Vol 40 No 3 May/June 2015

ACOUSTICS BULLETIN

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Approaches to noise control prioritisation for industrial plant

What is the Background Sound Level?

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ACOUSTICS BULLETIN

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Front cover photograph:
Environmental noise monitoring at Glastonbury Festival.

Institute of Acoustics

The Institute of Acoustics is the UK's professional body for those working in acoustics, noise and vibration. It was formed in 1974 from the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society. The Institute of Acoustics is a nominated body of the Engineering Council, offering registration at Chartered and Incorporated Engineer levels.

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

Conference programme 2015

13 May
Organised by the IOA
Noise impact and assessments and development constraints
Birmingham

19 May
Organised by the IOA
BS 4142: 2014 workshop
London

9 July
Organised by the Musical Acoustics and Speech and Hearing Groups
Hearing impairment and the enjoyment and performance of music
London

7-9 September
Organised by the Underwater Acoustics Group
Seabed and sediment acoustics: measurements and modelling
Bath

17 September
Organised by the Sustainable Design Task Force and the Building Acoustics Group
Acoustic design for sustainable buildings
London

27-30 September
Organised by the Galpin Society in association with the IOA
Musical instruments in science and history
Cambridge

15 October
Organised by the IOA
Acoustics 2015
Harrogate

29-31 October
Organised by the IOA with support from the French Acoustical Society (SFA)
Auditorium acoustics
Paris

10-12 November
Organised by the Electroacoustics Group
Reproduced Sound
Moreton-in-Marsh

Please refer to **www.ioa.org.uk** for up-to-date information.

Dear Members

I hope you are all refreshed after your Easter break. It's been busy at the Institute as we wrapped up last year's accounts and made progress in strengthening our foundations.

The annual report still needs approval by Council – members are reading the final wording so it can be approved on 16 June in time for the AGM, which will be held after the *Hearing impairment and the enjoyment and performance of music meeting* on 9 July at Kingston University. However, the Annual Accounts/Finance Statement have been submitted to the Charity Commission and Companies House.

The key points are we in a financially strong position and have the reserves to fund further development. Our surplus last year was £107,286, but this includes £55,000 spent on the website that has been capitalized. On top of this, a number of projects on which we had planned to spend money in 2014 will not happen until this year. There is £10,000 earmarked for the History Book and a further £12,000 on teaching, conferencing and a new phone system for the head office. So although last year's surplus is positive, all this expenditure will reduce the surplus significantly. Our reserves are £865,967 – against a target of £615,000 (now £625,000) – and we're now looking to use some of this money to further improve our services to members and secure our long-term education offer and associated income.

As part of implementing our strategy and securing the Institute's future, we will be conducting a strategic review of our education provision. This will be a wide-ranging review aimed at ensuring we meet the sector's existing and future needs. As a first step to producing a strategic learning plan, we're in the process of commissioning research to identify possible future market and stakeholder needs over the next 5-10 years. The promotion and understanding of acoustics is a key role of the Institute. There are three broad strands to our learning offer. First, we have a role to provide formal education to enable new graduates to specialise in acoustics (the Diploma) or to enable specialist technicians to be proficient in noise measurement in specific circumstances through our specialist courses. Second, we have a role to provide CPD opportunities for members, and last, as a charity we have a role to inform the public and other professionals about and encourage an interest in acoustics.

To date we have focused our learning provision on a formal education offer to new graduates and specialist technicians; about a third of our annual income is generated through these courses. Like any business, we need to strategically review our education provision against existing and future needs to ensure we continue to meet both the needs of the sector and secure our income stream. It has been identified that there could be an opportunity, or need, to widen our education offer. Historically the Institute has not concentrated on providing ongoing informal CPD training. Such CPD training would be for members, but there could also be an opportunity to provide it for those in other professions which interact with acoustics. Examples are architects, civil engineers, construction professionals, town planners etc. See page 6 for more details.

As part of our promotion of the Institute, the presentation of awards is a key and enjoyable responsibility. These awards raise our profile both nationally and internationally, as well as recognising the valued contributions of the winners. This year we have had strength and depth in the nominations, which meant the Medals and Awards Committee had great difficulty in choosing the winners; in fact, with the Peter Lord award, the committee agreed that two nominations were worthy of the 2015 award and recommended that both should receive it. The feedback from the winners has been magnificent and they are appreciative of the recognition and encouragement. It is always a pleasure to present these awards and it is wonderful to know they are cherished.

William Egan, President

Institute of Acoustics embarks on full-scale review of its education policy

Aim is to produce strategic learning plan to meet sector's future needs

The Institute has launched a wide-ranging review of its education policy aimed at ensuring it meets the sector's existing and future needs.

As a first step to producing a strategic learning plan, it is commissioning research to identify possible future market and stakeholder needs over the next 5-10 years.

The promotion and understanding of acoustics is a key role of the IOA, which has three broad strands to its learning offer:

- To provide formal education to enable new graduates to specialise in acoustics (via the Diploma) or to enable specialist technicians to be proficient in noise measurement in specific circumstances through its specialist courses.
- To offer CPD opportunities for members
- To inform the public and other professionals about and encourage an interest in acoustics.

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Advances in technology mean that there are wider options available to the Institute for the delivery of education and learning. Learning which does not need hands-on practical learning could, for example, be delivered through self-study online courses. Perhaps the Institute could develop a technician level certificate to enable surveyors or some other specialist to undertake noise measurements in a limited field related to meeting the requirements associated with construction sites. Another possibility is to increase the Institute's marketing and ability to deliver its courses overseas.

As a charity the Institute also has a role to increase the public's awareness of acoustics and particularly wishes to encourage undergraduates and school students to study or take an interest in acoustics.

This may be to encourage more young people to specialise in STEM subjects more widely, in acoustics itself, or to increase the awareness and understanding of those engaging in other professions of the nature of acoustics and its interaction with their chosen profession.

The research will help to identify the Institute's strengths and weakness for meeting stakeholders' and the sector's needs, threats to its existing educational offer, opportunities and actions required to secure our educational income, as well as commercially viable opportunities to increase this offer in the next 5-10 years. In line with its charitable role it is also seeking low cost opportunities and actions to broaden its educational offer to students and the public.

By the time you read this article the tender process for this work will have been completed and the name of the winning contractor will have been announced in the May e-newsletter.

This contractor may either conduct a survey of members and/or a number of telephone interviews. If you are asked to complete a survey or undergo a telephone interview please do so as your views and ideas are important.

The outcome of the research will be an evidence-based report. The Institute intends to invite key members to a workshop based on this report with a view to develop a strategic learning plan.

This strategy will use some of our reserves to: improve our services to members, ensure we are meeting the sector's education needs, secure our ongoing education income and help us meet our duty as a charity to promote and inform the public about acoustics.

IOA to run certificate course in Irish building acoustics measurements

The Institute is to run a course offering a Certificate of Competence in Irish Building Acoustics Measurements (CCIBAM).

The first will be held from 8-12 June at AWN, Clonshaugh near Dublin. It is planned that it will then be held twice a year.

The decision by the Education Committee is the result of an initiative by Jonty Stewart who helps deliver the Certificate of Building Acoustics Measurements at Southampton Solent University.

It follows the publication last December of an update to the Irish Building Regulations which will come into force for all new projects starting on site on or after 1 July 2015. This will require mandatory pre-completion acoustic testing by competent individuals.

The core contents of the UK and Irish Regulations are very similar. The primary differences between the UK and Irish content are that:

- UK syllabus makes reference to BB93 and HTM0801, but, as yet, there is nothing in the Irish Building Regulations regarding schools and healthcare buildings in Ireland.
- Building regulation tests are different, with particular regard to grouping and test regime requirements and the use of $D_{nT,w}$, in Ireland (as in Scotland and Northern Ireland) rather than $D_{nT,w}$ + Ctr which is used in England and Wales.
- There are different requirements for access to Quality Management Schemes (UKAS & ANC v the Irish Scheme)
- The UK syllabus refers to BS-EN-ISO 140-4 whereas the Irish syllabus is based upon IS-EN-ISO 16283-1: these differ in respect of (i) the assumption / non-assumption of room diffusivity; (ii) the mandatory use of omni-directional sound sources; (iii) the 'flatness' of the source sound spectrum (max. 6 dB between adjacent 1/3 octave bands in ISO 140; 8 dB in ISO 16283); and (iv) a different calculation procedure which, for example, does not permit 'arithmetic averaging' of data from multiple sources.

After this first course it is hoped to hold CCIBAM at similar times to CCBAM (April and September). It is intended to set a common examination which will require candidates to state which country's regulations or methodologies they are using.

Comments sought on amplitude modulation consultation document

By Richard Perkins and Gavin Irvine

The Institute's AM working group has worked very hard over the past six months to review the issue of amplitude modulation in turbine noise, and has published a consultation document on the IOA website revealing the three preferred metrics that most closely meet the criteria as set out in the group's terms of reference. The document was launched at the International Wind Turbine Noise Conference (organised by INCE) in Glasgow on 23 April.

All members are encouraged to review the findings of the consultation document, test each of the three metrics in the course of any wind farm investigations under way, and to feed back the results with any comments by the due date. Members are reminded that the AM metrics are part of consultation, and should not be cited until the final metric is agreed and published.

The working group is also pleased to report that the Department for Energy and Climate Change has recently tendered for a research contract to look into the setting of an appropriate limit (by Government) for AM based on the metric that the IOA proposes, following the consultation process.

It is therefore vitally important that all the available evidence is made available to the AM working group in response to the consultation, or by separate cover to any member of the working group so that the most up-to-date evidence is considered as part of the final decision on the AM metric. A launch event for the AM metric is planned for later in the year.

Visit to organ builders hits right note for Musical Acoustics Group

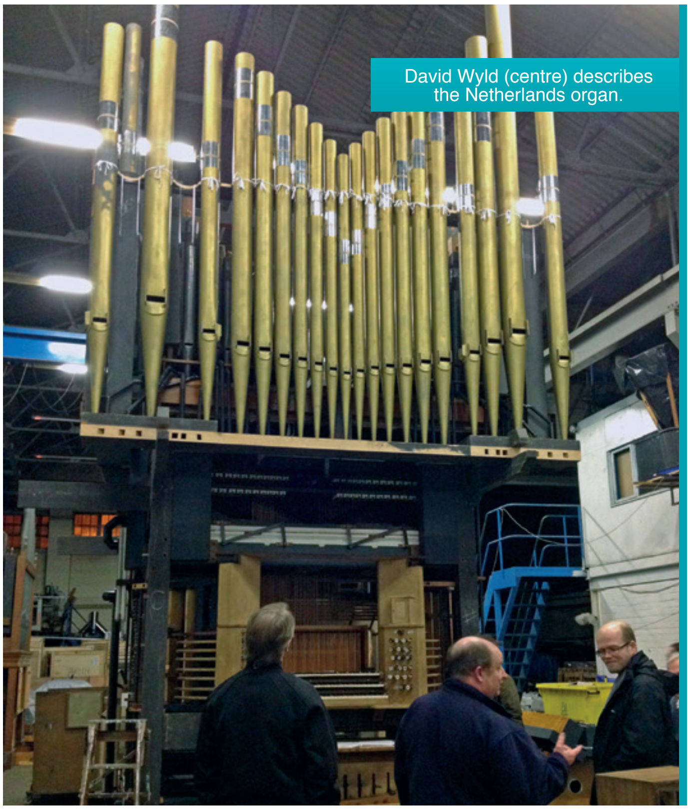
By Edgar Brown

Around 20 members of the Musical Acoustics Group visited the Liverpool workshops of the renowned organ builders Henry Willis and Sons in February. This firm was founded in the 19th century by Henry – "Father" – Willis and rapidly rose to fame through the excellence of tonal design and workmanship of its instruments. Many cathedral and concert organs, for example those of the Anglican Cathedral and St George's Hall, both in Liverpool, were built by the Willis firm. After being headed by four generations of the Willis family – all "Henrys" – its managing director is now David Wyld, who welcomed us and led us on a tour of the workshops.

The majority of organ pipes are "flue" pipes – like a recorder without the finger holes – and are made of "metal", a lead-tin alloy with minor additions. We saw the casting bench where the metal sheets were made. The alloy is strong enough for a pipe to withstand its own weight while allowing voicing adjustments to be made by cutting with a sharp knife. Mr Wyld showed us a newly-made pipe of typical organ ("diapason") tone, which he modified by cutting in several ways to produce a more "fluty" sound. Wooden pipes, mostly of rectangular cross-section, work on the same principle (although triangular ones were once a Willis speciality), but all air passages must be smooth to avoid roughness of tone. We were shown reed pipes, a brass tongue operating like a clarinet reed contained in an air chamber and surmounted by a resonator tube. These give tones such as those of the trumpet and oboe stops. The voicing of such pipes is a separate and delicate process!

Further along the workshop was a finished soundboard on which pipes would eventually be mounted. All those corresponding to each key of the keyboard stand behind each other and are actuated by the key's pallet valve. All those of the same tone are arranged parallel to the keyboard and brought into play by a long slide with holes to correspond with the pipes and operated by a "stop".

Very impressive was a complete organ from Stichting Cathedral, Leiden, The Netherlands. This was an original Willis which had "come home" for restoration and enlargement.



David Wyld (centre) describes the Netherlands organ.

In another workshop was another organ played from a detached console by a variant of electric action. Normally such action requires a multi-core cable to actuate the many electro-magnetic valves within the organ. More recently, time-division-multiplexing has enabled a single-core cable to be employed, impulses being sent in rapid succession. This organ had gone one stage further in transmitting the pulses by wi-fi – no cable needed at all. Mr Wyld's colleague gave us a short demonstration , adding additional electronic "tricks" such as transposition and control of the organ from an i-phone. The pipe-organ has caught up with the electronic one!

Institute Council approves more than 100 membership applications

Two applications for fellowship and two for sponsor membership were among the 103 membership applications approved by Council at its March meeting.

FIOA
Richard Perkins
Duncan Williams

MIOA
Dawit Abraham
Rachid Abu-Hassan
Daniel Bailey
Johnny Berrill
Kevin Bilton
James Bligh
Frederic Botte
Sam Bryant
Karol Bugaj
Daniel Clayton
Thomas Crabb
Jonathan Crawley
Dean Curtis
Jim Dunne
Christopher Flynn
Aglaia Foteinou
Natalie Goward
Philip Hainsworth
Thomas Jones
Imran Khan
Alexander Lees
Peter Leonard
Peter Nash
Pedro Rodrigues
Christopher Turner
Simon Waddell
Ian Wallbank
James Williams
Martin Wilson
Banting Wong

AMIOA
Richard Allard
Duncan Arkley
Michael Bateman
Ben Bielicki
Gemma Carda
Scott Castle
Jonathan Champion
Robbie Christie
Lewis Crabtree
Thomas Dixon
Christopher Dominy
Lee Faulkner
Daniel Finlayson
Alex Foster
David Gerard
Daniel Green
Stuart Griffith
Gareth Hance
Stephen Hargreaves
Simon Harper
Simon Harry
Scott Higgins
Benjamin Hymers
Ali Imtiaz
Rohail Javed
David Johnston
Kenny Joyes
Jonathan Kay
Iain Kelly
Daniel Kinsman
Francois-Xavier Lallemand
James Large
Christopher Last
Mike Ledbetter
Stephen Lewis
Simone Longo
Matthew Markwick
Adam Meakins
Rawan Mohammed
Andrew Morgan
Joe Oxenham
Graeme Parker
Martin Petrie
Romans Popovs
Sara Ripoll Gimeno
Sergio Salazar
Ben Saunders
Daniel Shaftoe
Andrew Sills
James Slater
Craig Storey
Jenefer Taylor
Gareth Thompson
Terry Vincent
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Richard Whitaker

TechIOA
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Andy Lou Dapin
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Raymond McGurk
Robert Martin
Kenneth Penny
Zoe Richardson
Steven Scott
Romeo Tormekpey
Geoffrey Venus

Affiliate
Leo Williams

Sponsor
Peter Brett
Mott MacDonald

London Branch report

Student projects: metamaterials and mitigating ground-borne vibration from trains

By Stephen Dance

In February Dr Bob Peters and Dr Stephen Dance (The Acoustics Group, London South Bank University) introduced two of last year's Masters students in environmental and architectural acoustics. Both students presented a thesis summary covering the following topics: metamaterials and mitigating ground-borne vibration from trains. The former is a winner of the Acoustical Society of America Newman Medal for architectural acoustics and the latter won the RBA prize for best dissertation.

The first dissertation, by Leo Weber, investigated the application of an acoustic metamaterial for sound attenuation with airflow. Leo introduced the concept behind metamaterials, based on electromagnetic waves, before moving on to the acoustic concepts such as negative compressibility and negative bulk modulus. This allows the sound to be separated from the medium. A very novel thought that was difficult to get your head around! Leo then introduced a 2013 Korean paper, the results of which he tried to reproduce using experiment methods. He built three acrylic Helmholtz resonators, 15 cm by 15 cm with a 20 mm hole, targeting the 500 Hz to 5 kHz range; these were stacked and arranged as a panel (approximately 60 cm by 40 cm). A wooden enclosure was constructed and the insertion loss of the full enclosure measured; 60 cm by 40 cm size hole was then cut and the metamaterial panel inserted. The results matched those of the Korean experiment with 800 Hz, 2 kHz and 4 kHz 1/3 octave offering peak insertion losses, giving a 3 dB higher insertion loss than with the full enclosure i.e. an enclosure with holes in it performed better than the full enclosure. Leo concluded with the results of the air flow measurements, by comparing static pressure losses. I'm sure there's a lot more work on this most interesting project. Leo now works for Anderson Acoustics.

The second presentation, by Ignacio Alonso Martinez of RBA Acoustics, recounted his work with the development of a proposed residential building just 7 m from a four-track railway line. This involved measuring the vibration from the trains, predicting the vibration levels and the consequent reradiated noise levels in the rooms of the proposed development. Based on ANC reradiated noise criteria, a 5 m deep concrete piled screen was proposed as a mitigation measure, but due to practical reasons this screen was located 6 m to 1 m below ground level. An additional 1 m baffle was installed above the screen. During temporary halts in construction accelerometers measured the vibration levels on the ground floor slab. It was found that the overall predicted accelerations closely agreed with the measurements, although certain frequencies were less accurately predicted. Ignacio stated that there were many uncertainties when undertaking on-site vibration measurements, such as ground conditions, temperature and saturation, in addition no train speeds were measured. He concluded by saying that the reradiated sound levels were at low levels 35-38 dBLAMax, s, as a worst case within second floor rooms.

The branch would like to thank Leo and Ignacio for presenting their dissertations and WSP for providing the venue.

Topics and speakers for the evening meetings are generally identified and organised by the London Branch Committee, but we always welcome new ideas and suggestions for future presentations. If you have any ideas or suggestions, or may even like to give a presentation yourself, please contact Nicola Stedman-Jones at stedmann@rpsgroup.com or nathan-nicola@talktalk.net

London Branch report

BS 4142:2014: an opportunity to learn about/discuss the new edition of this widely (mis?)used British Standard

By Nicola Stedman-Jones

In January Richard Collman (Acoustical Control Engineers Limited and Belair Research) gave a presentation entitled BS 4142:2014: an opportunity to learn about/discuss the new edition of this widely (mis?)used British Standard. As you can imagine, the meeting was very well attended, with numbers exceeding 100.

BS 4142:1997 Method for rating industrial noise affecting mixed residential and industrial areas was published 17 years ago and after many years of anticipation the new edition was released in October 2014. One of its main aims was to make practitioners think more carefully about the assessment rather than just focusing on the numbers. In addition to changing the rating penalty from 0 dB or 5 dB to a graduated level of up to 15 or 18 dB and altering the night time reference period to 15 minutes, other significant changes include clarification about a representative background level, weather, uncertainty and context. The outcome is no longer a possibly ambitiously estimated likelihood of complaint but consideration of the likely significance of the impact.

