Acoustics BULLETIN

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Auditorium Acoustics

Royal Albert Hall - past present and future
Birmingham Hippodrome acoustic design
Renovations of the Brighton Dome
Commonwealth Games venues

Institute of Acoustics

Acoustics BULLETIN
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Institute of Acoustics

The Institute of Acoustics was formed in 1974 through the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society and is the premier organisation in the United Kingdom concerned with acoustics. The present membership is in excess of two thousand and since 1977 it has been a fully professional Institute. The Institute has representation in many major research, educational, planning and industrial establishments covering all aspects of acoustics including aerodynamic noise, environmental, industrial and architectural acoustics, audiology, building acoustics, hearing, electroacoustics, infrasonics, ultrasonics, noise, physical acoustics, speech, transportation noise, underwater acoustics and vibration. The Institute is a Registered Charity no 267026.

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Dear Members

Two areas that I consider important to the Institute's future are the number of young members getting involved in our activities at all levels, and the role of Branches. In the case of the former we have made a start by reserving one of the co-opted Council positions for a young person. The scheme was run on a trial basis last year and I'm pleased to say that Steven Chiles, the first incumbent, was able to make a very positive contribution both to Council and to the general business of the Institute. Council agreed to continue this practice to give as many as possible of our promising younger members an opportunity to help run the Institute. Rachel Canham has been nominated by Council for this year and if any young members wish to contact her to suggest ways in which the Institute can provide a better service for them, they can do so via the office.

Considering the role of Branches, I count myself lucky working here at Salford, because if I have a problem there are colleagues down the corridor to whom I can turn for assistance. However many members work on their own, and have nobody on hand to ask for advice and comments on their ideas. I think that Branches and their members can fulfil that role at the same time they perform their more traditional duty: running local technical meetings. I suggest that branch committees try to build into their programmes adequate time for members simply to talk together more often.

This year sees another conference in the Building Acoustics Group's biannual Architectural Acoustics series. It is to be held at Imperial College, with visits to the Royal Albert Hall, taking in a Prom concert, the Royal Opera House, and the Milton Keynes Theatre. It is an important conference, attracting as it does many delegates from overseas, and it requires a significant organisational effort by the BAG committee. This illustrates just one way in which members, again young and old alike, can work together to the benefit of themselves and their colleagues in our acoustics profession. The more you put in, the more you and everyone else gets out. I look forward to seeing many of you there.

Best wishes

Geoff

Geoff Kerry
President

NORTH WEST BRANCH REPORTS

BS:4142 - reviewed

Nearly 50 people attended the Branch's first 'early evening' - or should that be 'late afternoon' - meeting on 23 May 2002. **Ian Flindell** of ISVR had notched up a few hundred extra air miles to speak to us on the popular and controversial subject of the latest version of BS:4142. This standard, in its 1997 manifestation, has been out for five years and is therefore due for review, a process which is likely to take another two years. We can probably expect a new version sometime in 2004, although Ian was at pains to point out that its content was entirely open at this stage. The review process involves input from many sources, the most important being users of the standard.

Ian took us through its origins and development, contrasting the excess-over background-noise approach used in the UK with other European practices. Only Ireland and Portugal use similar approaches to Britain, with other countries, if they have any regulation at all, favouring absolute noise limits for industrial noise. It was pointed out that the forthcoming ISO standard is likely to move in the European direction rather than favouring the GB/IRL/P practice.

Examining the current BS:4142 in detail, we were reminded that its objective is to predict the likelihood of complaints about noise, and thus possibly the degree of annoyance, but it did not claim to determine whether or not there was a noise nuisance (let alone a statutory nuisance). The 5dB and 10dB margins by which L_{Aeq} exceeded background noise in terms of L_{A90} were arbitrary, and had no basis in scientific research. They had simply been found to work reasonably well in most circumstances. Moreover, there was no basis for the 5dB character penalty applied to the rating noise level (for intermittency, tonality, or attention-drawing features of the noise), and the size of this penalty should probably vary according to whether the overall noise levels were high or low.

A lively discussion about several of the issues raised then ensued. However, the consensus of the meeting was that BS:4142, although flawed, was a great deal better than no guidance at all. Ian encouraged all those attending to make their views known, either to the relevant BSI committee or by writing to *Acoustics Bulletin.*

Thanks are due to the University of Salford for hosting the meeting, and to Geoff Kerry and his team for organising it. The secure car parking was free, and nobody found wheels missing afterwards!

Ian Bennett **CEng MIOA**

Floating floors and acoustic performance

In his presentation to Branch members, 'Getting more dB's from less mass', **Alan Fry** provided the background to floating floor design using his experience with Sound Attenuators Ltd. He described the lack of guaranteed acoustic performance for the initial floating floor design of mineral wool mats below a layer of concrete.

This concept had been used for over 60 years and was subsequently developed for broadcasting studios and then noisy plant rooms, where a guaranteed performance was required. This led to both the jack-up floating floor system, typically with coil spring isolators, and the 'formed in situ' floating floor supported on neoprene or glass fibre pads, using plywood shuttering, or sheet metal, if termites were present.

Alan described the effect of the cavity depth on resonant frequency and the difficulty in measuring the high sound insulation performance, even in a laboratory, due to flanking. Using floating floors in a plant room requires careful design, owing to the potential for point loadings. Alan explained how either local plant supports penetrated the floor, or the design of the isolators allowed point loading to be dealt with adequately.

Examples of buildings where floating floors had provided effective sound insulation were discussed, including the Royal College of Music.

Our thanks are offered to BDP Acoustics for hosting the meeting, and to Ken Finch for arranging Alan's presentation.

MEASUREMENTS AND INSTRUMENTATION GROUP

Weather or not - to measure

Over 70 delegates attended the one-day meeting, *Weather or not....to Measure,* organised by the Measurement and Instrumentation Group and held at the National Space Centre, Leicester, on 22 May 2002.

The presentations opened with a short overview of the influence of meteorology on the propagation of sound and its measurement, given by the new IOA President, **Geoff Kerry** of Salford University. All those present were reminded of the basic effects temperature, humidity and wind have on the propagation of sound.

This introduction was followed up by two Salford University colleagues, **Prof Stuart Bradley** and **Dr David Waddington,** who each expanded on Geoff's introduction with more detail and showing the influence from practical results of the effects of wind speed at different heights, turbulence and vector to the source and measurement positions. They also made recommendations for the conditions acceptable for outdoor noise measurements taking all environmental effects into account.

Carole Murray from Qinetiq discussed the value of windshields around microphones when measuring outdoors. Graphs of measured improvement in self-induced noise were shown and compared with manufacturers' data. The value of the windshield was clearly demonstrated.

Ian Campbell of Campbell Associates then gave a paper on behalf of **Bjørn Winsfold** of Norsonic (Norway) showing the new meteorological measurement system designed by them and capable of integration with other Norsonic sound measuring equipment as well as operating on its own. Although the system reports most of the required data, a remote indication of wet or dry road surfaces and real-time rainfall as it occurs is still being worked on.

The final paper before lunch was given by **Phil Morgan** of the Transport Research Laboratory, who showed with measured data the influence that weather conditions have on traffic and vehicle noise. Different road surfaces, and especially rain, were shown to make significant differences to noise levels.

After lunch the revision of ISO 1996 'Description, measurement and assessment of environmental noise' was discussed by **Charles Greene** of Brüel & Kjær. The effects of weather on the uncertainty of measurements is to be included in this revision, and information was provided on the methods to be used, although the audience questioned the use of a confidence level of 90% when most other Standards are based on 95%.

Gunnar Rasmussen of GRAS AS (Denmark) then discussed the development and capabilities of microphones designed to be used outdoors, and the care necessary to ensure that the correct microphone and weather protection system were used for the particular task.

Delegates were then invited to take a break from the earth-bound problems our weather systems create. They moved to the special cinema in the Space Centre for a spectacular 3D presentation asking the question 'How big is the universe?'. Special cinematic effects transported us to distant planets and beyond, with data given on the timescales of light (and any other matter) traversing these vast spaces. It certainly made local meteorological effects look very small indeed.

> **'We were transported to distant planets and beyond'**

The day concluded with two presentations dealing with the measurement of background noise. **Andy McKenzie** of the Hayes McKenzie Partnership, deputising for **Malcolm Hayes** who was delayed in the USA, discussed the effects weather can have on background noise in rural areas, especially where the siting of wind farms might be considered. He showed that topography can make significant local variations to the measured noise, and stressed the importance of making more than one site visit for measurement under differing conditions.

This was followed by **Andrew Bullmore** from Hoare Lea and Partners, in a joint paper co-authored by **Andy McKenzie** and **Ian Flindell** of Flindell Associates. The emphasis was on measuring background noise in suburban environments as opposed to rural ones, looking at the effects of time of day on the predominant sources of background noise. Measurements taken in Birmingham and near Heathrow Airport clearly showed the importance of measuring at the correct time for identification of the predominant sources.

Following the presentations there was a short question-and-answer session chaired by the meeting organiser, **Simon Bull** of Castle Group. Discussions took place on the need to understand the limits of the measuring equipment as well as to take all reasonable steps to ensure accurate measurements in the prevailing conditions.

The Annual General Meeting of the Measurement and Instrumentation Group was held immediately afterwards, and the committee for the forthcoming year was elected.

Richard Tyler FIOA
Chairman, Measurement and Instrumentation Group

Venues for Sport and Entertainment

Spring 2003

Organised by the Building Acoustics, Environmental Noise and Electroacoustics Groups

The staging of the Commonwealth Games in Manchester this summer, and the UK bid for the World Athletics Championships in 2005, have fuelled an upsurge of interest in large sports and entertainment venues, both in the national press and within the building industry. The very nature of such buildings and their location in populated areas leads to many questions being asked in relation to noise; by politicians, Local Authorities, residents, clients and other industry professionals. With plans for future venues including Wembley Stadium and Pickett's Lock, and involving football clubs such as Arsenal, Fulham, Coventry, and Liverpool, the debate will no doubt continue.

The design of venues such as stadia, arenas and velodromes involves many aspects of acoustics. The Building Acoustics, Environmental Noise and Electroacoustics Groups are therefore joining forces for this one day meeting to explore the acoustic implications of these spaces.

The meeting will be based around one of the new national venues, with an opportunity to take a guided tour *(to be confirmed).*

The Groups are inviting contributions on all relevant aspects of venue design, including:

❑ Case studies ❑ Environmental impact and planning ❑ Sustainability ❑ Audio and visual systems ❑ Speech intelligibility ❑ Broadcast facilities ❑ Sports event noise ❑ Music event noise ❑ Room acoustics and the effect on 'ambience' ❑ Modelling and prediction techniques

Offers of contributions and short abstractsshould be sent to the meeting organiser:

Adrian Popplewell, Arup Acoustics, St Giles Hall, Pound Hill, Cambridge CB3 0AE
Tel: +44 (0)1223 531100 Fax: +44 (0)1223 560196 Email: adrian.popplewell@arup.com

Institutions 'have a duty to enforce codes of conduct'

The UK Engineering Institutions must actively enforce codes of conduct for their members if they are to avoid the possibility of being sued for negligence, **Professor John Uff,** Professor of Engineering Law at King's College London, told the Royal Academy of Engineering. Giving the *Lloyd's Register Lecture* in London on 22 April, he said engineers have an ethical duty to the public, reflected in their Institutions' codes of conduct. Although it has never happened, an Institution could be held to account by members of the public who suffer damage through the actions of an engineer it had held out as competent to practice.

Prof Uff pointed out that institutions do not enjoy any degree of immunity or legal protection, and cannot regard their role as being limited to giving advice and encouragement. This must encompass some degree of monitoring and enforcement and they should not wait for the courts to define that role for them. Such enforcement procedures are more familiar in other professions, particularly medicine, but there is no such precedent in the UK engineering profession, partly through lack of any body of reported disciplinary proceedings and partly because there are few areas in engineering where professional registration is a requirement of practice.

He cautioned that enforcement by the UK Institutions must be systematic and inter-Institutional to avoid fragmentation. Support from both members of the engineering profession and the public will be vital to the establishment of a credible and respected procedure. Prof Uff also challenged the Institutions to consider how they can support individual engineers who publish warnings about preventable disasters.

'Engineers have an ethical duty to the public'

The US engineering institutions helped to pioneer action in support of 'whistleblowers' through amicus curiae or intervention proceedings in court actions. This enables an institution to place material before a court supporting the action of the member in question and upholding the public interest. One of the first such interventions over 20 years ago was by the IEEE on behalf of three engineers sacked for raising concerns about the safety of the San Francisco Bay Area Rapid Transit system. An accident later occurred which was due to the fault they had identified. IEEE members can now request the Institution to file an amicus brief in cases where ethical questions are raised.

The use of this procedure has increased exponentially in the US and there are strict rules on how it can be used at both federal and state level. Amicus briefs were filed in over 85% of all Supreme Court cases between 1985 and 1996. The UK is still at an early stage in considering the usefulness of amicus briefs in maintaining ethical standards, but Prof Uff said that the US experience indicates caution will be required when seeking to establish appropriate procedures, and there will be a need to distance true ethical considerations from the interests of pressure groups.

Professor John Uff CBE QC FREng is an internationally renowned barrister and arbitrator and an authority on construction law. He is best known for chairing the Yorkshire Water Inquiry in 1996, the Southall Railway Accident Inquiry in 1999 and the Joint Public Inquiry into Railway Safety in 2000. He graduated in engineering from King's College London, gained a PhD in geotechnics and then trained as a barrister and was called to the bar in 1970. He served on the Council of the Institution of Civil Engineers in the 1980s and helped to develop new ICE contract forms and arbitration procedures. In 1987 he established the Centre for Construction Law and Management at King's College, where he continues teaching and research.

For more information: Jane Sutton, Royal Academy of Engineering, tel: 020 7227 0536 (direct) mobile: 07989 513045
email: suttonj@raeng.co.uk

A note from the President

Retirement of Roy Bratby - our Chief Executive

Roy Bratby is approaching retirement age and has indicated that he would like to leave full time employment at the end of the year. Roy has been chief executive for the past five years and, although not an acoustician, he manages our activities in a very competent and professional way and couples this with a very personable approach to the membership.

The Executive Committee is seeking a replacement and feels that the time is right to explore the possibility of engaging someone from within the profession itself. Therefore, before we follow the normal route of placing an advertisement in the press, I have been asked to write to see if any members are interested or know anyone in the profession who may be interested in the post.

The Chief Executive and Company Secretary is responsible to the Board of Trustees (Council) through the President for the management and administration of the Institute of Acoustics, a registered charity.

The post is full time and located at our office in the centre of St Albans.

Applications are invited from suitably qualified individuals with administrative and financial management experience. An adequate knowledge of standard office computer systems is essential, together with the ability to work with and manage a small and dedicated office staff and to service voluntary committees drawn from the acoustics profession.

Interested persons should write as soon as possible, enclosing a detailed CV, marking the envelope Private and Confidential to:
Dr R Orlowski FIOA, Honorary Secretary, Institute of Acoustics, 77A St Peter's Street, St Albans, Herts, AL1 3BN.

Further details of the post may be obtained by contacting me by telephone during normal office hours on 0161 295 5582 or any member of the Executive Committee.

Geoff Kerry
President

Building Acoustics Group AGM looks to the future

This year's Annual General Meeting was held during the Spring conference. It has been a busy year, particularly with revision of the *Building Regulations Approved Document E*. This proved a source of much discussion throughout the year, culminating in the Group's response to the consultation document on behalf of the Institute.

Raf Orlowski, Neil Spring and John Seller retired from the management committee this year. All three were thanked for the considerable contribution they have made to the group's success over many years. Following in their footsteps, four new members were elected: Sean Smith, Jian Kang, Roger Kelly and Alisdair Somerville.

Following the AGM, the management committee met in April to discuss the group's future activities. Although formal committee meetings have not been a particularly regular event in the past it is intended to met twice yearly from now on.

There was a wide ranging discussion about the topics and organisation of future group meetings. These will be organised on topics ranging from sports and leisure venues, through statistical energy analysis, to non-technical subjects relevant to acoustics professionals. It is intended to organise a one-day meeting on the implications of *Approved Document E,* whatever its final form. This will be targeted at architects, housing associations and contractors. Institute members will also be encouraged to respond to the final document, though this will be through a separate mechanism.

The committee felt strongly about the need to provide better representation and input to future British and International standards. In the same vein, **Peter Wheeler** joined the meeting to discuss possibilities for disseminating the group's knowledge and experience outside the acoustics community.

Adrian Popplewell, MIOA

Rayleigh Gold Medal
awarded to
Professor Hideki Tachibana

Hideki Tachibana receives the Rayleigh Gold Medal from IOA President Geoff Kerry at the Spring Conference 2002

THE CITATION

Hideki Tachibana is Professor of Applied Acoustic Engineering in the Institute of Industrial Science at the University of Tokyo where he has worked over the past thirty years in the fields of building acoustics, noise control engineering, psychoacoustics and acoustical measurements.

In the field of building acoustics, he has developed calculation methods for sound transmission through multi-layered walls and his work on the measurement and rating of sound insulation in buildings has been incorporated into Japanese Industrial Standards. In room acoustics, he has advanced the technique of acoustic scale modelling which he has used in the acoustical design of more than twenty concert halls and theatres in Japan.

