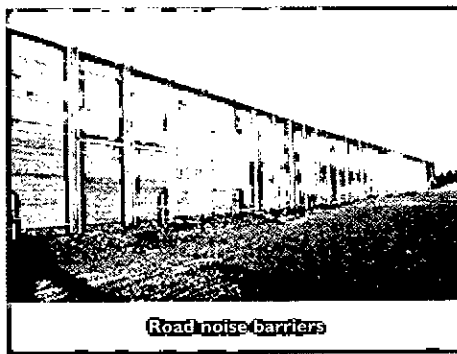
- BS EN 1794 Part 1 (Annex A, B, C, E)
- and is designed in accordance with BS EN 1794 Part 2 (Annex B, C, D, F)

Jakoustic Highway Plus absorptive barrier has certification to

- BS EN 1793 Part 1 (Category A3), Part 2 (Category B3)
- BS EN 1794 Part 1 (Annex A, B, C, E)



Jakoustic Highway Plus



Road noise barriers

- and is designed in accordance with BS EN 1794 Part 2 (Annex A, B, C, D, F).

Speaking of the latest certification, Richard Jackson, chief executive of Jacksons Fencing said that since developing the Jakoustic system, it had been subjected to a raft of tests to prove that an easy-to-install and attractive environmental noise barrier system could also meet with the most stringent performance standards in terms of noise reduction, strength, durability and sustainability. This latest certification completed the picture, and importantly, provided contractors and designers to the Highways Agency with a greater choice.

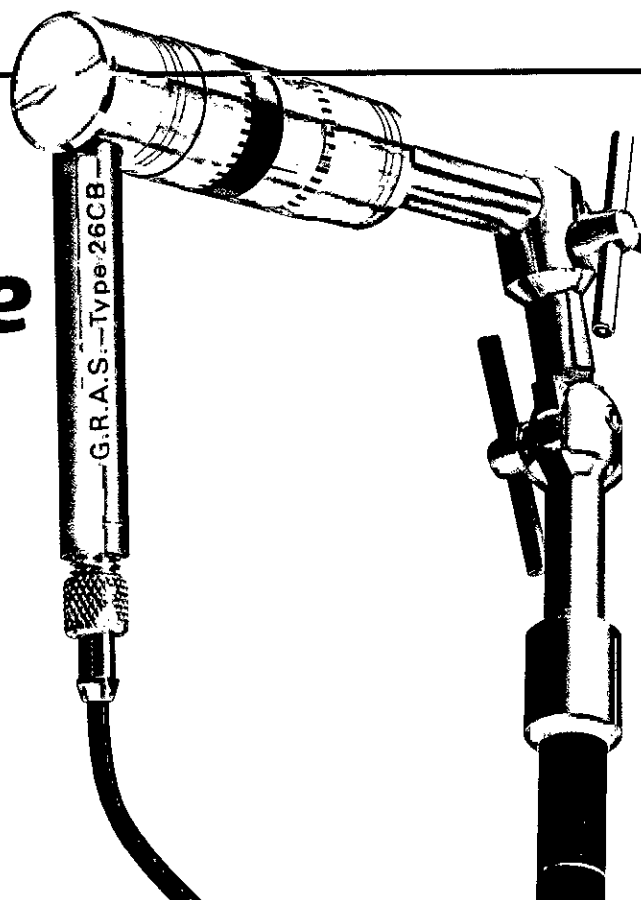
For further information on *Jakoustic Highway* environmental noise barriers and Jacksons Highways compliant post and rail fencing, contact Justin Khadaroo or Sarah Egan on 01233 750 393. Email acoustic@jacksons-fencing.co.uk for a electronic copy of the Jakoustic Specifiers Guide.