The presentation was followed by a lively discussion which focused on how to assess the tonality of a source that does not exist, what happens when BS 4142:1997 is referenced in local guidance documents and where, when and how to measure weather conditions to comply with BS 4142:2014.

The branch would like to thank Richard for joining us for what proved to be an extremely interesting and popular topic and WSP for providing the venue.

Measurements of impulsive noise

By Liz Brueck MIOA, Health and Safety Laboratory, Buxton

Excessive noise exposure is a cause of hearing loss. The hearing loss normally gets worse over time as repeated excessive exposures occur. However, extreme high level short duration sounds (bangs) can also present an immediate risk of hearing damage.

Risk of immediate damage is indicated by the C-weighted maximum instantaneous peak sound pressure level of the event. There is also a risk associated with the overall A-weighted noise exposure. The Control of Noise at Work Regulations require a risk assessment when anyone is likely to be exposed to instantaneous peak sound pressure levels at or above 135 dB(C). The Supply of Machinery (Safety) Regulations requires the manufacturer to report the C-weighted workstation peak sound pressure level of a noisy machine if it exceeds 130 dB(C).

I've spent many years making measurements of noise exposure from high level impulsive sound including firearms and explosions to assess the risk to hearing. What I've included here are some tips based on my own experience of high level impulsive noise measurements, and measurements of hearing protector performance.

Instrumentation

The right sound level meter

Your sound level meter or instrumentation should meet IEC 61672-1, or be at least Type 2 to the older standards IEC 60804 and IEC 60651. This is important. Instruments not meeting these standards may give errors of over 15 dB in impulsive sound. Unfortunately sometimes meters are falsely specified as meeting these standards so look for an additional guarantee. Use a sound level meter that has also passed a standard verification test (IEC 61672-3, or BS 7580 are the standards for this) or check with the manufacturer that the instrument model or a similar model in the range has passed pattern evaluation.

Close-to sounds can be dominated by high frequencies, creating more of a crack than a bang. Here a Class 1 or Type 1 instrument should be preferred as it has a tighter specification at higher frequencies.

If you are using a device that has a variable sample rate ensure this is sufficient to capture frequencies up to 20 kHz.

Low sensitivity microphones

Most sound level meters are designed to measure sound pressure levels within our normal environment. They typically overload on the least sensitive range around 140 dB. The capability to measure higher sound pressure levels can be achieved by using a microphone that has lower sensitivity and a dynamic range to higher sound pressure levels. Typically the use of a ¼ inch microphone in place of a ½ inch microphone will allow measurements to around 160 dB, and there are also microphones specified to measure above 190 dB. The manufacturer of your sound level meter should be able to advise on a suitable microphone.

Alternative transducers for extreme conditions

Peak levels over 170 dB(C) occur from stun grenades, military weaponry and explosions. In these extreme sound pressure levels your choice of microphones is limited, and expensive. In addition, if you are working outdoors and with explosive events you might prefer something rugged.

Hydrophones are a traditional and often recommended alternative to a microphone for the measurement of high sound pressure levels. Another relatively inexpensive and tough alternative is dual purpose microphone/pressure sensors designed to measure pressure fluctuations in both air and fluid environments.

If you use alternative transducers you may have no specification of the overall measurement accuracy of your instrumentation. Laboratory tests or comparative measurements in the field may be required to confirm the performance of your chosen equipment combination.

Other practical issues

There are some further practical considerations:

- You will need a sound calibrator that provides a suitable sound pressure level for the field checks of sensitivity. For example, a device providing a nominal level of 114 dB at 1 kHz or a pistonphone providing a level of 124 dB at 250 Hz are readily available. You will also need to confirm the actual level provided by the calibrator at your microphone or transducer.
- Low sensitivity devices can have a comparatively high sensitivity to vibration. You may need to provide vibration isolation for the microphone supports.
- In high level noise you can get a gradual deterioration of the sprung contacts between the microphone, preamplifier, and any adaptors. This can result in a low frequency vibration signal superimposed on the impulse event sound.

P12

◀ P10

What should you measure?

To assess exposure

If you are assessing personal noise exposure you will need to measure the maximum C-weighted peak sound pressure level over one or more impulse events. In addition, you will need to measure the sound exposure level (L_{AE}) over a number of events. You can then calculate the daily personal noise exposure ($L_{EP,d}$) for the number of events a person is exposed to in the working day. (Guidance on how this is done is provided in HSE publication L108 *Controlling noise at work*).

To select hearing protection

EN 458 Appendix B gives a method to make a crude estimate of the hearing protector attenuation in impulsive noise without the use of measurements. This method is informative, leaving it open for alternative methods to be used.

The Health and Safety Laboratory has recently validated a measurement method. The results confirm it is possible to use a variation of the H, M, L method given in the EN 458 Appendix A.3 to predict protector attenuation in impulsive sound.

In this alternative method the measured C and A-weighted Fast maximum values of the impulse event (L_{CFmax} and L_{AFmax}) are used to obtain an essential L_C minus L_A value that characterises the impulse spectrum. (Ideally the A and C-weighted measurements should be made simultaneously at the same location. And just a word of warning: don't calculate weighted maximum values from a spectrum. You will get the wrong answer.)

The H, M and L values for the protector correspond to spectra with L_C - L_A values of -2, 2 and 10 dB respectively. If you plot the H, M and L values against the L_C - L_A values you can simply read across from your measured L_C - L_A value to obtain the estimated attenuation (as shown in Figure 1 for an L_C - L_A value of 6dB). This estimated attenuation can be subtracted from the measured C-weighted peak sound pressure level and the A-weighted sound exposure level to obtain an estimate of the effective level at the ear when the protector is worn. Note that it is also recommended practice in the UK to reduce an estimated attenuation by 4 dB to account for a reduced attenuation in use.

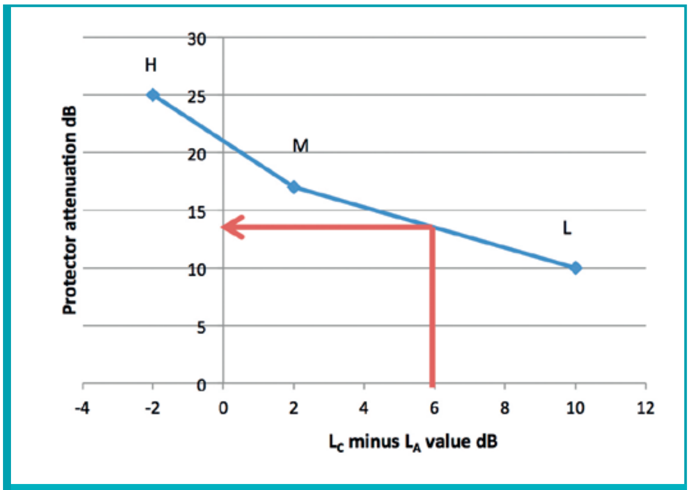


Figure 1. Protector attenuation estimate

References

- **Controlling Noise at Work** HSE publication L108 available as a free download from www.hse.gov.uk
- **Hearing protectors – Recommendations for selection, use, care and maintenance – Guidance document** EN 458:2004

This article was funded by the Health and Safety Executive (HSE). Its contents, including any opinions and /or conclusions expressed, are those of the author alone and do not necessarily reflect HSE policy.

An example of things that go bang here at the Health and Safety Laboratory (provided by HSL Visual Presentation Services team)

WHO warning: one billion plus young people risk hearing loss due to noise

Some 1.1 billion teenagers and young adults are at risk of hearing loss due to the unsafe use of personal audio devices, including smartphones, and exposure to damaging levels of sound at noisy entertainment venues such as nightclubs, bars and sporting events, according to the World Health Organisation (WHO).

Data from studies in middle- and high-income countries analysed by WHO indicate that among teenagers and young adults aged 12-35 years, nearly 50% are exposed to unsafe levels of sound from the use of personal audio devices and around 40% are exposed to potentially damaging levels of sound at entertainment venues. Unsafe levels of sounds can be, for example, exposure to in excess of 85 decibels (dB) for eight hours or 100dB for 15 minutes.

"As they go about their daily lives doing what they enjoy, more and more young people are placing themselves at risk of hearing loss," said Dr Etienne Krug, WHO Director for the Department for Management of Noncommunicable Diseases, Disability, Violence and Injury Prevention. "They should be aware that once you lose your hearing, it won't come back. Taking simple preventive actions will allow people to continue to enjoy themselves without putting their hearing at risk."

Safe listening depends on the intensity or loudness of sound, and the duration and frequency of listening. Exposure to loud sounds can result in temporary hearing loss or tinnitus which is a ringing sensation in the ear. When the exposure is particularly loud, regular or prolonged, it can lead to permanent damage of the ear's sensory cells, resulting in irreversible hearing loss.

WHO recommends that the highest permissible level of noise exposure in the workplace is 85 dB up to a maximum of eight hours per day. Many patrons of nightclubs, bars and sporting events are often exposed to even higher levels of sound, and should therefore considerably reduce the duration of exposure. For example, exposure to noise levels of 100 dB, which is typical in such venues, is safe for no more than 15 minutes.

Teenagers and young people can better protect their hearing by keeping the volume down on personal audio devices, wearing earplugs when visiting noisy venues, and using carefully fitted, and, if possible, noise-cancelling earphones/headphones. They can also limit the time spent engaged in noisy activities by taking short listening breaks and restricting the daily use of personal audio devices to less than one hour. With the help of smartphone apps, they can monitor safe listening levels. In addition they should heed the warning signs of hearing loss and get regular hearing check-ups.

Governments also have a role to play by developing and enforcing strict legislation on recreational noise, and by raising awareness of the risks of hearing loss through public information campaigns. Parents, teachers and physicians can educate young people about safe listening, while managers of entertainment venues can respect the safe noise levels set by their respective venues, use sound limiters, and offer earplugs and "chill out" rooms to patrons. Manufacturers can design personal audio devices with safety features and display information about safe listening on products and packaging.

To mark International Ear Care Day, celebrated each year on 3 March, WHO has launched a "Make Listening Safe" initiative to draw attention to the dangers of unsafe listening and promote safer practices.

Too loud: young people risk hearing damage

Want better acoustic insulation? The future is orange

Researchers have converted orange tree fibres into boards that provide a 150% improvement in acoustic insulation compared with conventional gypsum boards.

The raw material to obtain this new insulating board comes from the classic orange tree pruning, which later undergoes a defibration process.

Together with the orange tree fibres, the insulator incorporates polypropylene, a very common plastic found in toys or automobile parts, among other products. Their work was published in *The Journal of Construction and Building Materials*.

"The boards that we have obtained provide an acoustic insulation potential of about 29 dBA and the conventional laminated gypsum boards are usually at 27 dBA," explained Dr. Jesús Alba and Dr. Romina del Rey, researchers at the Campus de Gandia of the Universitat Politècnica de València.

"That difference of 2 dBA is important because it is a 50% improvement in the acoustic efficiency of the boards, in comparison with gypsum boards. If we use a double solution material, that is, a material that incorporates two boards and an absorbent wool in between, like a sandwich, the improvement is about 5 or 6 dBA, which means it will insulate more than double the conventional system."

Dr Alba added these boards met the objectives defined in the European research programme Horizon 2020, "which focuses on the use of new materials with a natural or recycled raw material. They will replace materials used currently that are more aggressive with the environment".

In the study, the researchers have analyzed the mechanical properties of the new material, comparing them with those of conventional compound materials. "The mechanical properties are better than those of gypsum boards; this means that with the same board thickness, the acoustic insulation is higher; or that we can reduce the thickness to obtain the same insulation", said Dr Alba.

Orange tree fibres provide excellent insulation properties

Controlling information – with sound and light

By Jim Shelton

A laboratory at Yale University in the US has developed a new, radio frequency processing device that allows information to be controlled more effectively, opening the door to a new generation of signal processing on microchips. One of the keys to the technology involves slowing information down.

The new system combines photons and phonons – electromagnetic energy and sound energy – to conduct sophisticated signal processing tasks by harnessing the properties of lower-velocity acoustic waves. In this case, the sound waves are a million times higher in frequency than anything a human can hear.

For decades, researchers have explored ways to shrink down signal processing technologies by encoding information on light. Using circuits that control photons rather than electrons, individual components can be made far smaller and support immense information bandwidths. Yet one thing was missing: an effective way to incorporate acoustic waves, which hold onto information longer, in an even smaller space.

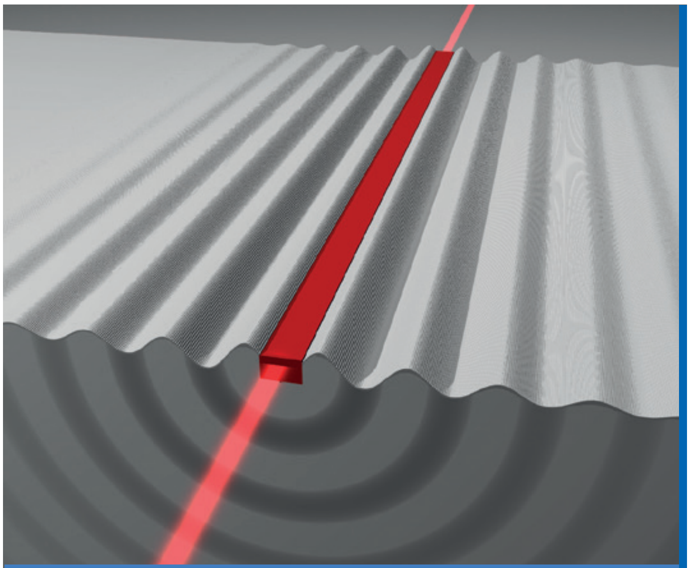
By creating new circuits that can control light and sound, researchers at Yale have developed hybrid technologies that combine the best of both worlds.

"This is definitely something that's going to be built-upon in the years to come," said co-author Peter Rakich, a Yale assistant professor of applied physics and principal investigator of the research. "It's a very different approach because of its flexibility. We've made something that is smaller as well as lighter, and can go on the same microchip with a processor."

The result is that information can be stored, filtered, and manipulated with far greater efficiency. Because the device is small enough to be placed on a silicon chip, it has the potential to be less expensive than other systems. It also has the potential to be adapted to a variety of complex, signal processing designs.

"Our work here is a combination of physics and engineering," said Heedeuk Shin, an associate research scientist in applied physics at Yale, and the study's first author. "We demonstrate a powerful new signal processing operation that isn't possible with photons alone."

This article is based on one that first appeared in *Yale News*.



The emission of phonons (sound waves) from a nanometer scale waveguide, as optical waves flow through it. (Image courtesy of Yale University)

Tuning into the secrets of the world's most prized violins

Acousticians and fluid dynamicists at the Massachusetts Institute of Technology have identified key design features of some of the world's most prized violins such as Stradivari that contribute to their acoustic power.

Working with the North Bennet Street School in Boston, the team acquired technical drawings of violins Cremonese-era of the 17th and 18th centuries from museums, collector databases, and books, as well as X-ray and CAT scans of the instruments. They compared the dimensions of various features from one instrument to another, as well as measurements of acoustic resonances across instruments.

The researchers found that a key feature affecting a violin's sound is the shape and length of its "f-holes," the f-shaped openings through which air escapes: The more elongated these are, the more sound a violin can produce. What's more, an elongated sound hole takes up little space on the violin, while still producing a full sound — a design that the researchers found to be more power-efficient than the rounder sound holes of the violin's ancestors, such as medieval fiddles, lyres, and rebecs.

The thickness of a violin's back plate also contributes to its acoustic power. Violins carved from wood are relatively elastic: As the instrument produces sound, the violin's body may respond to the air vibrations, contracting and expanding minutely. A thicker back plate, they found, would boost a violin's sound.

The researchers found that as violins were crafted first by Amati, then Stradivari, and finally Guarneri, they slowly evolved to more elongated f-holes and thicker back plates.

But were the design changes intentional? To answer this question, the researchers worked the measurements from hundreds of Cremonese-era violins into an evolutionary model, and found that any change in design could reasonably be explained by natural mutation — or, in this case, craftsmanship error.

In other words, makers may have crafted violins with longer sound holes and thicker back plates not by design, but by accident.

"We found that if you try to replicate a sound hole exactly from the last one you made, you'll always have a little error," said Nicholas Makris, a professor of mechanical and ocean engineering at MIT. "You're cutting with a knife into thin wood and you can't get it perfectly, and the error we report is about two percent ... always within what would have happened if it was an evolutionary change, accidentally from random fluctuations."

Makris stressed that while each violinmaker inarguably possessed a good ear — in order to recognize and replicate the violins that sounded best — whether they recognized the particular design elements that contribute to a more powerful sound is still up for debate.

"People had to be listening, and had to be picking things that were more efficient, and were making good selection of what instrument to replicate," he said. "Whether they understood, 'Oh, we need to make [the sound hole] more slender,' we can't say. But they definitely knew what was a better instrument to replicate."

Environmentalists warn more action needed to cut noise pollution in Europe

Reduction of exposure to noise is an important public health measure that must be addressed by both European and local measures.

This is one of the key messages from the European Environment Agency's latest five-yearly assessment, *The European environment - state and outlook 2015'* (SOER 2015).

It states noise pollution has long been recognised as a quality of life and well-being issue, but is increasingly being recognised as a public health issue. Road traffic is the greatest contributor to noise exposure in Europe. While its potential to contribute to harmful impacts is clear, tackling noise pollution is challenging, as it is a direct consequence of society's demand and need for mobility and productivity.

Examples of local measures to tackle the problem include installation of road or rail noise barriers, where appropriate, or managing flight movements around airport locations.

However, the most effective actions are those that reduce noise at source, for example by decreasing noise emissions of individual vehicles by introducing quieter tyres.

Green areas can also assist in reducing urban noise levels. There are opportunities to rethink urban design, architecture and transport in order to improve the management of urban noise

There is also emerging evidence that environmental noise may interact with air pollution, leading to greater impacts on human health. This illustrates the value of considering integrated mitigation approaches that address common sources of both air pollution and noise, such as road transport.

Further efforts to significantly decrease noise pollution in Europe by 2020 will require an updated noise policy aligned with the latest scientific knowledge, as well as improvements in city design and measures to reduce noise at source, the report states.

New study reveals 'nano-earthquakes' hold the key to smarter electronics

The performance of mobile phone cameras and solar cells could be boosted by "nano-earthquakes", researchers in Australia have found.

Dr Sumeet Walia and Dr Amgad Rezk of RMIT University in Melbourne have, in a study led by Dr Sharath Sriram, examined the use of sound waves to controllably change the electronic properties of 2D materials

The finding has important implications for electronics and optoelectronic devices made from 2D materials, opening the door to a new era of highly efficient solar cells and smart windows.

Other possible fields of applications could include consumer imaging sensors suitable for low-light photography, for example in mobile phone cameras, which currently suffer from poor low-light performance, or in sensors for fluorescence imaging.

The RMIT research looked at ways of using surface acoustic waves or "nano-earthquakes" to control the properties of 2D materials.

"Sound waves can be likened to ripples created on the surface of water, but where we can control the direction and intensity of these ripples," said Dr Walia

"In this work, we use these ripples which occur on a crystal surface and couple it into a material that is a few atomic layers thick (2D material), which causes a change in its electronic properties.

"As the surface acoustic waves are turned on and off or increased and decreased in intensity, the change in electronic properties of the 2D materials follows the same pattern."

Dr Rezk said: "We've found that 'nano-earthquake'-like waves under the surface of the 2D materials drag electrons along their path, thereby tuning the amount of light emitted by the material. Remarkably, the acoustic wave based tunability did not result in any structural or compositional change in the material.

"As soon as the acoustic waves were removed, the material retracted back to its initial optical state, and therefore this mechanism is highly adaptable for a variety of dynamically operating systems."