In noise control engineering, he has researched outdoor sound propagation and developed traffic noise prediction models. In addition, he has been working as the chairman of the Technical Committee of Road Traffic Noise in the Acoustical Society of Japan. In psychoacoustics, he has considered the concept of Loudness Level and has developed a new rating method for the sound insulation of walls.

Professor Tachibana has been at the forefront of research on sound intensity in Japan and contributed greatly to the development and spread of sound intensity technology. He is now working as chairman of the ISO Committee which is drafting an international standard of a precision method of sound power level measurement by sound intensity.

He has published over 55 papers in acoustical journals and presented over 120 papers at international conferences. He has co-authored 11 text books in Japanese and translated Frank Fahy's book on sound intensity into Japanese. Furthermore, he has contributed greatly to the development and harmonisation of national and international standards on acoustics.

For these major contributions to the field of building acoustics and noise control engineering, the Institute of Acoustics awards Hideki Tachibana the *Rayleigh Gold Medal.*

Electronic small ads

As an additional service to members the IOA web site at www.ioa.org.uk is now accepting 'small ads'. These will be submitted by filling in an electronic form on the web site.

For further details please contact Mark Tatham, the Institute's webmaster, by e-mail to: mark.tatham@essex.ac.uk.

INSTITUTE OF ACOUSTICS CODE OF CONDUCT

The Membership Committee's response to Richard Collman

(Letters, Acoustics Bulletin, Sept/Oct 2001)

The Membership Committee, as the initial forum for matters concerning the Institute's **Code of Conduct,** welcomes any discussion on the Code, and the letter from Richard Collman in the *Bulletin* (Sept/ Oct 2001) is an important contribution. The Code is an essential document that affects everyone in the profession, and it is right and proper that it should be discussed openly. Richard makes many good points about the conflict between the need for critical review while still allowing for competition and differences of opinion between professionals working in the same market place; he has made it clear that he would welcome peer review, and the Committee supports this. However the Committee believes that he has misinterpreted the Code. Richard draws the conclusion that the Code is aimed at suppressing any critical review of the work of members, but this is a misunderstanding both of its wording and spirit.

In the Code itself, the fundamental rules are in the paragraph headed *'Code of Conduct'*, and the section *'Rules of Conduct'* expands on this and goes into details which cover many situations. *Rule A1.2* does allow a client to employ any acoustician and to seek a second opinion if he wishes but it discourages him from employing two or more consultants in the same project unless all parties are aware of the situation and have consented to the arrangement.

Rule A1.3 covers the case where the client asks one member for an opinion on the work of another member, and here the Rule requires that the member giving the first report must be aware that his work is being reviewed, although there is no requirement that he should consent. Conversely, it is implied that the client is entitled to seek a second opinion, but he must do so openly.

The Code does not aim to suppress critical reviews of members' work

In situations covered by either of these rules there are questions of client/ consultant contracts and confidentiality, covered under *Rule A3, Duty to Employers and Clients*, which can operate against openness, but criticism of members' work is otherwise covered under *Rule A1.4*, whereby members must not injure another person's professional reputation.

A situation not covered explicitly in the Code arises where a member is approached by a client who has already received advice on a related matter from another member, and the second member offers without being asked an opinion disagreeing with the work of the first member. This is distinct from the case where the client is formally asking for a second opinion, a situation covered explicitly in the Rules, but it is the background to Richard's letter and to his more detailed communication to the Chairman of the Membership Committee. It is suggested that in this particular situation the second member should either withdraw his dissenting opinion and not act on it in any way, or insist that the client refers the matter back to the first member. Further action by the client may include his formally seeking a second opinion, but his actions should not put either member in danger of breaching the Rules.

In many legal systems interpretation in a particular case depends on cases which have been determined previously, but new situations arise not previously covered in detail. In the Institute's Code the fundamental 'Code of Conduct' should be sufficiently general so as not to require revision, but in the light of experience the 'Rules of Conduct' and the 'Complaints Procedure' may have to be revised, this being so for the last revision of the Code (the main changes were concerned with the procedures). The Membership Committee keeps in mind any need to revise the Code as new cases arise and is always willing to advise on the interpretation and application of the Code in particular situations, preferably before matters go so far that procedures for a formal complaint are commenced.

James Dunn
Chairman, IOA Membership Committee

Editor's Notes

Ian F Bennett *BSc CEng MIOA*
Editor

With the forthcoming one-day meeting on *Auditorium Acoustics* the opportunity arose for an issue of the *Bulletin* featuring technical contributions on this fascinating subject. Refurbishments and major reworkings of the acoustics have recently taken place at the Royal Albert Hall, the Birmingham Hippodrome, and the Brighton Dome, and the technical contributions in this issue show the variety of problems and solutions encountered by colleagues in perhaps the most glamorous branch of our profession.

Now that summer is here, of course, we have two months of music to look forward to in the BBC Proms. The Royal Albert Hall, it was once said, was the only place you could hear bad music twice, but it seems that 21st century acoustical knowhow has at last put a stop to that. Full details of the Proms season can be found at www.bbc.co.uk/proms. If you cannot get to a concert in person, they are all broadcast live on Radio 3.

By the time you read this, the *Commonwealth Games* will be well under way, and at least some of the venues will be familiar to TV sport viewers. Many of the Arup Acoustics staff who worked on the various projects have contributed to the article beginning on page 23 but I am particularly grateful to Jo Webb for collating the pictures and getting us permission to reproduce them.

As always, your letters and offers of contributions are welcome, as are further suggestions for *Pioneers of Acoustics.* Material for the September/October 2002 issue should reach me by the end of July. That's before you go on holiday, probably!

Ian Bennett

A need for bigger noise mapping budgets

We acoustic consultants are notorious for never agreeing, but for once I will say that I do agree wholeheartedly with Bridget Shield's concerns in her letter *(Acoustics Bulletin May/June 2002).*

Measurement is no more an answer than is predictive computer mapping, as those of us who are old enough to remember Noise Abatement Zones will recall. Those were intended to provide strategic information on noise from premises to aid planning and reduce environmental noise levels. Nearly thirty years on, I don't believe that this has led to a significantly quieter world.

NAZs were not only fundamentally flawed, but also suffered from insufficient resources in terms of staff, equipment and finances to implement. The government budget for producing the noise mapping also looks very small given the size of the task. I was recently involved in a project to produce noise maps for fairly simple sections of urban railway, and can endorse Bridget's comments about the time required for acquisition and input of data. I would add that in some cases the data required for noise prediction simply isn't there. If work were commissioned to obtain the fundamental information on input parameters it could consume much of the available budget.

The efforts of the experienced noise consultant with the street map and red pen could be further enhanced if consultation took place with the people who live and work in the vicinity as well as the local planning and environmental officers who know very well where the noise hot spots on their patch are.

Mapping and measurement are tools that should help implement rather than inform policy. A national strategy to deal with all sources of environmental noise may be too wild a dream, but maybe a transportation noise strategy, or at least a transportation strategy?

In the meantime a little of my taxes will be fed back into the mouths of fellow consultants. Enjoy the crumbs, you will earn them.

Chris Manning

Noise mapping - accuracy is our priority

As a UK producer and user of noise mapping software, I am responding to Bridget Shield's letter on noise maps. She expresses several concerns: that few people are interested in the accuracy of noise maps, that they are unjustifiably expensive to produce, and that a national noise strategy should be independent of noise mapping.

I should make it clear that we at Atkins are intensely interested in the accuracy of noise maps, and spend a great deal of time on the issue. However, a clear definition of accuracy is not obvious. Bridget Shield refers to measurements but if I go into, say, my local park and take a noise measurement, and then go back the next day to repeat it, I would not expect to get the same answer twice. There can be many reasons for this, but would I blame it on the meter? If I ask how accurate is a noise measurement, what is the answer? With noise maps, there are many additional factors to consider and the calculation is usually compared with a measurement rather than the 'real' answer.

Environmental noise predictions are hardly new: Atkins has been writing and using noise prediction software since 1975, and producing noise contour maps for about the same time. Quite a bit of the UK motorway network was designed using our RoPlan/RoadNoise software. And yes, noise levels have usually been pretty much as predicted. I have often stated the accuracy as a standard error of ± 2dB(A) on facades exposed to traffic noise, for a properly constructed noise model used within its design limits.

I recently polled some of our 150 *RoadNoise* users on the question of accuracy and got some puzzled responses, along the lines of 'We are happy with the accuracy - why would we continue to use CRTN/RoadNoise if it didn't give a sensible answer?'

Bridget's image of noise maps being conjured by experts with red pens does nothing to dispel the image of noise as a black art not susceptible to the laws of physics or capable of mathematical description. How can we expect politicians to treat noise as a scientific discipline if we have that approach? Moreover, how can we improve our ability to create, understand and use noise maps if we turn our backs on them?

On the question of time and expense, it is relevant to note that the Highways Agency has an annual budget of £5m for retrofitting noise barriers to existing roads alone. Noise barriers on just one short section of the M25 cost over £10 million. In the context of expenditure on noise mitigation the £13 million budget for a national noise map seems very modest. Moreover, noise maps need not take 'several weeks' of computer time: for most of our design work covering scheme-sized areas, we expect a turnaround of minutes.

The National Noise Strategy should not be driven by mapping, but mapping would provide a rational basis for it, ensuring that problem areas are identified and prioritised, and workable solutions are designed and costed.

We would be very pleased to invite Bridget to our offices any day, to see noise mapping in everyday use solving work-a-day problems in sensible time-scales and at lower cost and equivalent accuracy to measurements.

Roger Tompsett
Technical Director, Atkins Noise & Vibration

The acoustics of the Royal Albert Hall auditorium *before and after redevelopment*

R A Metkemeijer

When the Royal Albert Hall was opened in 1871 by the Prince of Wales (later King Edward VII), *The Times* reported: '*The address was slowly and distinctly read by His Royal Highness, but the reading was somewhat marred by an echo which seemed to be suddenly awoke from the organ or picture gallery, and repeated the words with a mocking emphasis which at another time would have been amusing*'.

This is the first comment and even a first analysis of the hall's acoustics. Many comments would follow, positive and negative. The positives usually concerned large musical events, organ play and community singing. The negatives were usually about the echo, the large differences in acoustics for different positions in the public area, and the relative quietness of the hall for unamplified musical events.

Fighting the echo has had major impacts on appearance of the hall. Shortly after its opening a velarium was hung underneath the then-glazed dome, which must also have migitated the effects of daylight *(Figure 1)*. The effect of this velarium in attenuating the echo must have been very limited.

In the 1890's wires were even stretched across the hall to cure the echo problem, but without success. In the following years many experiments were made, such as changing the height and the sagging of the velarium, and by adding banners around its perimeter. Generally these measures had little or no effect, and could even have made matters worse, possibly because the rather long reverberation time was unaffected. Apart from the echo effects, the articulation in the hall was not very good anyway by reason of the long reverberation time, and there were no sophisticated sound systems available at that time.

Scientists were asked for advice several times, and although knowledge of the acoustical behaviour of buildings was limited, the analyses that were made show good understanding of the problems. In 1928 The National Physical Laboratory, for example, adopted a two-dimensional approach but this clarified only a part of the complex problem.

When the Proms had to move from the bombed-out Queen's Hall to the Royal Albert Hall in 1941 it was the first time it was adapted specifically for a symphony orchestra. The Building Research Station proposed a sound reflector over the stage and a dramatic lowering of the still existent velarium – this was far heavier than originally intended because of the build-up of 60 or 70 years of dust. These steps improved the acoustics for orchestral music: *(Figure 2)*, taken from the BRS's original paper, illustrates the actions that were implemented.

In 1949 the velarium and the glass dome were replaced by a fluted perforated aluminium inner dome, which still exists. This was intended to absorb the sound and attenuate the focusing effects of the

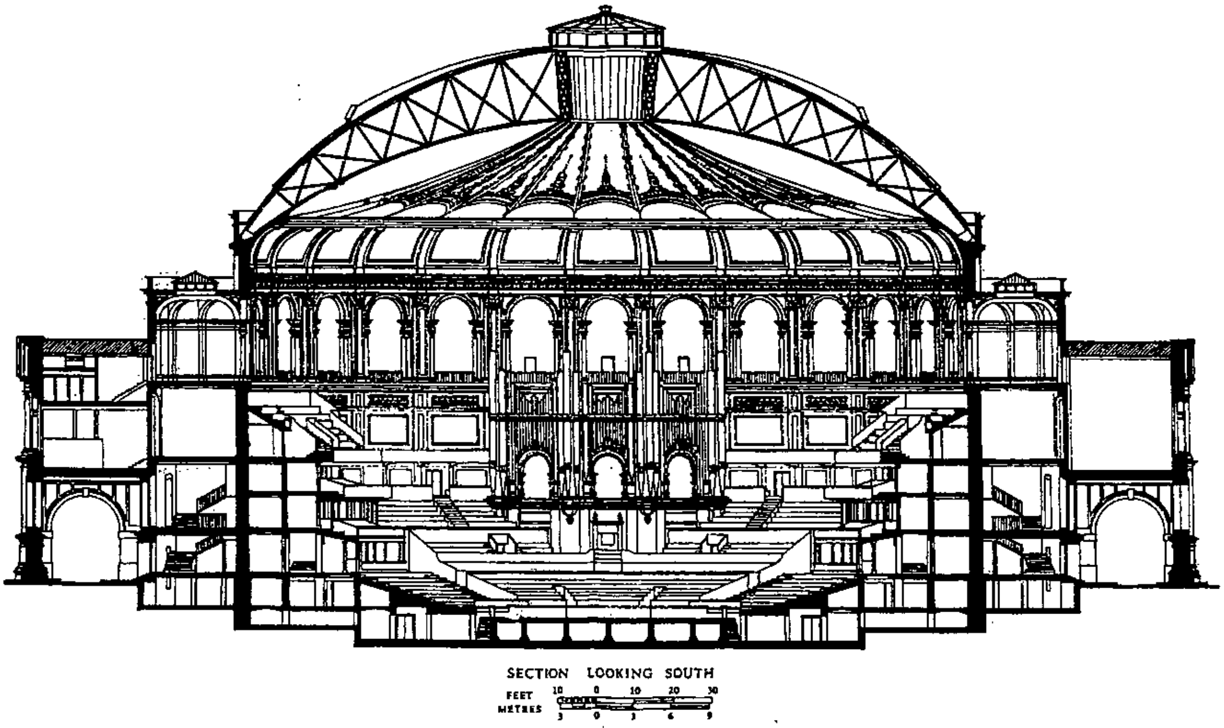

Figure 1: Section of the hall with the original velarium

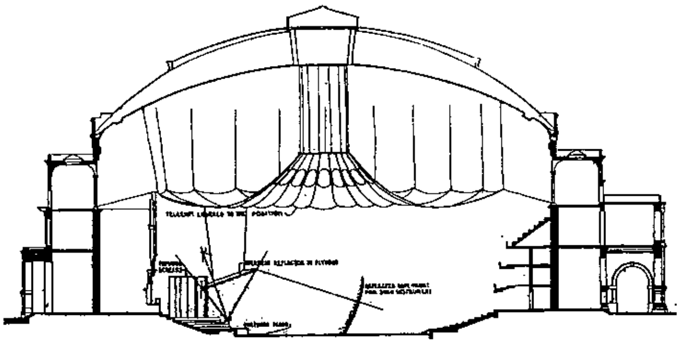

Figure 2: The velarium at the beginning of the proms in the Albert Hall in 1941 (original sketch from Hope Bagenal Building research station)

inner dome surface. However, owing to reasons we understand better nowadays, this modification probably had a negative effect on the acoustics compared with the 1941 attempts sketched in *Figure 2.*

In 1968 the famous – or infamous – mushrooms were installed. They are still there, having originally been proposed by Ken Shearer of the BBC after an intensive study of echo paths *(Figure 3)*, accompanied by acoustic measurements in the hall. The mushroom arrangement considerably reduced the strength of the echo and also brought the reverberation time down from approximately 3.5 seconds to under 3 seconds.

In 1996 a 1:12 scale model was built in the acoustic laboratory of Peutz BV, in order to study possible ways in which the acoustic could be optimised after the refurbishment, and thus to make detailed proposals.

With the model and modern computer-based measurement tools it was possible to build the hall in its original (1871) shape and follow its evolution by measurement. Peutz BV was also able to listen to the changes in the acoustic of the hall, by processing

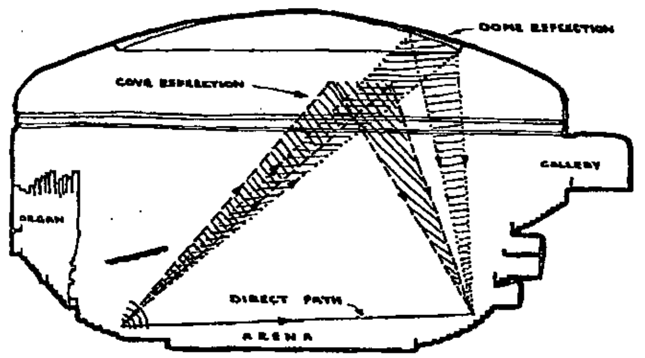

Figure 3: Echo analysis by Ken Shearer of BBC in 1968 (original sketch)

anechoic recorded music using the room responses measured in the model. The techniques used for this auralisation were presented at an Institute of Acoustics meeting in Manchester in 1999. It was thus possible to reconstruct some of the acoustic effects that could have been heard by the audiences over the last 130 years and, more importantly, to understand which elements in the hall were responsible for its acoustic behaviour.