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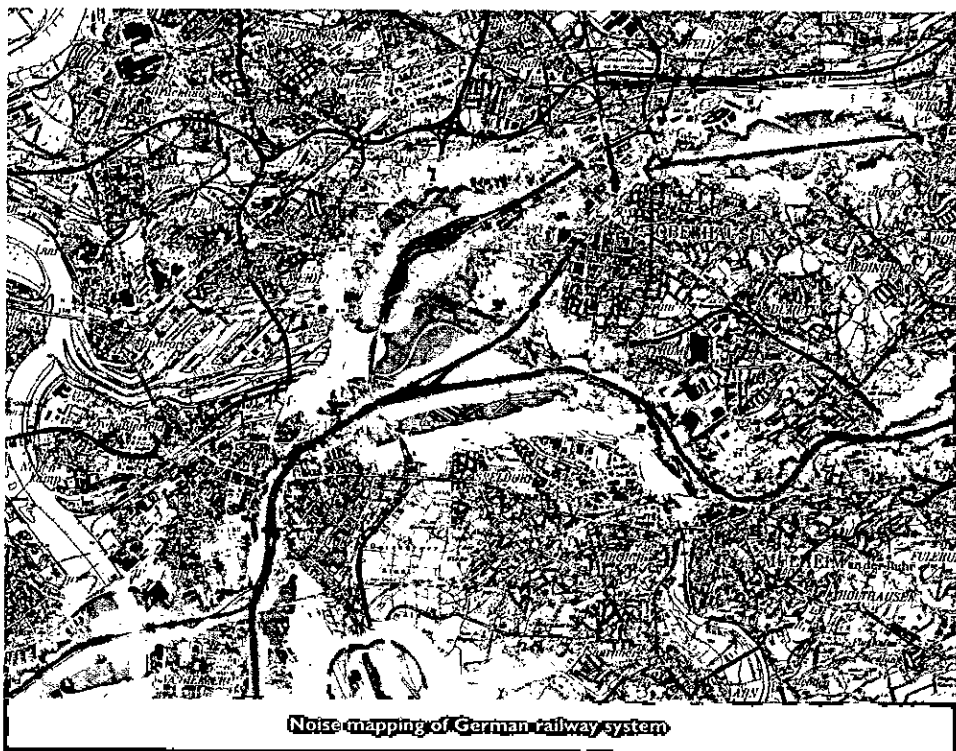
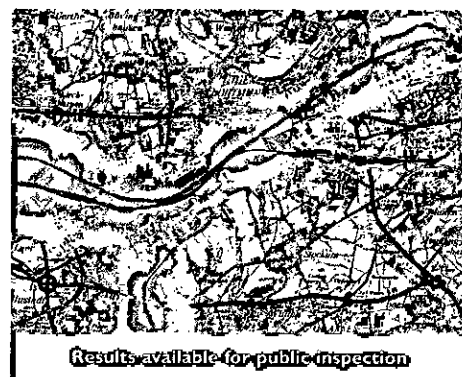
Better noise mapping with dynamic search method

Braunstein + Berndt GmbH has announced the release of their newly developed dynamic search calculation method. Dynamic search estimates the contribution for each receiver and ranks the influence of all sources. Only the sources important to the final result of a receiver are calculated; the rest are estimated. By dynamically selecting the sources that need to be calculated rather than estimated, more data can be calculated more quickly than was ever thought possible.

This new method was used successfully to complete the world's largest noise map, the END noise mapping of the railways throughout Germany. In all, 12,000 kilometres of railway were mapped, which included 11 Gb of terrain information, eight million buildings and 36 million receiver points. All of this was calculated on four personal computers in less than 30 days run time, using 32-bit Windows XP.

The dynamic search method makes it possible to calculate huge noise maps with complex geometry, and to simulate details previously not possible in noise control programs. This method was adapted not only for rail noise calculations, but also for other noise source types. The dynamic search method, unique to SoundPLAN noise and air pollution evaluation software, makes it practical for consultants to map any size of project regardless of terrain, with any number of noise types (road, rail, aircraft, industry, leisure pursuits) and an unlimited number of sources, in a timely and efficient manner as demonstrated with the noise mapping of the German railway system.