Dr Amgad Rezk (left) and Dr Sumeet Walia

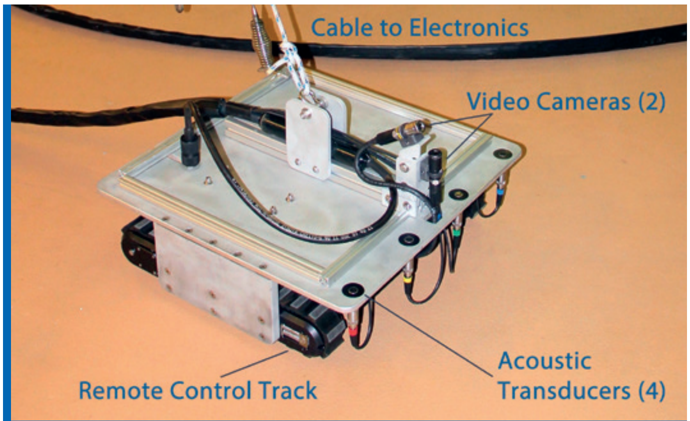
Sound waves to help gauge thickness of oil slicks

Researchers at William & Mary's Virginia Institute of Marine Science in the US have developed a remotely operated underwater vehicle that uses acoustic technology to assist in determining the response to major oil slicks.

Knowing the spill volume and thickness of a slick is a key factor in mounting an effective response, including decisions about applying enough – but not too much – chemical dispersant.

Project leader Paul Panetta said: "Gauging the volume of a spill, and the extent and thickness of its surface slick, is usually done by visual surveillance from planes and boats, but that can be quite difficult. Our ROV [remotely operated vehicle] uses acoustic signals to help more easily locate and focus on the thickest part of the slick.

"Our ROV will measure the thickness of experimental slicks to aid in developing and testing oil-spill-response tools. It will also provide a test platform for developing other sensors and for field applications. It's one step along the path to developing platforms for use in the ocean to measure slick thickness and other oil properties using acoustics."



The 'Acoustic Slick Thickness ROV' developed by Paul Panetta and colleagues at the Virginia Institute of Marine Science.

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Rather than using visual cues from above, the ROV developed by Panetta and his team gauges the thickness of a slick by emitting sound waves from below – waves that reflect off the density boundaries between water and oil, oil and air, or oil and ice.

Measuring the slight delay between the reception of these reflected echoes allows the vehicle's software to gauge the thickness of surface and below-ice oil slicks at very fine resolution – from slicks less than 0.5 millimetres thick to more substantial accumulations of up to several centimetres.

Dale McElhone and Paul Panetta with their 'Acoustic Slick Thickness ROV', in front of the 8,460-gallon tank they used for testing the vehicle.

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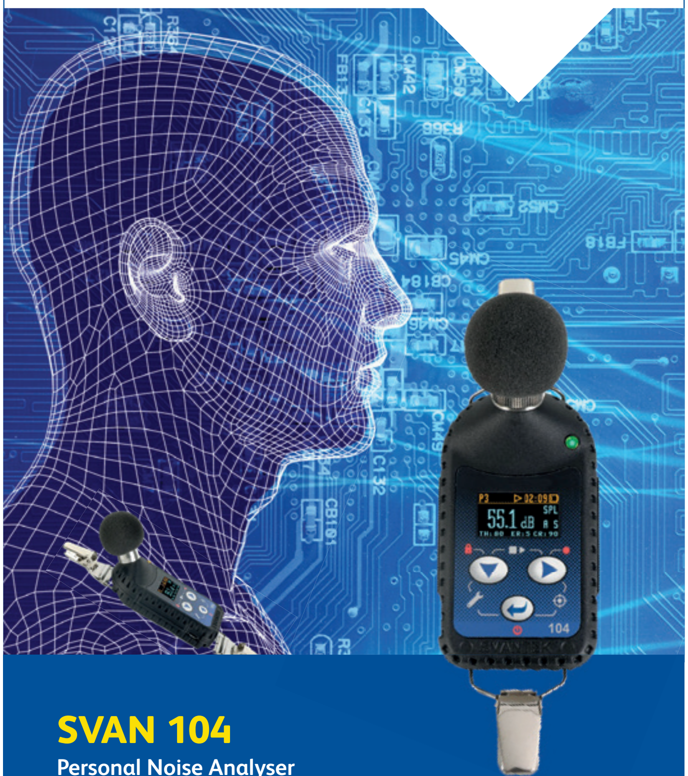

'Elastic' road surface aims to reduce tyre noise

Researchers have covered part of a road in Denmark with an experimental "elastic" surface as part of an EU-funded project aimed at dampening tyre noise.

The surface, which is made from crushed rubber from used car tyres and crushed granite, glued together with polyurethane, removes about 85 percent of the energy from the traffic noise.

Researcher Hans Bendtsen measured a "remarkable" 8dB reduction in noise. "If you wanted to create the same noise reduction, you would need to have a noise barrier of a height of around 3 metres," he said.

Covering roads with recycled tyres is not a new idea, but previous attempts had serious durability issues and were expensive.

"We're trying to develop a material that has a high, good noise reduction, has a good durability, a good price, and also a good friction," said Mr Bendtsen.

Friction is being studied at another road track in Sweden where it has been found that the rubber-containing material yields a better grip in winter than normal asphalt.

Research engineer Ulf Sandberg said that while said it was more expensive than a normal surface, it should be used as an alternative to noise barriers, which were "terribly expensive".

But will it be durable enough? Researchers use a specially designed carousel to simulate years of traffic load on the test surface. It shows how fast the material deteriorates and how much pollution it produces.

The project, codenamed PERSUADE, will last for six years and has a budget of €4.5 million. Twelve partners from seven European countries are co-operating in the project, including research institutes, universities and companies representing the sectors of industry involved.

For more information visit **http://www.persuadeproject.eu**

Sound waves could spot dangerous cracks at nuclear power plants

A system for using sound waves to spot potentially dangerous cracks in pipes, aircraft engines and nuclear power plants has been developed by a University of Strathclyde academic.

A study found that transmitting different types of sound waves can help to detect structural defects more easily. This is achieved by varying the duration and frequency of the waves and using the results to recreate an image of the component's interior.

The system is a model for a form of non-destructive testing (NDT), which uses high-frequency mechanical waves to inspect structure parts, and ensure they operate reliably, without compromising their integrity. It will be developed further and could potentially also have applications in medical imaging and seismology.

Katherine Tant, a Research Associate with Strathclyde's Department of Mathematics and Statistics, led the study. She said: "Welds are vitally important in 'safety critical' structures, like nuclear power plants, aeroplane engines and pipelines, where flaws can put lives at risk. However, as with any type of bond, they constitute the weak part of the structure.

"One particular type of weld, made of austenitic steel, is notoriously difficult to inspect. We were able to devise solutions involving the use of 'chirps' – coded signals with multiple frequencies which vary in time.

"The type of flaw identified depends on the method used. An analogy would be the type of echoes produced by clapping loudly in a cave – a single clap may allow you to judge the depth of the cave while a round of applause will give rise to a range of echoes, perhaps allowing you to locate boulders."

Monitoring noise levels on an 'elastic' road

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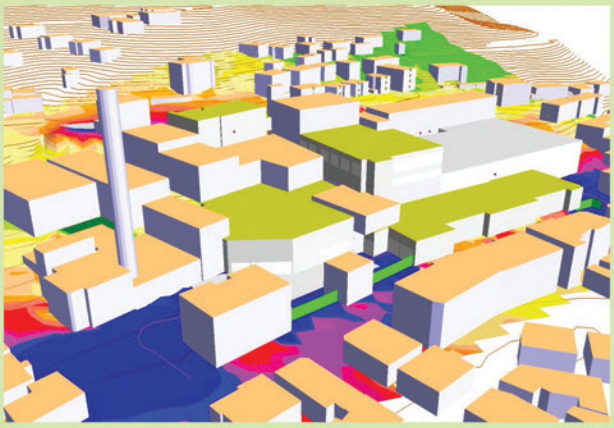

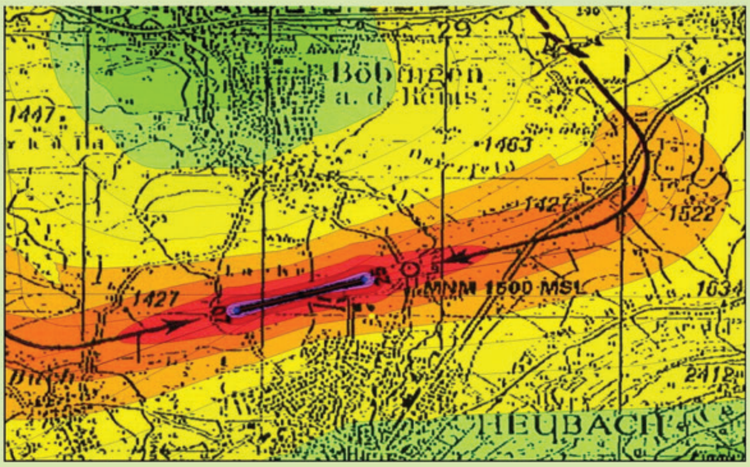

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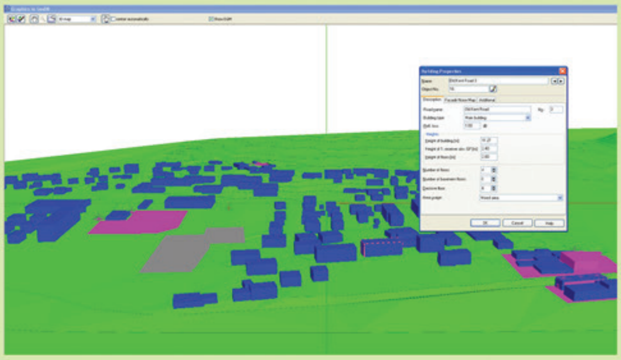

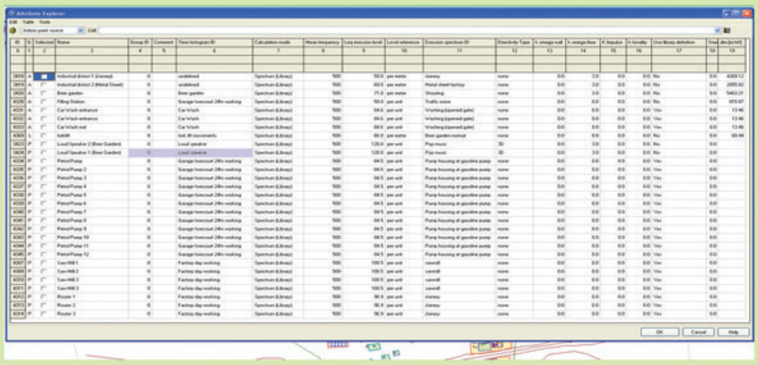

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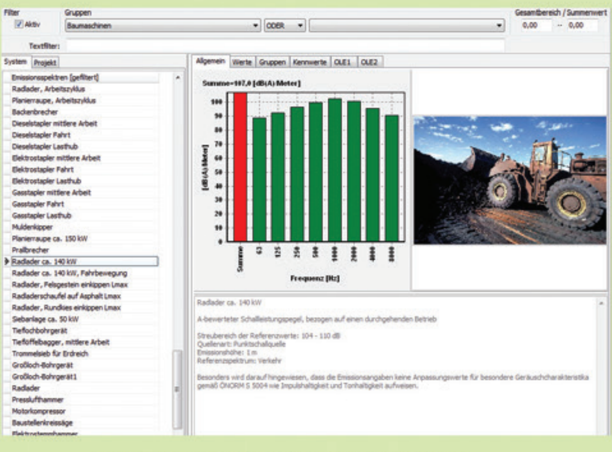

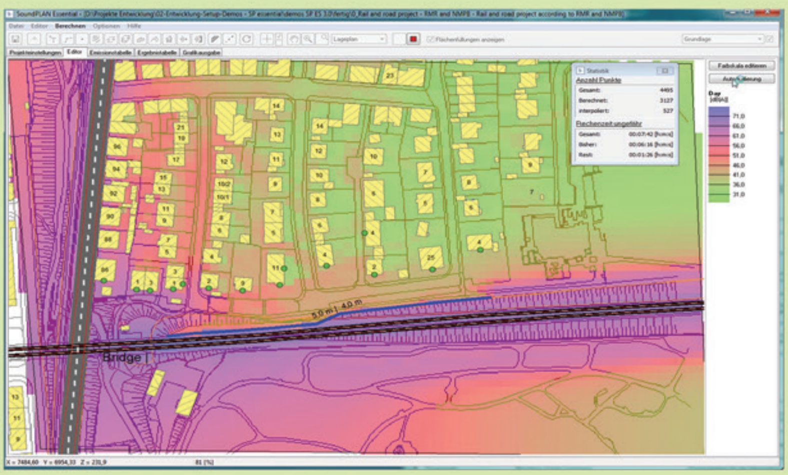

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Landmark study shows magnets can be used to control heat and sound

American researchers have discovered that magnets can be used to control both heat and sound.

In an article published in *Nature Materials*, a team from Ohio State University described how a magnetic field roughly the size of a medical MRI reduced the amount of heat flowing through a semiconductor by 12 per cent.

The study is the first ever proving that the so-called acoustic phonons, elementary particles transmitting heat and sound, have magnetic properties.

"This adds a new dimension to our understanding of acoustic waves," said Joseph Heremans, a professor of mechanical engineering at Ohio State. "We've shown that we can steer heat magnetically. With a strong enough magnetic field, we should be able to steer sound waves, too."

The discovery could possibly allow controlling heat in materials such as glass, stone and plastics, which are not conventionally magnetic.

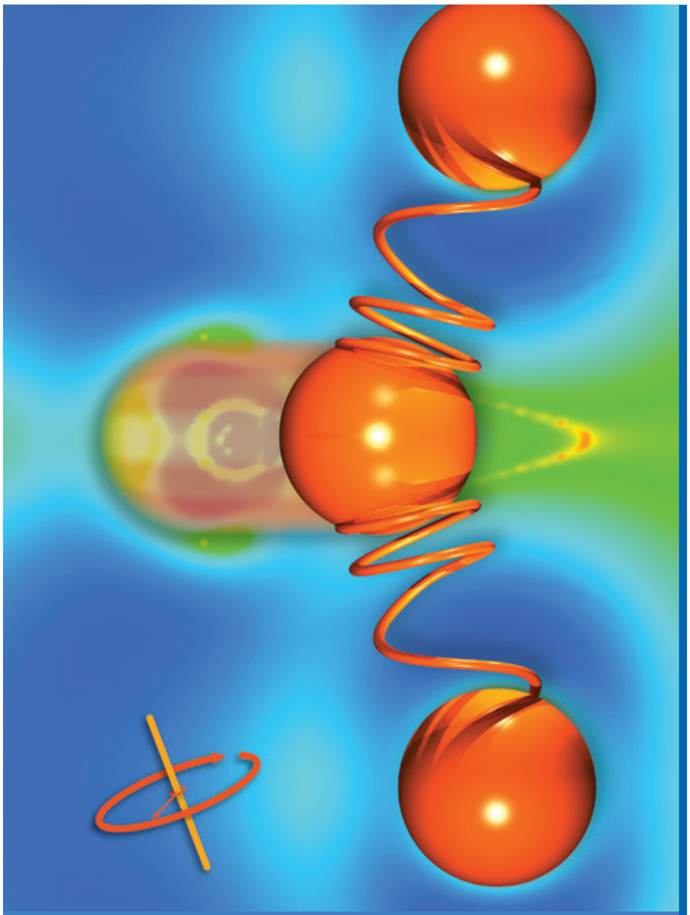
However, there is a catch. Magnets strong enough to have a measurable effect currently exist only in hospitals and research laboratories. Moreover, the heat-carrying semiconductor needs to be cooled down to minus 268 degrees Celsius, near the absolute zero, which is not practical for real-life applications.

Acoustic phonons, the particles responsible for the magnetic properties, have been described by scientists as a sort of cousin-particle to photons, particles of light. Unlike photons, acoustic phonons have so far escaped scientific scrutiny.

Professor Heremans explained that although heat and sound may seem not to have much in common at the first glance, they are, in fact, expressions of the same energy.

"Essentially, heat is the vibration of atoms," he said. "Heat is conducted through materials by vibrations. The hotter a material is, the faster the atoms vibrate. Sound is the vibration of atoms, too."

The lead author of the study, Ohio State postdoctoral researcher Hyungyu Jin, said the properties are likely to be present in any solid material.



An artist's rendering, based on computer simulations, depicts a phonon heating solid material

Image by Renee Ripley, courtesy of Ohio State University

New device that puts out fires with sound

Two engineering students in the US have invented a fire extinguisher that puts out flames by using sound.

Seth Robertson and Viet Tran have built a portable sound generator which uses low frequency sound waves to separate oxygen from fuel to stop a fire from burning.

The development of their gadget is still at an early experimental stage, but they hope that one day it could revolutionise firefighting.

Among the benefits over a conventional extinguisher is that it is free of toxic chemicals and does not subject buildings to water damage.

Originally the students, from George Mason University in Virginia, thought that big speakers and high frequencies would dose a fire.

"But it's low frequency sounds in the range of 30 to 60 hertz, like the thump-thump bass in hip-hop that works," said Mr Tran.

The 20lb device is the result of an idea for a senior research project and has involved a year of trial and error as well as $600 of their own money to get to this stage.

The students have applied for a provisional patent, which gives them a year to do further testing on other flammable materials – so far they have put out only fires started with rubbing alcohol – and to continue to refine their device.

Seth Robertson (left) and Viet Tran, test their sound-blasting fire extinguisher prototype

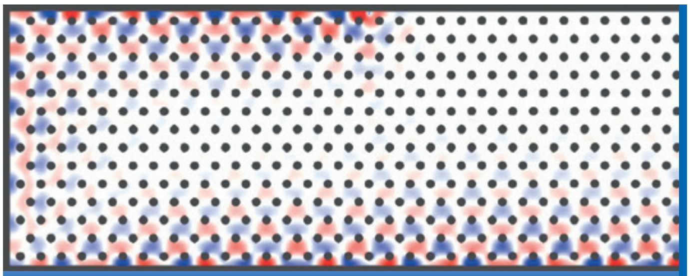
Picture courtesy of Evan Cantwell/Creative Services/George Mason University

New material could provide sonar invisibility

A proposed acoustic version of a material that conducts electricity along its surface could lead to an improved way to hide submarines from sonar.

Materials called topological insulators conduct electricity only along their surfaces and have a range of potential uses. A team in Singapore has now proposed a structure that could do the same thing for sound waves, causing them to be guided in just one direction around the surface of a region and to ignore imperfections that would scatter the sound in an ordinary material. If it can be built, such a structure might find uses in acoustic technologies, such as soundproofing and sonar stealth systems. In topological insulators, electrons flow on the surface of a material and travel with less scattering from impurities than in ordinary conductors. The mathematical description of these materials treats the electrons as waves in a periodic structure and generates a range of frequencies (a band gap) in which waves cannot propagate through the interior. Researchers have high hopes for using them in new technologies, but they have also wondered whether the effects could be duplicated for other types of waves, such as light and mechanical vibrations. Now Professor Baile Zhang and co-workers at Nanyang Technological University in Singapore have created an acoustic topological insulator that they say could be used to control sound waves in new ways.

One example of a topological insulator is a two-dimensional material with a strong magnetic field applied along the 3rd dimension. Under the right conditions, in response to the field the electrons move in circles arranged in a periodic pattern. But at the edges of the material, electrons can only execute half-circles. These semicircular routes can link up to form a circuit around the edge, a path that electrons can travel in only one direction (because of the direction of their orbits). In addition, current through this channel is resistant to the scattering that would usually occur if there were any flaws present in the crystal lattice, because the one-way motion prevents all backward scattering.



Sound surface: simulation of the acoustic topological insulator

In the acoustic version proposed by Professor Zhang and his colleagues, the periodic lattice of orbiting electrons is replaced by a two-dimensional array of spinning metal cylinders in a triangular lattice. Each cylinder is surrounded by a fluid, which could simply be air, contained within a larger cylindrical shell made of a material that is transparent to sound waves. The space between the cylindrical shells is filled with the same fluid, but it's stationary. The rotation of each metal cylinder produces a little vortex in its surrounding fluid within its shell.