An important and interesting finding was that the gallery never actually contributed to the famous echo, but in fact acts quite effectively as a reverberation chamber coupled to the hall. Adding absorbing

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Royal Albert Hall auditorium
before and after redevelopment

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materials here, thus no longer projecting amplified sound into the gallery, significantly reduced the general reverberation of the hall.

Although the principal cause of the echo was known for a long time, the model measurements made it possible to distinguish between the effects of the inner dome (originally glass, now sound absorbing), the cove with and without its ornamentation, the plaster area between the inner dome and the cornice, and the elliptical plan of the hall with its 'walls' of boxes.

One has to realise that since an ellipse has two foci, any elliptical plan must have two focal points. In this case, one is in the stage area and the other in the stalls opposite the stage. However, the main cause of the echo problem is that the hall's ceiling is close to a three-dimensional ellipsoid, with a focus almost exactly on floor level. It thus gives an extremely strong echo for natural sound sources on stage: for example, a symphony orchestra produces an echo more than 20dB greater than the direct sound if the dome is uncovered!

For a loudspeaker cluster flown 10m or more above stage level, the concentration of sound from the ceiling moves away from the audience level, which is the reason why there is no major echo during a properly amplified performance.

The model studies also showed the importance of the canopy over the stage. It prevents much of the sound energy from reaching the dome by reflecting the sound directly back onto the audience. A larger and somewhat higher position of the canopy would be acoustically beneficial, but the rigging does not allow major changes of that nature.

In 1997, these findings were presented in a paper given at an Institute conference in Dublin. Since then, the velarium option has been studied, but this was rejected for a number of practical reasons. Finally, a new mushroom arrangement was developed in order to maximise the audience's view of the restored cove, and optimise the acoustics. The findings of these studies are reported below. At the time of writing, the cove ornamentation work as well as the rearrangement of the mushrooms had just been completed in the Hall, and post-refurbishment measurements were in progress. The results will be presented during the *Auditorium Acoustics* conference in July 2002.

Studies of a velarium design and an optimised mushroom arrangement

Topics studied

The auditorium acoustics studies in 1997 and 1998 were carried out on the 1:12 scale model *(Figure 4)*. The objectives were to:
- optimise a velarium design;
- assess the acoustic effects of the cove after restoration; and
- optimise the mushroom arrangement.

The velarium design was studied in the second half of 1997, and the optimisation of the mushroom arrangement in the second half of 1998, after the velarium option had been rejected.

The studies on the effect of the cove treatment were made both for the velarium and the modified mushrooms. The need for a more-or-less free view of the cove, which was to be restored, was the architectural starting point. Both options proved to give improvements over the existing mushroom arrangement, but in different ways.

The velarium and mushroom options needed to be studied in detail to find the right acoustic treatment to achieve satisfactory results, and to optimise the design.

Optimised acoustics for the Royal Albert Hall would include:
- echo suppression;
- an increase in sound levels during unamplified events; and
- evenness of responses over the audience.

The canopy over the stage (the existing one) was a constant factor in almost all the experiments, but in a few cases, the reflector area and shape were changed in order to study the causes of echoes.

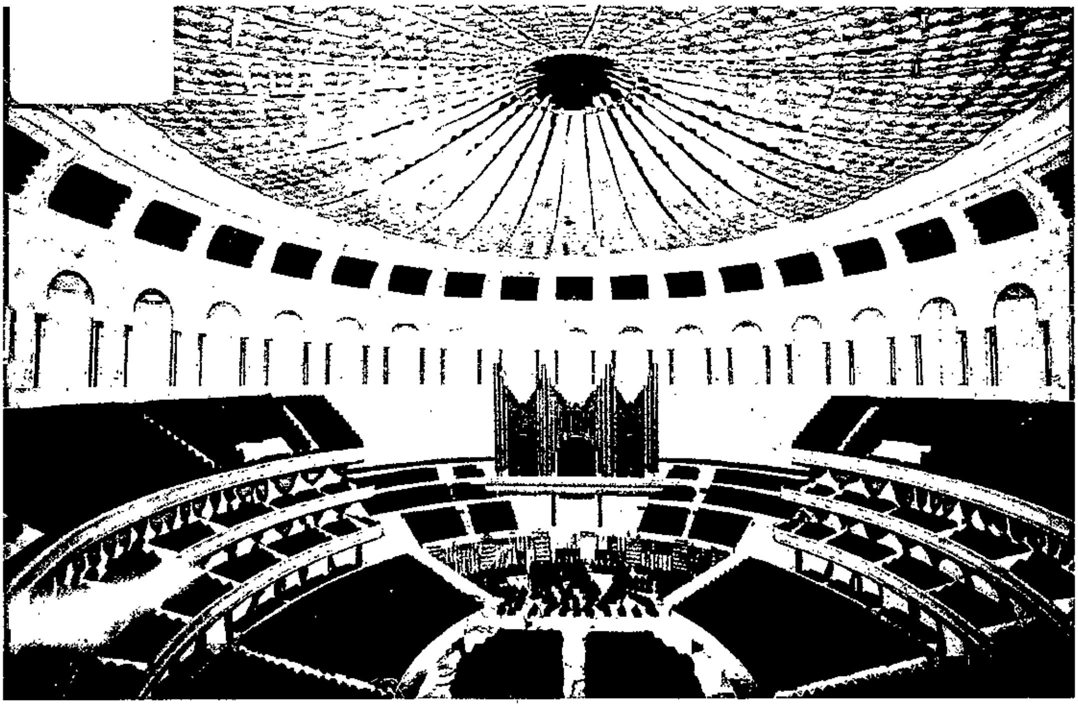

Figure 4: The scale model with a reflecting and diffusing velarium and added diffusion and absorption in the cove

Velarium design

The principle of the acoustical reflecting velarium is sketched in *Figure 5*. The critical parameters for such a velarium were found to be:

- the height at the perimeter (approximately the height of the cornice);
- the treatment of the cove area;
- the treatment of the upper cove area (just above the cornice); and
- its surface properties (diffusivity).

The advantages of a velarium are:

1. The surface is basically convex, which does not concentrate the sound (like a dome) but rather spreads it.
2. The hall's acoustic volume is reduced, giving more strength to the sound if the reverberation time is kept at the existing value. To achieve this, since the absorption of the perforated aluminium dome would be lost, absorption would have to be added, for example by fitting heavy curtains in the gallery.
3. The diffuse reflection of sound by the velarium spreads the reflected sound more evenly over the audience.

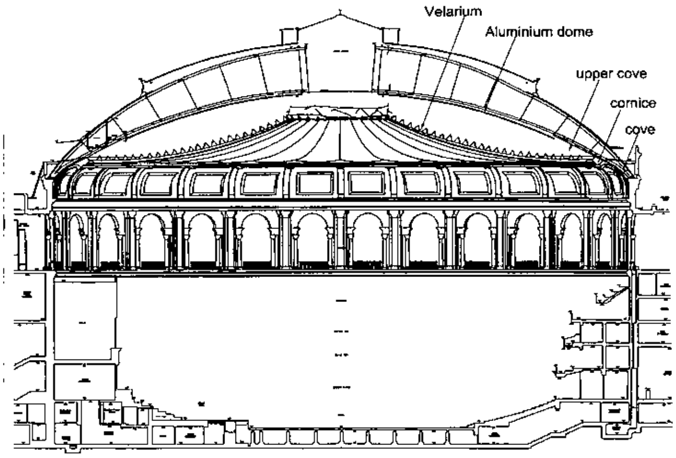

Figure 5: The principle of an acoustically reflecting velarium

At least five complications were found to arise if a velarium were used.

1. Since its position is approximately 4m higher than the mushrooms, the cove would be revealed to the direct sound field and may cause echoes. The position of the velarium makes it act as a 'mirror', so this effect is even stronger. Acoustic treatments such as absorption and extra diffusion to the higher and lower cove appeared unavoidable.
2. The velarium's position higher than the existing mushrooms delays the ceiling reflection, causing a gap in the acoustic response mainly on the side balconies, owing to the lack of wall reflections. These gaps in the response, although looking 'wrong', proved from auralisation experiments to be hardly noticeable. Nevertheless an improved (or electroacoustic) stage reflector would be desirable to compensate for this effect.
3. The architectural design of the modifications to the cove could be unacceptable in terms of heritage requirements (the listed building status).
4. Problems would be encountered in implementing the extremely flexible and adaptable rigging necessary.
5. Cost.

Although the acoustic problems arising in the velarium design were almost completely solved in the scale model, architectural, rigging and cost problems meant that the option had to be rejected.

Modified mushrooms

The earlier studies showed that it was not really possible to lift the mushrooms, to give an improved view of the cove and cornice once both had been restored to their original beauty. Possible modifications to the arrangement of the mushrooms therefore concentrated on moving them away from the perimeter, grouping them more closely together nearer the centre, but keeping them at the same level so that the critical part of the dome would still be screened. The screening effect would in fact be enhanced because of the higher mushroom density. The principle of such a mushroom design is sketched in *Figures 6 and 7*.

The strengths of this approach are:

- improvement of early reflected sound, because of the more closed 'ceiling' at relatively low level;
- more effective screening of the dome, thus suppressing echoes; and
- more effective screening of the high cove area.

The combination of the effects of these modifications gives smoother and more even responses in nearly all measurement positions in the hall.

The main disadvantage is that no increase of loudness can be achieved. Furthermore it proved necessary to eliminate the acoustic effect of the higher cove area around the stage, because there are still no mushrooms benefiting this area, as was the case with the existing arrangement. This is dealt with by installing seven extra mushrooms at the rear. Extending the stage reflector to the sides and rear would have given the same sort of result, and may even have been slightly more effective.

It proved unnecessary to treat the lower cove acoustically, as it had been refurbished and was therefore more diffusive than in the existing case. This was true so long as the mushrooms at the existing (approximately gallery ceiling) level were retained. The contribution to the echo made by the cove is sufficiently suppressed, because the cove itself has a relatively small radius of curvature, which makes it

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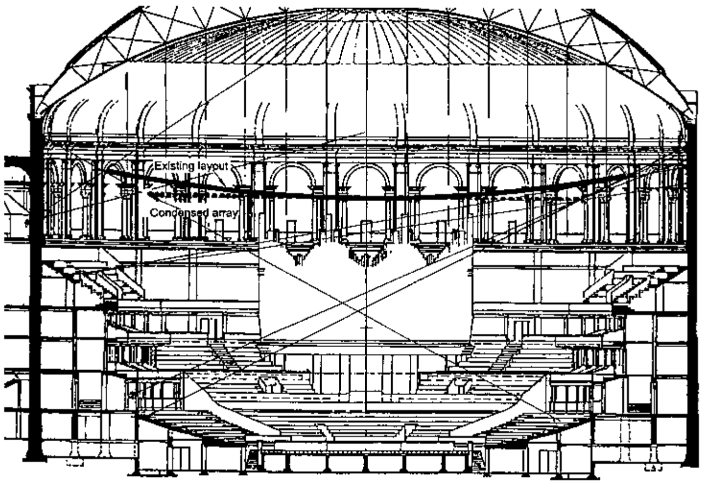

Figure 6: Section of the existing and the new, condensed mushroom array (section)

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a diffuse element when seen from a larger distance, and by the re-introduction of the cornice and the ornamentation in the cove. Investigations using both the scale model studies and the echo path analysis with an Odeon (ray-based) computer model agreed that screening of these features could be omitted without risk.

Reverberation time

The refurbishment of the auditorium contained many modifications which had an impact on the reverberation time. After analysing the various uses to which the hall would be put, it was concluded that if variable acoustics were not to be introduced, maintaining the reverberation time should be the objective. This requirement was included in the brief for the project, with a permissible change of 5% in each octave band.

Modifications which could have an effect on general reverberation included:

1. New seats at the balcony, the stalls and the choir.
2. Modification of the stalls floor to introduce quite a large area for air supply at the low velocity of less than 0.15ms^{-1} over the perforated vertical area of the steps, to a total area of approximately 120 m^2: the absorption of the floor area would increase by connecting the air supply plenum under the stalls floor, and by having perforated steps and perforated steel bars behind to support this floor.
3. The number of mushrooms (fewer than before) and the number of mushrooms with absorbing material on top.
4. The positions of mushrooms. The more concentrated arrangement meant that the acoustic coupling of the spaces under and above the mushroom 'barrier' changed or, in other words, the effective acoustic volume of the hall was different.
5. A change of stage layout.

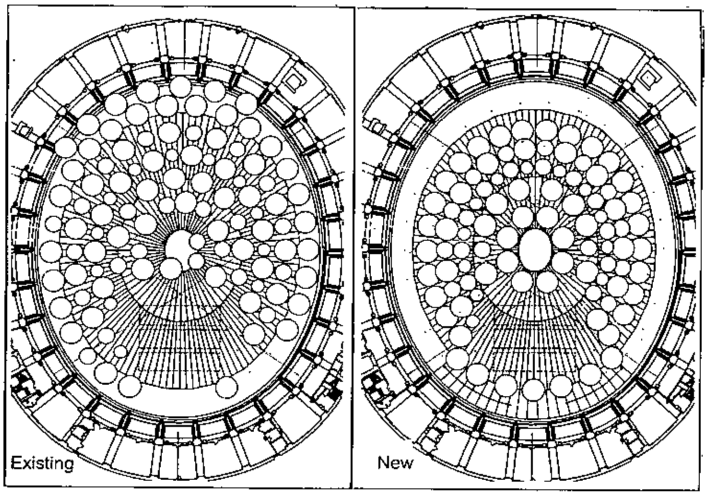

Figure 7: Existing and new mushroom array (plan). The configuration finally chosen is slightly more randomised than that drawn here

The effects of the seating and the floor were modelled in a laboratory set-up by BDP Acoustics at Salford University. The effects of the changed mushroom and stage layouts were studied in the 1:12 scale model. The results of these were put into the statistical reverberation (Sabine) model and in the Odeon ray tracing model to assess the effects on general reverberation. The conclusion was reached that the reverberation time would be maintained if about half the mushrooms were filled with mineral wool.

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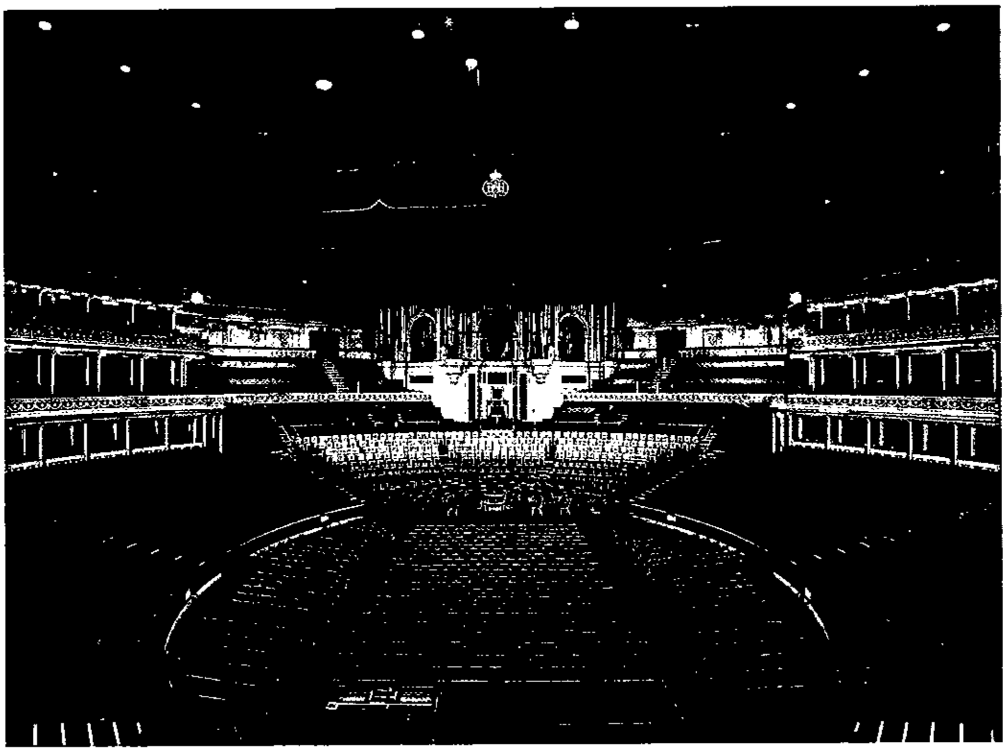

Re-engineering the Royal Albert Hall

Ian Blackburn

Lieutenant-Colonel (later General) Henry Scott, who master-minded the construction of the Royal Albert Hall, had robust views on acoustics. In his address to the RIBA on 22 January 1872 he asserted that: "The most delicate musical sounds are distinctly audible" and dismissed the suggestion that echoes, or reflex sounds (to use the language of the time), mattered. He reasoned that: "We now no longer hear them, because people go to listen to the music and not for reflex sounds".

Henry Scott, whatever his views on acoustics, had good reason to celebrate the completion of the Hall. It had been designed by fellow Royal Engineer Captain Fowke and executed on time under Scott's direction to a budget of £175,000. His address to the RIBA bore testimony to the courage and ingenuity of the team that built it and provides a fascinating insight into all aspects of its construction.