The results of the rail noise mapping project are available for public inspection. The mapping was conducted by PÖYRY and the database and viewer were supplied by Intergraph. View the noise maps at <http://laermkartierung.eisenbahn-bundesamt.de>.



CMS Acoustics

Regupol product range now available in NBS format

CMS Acoustics has enhanced its architectural specification support by making its portfolio of construction, industrial and anti-vibration products available through the NBS Plus online library. Published as part of the September 2009 update, products include the complete range of Regupol impact sound and vibration isolation systems, which are the most cost-effective and sustainable noise control materials available on the market.

All relevant technical information on listed products will now be linked to specific clauses within NBS Building, NBS Landscape, NBS Engineering Services and NBS Scheduler. This means the right product information will be always available at the point of specification, helping to ensure the correct acoustical control system is specified.

Paul Absolon, technical director, commented that the acoustical product market had become

increasingly crowded and there were now a greater number of low-end materials than ever before. It could be difficult for the time-pressured specifier to identify which product would not only meet the acoustical requirements, but also to determine its sustainable and longevity credentials.

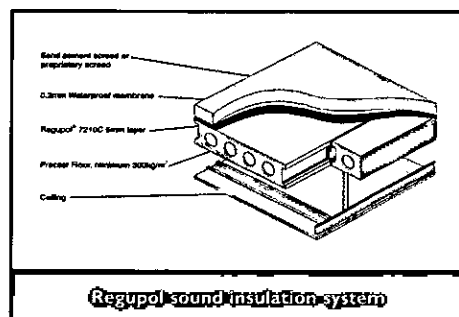
By making Regupol and other CMS products available in NBS format, it was easier for specifiers to select the right materials and ultimately deliver buildings that were acoustically and environmentally fit for purpose.

This is the latest in a long line of developments to ensure that specifiers can always access the right information when specifying acoustical products. Relevant and up-to-date technical information on the Regupol range is already available through RIBA product selector, on CMS's application-led website and in the *Sound*

guide, the specifier's guide to acoustics.

All specification support literature, including the Regupol 4515 range and Regupol underscreed brochures, are published with a RIBA classification code so that technical data can be easily archived and accessed in practice libraries. CMS Acoustics also publishes a series of specialist acoustics guides which currently includes education, mechanical and electrical, and acoustical wall coverings.

CMS Acoustic Solutions Ltd Warrington
tel: 01925 577711 fax: 01925 577733
email: enquiries@cmsacoustics.co.uk



Selectaglaze combats intrusive noise

Secondary acoustic glazing systems

Intrusive noise is a real problem in today's society and failure to deal with it can lead to loss of sleep, lapses in concentration and increased levels of stress that can affect general health.

Noise emanates from a multitude of sources including road traffic, aircraft, plant and equipment, venues such as pubs and clubs and crowded town centres.

Acoustically speaking, the windows are often the weakest point in a building with most single-glazed windows reducing noise by just 25 to 30 dB, and less if they do not fit properly. Even modern double-glazed windows only achieve 30 to 35 dB overall. Set against potential external noise levels of 70 to 80 dB(A) and referencing guidelines such as BS.8233 *Sound insulation and noise reduction for buildings* and BB93 *Acoustic design of schools*, it is evident that additional protection has to be considered.

One very practical solution is to add secondary glazing, which is a fully independent tailor-made window system, set 100mm or more from the existing window. The sizeable air gap and additional sealing can provide overall noise reductions in the range 40 to 45 dB.

Selectaglaze secondary glazing systems are designed for high performance, which is backed up by test data from Taywood Laboratories in accordance with BS EN ISO 140-3:1995. Detailed performance figures are available to

acousticians and architects to assist with calculations and recommendations. In combination with double-glazed systems, overall noise reductions up to 56dB have been achieved.