Sound waves cannot propagate through the middle of this structure because the periodic pattern produces a sonic band gap, just like the electronic band gap in earlier topological insulators. But the edges are different—the rotating fluid supports propagation in one direction around the perimeter.

This report is based on one that first appeared in *Physics*.

Using sound waves to detect rare cancer cells

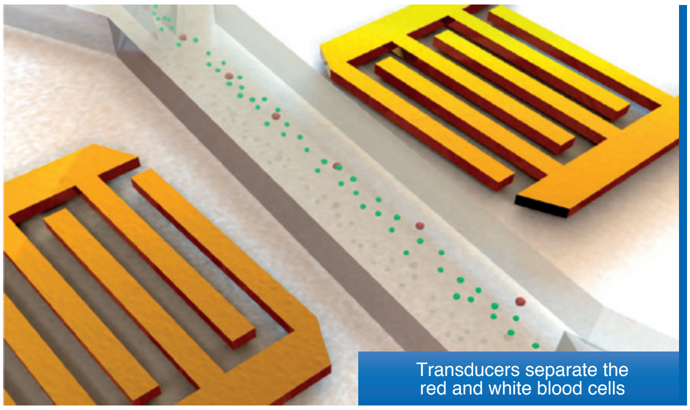
A team of engineers from Massachusetts of Institute of Technology, Penn State University, and Carnegie Mellon University in the US is developing a novel way to isolate cancer cells: using sound waves to separate them from blood cells.

Their new cell-sorting device is 20 times faster than the original version that they first reported last year, approaching the speed that would be necessary to make it useful for testing patient blood samples.

The researchers have also demonstrated that the device can successfully capture circulating tumour cells from patient samples, which could enable many clinical applications as well as fundamental research on how these cells escape from their original tumour site.

Most existing cell-sorting technologies require tagging cells with chemicals or exposing them to strong mechanical forces that may damage them. To sort cells using sound waves, which offer a gentler alternative, the researchers built microfluidic devices with two acoustic transducers, which produce sound waves, on either side of a microchannel. When the two waves meet, they combine to form a standing wave (a wave that remains in constant position). This wave produces pressure nodes, or lines of low pressure.

Because the sound waves are tilted so they run across the microchannel at an angle, each cell encounters several pressure nodes as it flows through the channel. As cells encounter each node, they are pushed further to the side of the channel; the distance of cell movement depends on their size and other properties, such as compressibility.



Transducers separate the red and white blood cells

Picture courtesy of the Massachusetts Institute of Technology

In the previous study, the researchers were able to separate cancer cells from red and white blood cells, but the sample flow rate through the device was only 1 to 2 microlitres per minute. At that rate, it would take more than 50 hours to process a typical patient sample of about 6 millilitres.

The new version of the device has a working flow rate about 20 times faster, allowing it to process a patient sample in about five hours.

To achieve this, the researchers used computer modelling of cell trajectories, confirmed by experimentation, to adjust some of the device's other features, including the tilting angle – the angle at which the sound waves strike the channel – and the distance over which the cells are exposed to sound waves.

The researchers tested the new acoustic device with samples consisting of a mix of cancer cells and white blood cells grown in the lab. In these studies, they were able to isolate at least 83 per cent of the cancer cells from samples that had as few as one cancer cell per 100,000 white blood cells.

Approaches to noise control prioritisation for industrial plant

By Nathan Thomas, Xodus Group UK

Introduction

Over recent decades the negative health impacts of noise pollution and noise exposure have become better understood. This has led to a range of environmental regulation and workplace health and safety legislation which requires noise to be controlled at source.

The Noise Policy Statement for England (Reference 1) reflects changing policy priorities, with industrial plant operators having a requirement to mitigate and minimise adverse impacts on health and quality of life; and where possible contribute improvements.

Industrial sites have a number of drivers requiring the control of noise at source. This can be as a result of permitting requirements, the demonstration of best available techniques, or to reduce occupational noise exposure. Retrofitting noise control to existing industrial plant can present engineering challenges and potentially high cost, therefore it is important to ensure that the most significant noise polluters are identified along with effective mitigation measures.

During industrial plant upgrades, when existing plant noise emissions are close to environmental noise limits, engineers are often required to design extremely low noise equipment. This can present complex engineering challenges and high cost. In many cases upgrade projects focus on the noise control options available for new plant, without considering potential control options for existing plant.

This paper presents a roadmap for identifying effective noise control mitigation measures at the lowest cost to industry. It includes considerations for a combined approach to identifying the most significant noise polluters which can reduce survey time and therefore cost. It also presents an approach to cost benefit analysis to assist in identifying the most cost-effective combination of noise control mitigation measures.

Environmental noise modelling

Environmental noise can be evaluated by the specific noise level due to the industrial plant received at chosen receptor locations. Noise limits will often be defined with reference to noise levels at the closest sensitive receptor.

All the individual noise sources on an industrial plant combine together to give the cumulative noise emission from the plant and contribute to noise levels at receptor locations. In order to select the most appropriate noise control solution an understanding is required of the most significant contributors to noise at receptor locations.

Evaluation of the impact of key noise sources at receptor locations and the benefits of various control options is most easily achieved using a noise model. If the sound power of all existing

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and proposed plant items can be determined, a noise model can predict the cumulative noise imission at receptor locations and identify the most significant noise polluters. These items can then be targeted for noise control mitigation measures.

Determining plant noise emission

A common approach to determining the existing noise emission of an industrial plant can be termed as the "full detail" method, whereby measurements are conducted to determine the sound power of every individual plant item. These are entered into a noise model which is used to predict specific noise levels at receptor locations.

Measurements at receptor locations can then be used to calibrate the noise model, correcting for factors such as source directivity, reflections, absorption, screening and ground effects. When the noise model and environmental measurements have a good correlation, this gives confidence to the accuracy of the model, and allows different noise control scenarios to be evaluated.

Whilst an effective approach, the "full detail" method is time consuming, potentially impacting both survey cost and schedule. This method does however give us two key pieces of information:

- Overall noise emission of the plant; and
- Most significant contributors to plant noise emission.

Knowledge of these is key to developing a noise control strategy. The question that arises is whether these key pieces of information can be determined without obtaining full details of every individual plant item.

In some cases it is possible to estimate the overall noise emission of the plant using environmental measurements and measurements at the plant boundary. This however, doesn't demonstrate the key noise sources. Identifying areas of plant containing the key noise sources, and excluding less significant areas of plant from a detailed study, can give similar results with a significantly reduced survey time.

If the plant is broken down into discrete modules, sound power estimates can be conducted for these. It will then be possible to identify modules which do not make a significant contribution to plant noise emission. These modules can be included in the noise model, but discounted from a more detailed measurement exercise.

Figure 1 presents an industrial plant with discrete modules identified.

Modules identified as making a significant contribution to noise emission can be rank ordered and detailed measurements conducted to identify the key plant noise sources. In this way both the overall plant noise emission and key sources can be identified, potentially with a significant saving in survey time.

Module sound power estimation

If plant modules are spaced far enough apart distance measurement methods can be used to estimate the sound power of individual modules. If a module does not contain significant numbers of elevated sources, measurements of sound pressure level can be conducted at a distance of at least one times the largest source dimension, back from the assumed acoustic centre of the plant. Normally four directions will suffice, with measurements ideally conducted at a height of at least 4 m.

Figure 2 outlines this approach to measuring at distance.

This assumes that other modules will be far enough away not to influence the measurements. Modules on many industrial sites will be placed too close together for such an approach to be valid, so other methods are required.

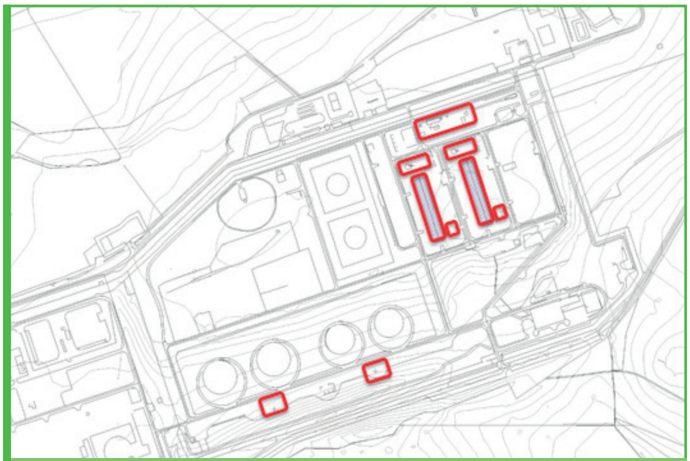

Figure 1. An industrial plant represented as discrete blocks

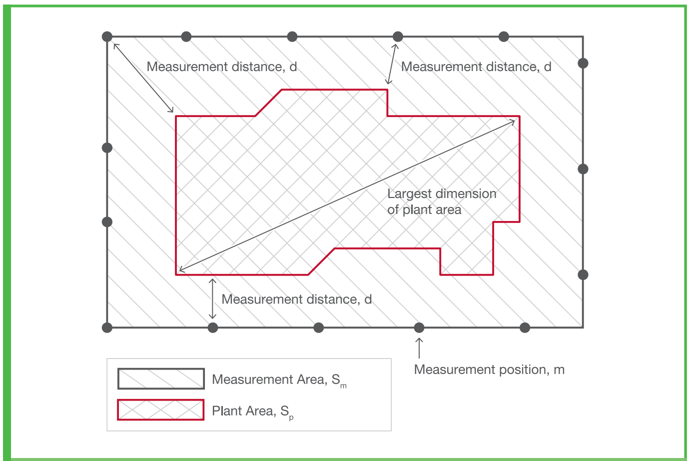

Figure 3. ISO 8297 measurement method

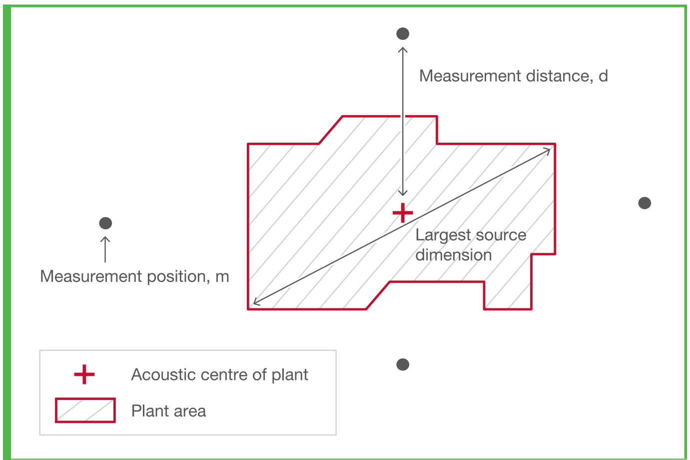

Figure 2. Distance measurement method

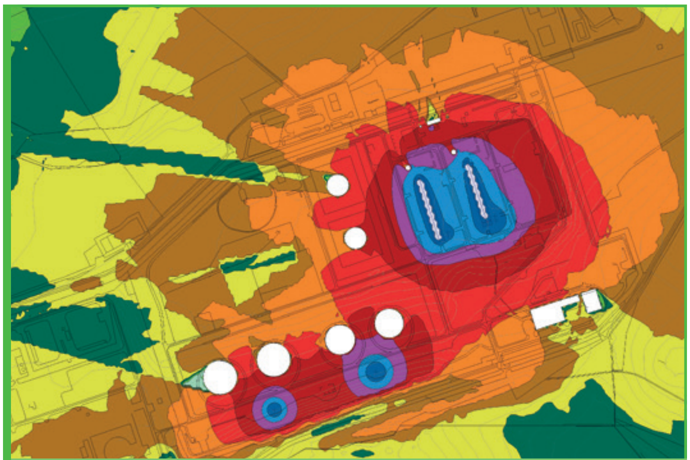

Figure 4. Noise contour plot of an industrial plant, obtained using the ISO 8297 measurement method

ISO 8297 (Reference 2) specifies an engineering method for determining the sound power level of multi-source industrial plants for the assessment of noise in the environment. The standard presents an approach which allows acoustic measurements to occur much closer to a module. This reduces the problem of other nearby noise sources influencing the results. The standard is based on the measurement of sound pressure levels on a closed path surrounding a module with sources combined and treated as a single source at the geometrical centre of the plant.

Figure 3 outlines this approach to closed path measurements

This method was first proposed by Stüber in 1972 and submitted to ISO for consideration as a standard in 1982. The standard is applicable to industrial areas where most of the equipment operates outdoors and for which the largest horizontal dimensions of the plant area lie between 16 m and 320 m. It is understood that these limitations are based on the limits of the measurement exercises carried out when developing the method, rather than acoustical or physical constraints. A key assumption of the standard is that the sound power is uniformly distributed across the module area, with noise radiation substantially uniform in all directions.

The allowable distance of the measurement points to the perimeter of the noise sources is very precisely defined, varying from 5 m to 35 m, with a defined spacing between the measurement points, on a fully closed path. The standard has a requirement for background noise levels to be 6 -10 dB lower than the industrial source, which often requires measuring at the lower distance limit of 5 m from the source.

The height of measurements around the industrial plant needs to be determined from the average height of the sources on the site and the plant measurement area. For modules with a large area, the measurement heights suggested by the standard can be difficult to implement practically; for example, a 1 km^2 area would require a measurement height typically greater than 30 m. The standard does allow for this and states that the microphone should be placed as high as possible above the minimum height of 5 m. Elevated sources of noise (such as airfin coolers and exhaust stacks) are excluded from the method and need to be measurement separately.

The method was initially intended for whole site evaluation, however, reliable results have been obtained when used for measurement of specific modules within industrial sites. Other published work in this field suggests that for larger sites, it can be more effective to determine the sound power of individual modules separately, as proposed in EMMUA 140 (Reference 3) and DEFRA (Reference 4).

An example industrial site noise contour plot with sound power data obtained using this method is shown in Figure 4.

The next phase is to rank order the modules making the most significant noise contribution at sensitive receptors. Detailed measurements can then focus on these specific areas.

Detailed sound power determination

Once key modules have been identified detailed measurements are required to determine key noise sources. Measurement options for detailed source identification include sound pressure, sound intensity and vibration velocity. Some of the benefits, drawbacks and practical considerations of the different measurement systems are discussed here.

Sound pressure measurements can be used to determine the sound power of individual items of plant such as the methodology presented in ISO 3746 (Reference 5). This can be effective when background noise is low, and free-field conditions can be assumed. This is rarely the case on many industrial sites where acoustic environments are often acoustically congested and excluding extraneous noise from measurements is problematic. This can lead to large uncertainties tending to overestimate source strength (if influenced by extraneous noise).

Sound intensity is generally preferred for determining individual source strengths in acoustically congested environments. Sound intensity is a vector quantity which provides a measure of the magnitude of noise travelling in a given direction. As such it can

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reject off axis noise and give a specific measurement of a particular sound source.

Sound intensity can be determined using either two phase matched microphones (p-p probe) spaced apart by a known distance, or by a combination of a microphone and particle velocity transducer (p-u probe) which determines particle velocity using ultrasonic transduction. There is evidence to suggest that this form of p-u probe is more sensitive to turbulence and unsteady flow than p-p probes (Reference 6). P-p probes are therefore currently considered more robust for measurements in outdoor environments. A phase matched microphone arrangement is shown in Figure 5 which measures sound travelling parallel to the probe axis.

Standard intensity measurement methods are either via surface scanning, or by measurement at discrete points. The scanning methodology presented in ISO 9614-2 (Reference 7) is more appropriate for measurements outdoors on industrial plant. Discrete point methodologies can be time consuming, and requires a standard of repeatability which can be hard to achieve in the fluctuating meteorological conditions typically encountered outdoors.

Engineers must be aware of the limited frequency limits of intensity measurement systems. Increasing the microphone spacing lowers the applicable frequency range of measurements. Measurements using two different spacings may be required if accurate results are needed in each of the nine key octave bands from 31.5 Hz to 8 kHz. It can often be helpful to first evaluate environmental measurements and determine the most critical frequency bands of noise imission at sensitive receptors. For many sources accuracy may not be required at frequencies below the 125 Hz band for instance. If pressure measurements from one of the microphones will suffice at these frequencies then measurement time can be reduced (not to mention the practical implications of changing small intensity spacers on site, whilst wearing industrial gloves).

Figure 5. Sound intensity probe

Sources with a high sound power due to a large radiating surface area (such as pipework and ducting) can have relatively low sound intensity levels. In these cases measuring either sound pressure, or the positive intensity vector on an acoustically congested site can be difficult and direct measurement of surface vibration levels can give more effective and repeatable results. Vibration velocity is directly proportional to surface sound pressure, therefore if the radiation efficiency of the surface can be established, then the item sound power can be determined.

The benefit of this approach is that, like intensity, extraneous noise is excluded from the measurements. A measurement procedure is presented in ISO/TS 7849-1 (Reference 8). The drawback of this standard is that it assumes a radiation efficiency of 1. Figure 6 presents a typical radiation efficiency curve for a steel pipe. This demonstrates that sound radiation is less efficient at low frequencies, tending to 1 at frequencies above the critical frequency.

The inherent assumption of ISO/TS 7849-1 may give acceptable accuracy at higher frequencies, but is generally not applicable for cases where lower frequencies are of interest (which are usually required for environmental noise control).

A method for establishing radiation efficiency is presented in ISO/TS 7849-2 (Reference 9) however this requires determining the radiation efficiency by first establishing machinery sound power using intensity. Clearly for this application, if the sound power can be determined using intensity then there is no requirement for vibration measurement! A more practical approach is to estimate the radiation efficiency for different types of vibrating surfaces using established methods presented in the literature. These include methods for pipes (Reference 10) and plates (Reference 11).

Evaluation and cost benefit analysis

Once a noise model is constructed to include the noise emission from both existing plant and any new plant, the future predicted specific noise level at sensitive receptors can be determined. The most significant noise sources can be evaluated for potential noise control mitigation.

To produce a cost benefit analysis, a measure of benefit needs to be determined. Typically this would be the reduction in specific

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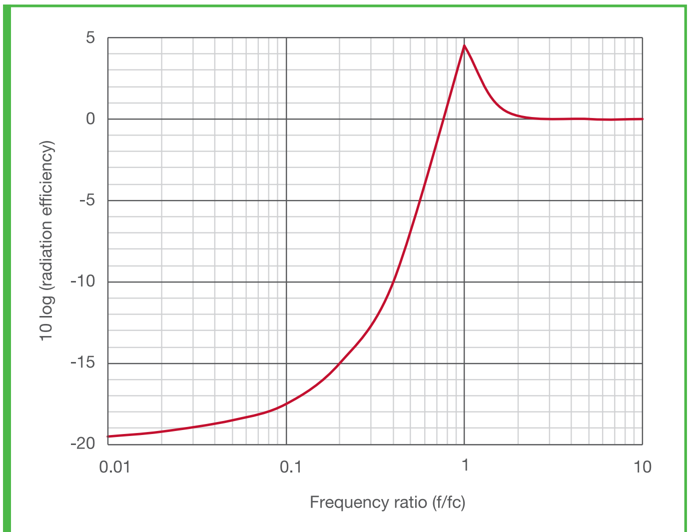

Figure 6. Typical radiation efficiency curve

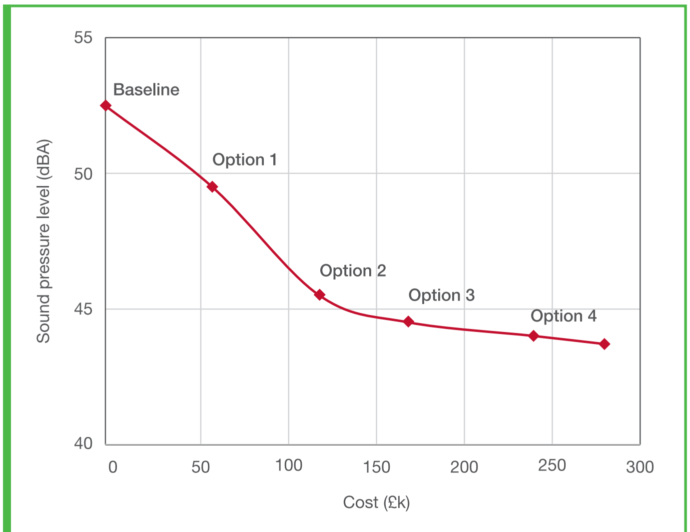

Figure 7. Typical cost benefit analysis curve

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noise level at the closest sensitive receptor, however for very large sites with multiple receptors, more complex analysis may be appropriate.