Throughout its eight-year life the Hall's £70m Lottery funded project has maintained quite a low profile, only attracting interest from time to time within the entertainment industry, the construction industry and acousticians.

This paper will be presented by the author with Martin Ward, project architect Building Design Partnership, at this month's (July) *Auditorium Acoustics* conference in London. It follows Scott's model in describing the team and its management, and the creative approaches taken to planning, design and implementation of the Royal Albert Hall's development project in a uniquely challenging environment.

Unlike Scott's paper, specific acoustical matters have been left to the experts. These have been addressed by Rob Metkemeijer of Peutz Associates in a further paper to be presented at the same conference (and reproduced on pages 10 to 14 in this issue of *Acoustics Bulletin*). They were also considered in earlier presentations to the IOA in Dublin (1997) and Manchester (1999).

This paper describes the Hall, its development master plan and programme. Some of the techniques employed are described with reference to specific projects to illustrate how so much work has been carried out without disruption to one of the busiest programmes of events to be found at any venue in the world.

The Hall

It was Lieutenant-Colonel Henry Scott who masterminded construction of the Royal Albert Hall to designs by fellow Royal Engineer Captain Francis Fowke. The latter had established a reputation for inventiveness through a collaboration with Henry Cole over two decades of ambitious development in South Kensington. His design for the Hall evolved slowly from grandiose schemes contributed by Gottfried Semper, Gilbert Scott and at least half a dozen other eminent architects, but he died before it was complete. However, Henry Cole preferred to work with the Royal Engineers rather than pander to contemporary architectural fashion and the design was finished by

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Henry Scott. Fortunately Cole retained the confidence of the Prince Consort, who advised his children on one occasion that 'you can't have steam without Cole'.

Grade 1 listed, the Royal Albert Hall now enjoys almost iconic status as a national monument. Events such as the Proms have enhanced its place among the world's entertainment venues. As an institution, and for cultural diversity, it has always been hard to match. From Emily Pankhurst's suffragettes to Oswald Mosley's blackshirts it was always the venue of choice.

Currently, the Hall hosts more than 300 different performances each year, including the BBC Proms, rock and pop concerts, ballet and opera, sporting events, charity concerts, galas, award ceremonies and national events.

The Auditorium contains 5,200 seats at full capacity and is extremely versatile. It always has been. Performances can be held 'in the round' or on the stage and a bewildering variety of designs can be accommodated. For example, the great floor first introduced in the nineteenth century spanned the entire Arena and Stalls. A version is still used today for tennis and to create a vast area for exhibitions and gala dinners.

The Auditorium presents an unusual combination of size and intimacy, twenty-first century rigging with Victorian theatrical plush. It shrugs off the incongruity of its fluted aluminium dome lining, which might have been assembled from fuselages of a squadron of 1940s airliners, and the suspended glass fibre diffusers, affectionately known as mushrooms, add a uniquely 1960s flavour.

The organ is one of the finest, largest and tonally most comprehensive instruments in the world. Built by Willis in 1871 and re-built by Harrisons in the 1930s, it will be the largest in the United Kingdom when the current refurbishment is completed by Manders in 2003.

The appearance of the Auditorium has altered little during the course of the current development despite numerous interventions, including three large lifts which have been installed to handle equipment and materials between a new basement, arena and stage.

Planning

If collaboration, rather than grandiloquent design, lay at the heart of the successful completion of the Hall in 1871 then, today, it may be said that history is repeating itself. The master plan prepared by Building Design Partnership (BDP) in 1991 was the subject of wide consultation. At its heart was the simple idea of the removal and concentration of all services to an underground basement and service yard under the south steps. This in turn frees considerable space, rationalising and improving all the Hall's facilities, enabling the interior to be restored and improving approaches to the building.

Work in the public circulation areas is almost complete. New restaurants and bars have been in operation in the Circle for some years now and new bars have been opened at ground level and in the new arena foyers during the past year. The number of public lavatories has doubled and an auditorium ventilation system installed. Refurbishment of the organ is under way and a new South Porch is under construction.

The programme

The works are being procured in thirty discrete projects. Most are now complete, four are currently under way and three have not yet started. Work started in 1994 and will continue until 2003. Each project must be delivered within the usual quality, cost and time parameters, with the added challenge of there being no disruption to the Hall's operations.

It has been necessary to maintain a full calendar of events throughout this period in order to provide the income to support the development. There have been only two brief closures: one in May 1996 for the Circle re-seating; the other in January 2000 for the Stalls, each for a period of one month.

Project examples

The potential consequences of disruption to events at the Hall are too awful to contemplate. Complaints are no guide to disaffection, and it is well known in the entertainment world that few disaffected patrons return to a venue once it has failed to live up to their expectations. Since few make their disappointment known to the management, it is necessary to be especially attentive and imaginative in anticipating problems and resolving them in good time.

Excavation below the Hall proceeded simultaneously with rehearsals and performances of *Swan Lake* in performance on the Arena above. A route had to be provided for Rothbart to make his entrance from below the Arena floor. Sir Cliff Richard had to be led across the same excavations for each of 32 performances in late 1998 and early 1999.

It may come as no surprise to learn that the accommodation, human and financial demands of this development require as much effort as the management of the projects themselves. Ear muffs were issued to staff in the artists entrance at one point.

Great attention to people issues has been demanded and a series of key initiatives was taken:

- ❑ client, designer and constructor were co-located on site to comprise an integrated team;
- ❑ surveys of environmental conditions were provided by the Institute of Occupational Medicine, who also provided expert advice;
- ❑ an experienced professional personnel manager was appointed, induction training undertaken, and job descriptions and regular appraisals were given greater emphasis;
- ❑ communications were improved, through the publication of weekly bulletins, regular briefings and occasional presentations by the construction team to operational staff; presentations were also given by operational staff to the construction staff, and achievements were given more recognition;
- ❑ project and operational managers met first thing each Monday (they still do) to review the development impact for the week ahead;
- ❑ a draft policy and code of standards of conduct for both staff and contractors was published; and
- ❑ a risk register together with contingency plans was implemented.

For several months 1000 meals a day were prepared in camp kitchens distributed through the Hall while the basement kitchens were being refurbished. The star dressing rooms and Artists' Corridor were re-built, whilst in continuous occupation. The Stalls and Choirs were each reconstructed in a period of less than a month. There was no closure for the reconstruction of the Choirs, which proceeded behind hoardings without disruption to the programme of events.

Boxes and public circulation areas were refurbished by day and returned to use for each performance.

Access

Special attention was needed to maintain access. The Cove was constructed from a purpose built gantry suspended from new tracks. The whole installation was designed and installed by Unusual Rigging to repair the existing ceiling and install more than 1000 linear metres of fibrous plaster without loss of a single seat for a single performance. It was necessary to train the plasterers in abseil escape procedures in case of fire.

For the Roof to be reglazed without interruption to the Hall a siege tower 40m high and including stairs and hoist was erected outside the building. A similar approach was adopted for many projects.

During the course of developing the South Steps it was also necessary to maintain access to neighbouring buildings, and ensure that fire escape routes were unrestricted.

Communication

From the outset, an array of communications techniques has been employed. The Hall has consulted widely, published newsletters and held meetings with all interested parties.

Weekly planning meetings have been attended by the construction managers to co-ordinate the development works with the Hall's diary of events and operations.

Special measures have included the use of solid object modelling, for example to illustrate the impact of building development on the South Steps.

Some of the key lessons learned were:

- the importance of accurate information;
- the constant need to update risk assessments and contingency plans;
- the necessity of shared standards, with regular reviews of impact and a flexible approach.

Handover

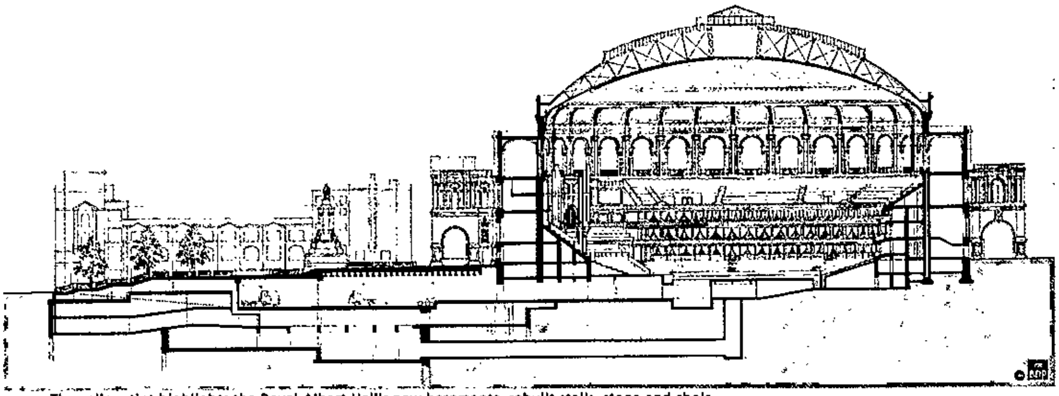
The South Steps project was completed in May 2001 and the service bay, plant rooms and parking for residents have now been operating for some time. Shows have been loaded into the auditorium via the new loading bay since February 2001. Yet the task of commissioning and handover is far from complete, and the auditorium ventilation faces its first severe test during Proms 2002. As with so many venues, the services are ultimately the single largest and most complex element of work in the entire programme.

Forthcoming projects

The new South Porch is already rising above the construction hoarding and will be completed in 2003. Work commences on the East Porch bar in the autumn, and this will be followed by the West Porch bar in early 2003.

The organ is currently in pieces, mostly in Manders works at Bow, East London, but it will start returning to the Hall very shortly.

There are ambitious plans to transform the setting of the Hall in collaboration with local residents and institutions.



The yellow tint highlights the Royal Albert Hall's new basements, rebuilt stalls, stage and choir.

Conclusions

Pressure on the staff and management team has been relentless but, in the best traditions of a great venue, the shows have gone on.

A week in the Royal Albert Hall remains eventful, with many surprises, and it is clear that resources have been stretched from time to time, and no more than the minimum demands met - there are few frills backstage. But the experience to date has been that, through collaboration, re-engineering of the Hall has achieved a degree of innovation comparable with that applied by the Royal Engineers who built the Hall in the nineteenth century.

It is heartening to conclude with a degree of confidence that all the key objectives set for this complex development will be achieved by the end of 2003 - and without losing a single performance.

Ian Blackburn is Director of Building Development, Royal Albert Hall, with responsibility for the Hall's lottery-funded £70m building programme, which is due to be completed in 2003.

Postcript: The Hall is still seeking to raise £3m towards the cost of development. If you would like to contribute there is a range of schemes. Please contact the author or: Sarah Dixon, Head of Development Fundraising, Royal Albert Hall Trust, Kensington Gore, London SW7 2AP.
Tel: 020 7589 3200 Fax: 020 7225 0899

Renovating Brighton Dome's concert hall acoustics

The newly refurbished Brighton Dome, restored to its art-deco glory after a £22 million renovation project, is now one of the leading arts and conference venues in the south of England. The Dome was last refurbished in the 1930's; inevitably over the course of the last sixty years the fabric of the building had decayed, while the expectations of audiences and artists became more demanding. The challenge was to design a centre for the performing arts which would satisfy the needs of a very sophisticated audience, while maintaining the integrity of both the grade 1 listed Regency exterior and 1930's interior.

Brighton Dome Concert Hall was originally built in 1805, as the Prince Regent's riding stables. In its heyday the Dome was the most fashionable and culturally significant venue in the area. First converted into a concert hall in 1866, it was restored again in 1935 when the famous art deco interior was introduced. After the second restoration its opening programme in 1935 featured Richard Tauber, Paul Robeson, Fritz Kreisler, and the Berlin Philharmonic Orchestra conducted by Furtwangler. However, the volume of the space remained inadequate for the development of sufficient reverberation.

During the 1960s and 1970s the Dome presented rock legend Jimi Hendrix, as well as the Rolling Stones, and it was here that Abba won the Eurovision Song Contest with 'Waterloo'.

Now the concert hall been lovingly restored to its former glory but with improved sightlines, new front-of-house facilities, and comfortable new seating. The

Brighton Dome auditorium

Arts Council of England's Lottery Fund contributed three quarters of the total amount with additional funding from Brighton and Hove City Council, The Brighton Festival Society, and the Single Regeneration Budget.

Resolving volume limitations

At the outset of the renovation project it was determined that this limited volume was the principal obstacle to the creation of a world-class acoustic for classical orchestral music. Arup Acoustics, working closely with the client, RHWL arts team, and Theatreplan, explored options for developing a range of acoustic responses for a variety of users.

The new auditorium uses greatly improved formats. There are up to 1800 seats, with the centre stalls seating mounted on pallets to allow for flat floor use. The stage has been radically altered, as organ screens on tracks allow proscenium or thrust stage formats to be used. A forestage lift, a seat and pallet garage below the stalls, tip-and-store choir seating, and new air and technical systems have also been installed.

Because of the limited room volume, it was decided at an early stage to explore sound enhancement systems. After outline tendering by three system suppliers, and listening trials in venues using reverberation enhancement systems, it was agreed that the Carmen system provided the preferred sound quality.

Another key consideration was how readily the system could be integrated into the historic interior. The overall system stability, the technical expertise available as backup from the suppliers - and their commitment to providing such service - and the achievement of specified performance levels were also important.

The Carmen system, based on an 'active wall'

Birmingham Hippodrome 2000

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open to the ground floor foyer through large slots cut into the perimeter of the floor slab. It was the client's wish that noise from the foyer would not become a problem within the restaurant, but it was felt that if some foyer noise were to reach the restaurant its atmosphere would be enhanced by providing a 'buzz'.

Were these areas to be glazed, a high level of sound insulation could of course have been achieved, but this would acoustically separate the spaces too much. It was therefore recommended that acoustic absorption was provided on the slab edge and on the vertical wall opposite, thereby providing some attenuation between the two spaces. Reverberant sound levels were also controlled by installing areas of absorbent ceiling in both the foyer and restaurant.

The outcome proved satisfactory for both of the public spaces.

Acoustic cavities

Construction of the floating studios and the Patrick Centre was slow, painstaking and frustrating both for the design team and the contractor. The construction of these sensitive and critical elements was programmed for completion before the building was watertight. Unfortunately, this phase of the project coincided with the wettest winter in Birmingham for many years.

The cavities between fixed and floating structures ranged from 50 to 500mm wide, and all had to be kept clear of rigid debris. In some cases, it was easier to fill the cavity with mineral fibre before forming the cavity wall, thus preventing debris from bridging the cavity. In larger cavities, cleanliness was achieved on a lift-by-lift basis, whereby the cavity was protected as construction progressed. For the largest cavities, it was possible for workmen to enter them and remove debris once the walls were complete.

Patrick Centre finishes

The acoustic design of the Patrick Centre required the room to be suitable for amplified music and speech. This condition had to be met whether the retractable seating was extended and occupied by an audience, or retracted.

The target reverberation time for the auditorium was less than one second. Absorbent wall and ceiling finishes - typically 100mm thick - were designed to provide a reverberation time of about 0.7s in both seating configurations. The bass rise was controlled so that the space was suitable for the performance of amplified music.

Dance studio finishes

Absorbent wall and suspended perforated ceiling panels were designed for the dance studios. Performance of the suspended absorbers is surprisingly good, as both sides of the mineral fibre panels are open to the space on both of its surfaces. Nevertheless, these spaces remain quite lively as they have mirrors on nearly half the wall area, full height windows at one end of the room, and a wooden floor. A reverberation time of about 1.5 seconds was achieved.

Acknowledgements

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The authors would like to thank the joint project architects Law Dunbar-Nasmith and Associated Architects. Thanks are also due to the Birmingham Hippodrome for kindly permitting the publication of this article.

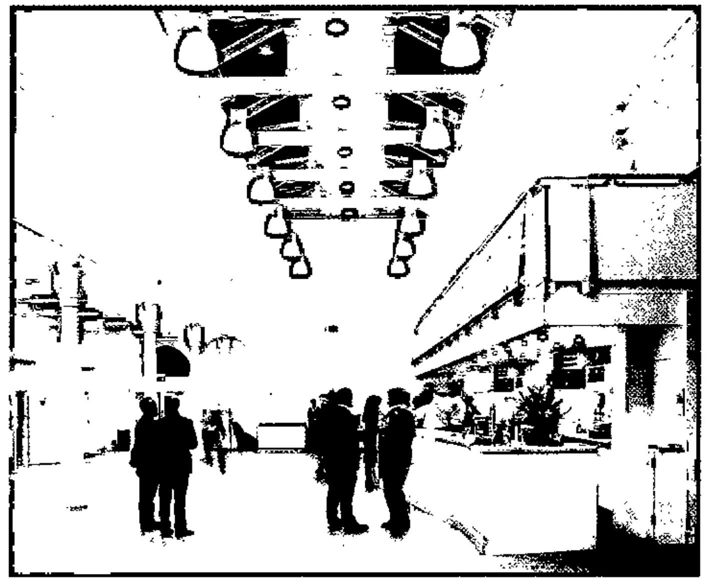
principle, uses cells distributed around the room boundaries, on balcony fronts, and inside column heads under the balconies, to feed 'diffused' reflections into the auditorium. The listener can move as close as 1m to the cells without being aware of their output. The most important aspects of system performance were:

- ❑ extension of room reverberance with appropriately timed sound power development;
- ❑ contribution to early lateral energy to improve the involvement of the listener; and
- ❑ an aural sense of height.