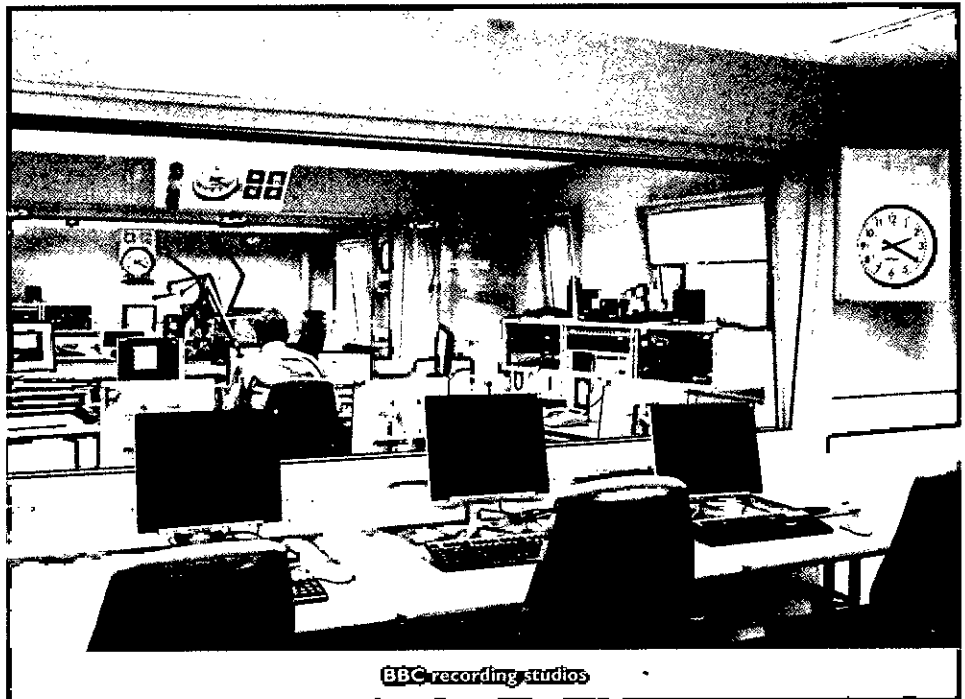
Purpose-designed secondary glazing can be unobtrusive and remain sympathetic to the character of a building. Full factory assembly allows the installation to be completed rapidly with minimal disruption to the building's occupants. As well as its

acoustical advantages, secondary glazing also markedly improves the thermal efficiency of the window.

Selectaglaze has been the leading designer of secondary glazing systems since 1966 and a Royal Warrant holder since 2004. Working to consistently high standards, the company has gained a wealth of experience in all types of building including those with Grade I listed status.

The company has produced an extensive range of literature covering acoustics, energy efficiency and security, all of which are free upon request from **01727 837271**,

email: enquiries@selectaglaze.co.uk or via their comprehensive web site: www.selectaglaze.co.uk



Musical modelling

Brüel & Kjær launches new room modelling software

Brüel & Kjær's latest room acoustics prediction and auralisation software - ODEON version 10 - has a range of significant enhancements, including full orchestra music for simulated room acoustic testing.

The high-quality anechoic recordings, courtesy of Helsinki Technical University, contain each orchestra member playing four different pieces of music. This library allows the user to simulate symphony orchestras of different sizes and with different spatial configuration. Each musician can be placed separately and mixed into the auralisation of all the musical instruments.

As array loudspeakers and beam-steered arrays are typically used in large open spaces, ODEON version 10 (Auditorium and Combined) makes it possible for the sound testers to model or import their own arrays, to see how they interact in different rooms.

All necessary filters, equalisers and delays are included in the ODEON modelling. The visual displays include the near-field radiation pattern, far-field balloon and the sound pressure level coverage of direct sound over the audience area. Support for array loudspeakers makes ODEON ideal for testing room acoustics and public

address system design.

Brüel & Kjær has 1150 employees, with sales offices in 55 countries. It is a subsidiary of UK-based Spectris plc (www.spectris.com) which has annual sales of £787m and employs around 6,000 people worldwide in its 13 business units.