The base cost of each noise control option can be acquired from hardware vendors, for input into a cost-benefit analysis. When estimating costs, consideration should be given to materials, installation cost and any ongoing maintenance that may be required for a particular control option.

Inclusion of cost benefit analysis is recommended for the evaluation of Best Available Techniques (BAT). Cost may be a factor in justifying whether particular options can be considered 'available'.

Once the costs and benefits have been determined it is often useful to plot the cumulative cost and benefit. An example cumulative cost benefit plot is presented in Figure 7. The relationship shown, between cost and benefit, is typical for such an exercise. There is often a point where additional noise control will increase cost but give diminishing returns in noise reduction. Treating the most significant noise sources first will typically yield the best result, unless costs are an order of magnitude higher than costs for treating less significant sources.

Conclusion

A roadmap for identifying effective noise control mitigation measures at the lowest cost to industry has been presented. It includes considerations for a combined approach to sound power determination and cost-benefit analysis.

When applied intelligently, combining sound power estimation techniques with detailed sound intensity and vibration velocity measurements can offer significant efficiencies in survey cost and schedule.

Conducting a full plant noise survey in this way, allows a full range of noise control options to be evaluated. This enables detailed cost-benefit analysis to be conducted and the most cost-effective combination of noise control mitigation measures to be determined.

This approach will give plant operators confidence to robustly demonstrate the use of best available techniques and meet their obligations under environmental legislation.

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Design and acoustic performance of a spring isolated outdoor rooftop sports court

By Alex Campbell (WSP, Australia); Lloyd Cosstick (Embelton, Australia) Timothy Murray (Embelton, Australia); and David Yates (WSP, Australia)

Abstract

The proposal of a rooftop sports court used for basketball, netball and tennis created an issue of significant impact/footfall noise and structural vibration ingress to the sensitive environment beneath. As part of a new building now occupied by Medibank in a dense urban environment in Melbourne, a unique solution had to be designed due to the maximum weight capacity of the underlying rooftop structural slab and FFL design controls. Further challenges were faced in the form of fluctuations of up to 30 mm in the level of the underlying structural slab and subsequent excessive deflection caused by a relatively high live load. The final design incorporated the use of over 300 cast in 'jack-up' style mounts complete with 25 mm deflection springs within a 100 mm secondary concrete slab covering an area of approximately 630 m^2. Installation of the court encountered few problems and upon completion small deflections of the slab could be felt underfoot however there were no unfavourable 'trampolining' effects generated by live loads. Completion testing showed a significant reduction in impact noise levels between the isolated court and an exposed portion of the structural slab.

Keywords: Impact, Sports, Transmission
I-INCE Classification of Subjects Number(s): 51.4

Introduction

Basketball courts are subject to frequent impact forces from bouncing balls and people jumping. Typically basketball courts are constructed at grade to avoid issues of noise and vibration transmission through connected structures. In this case, a combined basketball/netball/tennis court was to be constructed in a dense urban environment, and limited spatial availability necessitated that it had be located on a rooftop directly above commercial space. Without sufficient vibration isolating measures, the impact forces from activity on the court would likely cause distracting noise to the people below in the connected structure.

The structural floor was a 150mm composite slab with large transfer beam spans which yielded a relatively low natural frequency for the structural slab (see Section 3.1). The natural frequency of the courts system needed to be calculated carefully to avoid resonance with both the underlying structural slab and with activities such as footfall and ball bouncing.

The proposed court size was approximately 630m^2 and the finished court height was restricted to 150mm from the structural floor. The court system was also to contain several large penetrations for poles which were to be supported from the structural slab. Other design constraints included the support capacity for a live load of 5kPa and an allowance for appropriate drainage measures.

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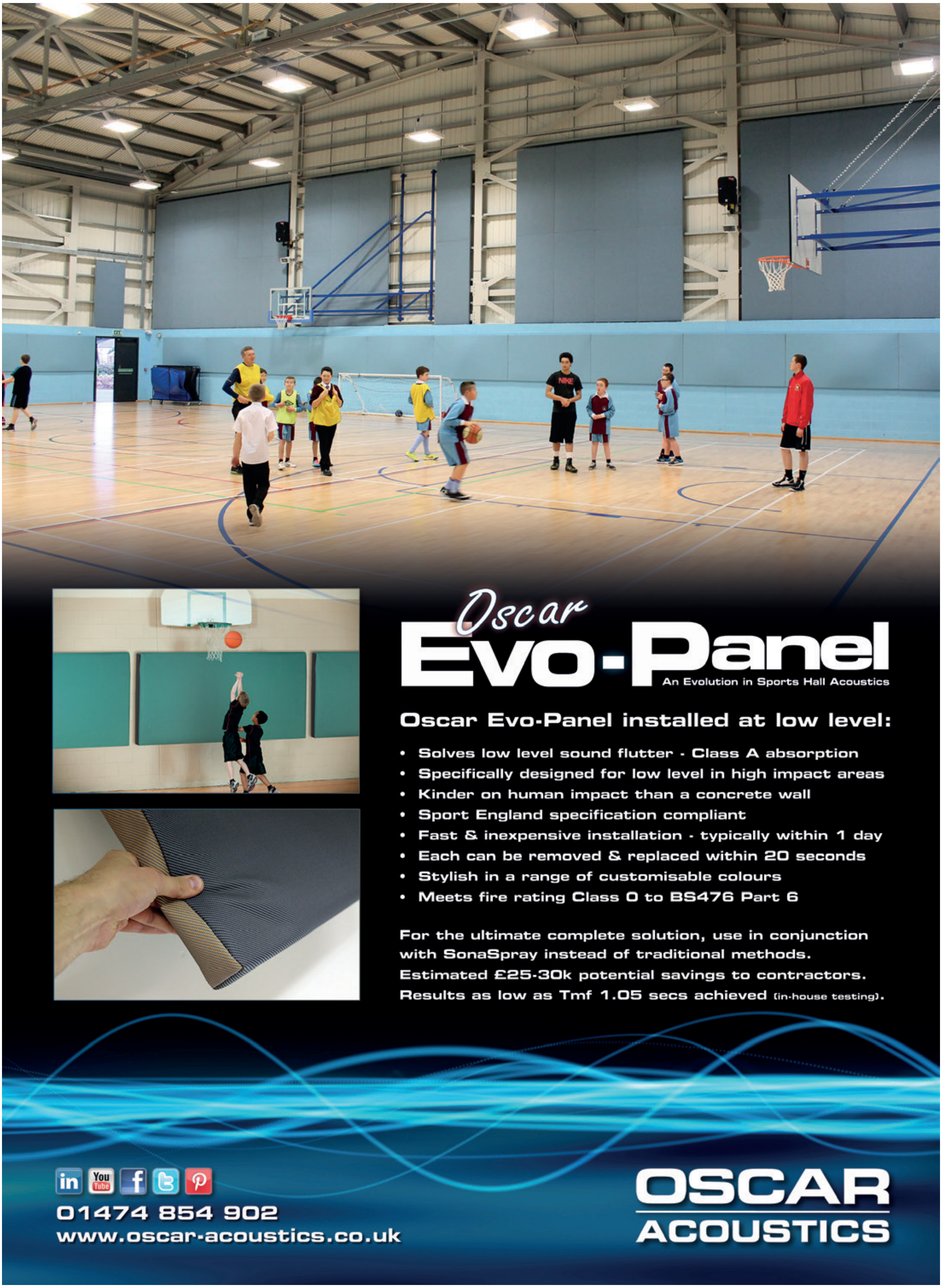
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The final design of the system incorporated a 100 mm thick concrete floating floor which was supported by springs with housings which were cast into the concrete. This design aimed to achieve a consistent air gap of 50 mm between the floor and the structural slab. From the experience of the authors it is much more common to use rubber mount isolation for sports floor applications due to factors such as cost, discomfort from vibrations due to large amplitude deflection where springs are used and resonance at walking frequencies. However, it was believed that the overall effect of these issues could be mitigated, as it was the only solution which satisfactorily met the design constraints.

Noise level criteria

It was important to develop design criteria which would result in acceptable levels of noise in the tenancies below the basketball court. The tenancies below would be constructed as part of a separate fit-out contract. As such, their use was not fully confirmed at the time of design. However, it was known that these tenancies would install a plasterboard ceiling in the space below to conceal structure and building services. Possible uses for the space included a medical clinic or small retail units, etc. From AS2107:2000(1) a medical clinic has the stricter requirements with a satisfactory design sound level for consultation rooms in health buildings at 40dB LAeq,T with a maximum of 45dB $L_{Aeq,T}$.

The average noise level ($L_{Aeq,T}$) from impact noise on the slab above is unlikely to be the determining factor in disturbance or annoyance to the users of spaces below. The primary factor in this would be the impulsive / maximum noise levels (L_{Amax}). As such, it was considered that if the L_{Amax} levels from activity on the slab above did not exceed the above criteria then the noise was not likely to cause disturbance to occupants.

Investigated alternatives

Due to the likely cost implications of providing an isolated secondary slab for the extent of the basketball court area, a number of alternative options were investigated during the early design stages of the project.

Isolation of spaces below

The option was explored to structurally isolate the spaces below, such that they did not share a direct connection to the slab above nor the columns passing through the space.

This was rejected due to the impact on the fitout design below, difficulty in predicting re-radiated noise on other parts of the building, and questionable cost / benefit.

Resilient matting on non-isolated slabs

The use of a resilient layer of 5mm matting below the finished sports surface had been implemented successfully in a number of education facilities. Two schools with multi-use games areas located above classrooms constructed were visited.

From testing the facilities, it was clear in both instances that noise from the court was clearly audible above background noise and even audible above low levels of activity noise in both cases. This was not acceptable in the proposed installation.

Structural performance

Structural slab

The structure of the building in this location was complex as it needed to contain a large span composite steel framed slab, designed to be constructed over an operating driveway which served the adjacent Etihad stadium.

The floor structure is typically a 150mm composite concrete slab (Bondek II Metal tray), supported at 2m centers by 900WB175 composite secondary steel beams spanning 15m.

The project structural engineers performed detailed finite element modeling on the full structure in order to assess the resonant frequency of the slabs. This work showed the resonant frequency to be 5.6Hz on the tenancy level, and 8.9Hz on the basketball court level above.

Spring selection

In order to avoid the 5.6Hz and 8.9Hz structural resonances, WSP required the natural frequency of the floating floor to be √2 or greater away from the resonances(2) under purely dead load (DL) conditions. The rationale for this was to ensure that with minimal damping the resonance of the floating slab would not induce a resonance of the two slabs. Therefore the system required a natural frequency of less than 4Hz or greater than 12.6Hz.

$$5.6/\sqrt{2}=3.96Hz \qquad (1)$$

$$8.9\times\sqrt{2}=12.58Hz \qquad (2)$$

A single degree of freedom system's natural frequency can be represented in terms of its static deflection as per equation 3. This equation is derived from the ideal single degree of freedom mechanical spring-mass-damper system, and is accurate for helical steel springs (4).

Avoiding the resonance of the basketball court level slab was considered the most important factor in the design. Additionally, a resonance of greater than 12.6Hz would limit the overall isolation that would be achieved in audible (>20Hz) frequencies. As such, it was decided that the natural frequency of the floating floor should not be greater than 4Hz.

Frequencies generated by human motion range between 1.7Hz for a slow walk up to greater than 3.2Hz for sprinting (3). A natural frequency of lower than 2Hz was not achievable within the constraints, so the floating floor was designed to have a natural frequency marginally lower than 4Hz under dead load conditions, which required precision in spring selection and load calculations.

The calculations determined that the system required isolation mounts to be used with a minimum deflection of 15.5mm.

$$d=g/(2\pi f_0)^2 \qquad (3)$$

Where g= 9.81 m/s2 and $f_0 = 4$.

Whilst the structure was required to support a live load (LL) of 5 kPa from a safety aspect, under normal use as a sports court this load equates to approximately six 80 kg people standing in each square metre, which is an unlikely scenario. Achieving this LL condition provided practicality issues with the requirement for a spring to provide the minimum deflection under DL and support DL + LL within the constrained space. For this reason, the upper bound of design load was reduced to DL plus a third of LL as a more realistic loading for normal use. Under this condition, at the full LL the springs would bottom out, which would cause an increase in the transmission of vibration but would not damage the springs, or the structural integrity of the slab. This was considered an acceptable compromise in order to achieve the acoustic requirements under realistic operating conditions.

For selection, springs needed to deflect at least 15.5mm under dead load without bottoming out under an additional third of live load. The calculated deflections can be viewed in Table 1.

Spring Type	DL	DL + 1/3LL	DL + 5kPa
85mm Diameter Spring	16.7	27.6	Bottomed out

Table 1. Calculation spring deflection (mm) of a typical spring located inside the court's playing area.

Concrete slab design

Standard AS3600 table 4.10.3.2(5) states that the reinforcement in the slab within 50km from the sea requires 40mm coverage. This resulted in a minimum concrete slab thickness of 100mm so that the reinforcement is adequately covered on top and underneath. The air cavity itself has an important role in vibration isolation, so it was logical to use a 50mm air cavity with a 100mm thick slab. This also allows for the full travel of the springs to be used so that the springs will compress to solid before the floating slab touches the structural slab.

The court slab was constrained around its perimeter by a 150mm high concrete hob, and was sealed with 20mm thick closed cell

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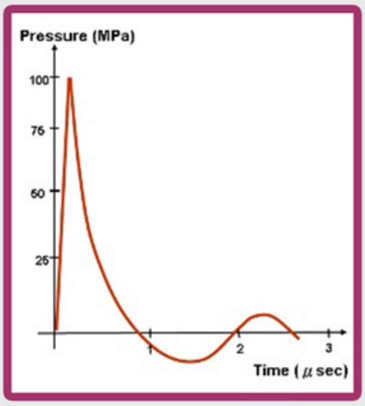
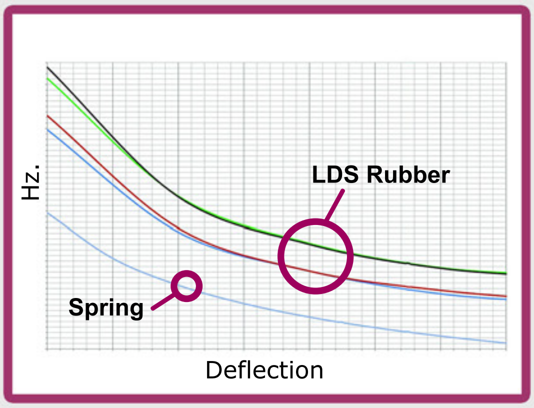
Engineering for Impact Noise
Engineered by Mason

It can be challenging to install gymnasia within existing buildings. The most effective solution is to construct a high mass concrete floating floor, isolated with high deflection springs. This is the only viable option to prevent impact energy from reaching the structure, as with this project in Westfield Stratford for free weights up to 300kg. The existing floor could not accept the weight of this, so we worked with the structural engineer to add steel beams, which reinforced and stiffened the existing structure.

Construction phases of a spring floating floor



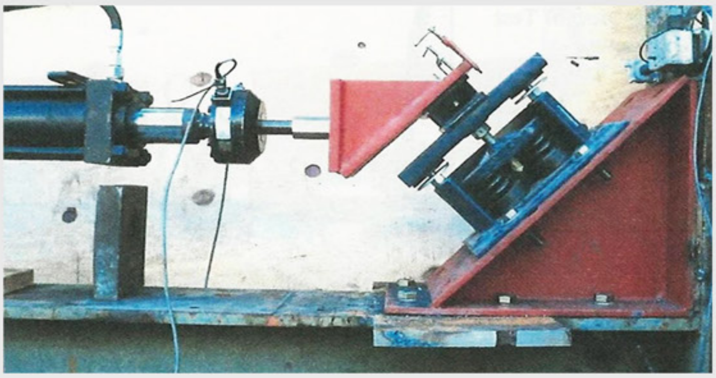
Shock Pulse



LDS / Spring Dynamic Stiffness Curves

Rubber or foam is not effective against shock pulses. Such layers can absorb the higher frequencies but are too dynamically stiff to react and absorb the problematic lower frequencies. These pass through and can easily travel throughout the building. Springs react virtually instantly, allowing each coil to absorb energy –the physical displacement of the shock pulse needs to be absorbed. The higher the deflection spring the more effective coils are available and the lower the frequencies which will be absorbed.

Mason UK regularly test our elastomers and other products in independent laboratories. As part of the Mason Industries group, We also have access to extensive testing facilities. As well as taking responsibility for our own design and engineering, we often have to fabricate bespoke solutions, some of which require very specific testing and certification. Whether a standard solution or a problem never tackled before, Mason UK can help.



Spring Mount testing

About Mason

A world leader in noise & vibration control products for over fifty years setting the standard for consultants & architects. In addition to a complete range of mounts, our floating floors, walls & suspended ceilings provide total acoustic isolation

Typical Applications:

• Music Rooms • Night Clubs • Plant Rooms • Recording Studios • Bowling Alleys • Building Isolation • Cinemas • Gymnasia • Microscopes • M+E Isolation • Suspended Ceilings • Industrial

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polyethylene foam to prevent rigid contact between the slab and the hob which would cause bridging. The edges were also sealed with flexible sealant to prevent water ingress under the floating slab.

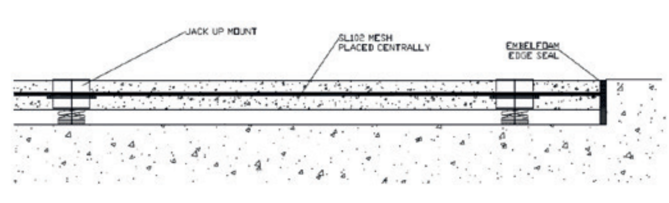

Figure 1. Section drawing of the court slab design.

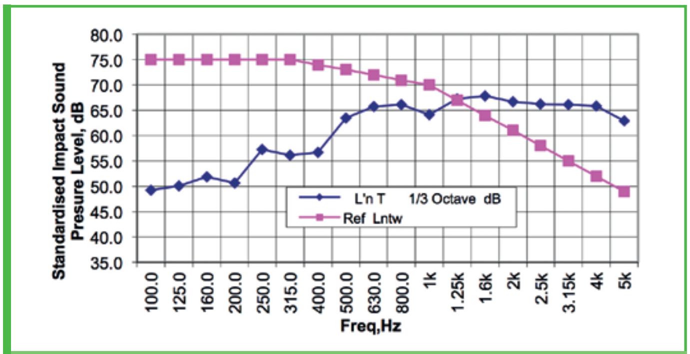

Figure 4. $L_{nT,w}$ measurement on the 150mm structural slab, in dB shown in 1/3 third octave intervals.

Basketball, netball and tennis post isolation

The posts for the basketball hoop were to be supported on hobs that were not on the floating floor. It was important that these were isolated from the structural slab while not allowing too much movement in the post as any movement would be amplified at the hoop due to the distance from the base.

It was decided to use pads underneath the base of the post with rubber washers located above so that there were resilient elements restraining the post in all directions. To separate the anchor and the base plate a rubber sleeve was also incorporated. This prevented direct contact between the post and any rigid connection to the structure.

The netball and tennis posts were placed in sockets that were recessed into the structural slab. The posts were separated from the floating slab by creating a larger penetration through the floating slab so that the posts could never come in contact and bridge the isolation. The penetrations were capped to resist the ingress of water and sealed around the perimeter with foam.