This last objective was enhanced by removing a central circle of plaster from the 1930s ceiling. It now incorporates a tensioned wire grid, so that an aural sense of the Dome is created.

Quiet air systems have been installed, and the sound insulation of the building envelope improved so that the standard of attenuation of noise from the adjacent Corn Exchange is greatly enhanced.

Early performances in the new auditorium have included the Royal Philharmonic Orchestra under Kent Nagano performing Messian's *Turangalila*, Nigel Kennedy with strings from the Berlin Philharmonic Orchestra performing Vivaldi and Jimi Hendrix; and



The new reception hall

a recital by Kiri Te Kanawa. All the artistes spoke very highly of the acoustic, and those who had performed in the Dome previously were of the opinion that the improvement was remarkable. The acoustic response now has the potential to bring out the best from world-class performances and a wide range of uses, and the hall has probably never sounded so good for orchestral music.

The other two main venues on the same site are the Corn Exchange and the Pavilion Theatre. Built at the same time as the Dome, the Corn Exchange was originally the Prince Regent's Riding House and had a gravel floor. A maple floor, still intact, was installed in 1935. Following its refurbishment, the space now has a capacity of 1200 standing, or forms a theatre seating 320. The Pavilion Theatre was built in 1935, and was first used as a supper room, but soon afterwards became a theatre. This intimate venue now has 240 seats, or can accommodate 350 standing.

Birmingham Hippodrome 2000

Acoustic design of the new theatre, dance studios and refurbished auditorium

Ian Knowles FIOA and Kyri Kyriakides FIOA

The Birmingham Hippodrome was built in 1899 and has since been at the heart of Birmingham's cultural life. It has been the home of the Birmingham Royal Ballet since 1990, and of Dance X change (the National Dance Agency for Birmingham and the Midlands) since 1994.

A £20 million National Lottery Grant through the Arts Council has permitted the establishment of Britain's first centre for the treatment and research of dance injuries. A 200 seat studio theatre and dedicated dance studios have been built for the Birmingham Royal Ballet and Dance X change, and the grant has also financed refurbishment of the original auditorium as well as providing new foyers and a new entrance.

The Lottery award was supported by a further £2 million from the European Regional Development Fund and Birmingham City Council, who restructured the lease arrangements to secure the Hippodrome's future for the next 125 years. The £2 million matching funding was by public donation and sponsorship.

SOUND INSULATION

Planning

The new Studio Theatre (named the Patrick Centre) and dance studios are located in a new building constructed on the site of an old nightclub adjacent to the Hippodrome.

It is important to realise that separate companies would be rehearsing and performing in the new building, so management controls on sound levels and activities were not desirable. The constrained site layout led to vertical stacking of the studios and the theatre. This inevitably resulted in onerous sound insulation issues.

These mainly involved effective isolation of the new Studio Theatre from impact sources within the dance studios and dance injuries centre above, and ensuring that the simultaneous use of all the dance studios would give rise to little or no disturbance in any adjacent space.

Strategy

The original sound insulation strategy was to provide a separate concrete box for each of the individual spaces within the concrete frame of the new building. All the spaces were initially resiliently supported. During a value engineering process, the dance studios were graded in terms of likely operational sound levels. The Royal Ballet studios primarily use a piano as the music source for their rehearsals, whilst Dance X change use high levels of amplified pop/rock music with occasional live bands.

It was decided to apply the maximum protection to the small Dance X change studio, allowing this to have the most flexibility (and to be the noisiest). The studio is therefore a completely isolated structure.

The 'lid' was omitted from the large Dance X change studio, thus placing some limitation on sound levels, as flanking transmission was possible through the common roof slab to other areas of the building.

Conversely, the Royal Ballet studio did not include any special airborne sound insulation measures other than a floating concrete floor. Airborne sound insulation was provided by the single dense concrete blockwork walls defining the space.

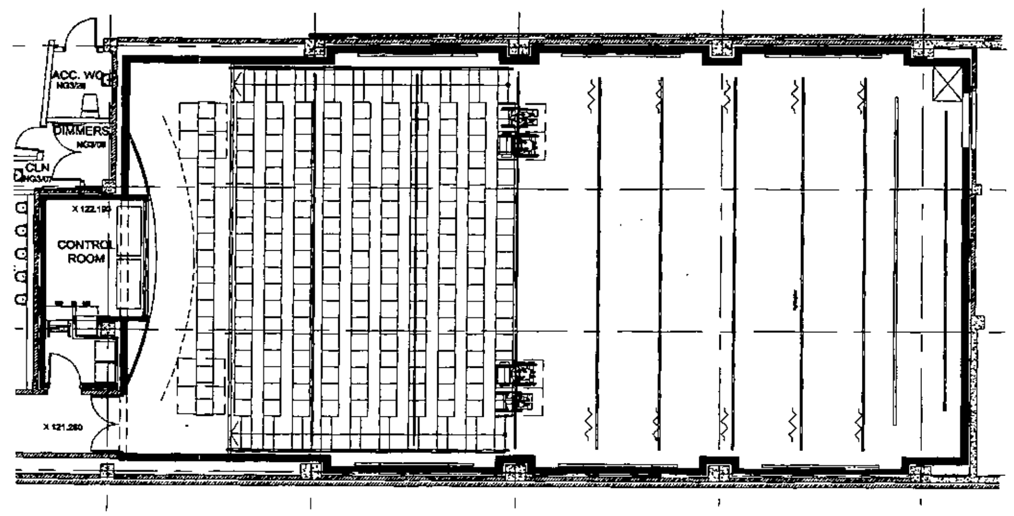
All studios were given a 150mm thick floating concrete floor supported on resilient bearings, with a traditional sprung timber dance floor on top.

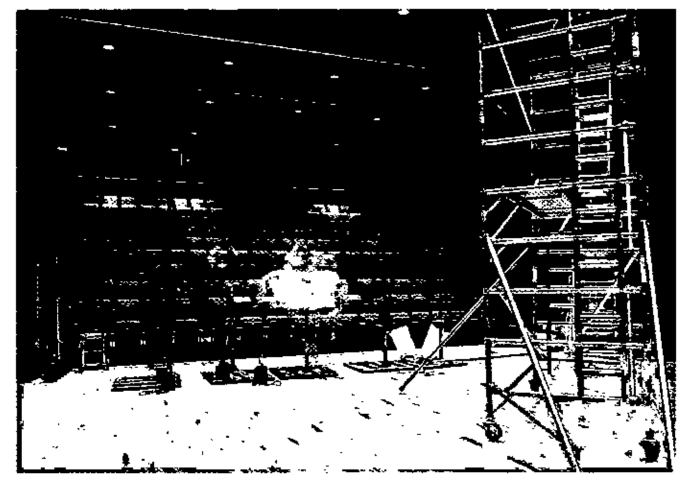
Structure

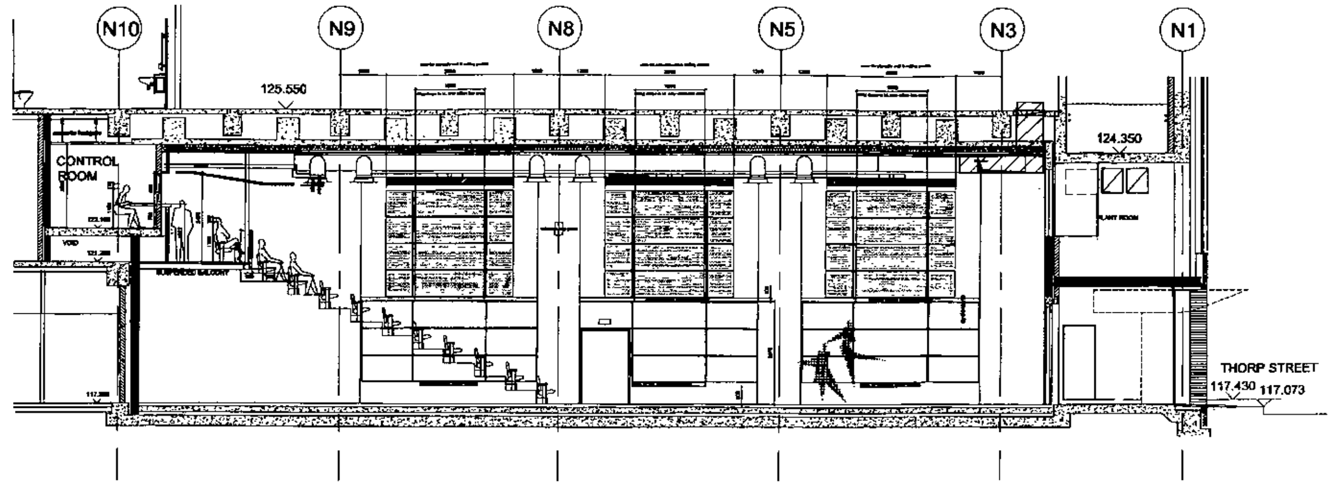
Patrick Centre: the section indicates the principles of the acoustic separation of the new theatre within the building. Of particular interest are the interlaced up-stand and down-stand beams supporting the concrete lid to the Patrick Centre, and the concrete floor to the centre for dance injuries above. This design allows for total physical separation between the two spaces, thereby preventing transmission of structure-borne impacts from the centre for dance injuries down to the theatre beneath. The blockwork walls to the theatre were supported on resilient bearings, as was the concrete floor.

Dance X change studios: these were designed with a resiliently supported concrete floor with resiliently supported dense blockwork walls. A laminated plasterboard 'lid', again on resilient supports, was provided for the small studio.

The Birmingham Royal Ballet studio: this has dense blockwork walls built off the structural building frame. The floor is a resiliently supported floating concrete slab.







THE PATRICK CENTRE
Pictures show above left: plan view of the centre; above right: auditorium from the stage; and bottom right: section indicating the principles of acoustic separation of the new theatre within the building

Auditorium

The design brief specified that any work carried out in the existing 1887 seat theatre did not compromise its good acoustic qualities. The brief required the entire circle containing 1018 seats to be re-seated. This meant that it was necessary to re-carpet and re-floor some areas. The whole auditorium was redecorated, and the control room re-sited.

Acoustic tests were undertaken in the theatre before commencement of the work to quantify the acoustic properties of the auditorium. The acoustic properties of the seats were also quantified and the data was used to specify the performance of the replacement seats.

Restaurant

The restaurant provided an unusual sound insulation issue. It is located on the first floor and

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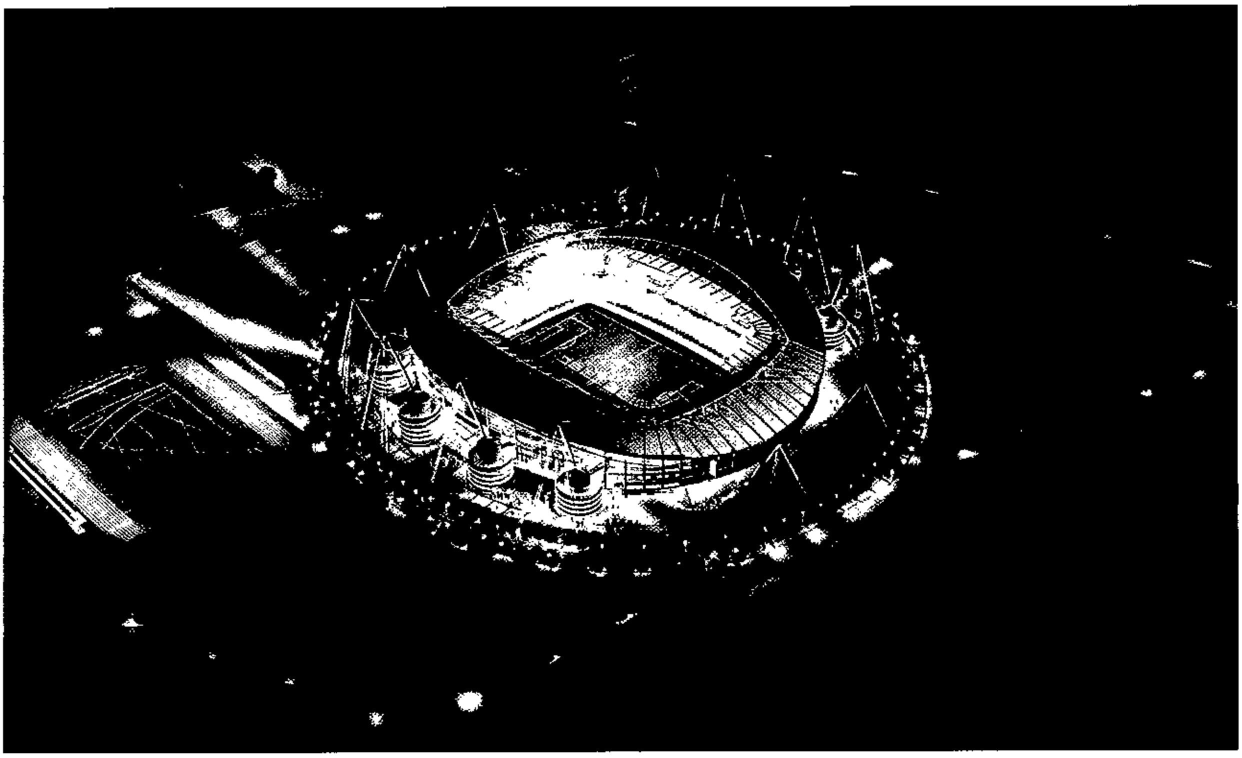
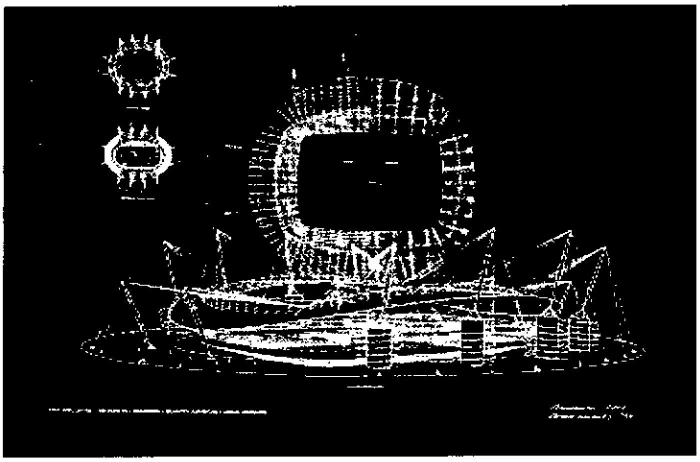


Figure 1: Visual of stadium at night

Acoustics of Commonwealth Games venues

The Commonwealth Games in Manchester this summer will be the largest sporting event the UK has ever seen. The hub of the games is the new City of Manchester Stadium, which has been built to the east of Manchester City Centre. Other events will take place in both existing and newly-built venues around the area. *Arup Acoustics* is responsible for the high-level acoustic design of the stadium and a number of other key venues. This article gives an overview of the technical issues involved.

Figure 2: Stadium in games and football modes



City of Manchester Stadium: Acoustic design

Arup Acoustics was an integral part of the design team led by Arup Associates, which won the architectural competition for the design of the City of Manchester Stadium. The £77m stadium, which was jointly funded by the City of Manchester and Sport England, is the centrepiece of the Commonwealth Games *(Figure 1)*.

The architectural brief initially required a stadium to seat 38,000 to host the athletics and the rugby sevens competitions. The programme for the games includes an athletics final every day of competition culminating with the rugby sevens finals, which feature most of the world's premier rugby nations including New Zealand, Australia, England and South Africa.

At the earliest stages of the project, a prime consideration was the future use of the stadium following the Games. During the preliminary stage, a strategic agreement was formed with Manchester City Football Club, whose fundamental requirement was a minimum seating capacity of 60,000 and that the stadium would be ready for the 2003/4 football season. This added a further layer of complexity to the concept as a whole - how to design a stadium intimate enough for the Games yet also meeting Manchester City FC's needs. The fundamentals required holistic design, split into two stages, to minimise reworking the stadium design between the two deadline dates *(Figure 2)*.

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Acoustics of Commonwealth Games venues

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The fundamental concept for meeting the stadium brief was:

'To build as much permanent structure as possible during the first design stage to meet the brief for the Games - this was met by deciding to complete the east, south and west stands and provide a temporary north stand around regulation track and field. This element was to be ready for occupation by the Games operational team by April 2002.

Following the Games in September 2002, the site would return to the possession of Manchester City Council. Dismantle the temporary north stand, track and field. Dig down a further 6m to accommodate the additional seating stands, install the pitch and construct the North Stand. Complete and have this ready for occupation in the summer of 2003'.

Fundamentally, the core structural elements of the scheme remained the same in both cases. The entry level to the building, the roof height, shape and form, and the location and angle of the terraces were all maintained. This was fundamental in assessing and agreeing the environmental noise criteria and designing the internal acoustics of the stadium bowl and sound systems.

The scope of acoustic design services for the project included:

- Environmental Noise Impact Assessment (EIA);
- architectural and building acoustics; and
- voice alarm and public address system design.

Environmental acoustics

Essential uses for the stadium were defined early in the project design process. The Commonwealth Games was considered a 'one-off' special event by the host city Manchester. After the Games, the main revenue-earning stream was football events. The council and Manchester City FC wanted the option of hosting between one and three large concert events per year.