For additional information please contact: Heather Wilkins, Brüel & Kjær UK Ltd, Telephone: **01438 739 000** Web: www.bksv.co.uk Email: heather.wilkins@bksv.com

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Committee meetings 2010

DAY	DATE	TIME	MEETING
Thursday	7 January	10.00	Meetings
Thursday	21 January	10.30	Diploma Tutors and Examiners
Thursday	21 January	1.30	Education
Thursday	28 January	10.30	Membership
Thursday	11 February	11.00	Publications
Thursday	18 February	11.00	Medals & Awards
Thursday	18 February	1.30	Executive
Thursday	4 March	10.30	Engineering Division
Tuesday	9 March	10.30	Diploma Examiners
Thursday	11 March	11.00	Council
Tuesday	6 April	11.00	Research Co-ordination
Tuesday	7 April	10.30	CCWPNA Examiners
Tuesday	7 April	1.30	CCWPNA Committee
Thursday	15 April	10.00	Meetings
Thursday	6 May	10.30	Membership
Thursday	20 May	11.00	Publications
Tuesday	26 May	10.30	CMOHAV Examiners
Tuesday	26 May	1.30	CMOHAV Committee
Thursday	3 June	11.00	Executive
Thursday	17 June	11.00	Council
Wednesday	16 June	10.30	CCENM Examiners
Wednesday	16 June	1.30	CCENM Committee
Thursday	24 June	10.30	Distance Learning Tutors WG
Thursday	24 June	1.30	Education
Thursday	1 July	10.30	Engineering Division
Tuesday	6 July	10.30	ASBA Examiners
Tuesday	6 July	1.30	ASBA Committee
Thursday	8 July	10.00	Meetings
Tuesday	3 August	10.30	Diploma Moderators Meeting
Thursday	2 September	10.30	Membership
Thursday	9 September	11.00	Executive
Thursday	16 September	11.00	Publications
Thursday	23 September	11.00	Council
Thursday	30 September	10.30	Diploma Tutors and Examiners
Thursday	30 September	1.30	Education
Thursday	7 October	11.00	Research Co-ordination
Thursday	14 October	10.30	Engineering Division
Thursday	4 November	10.30	Membership
Tuesday	9 November	10.30	ASBA Examiners
Tuesday	9 November	1.30	ASBA Committee
Thursday	11 November	10.00	Meetings
Thursday	18 November	11.00	Executive
Wednesday	24 November	10.30	CCENM Examiners
Wednesday	24 November	1.30	CCENM Committee
Thursday	25 November	11.00	Publications
Thursday	2 December	11.00	Council
Thursday	7 December	10.30	CCWPNA Examiners
Tuesday	7 December	1.30	CCWPNA Committee

Refreshments will be served after or before all meetings. In order to facilitate the catering arrangements it would be appreciated if those members unable to attend meetings would send apologies at least 24 hours before the meeting.

Examination dates

CCENM - 14 May and 22 October **CCWPNA** - 5 March and 5 November

CCHAV - 23 April **ASBA** - to be confirmed

Diploma - 10 and 11 June

Meetings Programme 2009/10

19 December 2009

ENG

ART OF BEING A CONSULTANT

Manchester

January (tba) 2010

ENG

WIND TURBINE NOISE

Cardiff

18 March 2010

S&H

MOTOR SPORT NOISE

Silverstone

7-9 April 2010

UAG

VALIDATION OF SONAR PERFORMANCE ASSESSMENT TOOLS

Cambridge

29-30 April 2010

IOA/ABAV

NOISE IN THE BUILT ENVIRONMENT

Ghent

26 May 2010

London/M&I

ASPECTS OF NOISE AND VIBRATION

MEASUREMENTS

London

13-14 September 2010

UAG

SYNTHETIC APERTURE SONAR AND RADAR

Italy

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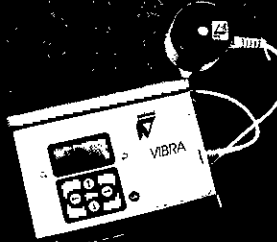
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