Figure 2. Basketball post isolation.

Installation

The structural slab was greater than 30mm out of level. To ensure a degree of consistency in the level of the base of the springs, the mounts were packed underneath to allow for the floating slab to be poured flat. Packers were placed in the correct position and a chamfer was created around them to allow for the floating slab to easily separate from the packer when it was jacked up. The variety of height of the packers used over the floor affected the amount of concrete being supported by each mount substantially. The result of this was that each mounting point had to be carefully recalculated to provide an even deflection over the whole area of the court. Installation of the court system did not encounter any major setbacks or delays.

Figure 3. Typical packing under jack-up mounts.

Performance analysis

ISO10140-1:2010 Impact Noise Testing Results

Field impact testing was performed on the 150mm bare structural slab prior to construction of the floating slab. Impact testing in accordance with ISO10140-1(6) offers a standardised $L_{nT,w}$ dB rating for the floor. This will provide a numerical value detailing the improvement over the bare slab floor. The test was conducted using a Brüel & Kjær 3207 tapping machine with a Svantek 958A analyser. 4 tapping machine positions were used with 5 microphone positions for a total of 20 measurements as well as background noise testing and reverberation time.

These measurements gave an $L_{nT,w}$ 73dB and an FIIC 15dB. Testing was then repeated once the floating slab was poured and jacked up. ISO10140-1:2010 specifies that all measured values must be at least 6dB higher than background noise and preferably 10dB above. From the test results, the largest variation was 3.5dB above background noise, so providing an in-depth analysis and graph of these values would not provide any benefit. Testing was performed at night after peak traffic times to minimise the background noise, however at the time of writing this paper the court was above an unfinished building site. While graphing the results will not give an accurate account of the performance, it will provide minimum values of performance. The measured values were $L_{nT,w}$ 37dB and FIIC 69dB.

Further tests were performed on the hobs around the perimeter to provide an indication of the improvement of the floating slab as opposed to a solid concrete slab 300mm thick. The single value results were $L_{nT,w}$ 59dB and FIIC 46dB so the floating slab offered a substantial improvement.

Additionally, the unfinished retail space from which measurements were taken was a concrete room larger in area than the court itself with an unfinished ceiling, and glazed door sets which were not sealed. Combined with a lower background noise, it would be expected that the finished space would measure significantly improved values than those shown above.

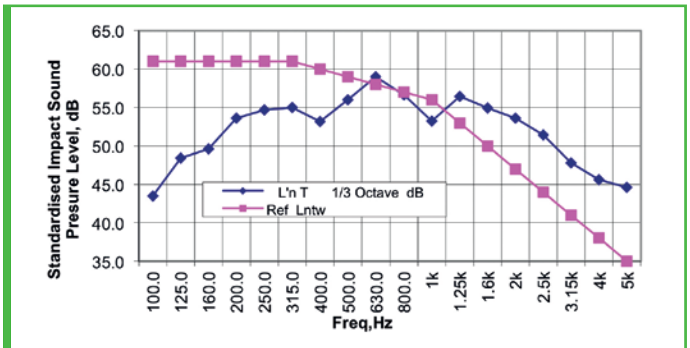

Figure 5. $L_{nT,w}$ measurement on the 150mm hob, sitting on the structural slab, in dB shown in 1/3 octave intervals.

Typical activity noise levels

To test the expected noise levels from court activities, an informal basketball game was played on the floating slab with L_{Aeq} and L_{Amax} measurements taken in the space below. Measurements were taken over a 15 minute period during a weekday morning, with background noise registering an L_{Aeq} of 37.2dB. The results from the testing can be viewed in Figure 7. The L_{Amax} circled in red are from impacts of the ball on the un-isolated position for the basketball backboard. Discounting these spikes, the L_{Amax} peaked just past 46dB. See Figure 6.

In order to further examine the sound insulation performance and noise mitigation of the floor system a number of scenarios were investigated. The focus of the testing was to obtain L_{Amax} for a number of simulation controlled basketball events that are likely to occur on the court. The three regular activities deemed likely to generate the greatest noise from on court activities were ball

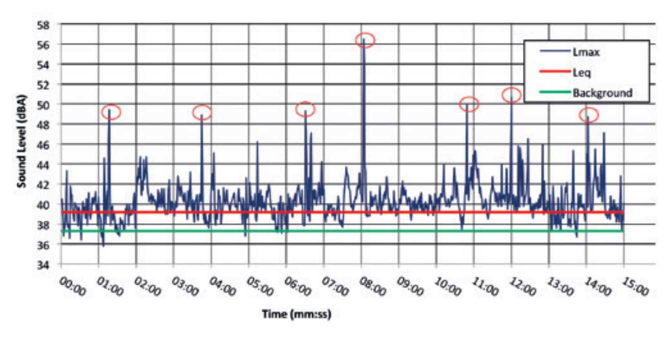

Figure 6. Measurements of sound levels (dBA) during typical court activity, including bouncing ball, running, passing and occasional shooting.

bouncing, jumping and shooting.

The results (as shown in Figures 7-9 and summarised in Table 2) indicated the following:

- For bouncing the ball on the court surface, the noise levels although perceptible were similar in value to external noise sources such as the flag poles. The characteristic and change in tone was noticeable above the typical external noise sources.
- Jumping and shooting created peaks in reading of the L_{AMax} that exceeded the typical background readings.
- There was a noticeable difference between the shooting with the hoop fixed back on the holding pole compared to when unhooked and in game position. The noise levels were higher in value and the event would last longer.
- The noise levels measured due to shooting would also be dependent on the outcome of the shot such as whether it hit the backboard or rim, force of the thrower, etc. To simulate this, the shooting style was varied with each attempt. P34

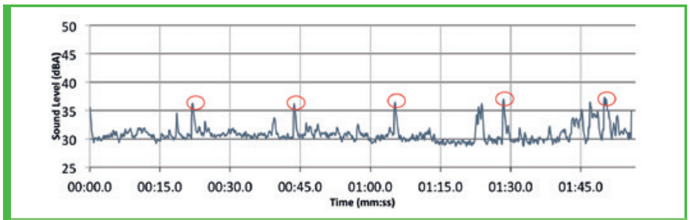

Figure 7. Measurements of sound levels (dBA) in the retail space during ball bouncing.

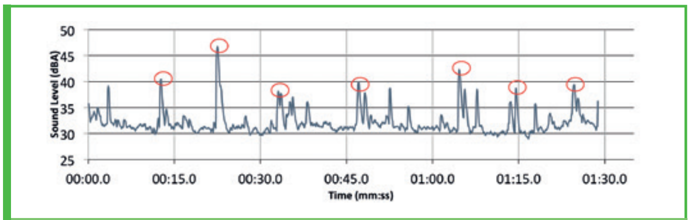

Figure 8. Measurements of sound levels (dBA) in the retail space during jumping.

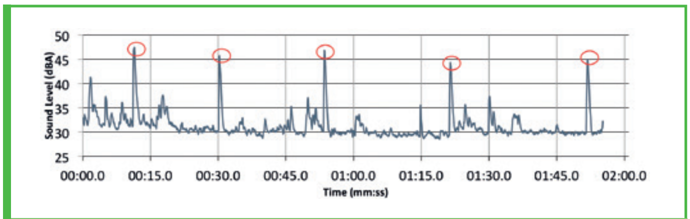

Figure 9. Measurements of sound levels (dBA) in the retail space during shooting with the hoop in game position.

Sound Level (dB)	Ball Bounce	Jump	Shooting-Hoop fixed off court	Shooting- Hoop in position	No activity
Average	37	46	49	41	32
Max	37	47	52	47	39

Table 2: L_{Amax} in dB for controlled events and typical noise levels

◂ P33

The main outcome from the testing was that all measured results were within 7 dB of the maximum target for the L_{Amax}. It is expected that the installation of the plasterboard ceiling in the commercial space will reduce peak noise levels in the space from basketball court activity by approximately 10-15 dB. The inclusion of mechanical services to the space will also create a steady masking noise level at circa 35-40 dB.

Conclusions

This paper has presented a spring mounted floating court system which provides effective noise and vibration isolation whilst meeting strict design constraints. The finished floating court system provided a substantial improvement over the performance of the structural slab with an $L_{nT,w}$ improvement of at least 36dB. Specific noise testing of typical on court activities resulted in a maximum L_{Amax} of 47dB. With a future ceiling to be installed, it is fully expected that this value will be reduced to below the established target criteria of < 40 dBA L_{Amax}. With the inclusion of mechanical services in the tenancies, the noise levels in the commercial space generated by a basketball game above may be inaudible and in any case are unlikely to be distracting or disturbing.

Acknowledgements

We would like to thank Brookfield Multiplex and CBUS for assisting with site testing and the permission to publish this paper. This paper could not have been prepared without the assistance of Johan Scheuer (Acoustics) and Matt Stapleton (Structures) of WSP Group.

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Environmental noise monitoring at Glastonbury Festival

By Mark Dowie (Brüel and Kjaer), Keith Horton and Graham Blanksby (Mendip District Council) and David Leversedge (Aria Acoustics)

The Glastonbury Festival is the largest green-field music festival in Europe, as illustrated by a few facts:

- 11km (almost 7 miles) perimeter fence
- 203, 000 maximum number of adults on site
- 16 "main" stages
- 67 smaller venues each with PAs >6kW plus 26 stalls and cafes each with PAs>2kW
- 06:00 closing time for some stages
- 08:00 Wednesday the gates open and the site cleared of public by 17:00 the following Monday.

The festival takes place in rural Somerset, where background sound levels are around 35dB by day and at night often around 25dB.

Each year, enclosed with the Christmas card to Mendip Council (MDC), Glastonbury Festival (GF) includes the first draft of the Event Management Plan (EMP), which includes a Noise Management Plan (NMP) for the following year's festival. The NMP is based on the previous year's plan, but amended to take account of any changes, experience of the previous festival, complaints and the formal debrief. There are sections which deal with communications, personnel, licence conditions, classification and hours of stages/venues, propagation tests, car parks, camping, unauthorised systems, the auditing of authorised systems, fireworks and pyrotechnic effects on the stages.

The premises licence runs from 2014 to 2024 and has nine noise conditions, the key ones being (not verbatim):

- the inclusion of an NMP in the EMP
- a numerical limit at up to four locations during the main stage times
- a subjective "limit" for music noise outside the above periods.

The numerical music noise limit is an $L_{Aeq,15min}$, free field of 60dB, until 18:00, then 65dB until 00:00 and then 57dB until 00:30 (23:30 and 00:00 on Sunday night). Controlled sound propagation tests, using white or pink noise take place from noon on Thursday until 16:00 when full tests with music at the show levels can start and run until 20:30 or extended to 21:30 with consent of the licensing authority.

The standard used for the night time noise has often exercised both teams' minds; considering simply "*inaudible*" and then "*not audible and discernible above the general site hubbub*". The latter was used for several years but MDC felt that the condition could mislead the public by implying that the music noise would not be audible at all. This could raise unachievable expectations, given the size of the site and the extensive late night activities. So, for the last two years the present standard of "*no music noise...shall be distinct above the general hubbub of all activities on the site and identified as coming from one or more distinct sources on site when assessed in a 'free field' location adjacent to any noise sensitive premises*" has been used successfully. Initially MDC's legal advisors were unclear on the enforceability of that condition but concluded that the enforceability will be ascertained by the professional interpretation of the standard.

A good working relationship has been developed between MDC and Aria over several years who share two objectives:

1. Compliance with licence conditions without recourse to legal action
2. Reducing the likelihood of a review by authorised persons.

Experience has proved that it has not been difficult to agree on ▸

the interpretation of the subjective condition which the authors believe is a credit to the professionalism of the "game keepers" and "poachers" both trying to achieve the same objective. It is a shame, in some respects, that a numerical value cannot be used in order to protect residents but it is difficult to see how this could protect against an intrusive bass. There are numerous generators on site, many producing low frequency noise, so the choice of parameter would be interesting, L_{eq}, L_{90}, L_{10} and what frequency, what level, internal or external and over what time period one, five or 15minutes?

The monitoring for compliance (or otherwise) with the noise conditions is carried out by a team of 20 noise consultants and three admin staff working for Aria. MDC and Aria jointly fund up to four static sound level meters, with some help from Brüel & Kjær (B&K), to check the off-site levels and compare with licence conditions. MDC then have a team (comprising highly experienced or qualified volunteers and staff) auditing Aria's work, responding to complaints and monitoring the sound level meters. Following long and helpful discussions between MDC and B&K, since 2013 three B&K 2250s were used each with the 1404 outdoor microphone system, a 3g router, 75AH lead acid leisure battery and waterproof case. 2014 saw the addition of a Barix Audio Streamer, connected to the most remote 2250, which streamed real time audio via the internet. The routers each have a fixed IP address and can be accessed via the internet and the meters can be controlled via a password protected web page. MDC and Aria monitor in their control rooms or via mobiles when out and about and Aria also monitor at front of house. For the past two years the boosted mobile phone network has provided very good coverage most of the time (better than normal!)

Additionally, last year B&K loaned a Noise Sentinel system which was configured to provide early warning of any possible exceedances and to provide real time online sound levels, with live audio and weather conditions at the measurement location. Five different alert levels were set-up to allow for the varying site limits and conditions throughout each day of the festival. Each of these alert levels used a 15 minute L_{Aeq} which updated every five minutes. For each alert level there was warning at 3dB below the site limit. Every time a warning or alert level was exceeded an email was sent to MDC officers and Aria consultants. The system also made a recording of the loudest period of the exceedance which then became available to listen to on the Noise Sentinel web interface.

There were several warning levels and exceedances during the festival. As audio samples of these were available almost instantly on the web interface MDC and Aria could quickly determine if the sound was from the festival or from unrelated sources. This meant that if there was an issue they could identify which stage was the source and react before a licence condition was breached. If the noise was unrelated then the event could be ignored preventing any unnecessary interference with the festival. The audio showed that the alerts and exceedances (with the exception of one) were not due to the festival but a range of sounds including dog barking, neighbours chatting near the microphone, lawn mowing and most notably the thunder storm that cut the power to the site on Friday afternoon. Sentinel only picked up one music related warning

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The festival is subject to strict noise controls

Emily Taner / Shutterstock.com

◀ P35

which was the Pyramid stage but there was also very heavy rainfall at the time which contributed to the noise level and no further action was necessary by either Aria or MDC.

When the storm knocked out the power and mobile phone transmitters the Sentinel monitor continued to store data which was uploaded as soon as the power came back on.

In figure 1 you can see the level increase as one act came to the grand climax of the set and the levels drop back down to show the general site noise before the headline act.

In addition to the monitoring etc, GF also has a drop in office in the village to receive and respond to complaints directly (in person, e-mail or phone) and undertake significant local liaison in the lead up, to as well as debrief sessions after, the festival.

The most common reasons for new complainants making contact appear to be:

"It is louder than last year"
"I have not heard it before"
"If I can hear it here it must be far too loud".

As is often the case with regular outdoor events there are a small number of familiar complainants. Complaints are usually made during the festival to the village office and dealt with by both GF and MDC, with MDC overseeing the response. MDC usually receives only two or three more after the festival. Most complainants are quite reasonable and some are more enquiries than substantive complaints. It is not uncommon to receive calls from around 12 km from the Pyramid Stage in particular meteorological conditions and although none have been a public nuisance nor a breach of the licence conditions.

As has been said many times, inevitably, the festival does have a range of impacts upon the local community, including noise. The elevation of the ambient and background noise levels due to vehicle movements, people and generators undoubtedly helps to mask the intrusion of the music noise from the late night venues. Meteorological conditions (wind speed, direction, inversions etc.) make an enormous difference to the noise impacts; especially after sunset and into the early hours. The stage noise is pretty well controlled due to diligence of Aria & GF's consultants and the co-operation of the professional sound engineers; but there can be the occasional one whose individual actions may threaten the licence and sadly, that responsibility is not always recognised. The night time noise impact control is always very intensive and for 2015 new ways are being considered to make it easier, including more front of house monitoring and propagation testing during late evening gaps in the main stage performances.

In conclusion there is good noise management by Aria/GF, auditing, etc by MDC and the significant public relations exercise undertaken by GF. Consequently, although there are occasional "professional moments" the Premises Licence Holder and the responsible authority probably get the balance right in terms of the objective of the prevention of public nuisance, balancing the desires of the authorised persons and the festival goers.

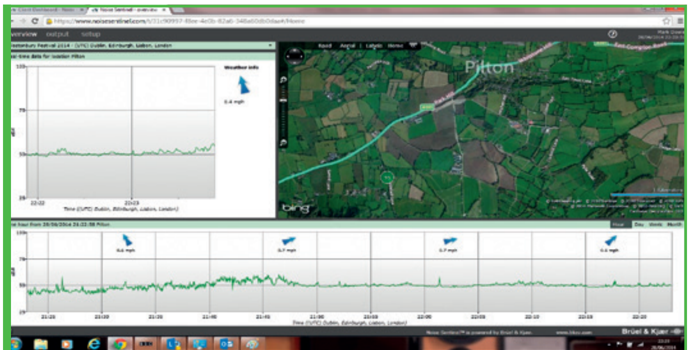

Figure 1.

Year	Total complaints (households)	Night	Day
2010	30 (14)	18	12
2011	34 (20)	18	16
2012	Fallow year		
2013	6(6)	2	4
2014	16(14)	12	4

Table 1. Music noise complaints for the last four festivals.

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What is the Background Sound Level?

By Richard Collman

Unless this term is used loosely to mean the Residual Sound Level, the Background Sound Level (BSL, formerly Background Noise Level or BNL) is generally taken to be the $L_{A90,T}$ i.e. the level exceeded for 90% of the time. The $L_{A90,T}$ for a time period duration T is obtained by logging the $L_{A,F}$ sound level at least 10 times per second to the nearest 0.5dB (or smaller interval) throughout the time period, ordering the samples by value, and reporting the lowest 10th centile (quietest 10%) value. However the way in which the $L_{A90,T}$ is determined is not precisely defined which means that two different sound level analysers may give slightly different values of $L_{A90,T}$ for the same sound signal.

Parameters such as $L_{A90,T}$ and the logarithmic average $L_{Aeq,T}$ are constructs that have been developed to conveniently quantify sound and provide an indication of its characteristics. They are not what we actually hear. The L_{A90} provides an understanding of how quiet the ambient sound level is for an acoustic environment during (occasional) lulls in activity, particularly where the sound level varies significantly with time. For relatively steady sound levels the L_{A90} will be similar to other parameters such as the L_{Aeq}.

A longer term L_{Aeq} average level can be calculated from a group of shorter duration measurements (which need not be contiguous), using the formula:

$$L_{Aeq,T} = 10\ Log_{10} \sum_{i=1}^{n} \left(10^{\frac{L_{Aeq,Ti}}{10}} \times \frac{T_i}{T} \right)$$

However, there is no equivalent relationship for $L_{A90,T}$. Methods such as calculating the arithmetic average, or the more bizarre 10th centile (L_{A90} of the $L_{A90,T}$s) are simply additional constructs applied to the original $L_{A90,T}$ construct. The only way to establish the L_{A90} for a specific time interval is to calculate the 10^{th} centile level for that complete dataset.

In the past there has often been a mistaken belief that the BSL is a specific and precise value rather than being "representative" or, more appropriately in many cases, a range of values. The new 2014 edition of BS4142 explicitly states that the BSL should be "representative" and provides examples of what this may mean. There are two aspects to this. One is what constitutes a representative value or range for the measurement data obtained? The other is what is representative at other times/ under different conditions than when measured?