The stadium is just one building forming part of the overall regeneration of the area known as the Eastlands Campus. This scheme includes the introduction of extensive new retail and commercial developments, re-routing the road system, and an extension of the existing tram system into the area. The whole development was subject to an overall EIA.

Noise surveys were conducted at existing noise-sensitive receivers as well as those proposed on the site. Design guidance was provided and agreed with the Council to ensure that noise from plant related to the operation of the building would not under normal conditions exceed the guidelines in BS 4142, and that sound levels from concerts would not exceed the guidance provided in the Noise Council's *Code of Practice on Environmental Noise at Concerts.*

Meeting these design criteria had an important impact on the stadium design. The original architectural concept called for a 'floating roof' achieved by the upper portions of the walls not being in direct contact with the roof itself. The resulting opening was seen as a weakness in the sound insulation of the building envelope. An assessment was conducted of both crowd noise and sound system noise break-out from the stadium for different stage configurations with all the stands occupied.

The sound power radiating from the gaps in the roof was not a significant contributor to the overall noise break-out. However, although the roof formed an effective barrier in terms of its height, a minimum sound insulation performance had to be achieved so that the full insulating effect of the barrier could be realised, meeting the environmental noise limits imposed by the local authority.

Analysis showed the roof could no longer be just a profiled metal deck with outer architectural finish. A number of configurations were examined and an additional mass layer, which also provided damping, was introduced to the roof construction to improve its sound insulation performance, thereby increasing the overall mass of the roof by around 7kg/m^2.

Architectural and building acoustics

From inception, the design team considered the stadium as an experience where spectators and performers gather together - 'the ultimate theatre'. Acoustics as well as sight lines were considered of foremost importance in the design process to achieve the desired end result.

Acoustics was integral to the architectural scheme from the concept design onwards. Three key factors were considered essential by the design team from the outset:

- achieving an ambience within the stadium bowl to enhance, encourage and amplify noise from the crowd as well as provide the players with a sense of crowd excitement;
- achieving high speech intelligibility from the sound system; and
- providing an integrated design for the loudspeakers and floodlights and locating these accessibly within the stadium roof.

Many stadia around the world meet one of the above criteria, but none until now have achieved all three. By taking these considerations on board at the concept design stage, an elegant solution was derived in conjunction with the engineers and design team.

The roof and acoustics

Achieving the speech intelligibility targets required of the voice alarm system was a key component in discussion with Manchester City Council, as described

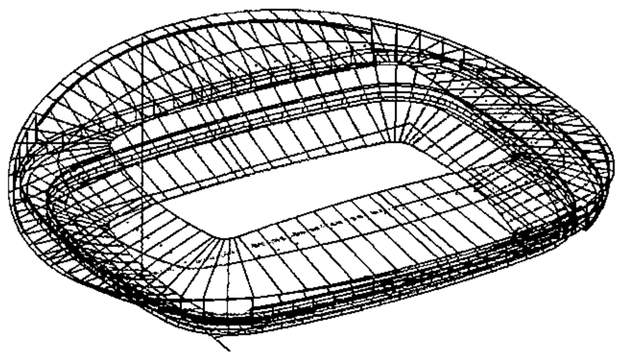

Figure 3: EASE still of stadium

below. It was clear from the outset that sound absorption would be required to control the acoustics of the terraces, particularly towards the rear where the height between spectator and roof is reduced. However, introducing sound absorption would be detrimental to the goal of crowd ambience within the stadium.

From inception, the roof design balanced the three primary aims by incorporating sound absorption to an optimised area of the roof in order to limit reverberation, particularly for second order reflections from the audience and loudspeakers. Moreover, there was curvature in two directions, creating an even spread of reflections across the listener plane to heighten crowd noise as well as send sound energy back towards the pitch.

Simultaneously, details were developed for the roof 'kick-up' approximately 10m from the front edge of the roof, incorporating the loudspeakers and floodlights. As well as performance considerations, maintenance and accessibility were considered key components in determining location of the 'kick-up' which would remain fixed for the life of the stadium. As a result, a second row of 'delay' loudspeakers would be difficult to access and maintain. Moreover, the architect wanted the loudspeakers to be as unobtrusive as possible within the kick up in order to achieve a continuous, discrete architectural element.

The design process was fully interactive and over the space of several months, as concepts for meeting the brief were explored, the acoustical issues were explored as parallel design activities.

Close collaboration with the architects ensured that the CAD models were produced bearing in mind their use by the acoustics team. An additional 'acoustic model' layer was added to the architect's drawings of the stadium bowl. This layer not only simplified some of the more complex geometries, but also constructed the key wall and roof surfaces using 3-D closed faces rather than the standard unconnected lines *(Figure 3)*.

This had two specific benefits:

- ❑ the roof design was constantly assessed using 2D ray tracing techniques in AutoCAD (developed in-house). This allowed the conceptual design of the roof to meet the requirements and optimise the reflection distribution; and
- ❑ the 3-D AutoCAD half model could be imported directly into EASE, Odeon and Catt Acoustic, allowing rapid iterations of room acoustic analysis, and PA system assessment.

The holistic review of all of these design aims allowed the early optimisation of:

- ❑ roof curvature;
- ❑ roof sound absorption;
- ❑ roof sound insulation;
- ❑ terrace depth; and
- ❑ loudspeaker location and distribution.

This was only achieved through the close collaboration of architect, engineers and acoustician.

Key decisions at the early stages of the project allowed us to determine that:

1. The second row of 'delay' loudspeakers was not necessary as the distance between the front edge and rear of the terraces was refined.
2. The location and configuration of the kick up was refined on the basis of the studies carried out by the floodlighting and loudspeaker designs. Finally,

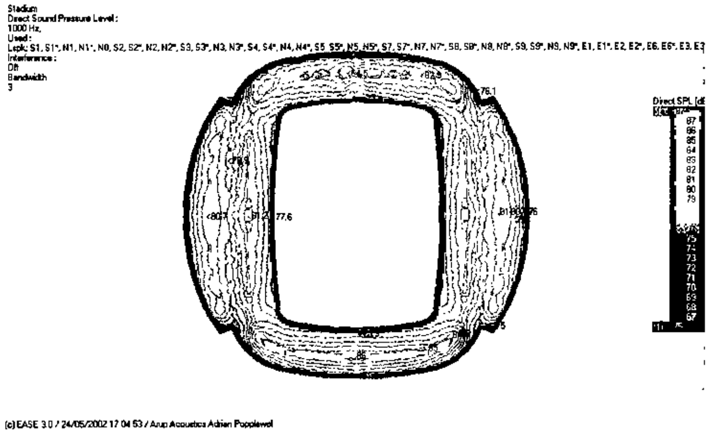

Figure 4: EASE plot showing loudspeaker coverage

the studies determined that the loudspeakers could be located within the kick up detail and arranged in pairs to serve each terrace bay, one covering the lower stands and one the upper. The angles of these could be fixed at Commonwealth Games stage and still provide the required coverage in football mode, with no need for re-configuration. *(Figure 4)*.

Voice alarm system design

Determining design criteria and approach: There are numerous determining standards and guidance documents governing the design of sound systems in sports venues but the most notable is BS.5839 Part 8: 1998 *Fire detection and alarm systems for buildings - Code of practice for the design, installation and servicing of voice alarm systems.* This contains prescriptive limits on the requirements for speech intelligibility criteria.

A common complaint expressed by voice alarm system designers is that the British Standards on intelligibility do not take into account the complexities of acoustics in an empty, half-full or full stadium and thus are too difficult to work with. Despite this many local licensing authorities insist on them.

Beyond the superficial view of the standard, BS.5839 Part 8 provides tolerances for system performance. It suggests a target value of 0.5 STI but suggests that discussion with interested parties should be the final arbiter on deciding the actual target. It was agreed with Manchester City Council that 0.45 STI should be the absolute minimum in a stadium or arena. Through a balance of good design of acoustic absorption and the sound system this should be achievable with no spectators present. However, intelligibility is more than a simple acoustic index. The goal should be to achieve a system that sounds natural, clear and intelligible.

The system design: Extensive discussions with Building Control and the Fire and Police Authorities allowed the design team to determine the exact requirements for the VA system. The final specification and a description of the Fire Evacuation process were ratified by Building Control.

The building operates in three modes: day mode, night mode and event mode. The greatest limitation on the system design was cost. The budget provision for the VA element of the life safety systems was

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Acoustics of Commonwealth Games venues

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£400,000, modest by the standards of some stadia. This proved not to be a significant limitation with respect to loudspeaker selection.

The key issue was system zoning. In order to envisage all possible future uses and allow flexibility, the system was originally split up into a large number of small PA zones, grouped into larger VA zones (simply split into each terrace - N, S, E and W - with an 'all call' facility). The large number of zones increased matrix size, amplifiers, cabling, and line monitoring and the system was then simplified to meet the budget target.

This required the client, MCFC, Romers Electronics (the VA system contractor) and the acoustician to refine the predicted uses for the building, define common usage scenaria on match days and non-match days, and come up with the most efficient overall circuit design. It was in this area that significant savings were made so that the budget was met. Key elements of the VA system were assembled by Romers using Baldwin Boxall Vigil system technology.

System ergonomics was important in the design of the microphone panels, particularly for the fire and VA microphones. A conceptual design was produced for an 8-digit LED display to show the status of each zone on the microphone panel. The Fire Authorities, Police and Building Control considered this an exceptional step forward in terms of the intuitive nature of the panel use.

The acoustic design of the City of Manchester Stadium shows what is possible when an architect and engineers unite in a goal to achieve something unique that surpasses the performance of any previous work. Good collaboration between the local authority, acoustic consultant and systems contractor can produce excellent VA design and intelligibility and bring design innovation even with cost constraints.

Manchester Aquatics Centre

The pool based events for the Games will be held at the recently completed Manchester Aquatics Centre for which Arup Acoustics provided design advice on building acoustics and PA/VA *(Figure 5a)*.

Acoustics

Swimming pools inevitably have a long reverberation time because of the hard surfaces and the large volume. Scope to incorporate acoustic treatment was limited and this meant the surfaces that were absorptive would need to be very effective. The decision was made to use the roof deck to provide acoustic absorption. By perforating the inner liner sheet, the mineral wool that made up the thermal insulation could also be used to provide sound absorption. The perforations reduce the structural strength of the liner sheet which limited how much perforation could be accommodated.

A series of acoustic tests was conducted in

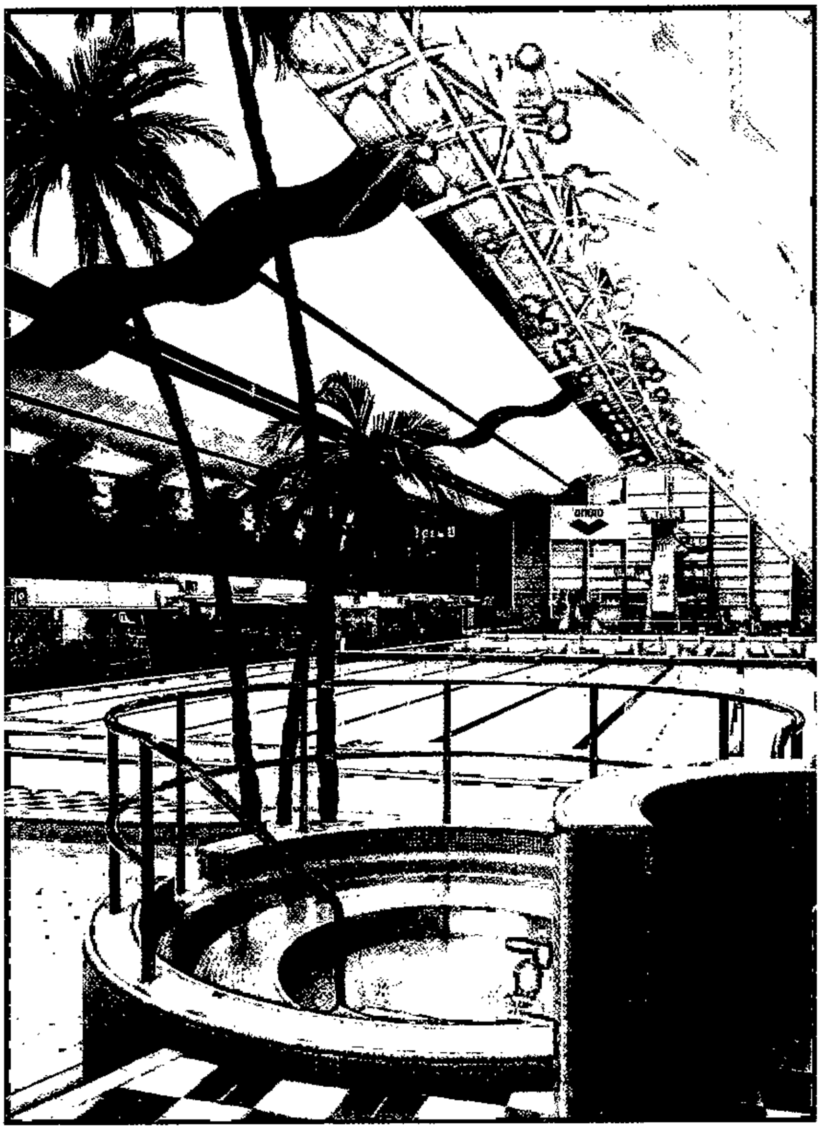

Figure 5a: Aquatics Centre

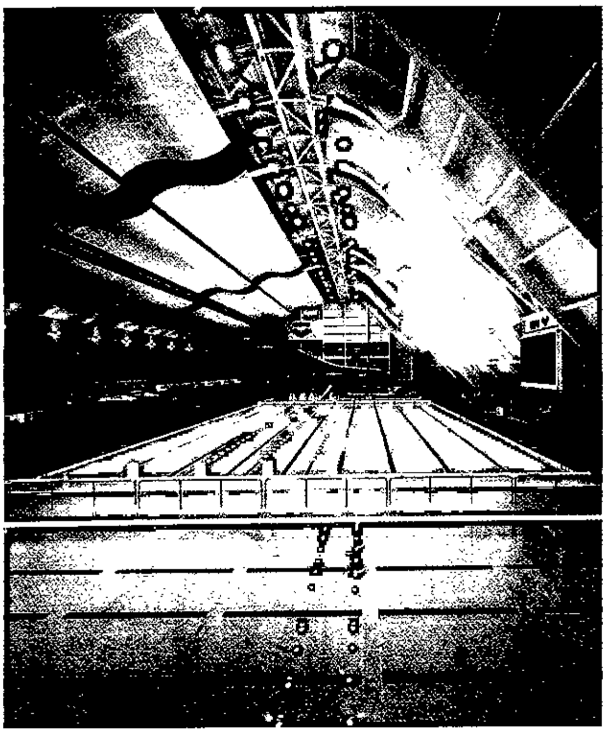

Figure 5b: Aquatics Centre showing ceiling absorption

conjunction with the architects to determine the effectiveness of the perforations to be used, which showed that additional absorption would be required. Previous experience had indicated that the standard used for these tests could over-estimate the acoustic performance. The tests were therefore carried out using a method which better reflected the actual installation, and these showed that the performance was significantly less than would be expected from the published data. The shortfall was made up with acoustics baffles hung over the seating area *(Figure 5b)*.

The Aquatics Centre is located close to some student residences and it was important to ensure that noise breakout from the pool did not disturb their occupants. A noise survey was conducted to determine the external noise levels in the vicinity of the pool. Whilst this was useful in setting limits for noise generated by the pool activities and associated plant, it was important to take into account the effect the pool structure was to have on the noise climate.

The acoustic screening afforded by the building envelope meant that background noise levels from road traffic behind the pool would be much lower than were measured during the survey. These effects were taken into account when setting criteria for noise leaving the pool complex. Although noise from the services was a primary concern, the potential for noise breakout from cheering crowds and from music used in the aerobics facility were also considered.

Voice alarm

To comply with the Building Control requirements the building is equipped with a voice alarm (VA) system fully integrated into the fire detection systems. The VA system loudspeakers are also used for public address purposes.

In the main pool, coverage is achieved using nine co-entrant high directivity horn loudspeakers mounted from the central roof gantry. These have an extended frequency range delivering high directivity, clear, natural sounding, intelligible speech for emergency broadcasts. The extended low frequency response ensures that the system is suitable for music, which is important during competition events such as synchronised swimming as well as for crowd entertainment during breaks in events.

In addition to these loudspeakers, connection points are provided along the pool side wall for underwater loudspeakers, which are weighted and dropped into the pool for specific events.

Head-worn radio microphones with a single ear piece are provided. These allow a commentator or announcer to be anywhere in the pool area, and talk at a normal speaking voice without feedback in the system. This element of the system will also be used for training purposes, allowing the trainers to walk up and down the pool side providing instruction on training technique. The system is replicated in the training pool.

The main pool is provided with an independent fixed lifeguard microphone located in an IP66 enclosure.

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Acoustics of Commonwealth Games venues

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The VA system is isolated in event mode via a key switch on the main fire panel. When in isolated mode, in event of a first stage alarm a coded message is broadcast to all areas of the building but no automatic emergency messages are broadcast to public areas. This ensures that the staff respond appropriately and take up predetermined evacuation locations. This allows a period during which the location of the emergency is checked. The senior Fire Officer in attendance decides when to evacuate the building, and whether to achieve this using pre-recorded messages or live broadcast via the fireman's microphone.

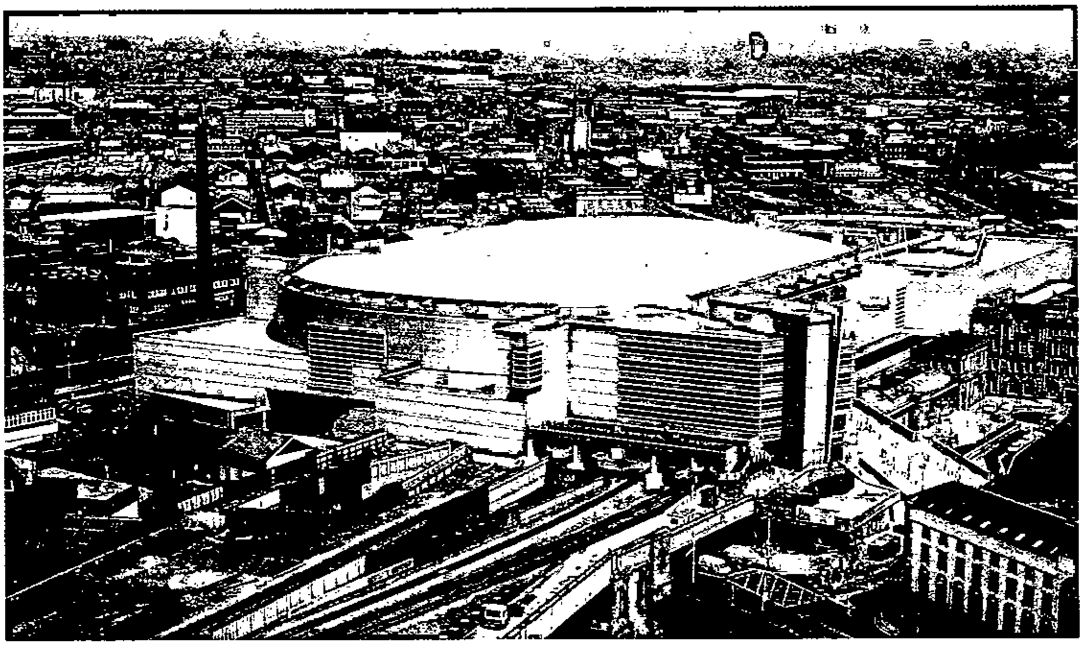


Figure 6: MEN Arena

MEN Arena

The Manchester Evening News (MEN) Arena will host the boxing finals and netball events at the Games. The arena is Europe's largest indoor multi-purpose venue (seating up to 21000 people) and hosts a wide variety of events from concerts to ice hockey matches. The arena was built opposite Boddingtons' Strangeways Brewery, adjacent to and partially over Victoria railway station *(Figure 6)*.

Site-wide issues

In terms of noise and vibration isolation the location of the arena was far from ideal. Four railway tracks were re-aligned as part of the scheme, with two actually under the southern concourse and higher tier seating, giving rise to concern over train-induced noise and vibration. Also, Chetham's Music School, Parker's Hotel, and the brewery offices nearby were sensitive to noise break-out. Two surveys were carried out, one to establish noise and vibration from rail activity, and the second - a targeted environmental noise survey - to determine the existing daytime, evening and night-time noise levels. The results led to:

- the provision of under-sleeper rail isolation beneath all tracks within a 20m radius of the arena;
- design of the structure to limit dynamic structural amplification of structure-borne vibration;
- use of reinforced concrete rather than steel;
- acoustic absorption to the station 'box' under the southern concourse;
- liaison with the Environmental Health Officer to agree appropriate criteria for limiting the noise emitted from the arena;
- specification of the arena roof and wall elements to ensure that adequate sound insulation and acoustic absorption were achieved; and
- detailed analysis of noise emission from the ventilation systems.

Arena Bowl

The acoustic factors considered were similar to those in the main games arena including intelligibility of the voice alarm system, stability of the acoustic between full and part-full events, and the liveness of the space to reinforce crowd cheering without allowing excessive noise build-up.

The public address and voice alarm (PA/VA) system integrates high quality sound reinforcement, voice alarm and general public address.

For speech to be intelligible, it was decided that a maximum of 2.8 seconds reverberation time at 2kHz was required. The roof deck incorporated an inner perforated sheet exposing the absorptive mineral wool, and wood wool slabs were attached to the top deck rear walls to prevent unwanted late reflections during music events. The PA/VA requirements dictated a fully distributed system of high powered cabinet speakers served from central rack rooms. The system, one of the largest of its kind in Europe, was fully tested during commissioning and achieved all design expectations *(Figure 7)*.

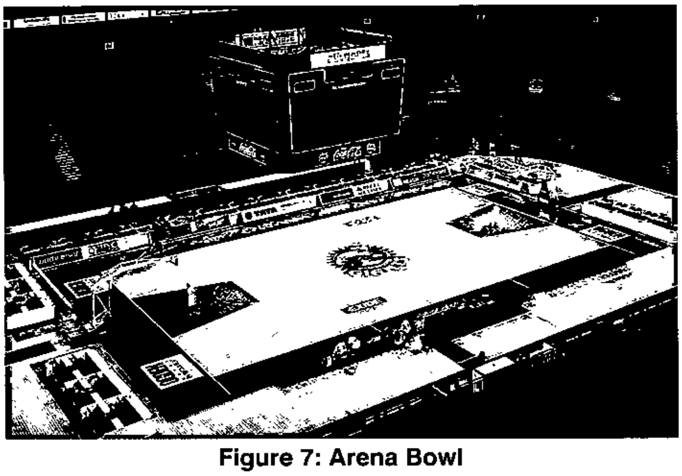


Figure 7: Arena Bowl

Manchester International Convention Centre (MICC)

The MICC plays host to the strong men of the Games - the weightlifters. Completed in 2001, it provides a world-class conference facility which complements the adjacent GMEX exhibition centre. Although perhaps not an immediately obvious choice for a sporting venue, the theatre-style main auditorium seats an audience of 800 and the large stage area gives ample room for the athletes (*Figure 8*).

Existing environment

The MICC site is not on a busy road and the ambient noise levels are generally low for a city centre site. However, there were important occasional noises that had to be taken into account during the design process. Of particular interest was the noise breakout from events in the nearby GMEX Centre and occasional overflights by helicopters.

Accommodation

Facilities at the MICC provide for conferences and conventions. The two main spaces are the auditorium and the multipurpose hall. Included within the auditorium is a range of control rooms, translation rooms and projection rooms. There is also a large stage which includes a fly tower and a large scene dock acoustic door. There is also a suite of breakout rooms for use by delegates.

Flexibility was key to the design of the multipurpose hall. A relatively dead acoustic and low noise levels were required to enable it to be used for banquets and similar functions as well as exhibitions. Ventilation was provided from above and one of the problems was to design a system that would deliver warm air with enough velocity to reach the floor of the hall yet still meet the noise limits. It proved very difficult to find diffusers which would meet both requirements in the space available but the problems were eventually solved using a type of swirl diffuser.

Early involvement in planning allowed the layout to be optimised with noisy and quiet activities physically separated. The two key spaces are separated by a central circulation space and buffer zones are incorporated around the auditorium. A sandwich roof construction was used to provide sound insulation and also to provide a route for ducting from the plant space over the stage.

The fly tower needed to incorporate some form of smoke vent and space restrictions dictated that this be a natural vent. This was potentially a major weakness in the envelope sound insulation. It was initially thought that a proprietary acoustic vent would be used but it proved impossible in the space available. In the end, a glass smoke vent system was used, with the glazing replaced with acoustic panels.

This proved very effective in practice although there were a few worried looks in the middle of the high-profile test event, when the maintenance staff decided it would be a good time to open the vent to check that it was operating correctly!

Room acoustics

The main hall's acoustics are designed around the need for clear speech. A mix of sound absorbing and sound diffusing panels is provided along the fan-shaped side walls to achieve this, and tests showed that the target reverberation times were met. In the multipurpose hall a sound absorbing 'crinkly tin' roof system was used. As experienced on many projects, this roof exhibited very variable sound absorption properties depending on how it was installed in the test laboratory.

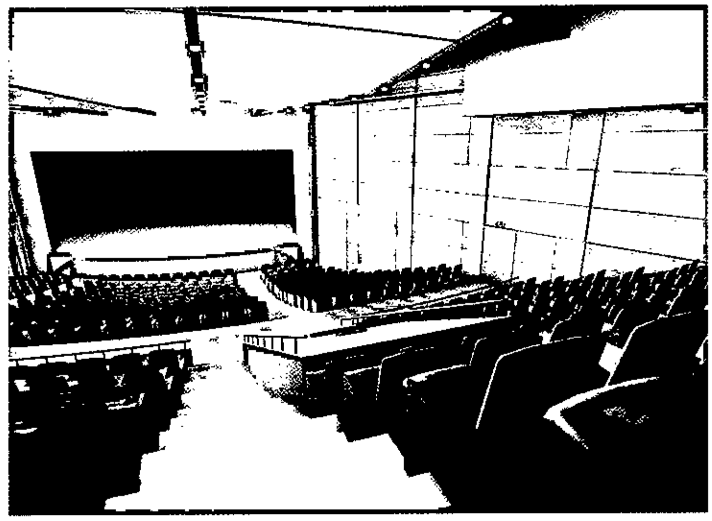


Figure 8: MICC

Conclusions

The impact of these world-class venues goes well beyond the 2002 Commonwealth Games. They can be seen as the next generation of sports and conference facilities, which will continue to serve the north-west well into the 21st century.

Their development is already acting as a catalyst in generating local participation in positive community action, encouraging sports locally and nationally, and this will continue after the Games. The facilities are acting as significant anchors to the regeneration of less affluent areas of Manchester. Considerable technical design challenges have been overcome in providing these excellent facilities and we are proud of our involvement.

This article was compiled jointly by several staff members at the Manchester, Cambridge, London and Winchester offices of Arup Acoustics.

Brain teaser

Test your knowledge of auditorium acoustics: try this brain teaser.

Charlie plays in the viola section of the orchestra. Despite her best efforts she is unable to play with the rest of the ensemble and, on average, plays 0.32 seconds behind the rest of the viola section, which is already 0.18 seconds behind the rest of the orchestra. If the orchestra is moving into a new concert hall with a reverberation time of 2.7 seconds, will she be able to continue playing this way undetected?

Wallace Clement Ware Sabine (1868 - 1919)

continued from page 31

strings, it did not work! Eisenhour was convinced that the machine was not tuned properly and suggested that they consult someone knowledgeable in acoustics.

During the consultation Fabyan learned of Sabine's frustration with his inadequate acoustic isolation laboratory at Harvard. Sabine was only able to make his acoustic measurements at night when the noise from street cars stopped, and before the milkmen started in the morning with their carts rattling over the cobble stones. The colonel offered to build him a suitable one in the quiet prairie country of Illinois at Riverbank Estate. Sabine accepted the offer and began to design what was to become the internationally recognised Riverbank Acoustical Laboratory. Because both Fabyan and Sabine were involved in various war projects, this was not completed until 1918.

An aside - Sabine's war work

Although not connected with his work in architectural acoustics, it is of interest in developing a balanced view of Wallace Sabine to describe some of the war work which had delayed completion of the Riverbank Acoustic Laboratory.

During the war Sabine became a staff member of Bureau of Research for the Air Service of the American Expeditionary Forces and provided services for the British Munitions Inventions Bureau in England, the French fleet at Toulon in the Mediterranean, and Italy on the Italian front.

One of Professor Sabine's developments that involved Riverbank was the use of cameras in aircraft for aerial reconnaissance. As a result of this work France awarded him the French Legion of Merit Medal for locating hidden German airfields. Glass negatives of photographs taken by Sabine discovered in one of Riverbank's Laboratories in 1980 showed aerial views of sections of actual World War 1 trenches at the front. The trenches had later been reproduced at Riverbank for army training purposes focusing on the effectiveness of new explosives and weapons, including a special type of trench mortar, in and around the artificial trenches.

Riverbank Laboratories

During 1917-18, Colonel Fabyan and engineer Bert Eisenhour (he who built the levitation machine), with guidance from Professor Sabine, supervised the construction of the laboratory on a day-to-day basis.

Apparently to this day the reverberation chamber is regarded as one of the best in the world. In the autumn of 1918 Sabine was able to see the completed laboratory for the first time, before his untimely death in 1919 at the age of fifty.

The great void left at Riverbank by Wallace's death was filled in turn by two other Harvard Physicists named Sabine; Paul Earls Sabine (1879-1958) and Hale Johnson Sabine (1909-1981).

After Wallace Sabine's death Fabyan again turned to Harvard University to find someone to direct the new Riverbank Acoustic Laboratory. He was referred to Paul Sabine, a physicist and a distant cousin of

THE WALLACE CLEMENT SABINE MEDAL

As part of the Wallace Sabine story, we should mention the acknowledgement to Wallace's pioneering work - the Wallace Clement Sabine Medal. This is presented to an individual of any nationality who has furthered the knowledge of architectural acoustics, as evidenced by contributions to professional journals and periodicals or by other accomplishments in the field of architectural acoustics. Recipients have been:

1957: Vern O Knudsen

1959: Floyd Rowe Watson for his pioneering research in architectural acoustics, which established criteria for acceptable reverberation in auditoria and stimulated the development of widely used acoustical materials, and for his services as Editor of the *Journal*.

1961: Leo L Beranek for internationally recognised achievements in all phases of architectural acoustics, and his publications on acoustical measurements, anechoic chambers, acoustic materials, building structures, noise control, psychoacoustic criteria, sound systems, broadcast studios, assembly rooms, and the world's great concert halls.

1964: Erwin Meyer for internationally recognised contributions to all aspects of architectural acoustics and his published works on sound propagation and diffusion in concert halls, theatres, and radio studios; investigations on sound transmission and insulation in buildings; and the design of anechoic and reverberation chambers for both acoustic and electromagnetic waves.

1968: Hale J Sabine for his contributions to the theory and practice of architectural acoustics, for his studies of the theory of sound-absorbing materials and particularly, for his vigorous leadership in the development of standard procedures for measuring the acoustical properties of materials.

1974: Lothar W Cremer for original and enduring contributions to the theory and practice of musical acoustics and acoustics in buildings, and for teaching these matters to the rest of us with clarity, giving inspiration in person and in print.

1979 Cyril M Harris for his contributions to the theory of room acoustics and for the application of these principles to the acoustical design of concert halls, opera houses, and theatres.

1982: Thomas D Northwood for important contributions to the theory and measurement of sound transmission in buildings and of the sound absorption of acoustical materials, for the development of acoustical standards, and for the general furtherance of architectural acoustics.

1990: Richard V Waterhouse for fundamental contributions to the understanding of sound fields in rooms.

1995: A Harold Marshall for contributions to the field of architectural acoustics, particularly for the understanding and design of concert halls.

1997: Russell Johnson for contributions to the understanding of the acoustics of performance spaces and the design of concert halls, theatres and opera houses throughout the world.

Wallace, who was working on a World War 1 research project in spectroscopy at the time and had had little contact with, or knowledge of, Wallace Sabine's work. Fabyan apparently charmed Paul Sabine into coming to Riverbank to direct what was then the only laboratory devoted to acoustical research and testing of acoustic materials and systems.

There, Paul began his research by utilising Wallace Sabine's formula for measuring sound absorption. Because there was very little equipment at the time, a set of organ pipes was used to provide sound while an observer conducted experiments from within a wooden box in the chamber, with only his head exposed. This prevented his clothing from interfering with the accuracy of the readings. At the time this 'man in the box' test was still the most reliable method available.

Paul directed Riverbank during the critical formative years and for nearly three decades until his retirement in 1947. He died in 1958.

His early investigations involved many different areas of acoustics. Besides calibration and absorption, he continued Wallace's experiments on plastered walls. This work developed into 'Sabinite', an absorptive acoustic wall plaster. He also worked on the development of a mechanical voice synthesiser and listening devices. Over 20 years, Paul devoted much time to studying the human ear and was involved in the development of electronic hearing aids. In addition to work on architectural acoustics, the activities of Riverbank in both world wars included groundbreaking research in the field of cryptology. This was applied to decoding and deciphering enemy messages during World War 1.

During this period Paul was also involved in founding the Acoustical Society of America and establishing acoustics as a respected and essential sub-discipline of physics.

The contributions of Paul Sabine and his successors, following on the pioneering work of his cousin Wallace Sabine, have established a solid reputation for the Riverbank Acoustical Laboratories in the field of architectural acoustics.

Paul's son Hale, whose physics training at Harvard ultimately led him to the profession of acoustics, came to Riverbank in 1957. Although he periodically devoted time, effort and services over some 38 years, to further the development of Riverbank Acoustical Laboratories, he was never officially on the payroll. He was a senior physicist for the Armour Research Foundation (now the Illinois Institute of Technology Research) where he was involved with acoustics. Hale Sabine wrote a number of articles on acoustics and a book entitled *Less Noise More Hearing*. He died in 1981.

Although this completes the history of the Sabines at Riverbank, the Laboratories continue today to be major contributors in the scientific world.