In order to better understand the latter of these, it may be appropriate to take further measurements, although it will never be practicable to gather sufficient data to properly characterize the BSL for all relevant times and conditions, particularly for multiple receptor locations. It will therefore be necessary to understand how the BSL (and usually other characteristics of the residual acoustic environment) may be affected by factors such as weather conditions, time of day, seasonal variations, etc. Clearly this will not produce precise numerical values, let alone a reliable associated probability of likelihood, which is neither realistic nor appropriate in this context. However, all is not lost, particularly when considering the effects of uncertainty in the BSL for a BS4142:2014 assessment. In this case the aim is not to quantify the uncertainty, but to assess its likely impact on the significance of the outcome, which requires considered thought rather than mechanistic number crunching.

Properly understanding the data that has been obtained is fundamental to the first aspect above i.e. what constitutes a representative value or range for the measurement data? This in turn requires an awareness of any shortcomings in the data or how it is being analysed, which brings us back to the previous discussion about how $L_{A90,T}$ values are derived for a measurement period.

Whilst the difference in value of L_{A90} between different implementations is negligible, there can be a significant difference in the value of $L_{A90,T}$ for a measurement period that is longer than T, depending solely upon when the sample period T starts and stops within the longer measurement period. For an extended measurement period the $L_{A90,T}$ is often shown as a series of values, with each corresponding to consecutive periods of duration T, from the start of the measurement series.

Table 1 shows twelve $L_{A90,5min}$ and four $L_{A90,15min}$ values using fixed consecutive sampling periods for an illustrative dataset covering a 1 hour period. This shows that, as would be expected, the range of variation of L_{A90} values reduces as the sample period T increases. For the $L_{A90,5min}$ values the range is 28dBA to 47dBA, whereas it is only 28dBA to 39dBA for the $L_{A90,15min}$ values.

Start	$L_{A90,5min}$	$L_{A90,15min}$
23:00:00	41	28
23:05:00	28	
23:10:00	28	
23:15:00	31	39
23:20:00	47	
23:25:00	44	
23:30:00	39	30
23:35:00	30	
23:40:00	28	
23:45:00	36	37
23:50:00	43	
23:55:00	36	

Table 1

Graph 1 shows these values together with the illustrative data from which they are derived. The L_{A90} values are shown as horizontal lines covering the period to which they apply. It also shows the rolling $L_{A90,15min}$ values and, although not of any direct significance to this article, also the rolling $L_{Aeq,15min}$ values for comparative purposes. In this example each of the rolling average values is shown centred in the 15 minute time period from which it is derived i.e. it corresponds to the period commencing 7½ minutes before the time when the value is shown to 7½ minutes after .

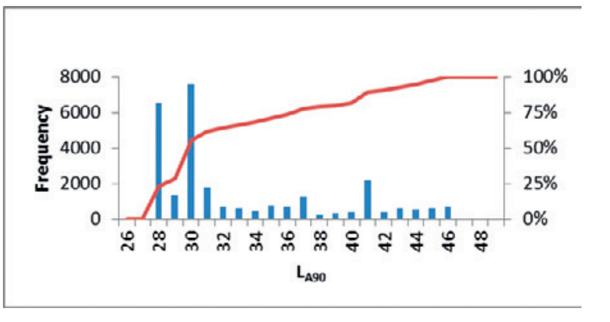
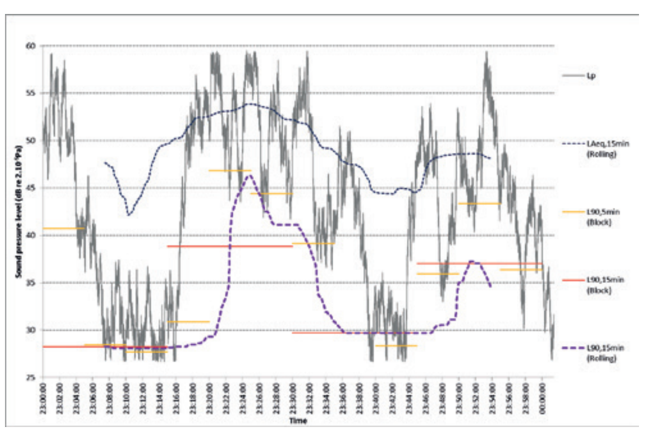


Chart 1



Graph 1. Example ambient and statistical sound levels

This means that the rolling $L_{A90,15min}$ value in the middle of each fixed 15 minute period refers to the same dataset and is therefore the same value as the fixed period $L_{A90,15min}$ which it bisects. The rolling values could however be shown differently such as at the start or end of their measurement period for example, although centring the rolling values helps to clarify relationships between the source data and derived parameters.

A histogram can also be used to show the distribution of LA90 values and may assist in identifying what constitutes a 'representative' value or range. For a measurement period P and sampling rate of S times per second, the number of different data points for LA90,T (T is the reference time in minutes) within that period is given by:

$$(P-T)\times 60\times S$$

For example the rolling $L_{A90,15min}$ for a 1 hour measurement period sampled ten times per second such as that shown in Graph 1 gives 27,000 data points. Chart 1 provides a histogram for this data.

Graph 1 and Chart 1 show that for approximately thirty minutes (65% of the time) the $L_{A90,15min}$ was around 30dBA or slightly lower. For most of the remaining fifteen minutes it was above 35dBA, and above 40dBA for nearly 10 minutes (approximately 20% of the time). Taking the four $L_{A90,15min}$ values derived from consecutive blocks of data gives two values of 28dBA and 30dBA and two of 37dBA and 39dBA, without any further indication of how the BSL varied throughout the measurement period. The $L_{A90,5min}$ values more closely follow the $L_{A90,15min}$ rolling values but because of the shorter sampling period they are more volatile, for example rising to 43dBA at 23:52 hours where the $L_{A90,15min}$ value is only 37dBA.

Table 2, Chart 2 and Graph 2 provide similar analyses for another illustrative dataset

These show that although the four fixed block $L_{A90,15min}$ values follow approximately the rolling $L_{A90,15min}$ values they indicate a range of only 28dBA to 37dBA whereas the full range of values for the dataset extends to 42dBA at 23:28 hours. The rolling $L_{A90,15min}$ is around 40dBA for more than 20% of the time, whereas one of the four fixed block values is 37dBA.

The increased level between 23:44 hours and 23:49 hours produces an $L_{A90,5min}$ of 39dBA whereas the $L_{A90,15min}$ value remains around 10dBA lower throughout this period. If the $L_{A90,5min}$ start time differed slightly it is likely that such a significant difference would not occur.

Table 3, Chart 3 and Graph 3 provide further similar data. In this case the final part of the series gives a single fixed block $L_{A90,15min}$ of 35dBA whereas the rolling curve shows that it actually varied between around 40dBA for much of the time, then falling to around 30dBA and that it was 35dBA almost none of the total period.

Graph 4 shows that the four fixed time block $L_{A90,15min}$ values are all close to 30dBA whereas on a rolling basis this rises to over 45dBA. This variation is heavily dependent upon the time when the

P40

◀ P39

sampling periods begin.

Graph 4A shows the same measurement data as Graph 4 but with $L_{A90,15min}$ values calculated for two different starting points. The red lines correspond to those on Graph 4 whereas the brown lines use a sampling period that is 9 minutes later, wrapping around the end of the measurement series to derive the fourth value. Table 4 shows this numerically, with the original range of $L_{A90,15min}$ values between 28dBA and 31dBA in the first column and the offset range of 28dBA to 45dBA in the second.

The capricious nature of the L_{A90} values illustrated above reinforces the fact that they are a construct intended to provide an indication of the characteristics of sound rather than being a precise and specific designator of the ambient sound level. Simply moving the sample time windows along the dataset can significantly alter the values obtained (by 14dB in this case).

The rolling L_{A90} shows the complete range and occurrence of all possible values and also provides an indication of the relative significance of each value within the complete measurement period. A histogram can be used to provide more specific information about the distribution if this is felt to be appropriate. Due to the large number of values involved, this type of rolling LA90 analysis is best undertaken graphically, which can also provide a good understanding of other characteristics of the changing sound level.

Richard Collman is a Director of Belair Research; soon to be renamed Acoustic Control Consultants to make better use of the synergy with their sister company Acoustical Control Engineers, of which he is Managing Director. Richard was on the drafting panel of BS4142:2014, has facilitated several IOA branch meetings on this subject and will be discussing uncertainty at the IOA conference on BS4142 on 19 May. Comments would be most welcome on this article either through Acoustics Bulletin or directly by email to: RichardAC@acoustical.co.uk

Start	$L_{A90,5min}$	$L_{A90,15min}$
23:00:00	29	28
23:05:00	28	
23:10:00	32	
23:15:00	34	37
23:20:00	39	
23:25:00	44	
23:30:00	40	31
23:35:00	29	
23:40:00	29	
23:45:00	39	29
23:50:00	28	
23:55:00	35	

Table 2

Start	$L_{A90,5min}$	$L_{A90,15min}$
23:00:00	28	29
23:05:00	30	
23:10:00	47	
23:15:00	41	37
23:20:00	36	
23:25:00	36	
23:30:00	44	40
23:35:00	39	
23:40:00	40	
23:45:00	41	35
23:50:00	47	
23:55:00	29	

Table 3

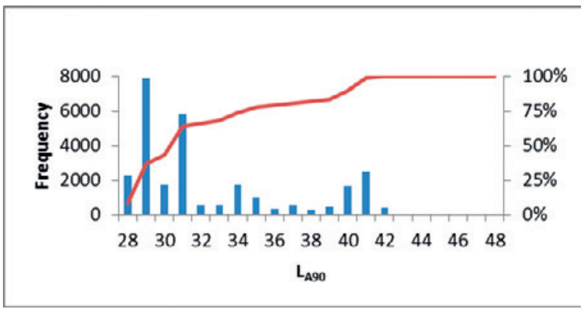


Chart 2

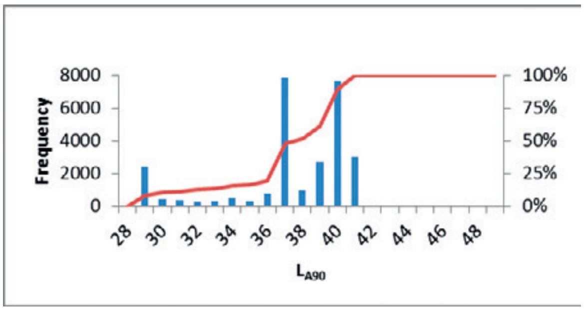
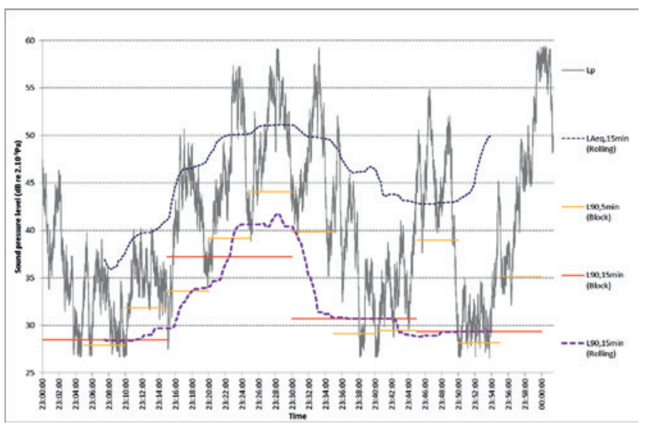
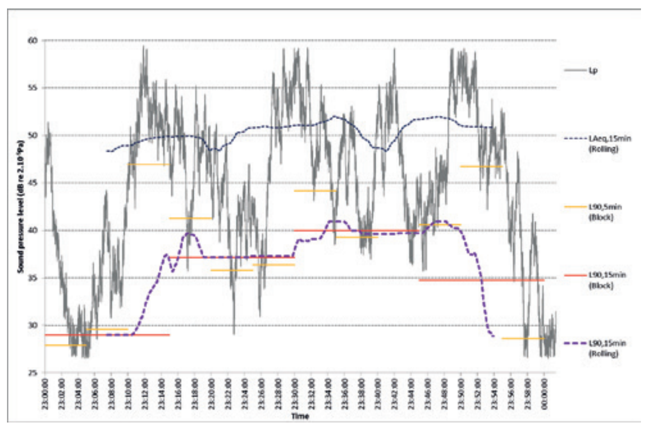


Chart 3



Graph 2. Example ambient and statistical sound levels



Graph 3. Example ambient and statistical sound levels

Start	$L_{A90,5min}$	$L_{A90,15min}$	$L_{A90,15min}$
23:00:00	30	28	
23:05:00	28		
23:09:00			33
23:10:00	31		
23:15:00	40	31	
23:20:00	33		
23:24:00			28
23:25:00	28		
23:30:00	28	29	
23:35:00	29		
23:39:00			45
23:40:00	45		
23:45:00	51	29	
23:50:00	35		
23:54:00			28
23:55:00	28		

Table 4

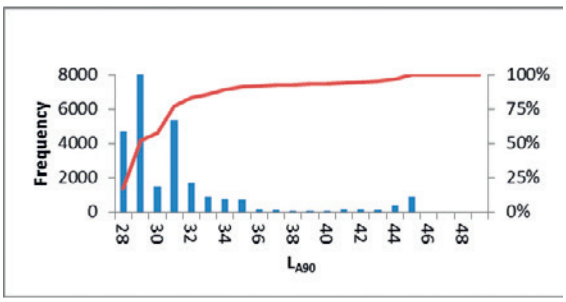
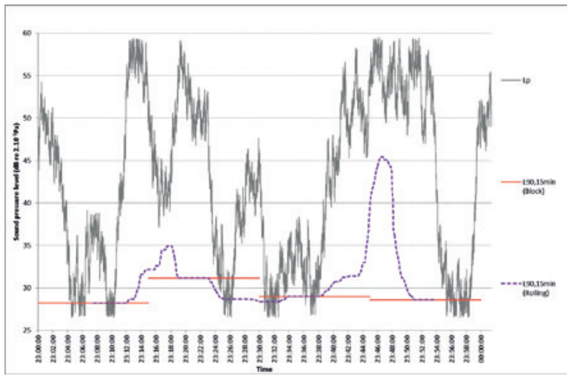
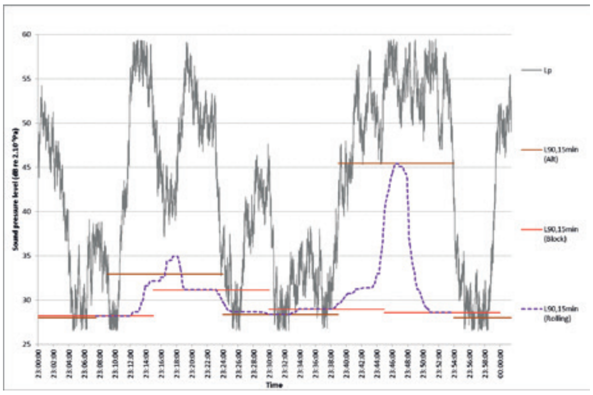


Chart 4



Graph 4. Example ambient and statistical sound levels



Graph 4a. Example ambient and statistical sound levels

Enhanced low frequency sound calibration strategies for cinemas

By Dr Adam J Hill

It's probably fair to say that the average cinemagoer doesn't view his or her choice of seat as critical to the listening experience of a film. Sure, there's the so-called sweet spot (centre, two-thirds of the room length back from the screen) but most people aren't likely to think that the person sitting next to them may be hearing something very different. As it turns out, this is verifiable fact in cinemas.

Acoustics consultant Philip Newell presented these surprising findings at the IOA's conference on Reproduced Sound in Birmingham last November, highlighting that in the low frequency band (below 120 Hz) there is significant seat-to-seat spatial variance in frequency response[1]. Philip stressed that an improved approach to low frequency sound reproduction was essential to ensure a consistent listening experience in cinemas and dubbing theatres.

Malcolm Hawksford, (Emeritus Professor, School of Computer Science and Electronics Engineering at the University of Essex) and I were in the audience for this presentation and immediately recognised the opportunity to help the cinema industry by developing some enhanced low frequency calibration options for the cinema industry to consider when reviewing their standards. In the days following the conference, Philip contacted us asking if we'd like to do some work on this to present at the AES's International Conference on *The Future of Audio Entertainment Technology*. With the paper deadline fast approaching, we quickly set to work.

Upon review of the current Society of Motion Picture and Television Engineers (SMPTE) standards[2] and recommendations[3], as well as other published research, we noticed that the issue of room modes was regularly highlighted as the key issue in the low frequency band.

So are room-modes the primary instigator of high-spatial variance across an audience?

The Schroeder frequency (upper limit of the modal band–where room-modes are perceptible) is around 35 Hz in both modelled venues (a large commercial cinema and a standard dubbing theatre). As this is the very bottom end of the low frequency band, we can't consider room-modes the primary issue here. It's more likely that comb-filtering between direct sound from loudspeakers and early reflections is the root of the problem.

Before developing our own recommendations, we analysed current practices in low frequency sound calibration in cinemas. We looked at two common approaches: single-measurement equalisation and spatially averaged measurement equalisation.

In both cases we found absolutely no reduction in spatial variance across the seating areas. Yes, the overall response may be "flatter", but the audience still receives equally dissimilar responses in the low frequency band because equalisation can't correct for comb-filtering; it is an effect stemming from the system's physical configuration and the coherence between loudspeaker signals/early reflections. In addition, previously published work highlights that local technicians demonstrate high-variability in system calibration and maintenance, resulting in inconsistent system performance from cinema to cinema[4]. A new approach is clearly required.

We identified two strategies as potential candidates for low frequency sound calibration: an optimisation strategy (many options exist) and diffuse signal processing (DiSP).

Optimisation strategies are well-known. They typically involve a number of measurements over a listening area, used to generate a set of filters that accurately calibrate the system to defined targets. The modelled venues benefitted from up to 60% reduction in spatial variance after optimisation, allowing for consistent listening experiences across all seats. This approach requires numerous measurements and accurate system maintenance (by a local technician).

The DiSP approach is less well-known. This strategy has been adapted from Malcolm's work focused on the optimisation of distributed mode loudspeakers (DMLs)[5]. DiSP uses an initial impulse followed by a rapid envelop decay (noise-like in nature) which is convolved with the source signal. The decay is frequency dependent to avoid perceptual coloration of the signal and each loudspeaker has a different temporally diffuse impulse applied. The result is inter-channel signal decorrelation, thus reducing comb-filtering, thus lowering spatial variance. The modelled venues showed up to 40% reduction in spatial variance. The clear advantage here is that DiSP requires no onsite calibration or maintenance.

The costs and benefits of a calibration strategy must be weighed before choosing a suitable option. Do we select an optimisation strategy (along with its often demanding calibration measurements and maintenance) to achieve significant spatial variance reduction or instead go with DiSP (requiring no calibration) to achieve moderate spatial variance reduction?

Based on our research, we developed a set of recommendations to those formulating the new set of standards on cinema sound:

1. Use spatial variance (or a similar metric) to judge a calibration system's effectiveness
2. Use all available loudspeakers for low frequency sound reproduction to maximise the available degrees of freedom for calibration
3. Select an appropriate and effective calibration strategy:
   - **Optimisation strategies:** significant spatial variance reduction, but calibration/maintenance is required
   - **Diffuse signal processing:** moderate spatial variance reduction and no calibration required
4. Ensure local technicians can easily maintain the system.

We hope that our recommendations will positively affect the future of sound reproduction in cinemas, allowing listeners to receive as close to a consistent low frequency response as possible. Of course, low frequency calibration is only one of many important issues that must be addressed in the new standards, but it's an area that can be addressed quite easily with our existing knowledge/technology. There's no excuse for sticking with old and ineffective strategies. Stay tuned for your new and improved feature film!

[This article is based on the research paper "Enhanced wide-area low frequency sound reproduction in cinemas: Effective and practical alternatives to current sub-optimal calibration strategies" by Adam J. Hill, Malcolm O J Hawksford and Philip Newell. AES 57th International Conference, Hollywood, CA, CSA, 6-8 March, 2015.]