Acknowledgement must be given here to the authors whose writings on the Sabines have provided much of the raw material for this article. They are John Kopek, the present manager of Riverbank Laboratories and author of a book *The Sabines at Riverbank;* and William J Cavanaugh, Fellow of the Acoustical Society of America, who wrote the preface to John Kopek's book giving valuable insights into Sabine's life.

Other sources of information on Wallace Sabine (not available at the time this article was written) are *Wallace Clement Sabine: A Study in Achievement* by William Dana Orcutt (Plimpton Press, Norwood, Massachusetts, 1933); and Sabine's *Collected Papers on Acoustics* (Peninsular Publishing, Los Altos, California, 1994).

House of Commons Written Answers

FROM HANSARD

Extracts are provided by Rupert Taylor FIOA

11 April 2002
Noise

Mr Clifton-Brown: To ask the Secretary of State for Environment, Food and Rural Affairs what information she has collated on the (a) health consequences and (b) public nuisance arising from traffic noise pollution; and if she will make a statement.
Mr Meacher: The government has supported a number of studies into the health effects of various sources of noise. A number of these consider road traffic noise including: 'Health Effects based Noise Assessment Methods: A Review and Feasibility Study', which is available on the DEFRA website (www.defra.gov.uk), and 'The effects of relieving traffic congestion on noise exposure, noise annoyance, well-being and psychiatric morbidity: annex to the by-pass study' which is available from the Department of Health. The government is also contributing to the European study: 'Road traffic and Aircraft Noise exposure and Children's cognition and Health' (RANCH).
Road traffic noise does not generally fall within the legal definition of a public nuisance and, as such, there are no figures available relating to this. The government does, however, take the issue of noise seriously and periodically records people's attitudes to noise. This exercise established that in 1991 29% of respondents who reported hearing road traffic noise stated that they were adversely affected by it. This survey has recently been repeated and the results are expected to be published in May.
The repeated survey and the development of the Ambient Noise Strategy, which includes establishing the number of people exposed to road traffic noise, will build on the work already carried out to address noise from this source.

16 April 2002
Traffic Calming

Mr Greg Knight: To ask the Secretary of State for Transport, Local Government and the Regions what assessment he has made of levels of pollution and difference in noise levels as a result of road humps and traffic-calming measures which involve narrowing of the highway and the construction of an uneven road surface.
Mr Jamieson: A number of assessments have been carried out examining changes in noise resulting from traffic calming measures, particularly resulting from different types of road hump. Results from these were published in Traffic Advisory Leaflets 6/96 *'Traffic Calming: Traffic and Vehicle Noise'* and 10/00 *'Road humps: discomfort, noise and ground-borne vibration'*. Changes in vehicle emissions and air quality relating to traffic calming measures have also been the subject of departmental research (see Traffic Advisory Leaflet 4/96 *'Traffic Management and Emissions')*, some of which is still on-going.

22 April 2002
Noise Pollution

Mr Rosindell: To ask the Secretary of State for Environment, Food and Rural Affairs what assessment she has made of noise pollution in the London borough of Havering.
Mr Meacher: No specific assessment has

been made of environmental noise across the whole of the London borough of Havering. The Government announced in its *Rural White Paper* (November 2000) the decision to consult on a national ambient noise strategy. The consultation on the development of this strategy - *Towards a National Ambient Noise Strategy* - closed on 15 March this year, the results of which will be published in due course. A significant contribution to the development of the strategy will be the determination of exposure to environmental noise through noise mapping. The London borough of Havering will be considered in this exercise.

25 April 2002
Noise

Mr Cousins: To ask the Secretary of State for Environment, Food and Rural Affairs what grants are available for noise insulation.
Mr Jamieson: I have been asked to reply. No such grants are available centrally. There are statutory requirements for the provision of noise insulation in specified circumstances, in respect of noise from various sources. Under the *Noise Insulation Regulations 1975* the appropriate highway authority will provide insulation in the form of secondary glazing to the windows and glazed doors, of dwellings and other buildings used for residential purposes, or payment of grants for this purpose, where such properties are not more than 300 m from the nearest point of a new highway, including an additional carriageway added to an existing highway, or an alteration affecting the line or level of an existing highway.
The provision of insulation or grant is subject to there being an increase, or expected increase, in noise on the facade of the property attributable to the traffic on the new or altered highway from that prevailing before construction started, provided this is above a prescribed level.
Under the *Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996* an authority responsible for constructing a new railway, tramway or other guided transport system, or for adding to an existing system, has a similar duty to provide insulation for dwellings and other buildings used for residential purposes, or to pay grant for that purpose.
Similar statutory schemes have been made under s79 of the *Civil Aviation Act 1982*, and previous powers, requiring provision of noise insulation in respect of aircraft noise at Heathrow and Gatwick airports. At other airports, noise insulation may be provided on a voluntary basis or in accordance with planning conditions.
Noise insulation schemes under any of these statutory provisions are subject to qualifying dates: they are not open-ended. Local housing authorities could consider whether it would be appropriate to award a discretionary Home Repair Assistance grant to private home owners and tenants for noise insulation. The Regulatory Reform (Housing Assistance) (England and Wales) Order 2002, if enacted, will provide authorities with a new general power which they could also use to this end.

15 May 2002
Ambient noise strategy

Mr Keith Simpson: To ask the Secretary of State for Environment, Food and Rural Affairs what the targets are for her Department's ambient noise strategy.
Mr Meacher: The proposal to develop a national ambient noise strategy was announced in the Rural White Paper in November 2000. The consultation on the development of such a strategy - *Towards a National Ambient Noise Strategy* - closed on the 15 March this year and the results of the consultation are currently being considered and may result in changes to our approach. However, currently it would only be at a later stage that the introduction of targets (if any) would be considered.

16 May 2002
Motorways

Mr Oaten: To ask the Secretary of State for Transport, Local Government and the Regions if the impact of noise on schools is part of the criteria used to consider noise reduction programmes on motorways.
Mr Jamieson: Following consultation on establishing priorities for the resurfacing of concrete trunk roads, one of the agreed criteria is to give priority to those sites where treatment would benefit the greatest number of people. Although not mentioned specifically, schools are generally found in areas of high population density, which would be given priority under the agreed criteria.

22 May 2002
DEFRA Committee mandates

Mr Bercow: To ask the Secretary of State for Environment, Food and Rural Affairs what the mandate of the Committee for the approximation of the laws of the member states relating to noise emission in the environment by equipment for use outdoors is; how many times it has met over the last 12 months; what the UK representation on it is; what the annual cost of its work is to public funds; if she will list the items currently under its consideration; if she will take steps to increase its accountability and transparency to Parliament; and if she will make a statement.
Ms Hewitt: I have been asked to reply. The mandate of the Standing Committee is contained in Article 18 of the noise emission in the environment by equipment for use outdoors Directive, 2000/14/EC. In essence it is convened to consider matters of interpretation which are brought to its attention by member states. It has, however only met in its capacity as an advisory committee. Officials of the European Commission chair these meetings with a view to providing advice based on consensus in order to ensure that there is uniform interpretation of the directive throughout the European Union and also to ensure that any technical barriers to trade within the Single Market are removed. The committee, in particular, assists the Commission in the adaptation to technical progress of methods of measurement of airborne noise emitted by equipment for use outdoors by means of amendments to the technical annexes of the directive.
In the last 12 months this committee has met twice. Representation from the United Kingdom is led by officials from the Department of Trade and Industry. It is not possible to calculate the cost to public funds of the work of the committee without incurring disproportionate cost.
Items under consideration vary from meeting to meeting but usually include issues of standardisation and interpretation. Current issues include a possible amendment to the directive in respect of noise limits of lawn mowers.

BOOK REVIEW

Music Engineering *(second edition)*
Richard Brice

This book would be primarily aimed at electronic engineers rather than acousticians, although anyone with an interest in playing or recording electric and electronic music would find it appealing (especially with a recommended price of only £21.99).
Although the first chapter does give a valuable 'crash course' in the basics of electronics, those readers without a prior knowledge of the subject may well become overwhelmed with some of the more complex circuit diagrams which are present throughout.
For those readers who are not familiar with the fundamentals of acoustics, *Chapter 2* provides one of the best explanations of the subject that this reviewer has read, with plain English explanations of the processes involved and 'optional' mathematical sections for those who would gain a greater understanding from seeing algebra.
Those with a background in practical acoustics will find the chapters entitled 'Stereo and spatial sound', 'Loudspeakers' and 'Microphones and their applications' of particular interest. All are composed in a very readable style, with plain English explanations of the theories, and examples of practical applications.
However, many of the chapters, although initially interesting, tend to delve by necessity too deeply into electronic theory to be of great benefit to the general acoustician. Those with a more moderate interest in hi-fi may reach *Chapter 9* with some relief: it describes the theory of magnetic tape recording and explains the CD, MD and DVD formats.
The book comes with an audio CD containing examples of some of the effects and techniques described in the text. Whilst listening to the CD proves very interesting to the reader, and adds an extra dimension to the publication, it is baffling that there is no reference in the text to the demonstration tracks on the CD. This necessitates having to flick from the chapter being read to the appendix at the back of the book which lists the CD track listing, and this can be frustrating.
There is a wealth of technical information in the book for those students or designers that require it, and the book is generally of interest to those without an electronic engineering background, provided readers are selective in their reading.
Rob Rooney AMIOA

A Proctor Group

Castle conversion

Scottish products have been used to refurbish a castle once used to provide protection from marauding Scots. Wimpey Homes is converting Wilton Castle into 45 luxury homes which retain many of the features such as wood panelling, chandeliers and fire surrounds.
The castle was constructed in 1210, but no recognisable part of that building remains, although an exceptionally thick wall in the middle of the current structure is thought to have formed part of the original central tower. However, considerable alterations were required to ensure compliance with the current Building Regulations governing sound insulation.
The **A Proctor Group** of Blairgowrie was requested to provide specifications for upgrading the floor and ceiling constructions to new build standard, taking into consideration the building's grade 2 listed status. The constraints included retention of the ornate ceilings, and large areas of oak panelling and flooring to the ballroom and library that would become the lounge areas of individual apartments. Beneath these would be more new apartments, in what were the wine cellars. *Profloor Dynamic Strip* and several other Proctor products enabled the constraints to be met.

Wilton Castle

On another project, *Profloor Levelling System* was recently installed in a prestigious Belfast development . The system was developed in order that a level finished floor could be laid on a cambered, stepped or uneven subfloor.
The method was quickly installed in 46 apartments at Rugby Parade in the city's Queens University area, where it provides a cavity to allow services to be run under the floor, accommodating floor depths between 48mm and 200mm. The requirements of the Building Regulations regarding impact and airborne sound insulation can be more readily met by floors incorporating Profloor.
For more information: Angela McIntyre tel: 01250 872261 fax: 01250 872727
e-mail: insulation@proctor-group.co.uk

A Proctor Group is a Sponsor Member of the Institute

ProsCon Environmental

HAV meter for HSE

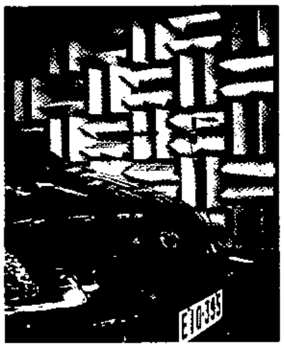
The *Larson Davis HVM100* vibration meter has been supplied to the Health and Safety Executive by **ProsCon Environmental Ltd.** The unit offers simultaneous measurements on all three axes with vector sum calculations together with exposure time determination based on the current criteria. It is available with either hand-arm or whole-body weighting curves, or both, and is very simple to operate. Once an original set-up has been created for hand-arm measurements, the operator attaches the accelerometer and begins measuring. Readings of rms, min, max and peak are measured simultaneously for the x, y and z axes, and summed. An exposure time calculation is then carried out. Up to 100 files can be stored automatically and printed out later, or downloaded to a computer.
ProsCon Environmental has recently moved offices, although telephone and fax numbers are unchanged. The new address is Unit 5, Claylands Road Industrial Estate, Bishops Waltham, Hampshire SO32 1HB.
For more information: tel: 01489 891853 fax: 01489 895488 Scottish office: tel: 01738 550176 fax: 01738 550197

Eckel Noise Control Technologies

New hemi-anechoic chamber for Toyota

A new metal wedge hemi-anechoic chamber, designed and manufactured by **Eckel Noise Control Technologies** using its EMW metallic anechoic wedge system, has been supplied to the Engineering and Training Centre, Belgium for Toyota (TMME). The chamber is used for noise vibration and harshness (NVH) testing and for company service training on the Toyota and Lexus car ranges. Measuring internally 8600mm wide, 13750mm long and 3600mm high, the chamber has an internal ambient measured sound pressure level of 18dB(A) and a cut-off frequency of 125Hz to ISO 3745.

The anechoic wedges have a perforated metal profile while the acoustic absorptive material within the wedge is encapsulated in an acoustically transparent nonwoven fabric, which is chemically resistant and has a Class 1 fire rating. This eliminates fibre migration from the wedge without reducing its acoustic performance. The metal profile makes the wedges robust and hard wearing, necessary for everyday use within an unforgiving environment such as the automotive industry. The structure for the chamber was an existing test room built from reinforced concrete. Eckel turned the room into a vehicle hemi-anechoic chamber by adding a two-wheel dynamometer, room ventilation, lighting, power, compressed air supply, and car exhaust extraction system.



To optimise the acoustic performance of the chamber, modular acoustic walls were built within the concrete room to modify its geometry.

Access is provided by single and double leaf acoustic door sets. The inner ceiling and walls are lined with anechoic wedges painted white, with red for access points and other important areas of the chamber.

For more information: Brian G Harris tel: +44 (0) 1252 375000 fax: +44 (0) 1252 371351 e-mail: brian@eckeleurope.co.uk website: www.eckeleurope.co.uk

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Casella CEL Sound advice

Anybody working in an area where noise assessment is an issue could benefit from the advice and information in a new video from **Casella CEL.** This gives a comprehensive overview on how to approach noise monitoring within the workplace and make competent assessments, all in a style that does not presume the viewer to be an expert within the field. It introduces various sound level meters and their applications, as well as giving guidance on how to achieve the best results from them in different environments.

Featuring interviews with Keith Broughton, the Principal Specialist Inspector for the Health and Safety Executive, and David Bull, Chief Examiner for the Institute of Acoustics workplace noise diploma, the video gives the benefit of their expertise and outlines how experience can be gained through the various courses that are available.

The video, *'Better noise assessments'* and its accompanying booklet are aimed at a broad audience within industry, from non-specialist safety executives wishing to conduct their own noise assessments, to noise consultants and even the company directors who may employ them.

Further information from: Natalie Seddon tel: 01234 844100.

Casella CEL is a Key Sponsor of the Institute

IAC Sound Attenuators' assets acquired

IAC Ltd has acquired certain assets of **Sound Attenuators Ltd.** The key area of acquisition is SAL's gas turbine business, which covers the provision of complete gas turbine silencing packages for power generation, combined heat and power, gas compression and fluid pumping. Equipment fitted to the packages includes combustion and ventilation air intakes, turbine and auxiliary machinery enclosures, and hot gas exhausts. The engineering and sales functions of the gas turbine business unit will remain at Colchester, and production will be undertaken at Winchester.

IAC has also acquired the rights to SAL's other product designs and licence agreements, and has recruited the general acoustics sales team. The company says it can now benefit from a larger, stronger and more responsive UK sales operation as well as developing its overseas representative network.

For more information: Susan Ramsden, tel: 01962 873050 fax: 01962 873123 e-mail: susanr@iacl.co.uk

Institute Diary 2002

19 - 21 July
Auditorium Acoustics: Historical and contemporary design and performance, Building Acoustics Group,
London

6 August
Diploma examiners' meeting
St Albans

5 September
Bulletin board of management, Publications Committee,
St Albans

6 September
Meetings Committee,
St Albans

9 September
Research co-ordination, professional development,
St Albans

12 September
Diploma tutors and examiners, Education Committee,
St Albans

17 September
Engineering Division Committee,
St Albans

17 September
Half-Day Workshop, Environmental Noise Group, Aircraft Noise,
East Midlands Airport

19 September
Membership Committee,
St Albans

26 September
Executive Committee,
St Albans

26 September
One-day Meeting, Yorkshire & Humberside Group & Environmental Noise Group,
SIPPC, Birmingham

9 October
One-day meeting, Did the Earth move for you? Measurement and Instrumentation Group,
London

10 October
Medals and awards, Council,
St Albans

23 October
One-day meeting, Environmental noise and health, London Branch,
London

25 October
CCENM examination,
Accredited centre

29 October
Meetings Committee,
St Albans

31 October
Publications Committee,
St Albans

5 November
Engineering Division Committee, *St Albans*

7 November
Diploma Tutors & Examiners, Education Committee,
St Albans

8 November
CCWPNA Examination,
Accredited Centres

13-14 November
Autumn Conference: Action on Environmental Noise in the UK, *Stratford upon Avon*

15-17 November
Reproduced Sound 18: Perception Reception Deception How do you know?, *Stratford upon Avon*

15 November
CMOHAV Examination,
Accredited Centres

18 November
Research Co-ordination, Professional Development,
St Albans

19 November
CCENV Advisory Committee,
St Albans

21 November
Membership Committee,
St Albans

28 November
Executive Committee,
St Albans

3 December
CCWPNA Advisory Committee,
St Albans

5 December
CMOHAV Advisory Committee,
St Albans

12 December
Medals & Awards, Council,
St Albans

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