Adam Hill is a lecturer in Audio Engineering in the Department of Engineering, University of Derby, UK. He received a PhD from the University of Essex, an MSc with Distinction in Acoustics and Music Technology from the University of Edinburgh and a BSE in Electrical Engineering from Miami University. His research predominantly focuses on analysis, modelling and wide-area spatiotemporal control of low frequency sound reproduction and reinforcement. Other research has included voice coil temperature effects in loudspeakers, acoustically-based classification of coral reef health and real-time equestrian horse tracking via GPS/IMU integration. Adam also works as a live sound engineer for Gand Concert Sound and is a member of the AES, IEEE, IET and IOA.

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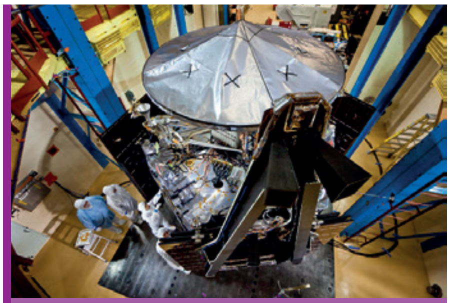
Brüel & Kjær system used for satellite testing

Aerospace giant Lockheed Martin has expanded its vibration measurement capabilities for testing satellite systems, with a 450-channel PULSE™ vibro-acoustic data acquisition system.

Supplied by Brüel & Kjær, the system is based on standard, commercial-off-the-shelf (COTS) PULSE LAN-XI Data Acquisition Hardware. The modular hardware allows individual modules to be used freely, as standalone front-ends or collectively in frame-based configurations, making it suitable for testing large structures such as satellites and spacecraft.

Further information about PULSE systems is available at: **www.bksv.com/pulse**



An example of spacecraft integration and testing

Courtesy of Lockheed Martin

Shakin' it up… at University of Warwick

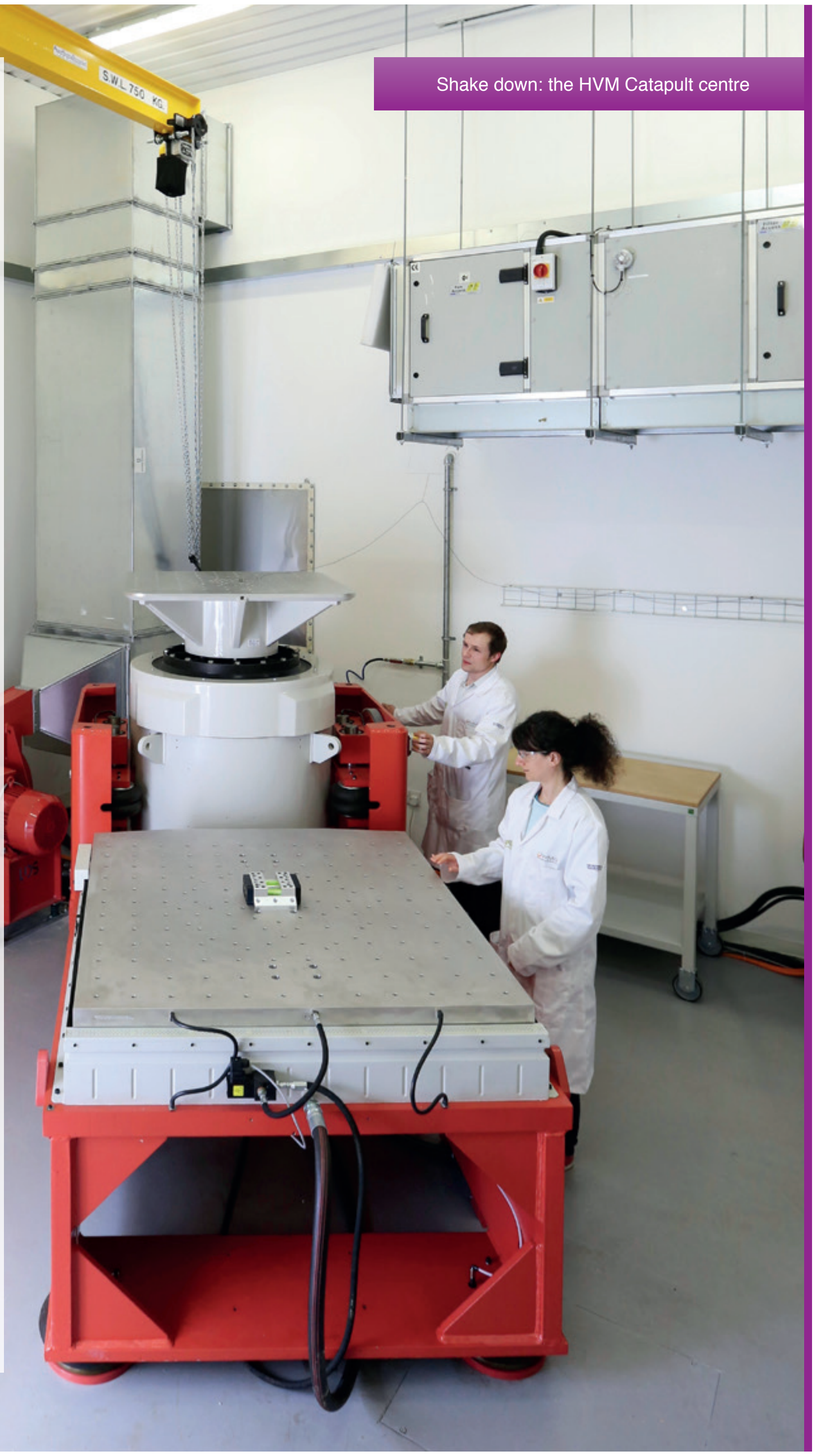
The University of Warwick (WMG) has acquired an LDS V8 combo shaker to support its government-funded research into low carbon mobility.

The V8 system enables WMG's team to carry out vibration tests on large lithium-ion battery systems (up to 600kg in weight) as they go through the cycling process (charge/discharge) at its High Value Manufacturing (HVM) Catapult centre

HVM Catapult is a government-funded programme, which encompasses research across a number of different themes – WMG's theme of "low-carbon mobility" has a specific focus on energy storage and weight reduction. As part of this programme, WMG is testing the robustness and lifespan of rechargeable battery systems.

The LDS V8 vibration test system from Brüel & Kjær combines high payload capacity with high-level performance across the frequency range, making it ideal for testing many applications, including automotive systems, packaging, satellites, air and spacecraft.

In future, WMG also hopes to add a thermal capability to the system, in order to carry out simultaneous vibration, cycling and temperature testing.



Shake down: the HVM Catapult centre

Picture courtesy of the University of Warwick

SoundLab creates the noise of an expanded Heathrow

An Arup auralisation studio is offering a simulated taste of what noise created by Heathrow would sound like if the proposed third runway is built.

The SoundLab uses the latest audio technology to accurately demonstrate changes in the level of sound, its character and its location relative to the listener.

Inside the listener sits surrounded by speakers at floor and ceiling levels, to get a 3D impression of a plane flying overhead, with images also screened.

Technicians can replay combinations of aircraft types, times of day, and both present and future scenarios, simulated in two locations: one in Hounslow 1.8 miles east of the airport perimeter, another in Richmond, nearly seven miles away, but both under the flight path of the southern runway

The SoundLab was originally created by Arup to help the acoustic design of buildings, such as concert halls. It has subsequently been used to demonstrate noise from the HS2 and now Arup has been commissioned by Heathrow to predict noise levels from an expanded airport.

Manchester branch for RBA Acoustics to serve expanding client base

Booming business in northern England and beyond has led to RBA Acoustics opening a branch in Manchester.

Director Torben Andersen said: “Over recent years we’ve worked on projects across the UK, such as Ulster Hospital in Northern Ireland, Everyman Cinema’s first northern enterprise in the Trinity Leeds complex and many of Unite’s student accommodation facilities in the main university cities. By opening an office in Manchester, it brings us closer to current and future projects to benefit our clients further.”

RBA was founded 13 years ago when Mr Anderson, Russell Richardson and Charles Bladon opened an office in south London. Within the first year of operation it was appointed on many large scale projects in the capital, which included Battersea Reach, Royal Free Hospital and the Thameslink expansion. Two years later, rapid growth resulted in a move to central London and then again four years ago to larger premises to accommodate the expanding workforce to its current headquarters in south east London.

Mr Anderson said business was still booming in London – it had recently been appointed as acoustic consultants to Mace’s Newington Butts regeneration scheme in the Elephant and Castle area of London – and so too was business outside the capital.

AcSoft becomes exclusive UK distributor for LEA Software

AcSoft has been appointed the exclusive UK distributor for LEA software by France-based Genesis S.A.

LEA software offers sound design, analysis, quality and synthesis across a wide range of industries, including automotive, aerospace, defence, rail and audio and telecommunications.

It is able to link sound to driving and flight simulators and virtual reality platforms and enables sound definition, brand sound creation, subjective and objective testing, component separation, troubleshooting and sound dataset preparation.

In welcoming the agreement, John Shelton, ACSoft Managing Director, said LEA would be of great help to existing and potential customers in aerospace, automotive and defence as well as other industrial sectors.

Patrick Boussard, CEO of Genesis, said: “This new and exciting partnership will help further build on our success in the French and Japanese automotive, aerospace, rail and defence markets.”

For more information contact Paul Rubens on **01296 682686** or **07815 087905**, email: **prubens@acsoft.co.uk** or visit **www.acsoft.co.uk**

LEA software in action

Letter

Consultants must take turbine noise effects on people seriously

I would like to respond to Geoff Leventhall’s letter (March-April 2014 issue) about a study in Australia into wind farm noise and residents’ reactions to it. I am sure there are many others who would also like to comment on his assertions.

I am in full agreement that further work is required. It is a shame that the wind industry has consistently tried to limit the amount of research done and accuse those who complain about turbine noise as being effectively mad.

It is refreshing that the wind farm operator allowed the complainants to choose their own consultant. All too often the operators and developers use their own consultants with mostly predictable results.

Leventhall mentions that Steven Cooper is a consultant used by many wind farm opponents. Does this mean he is any less qualified to carry out the work? The wind farm operator didn’t think so.

It is strange that low frequency noise was an issue when Leventhall wrote for Defra but then he decides later on in that it isn’t. WHO guidance is ignored.

He mentions that the low frequency noise is inaudible and that the low frequency noise level is too low at below 50 dB. Just because noise is inaudible does not mean it cannot be felt. Impulsive noise has been measured at wind farms up to 90 dB noise using narrowband analysis.

He also mentions that the final report by Steve Cooper claims new discoveries. What it does show is the relevance of his research and that carried out by NASA, which is often ignored by wind farm developers. He says that the latter was based on only downwind designs, but it was also based on upwind designs.

The study also discussed the necessity for considering noise inside buildings – something that has been deliberately excluded from ETSU-R-97, the new Good Practice Guide and any other “endorsed” arrangements.

And then we have the get out clause – stress-related effects which occur with a small number of persons.

I have witnessed this line used in many a planning application and planning appeal usually manifested as “people over sensitive to noise”.

This implies that there is a certain number of unreasonable persons and it’s their own fault they are affected by the noise so they should be ignored.

The vested interests of the wind industry will continue to live on until consultants start to consider these issues and those of the general public seriously.

Chas Edgington

Top Acoustical Society of America award for Ning Xiang


Ning Xiang receives his award from Judy Dubno

Ning Xiang, an IOA Fellow, has received one of the Acoustical Society of America's top awards, the Wallace Clement Sabine Medal.

He is only the 16th recipient of the award which goes to an individual of any nationality "who has furthered the knowledge of architectural acoustics". In his case it was for his contribution to measurements and analysis techniques, and numerical simulation of sound fields in coupled rooms.

In his citation, it states he is "well-known to the society and the worldwide acoustics community for his work in binaural scale-model measurements, theory and practice of maximum-length sequences and Bayesian signal processing. A consummate theoretician and experimentalist, his work reflects the growing importance of computational modelling and model-based signal processing across the broader field of acoustics, but is unique for making significant general contributions while maintaining a strong and specific focus on architectural acoustics."

Ning, who was presented with his medal by ASA President Judy Dubno, is Director, Graduate Programme in Architectural Acoustics at Rensselaer Polytechnic Institute, Troy, New York.

Matt Colman in new Audio Product Manager at TSL Products

TSL Products has appointed Matt Colman as Audio Product Manager. The role will see him championing TSL Products' range of audio monitoring solutions as well as supporting product development across the entire audio product range.

He has joined from SKY TV New Zealand where, as a Senior Audio Engineer, he led the outside broadcasts live sound team as well as working on post-production projects and providing expert guidance on multi-channel issues across various projects.

He previously spent six years at Dolby Laboratories in the UK and UAE in various broadcast engineering roles, supporting events, such as the 2011 Rugby World Cup and the 2010 FIFA World Cup. He also managed numerous technical projects: he was the lead engineer responsible for the first on-air Dolby Digital Plus channels in Spain, Serbia and the Middle East, and received an Emmy Award for his contribution to the development of the DP600 Program Optimizer.

Echo Barrier strengthens its head office team

New appointments (left to right): Richard Hedges, Sharon Butcher and Chris Long

Noise reduction specialist Echo Barrier has made three new appointments to its Sudbury head office team.

Chris Long is the new Operations Co-ordinator, overseeing barrier orders and managing stock levels.

Web developer Richard Hedges will oversee all website maintenance and builds, looking after sites for all UK operations and for the company's growing number of overseas offices.

Sharon Butcher has been appointed. Accounts Manager. She will work closely with Dave Lindsay, General Manager, to process all invoices and payments and keep the accounts up to date.

Echo Barrier has recently expanded, opening offices in Australia, the US, Abu Dhabi and several in Europe.

Success in 2014 was boosted by orders from some of the industry's biggest contractors including Balfour Beatty, which has used its Echo H series of noise reduction barriers on the London Underground station refurbishment programme and track upgrade project.

Colin Cobbing joins Arup's acoustics team as Director


Colin Cobbing

Colin Cobbing has joined Arup's UK acoustics business as Director from ARM Acoustics.

An authority on transport noise and vibration, he has more than 25 years' experience in planning and delivering major infrastructure projects. He has been the Noise and Vibration Manager at Crossrail and Thameslink and has had prominent consultancy roles on major projects such as HS2.

Colin is also known for his leading work in the acoustics industry, as principal author of British Standards, author of industry good practice guidance, and an active member, speaker and author for the Institute of Acoustics, Chartered Institute of Environmental Health and Association of Noise Consultants.

Chris Field leads Cundall's new acoustics team in Australia


Dr Chris Field

International multi-disciplinary consultancy Cundall has appointed Dr Chris Field to lead its new acoustics discipline in Australia.

Chris has worked a wide range of projects in Australia and across the globe. He is an award winning inventor, winning the Australian Acoustical Society 2004 excellence in acoustics award and the 2004 Invention of the Year on the ABC's *New Inventors* TV programme for his innovative passive noise control ventilator.

Andrew Parkin, Global Head of Acoustics, Cundall, said: "Chris's appointment is an important addition to Cundall, bringing a new dimension to the acoustics team and significantly enhancing our global reach. His vast experience and innovative approach to acoustic design will be a great asset.

"Cundall has been delivering acoustics since 2010; it is an exciting time to expand into the Australian market and was the logical next step in our expansion"

Board changes at TMAT following Blachford Acoustics acquisition

New board: (left to right) Jason Lippitt, Greg Smith and Laura Bawden

TMAT, the industrial and agricultural vehicles acoustic components manufacturer, has appointed a new board following its purchase by Blachford Acoustics Group.

Jason Lippitt, who remains as Managing Director, has been joined on the board by Financial Director Laura Bawden and Sales Director Greg Smith.

Laura, who joined TMAT in 2006, will lead on strategic direction, management and performance of the finance, IT and HR functions.

Greg, who joined in 2011, is responsible for sales and marketing. He will focus on "building a cohesive and talented commercial team with the skills and attitude to double TMAT's revenue".

Blachford bought TMAT in December 2014. TMAT continues to manufacture products at its headquarters in Chesterfield and now has access to Blachford's R&D laboratory and testing facilities in Canada.

Obituary

Per V Brüel (1915-2015): acoustics pioneer and founder of industry giant

Per V Brüel, one half of the duo who created leading sound and vibration company Brüel & Kjær, has died less than a month after celebrating his 100th birthday with nearly 100 guests at his home near Copenhagen. One of his last public appearances had been at the annual meeting of the Danish Acoustical Society, which he had helped found.

Per Brüel was born in Copenhagen on 6 March 1915. As a young boy, he moved to Jutland with his family, where it was expected he would follow his father's example and become a forester. However, he showed a knack for technology and ended up studying engineering at the Danish Technical University, where he met Viggo Kjaer. They both graduated in 1939, and in 1942 decided to follow their shared dream of starting an engineering firm.

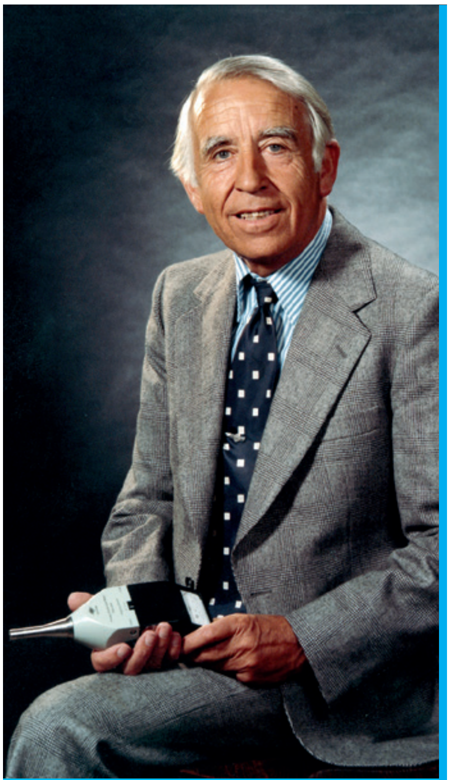
At this time, sound and vibration was not on the agenda of industry, and from the very beginning Per was a driving force behind setting international standards and establishing the importance of sound and vibration in product development, to measure and reduce vibration and noise levels. "Even then we could see that noise is one of the biggest problems of our time – it affects millions of people every day," he said. "Our instruments could not only measure noise but also help customers identify and eliminate noise problems."

From the onset, Per had a vision of creating a global enterprise and he travelled the world to meet customers and understand their challenges; he was determinedly customer-centric long before the term was coined. On these journeys, Per could combine two of his passions: sound and vibration, and flying. He was licensed in Denmark to fly single- and multi-engine planes, as well as gliders. From 1957 to 2000, he logged 9,476 hours of flight in more than 20 different aircraft. He also had a lifelong passion for motorcycles and cars, which gave his engineering insights a grounding in the everyday world.

Through the second half of the 20th century, Brüel & Kjær grew to become the world's largest specialist in sound and vibration solutions. The company is still inspired by the convictions of its founders. "We wanted to make products which had an impact on society, and we wanted to make money," Per said. "If I'm to talk about a motto for my work, it is that it must in no way be boring." Speaking on behalf of his partner, Viggo Kjær, who passed away in 2013 at the age of 99, he added an unofficial rule of conduct: "Running a business is about having fun. Having fun is the best way to use your skills. We wanted talented people who could think for themselves, who were creative and also a bit lucky. Employ good people; don't tell them what to do when they start work, because people will find that out for themselves, making them highly inspired."

In 1992 Per Brüel and Viggo Kjær sold Brüel & Kjær, and went on to pursue other ventures. Per continued his work in acoustics as a consultant, and was much sought after to lecture on sound and vibration. Over the course of his life, he received many honorary titles from renowned universities and organisations around the world in recognition of his contribution to the field of sound and vibration. These included the University of Bologna, Dresden University and the International Institute of Noise Control Engineering.

Paying tribute to him, Torben Rask Licht, product manager of vibration calibration systems for Brüel & Kjær, who worked alongside Per for more than two decades, said: "He literally created the field, as industries didn't measure sound and vibration at all in the days when he started. Per was a driving force behind setting standards and establishing the importance of sound and vibration. In today's terminology, he branded the idea."



Per V Brüel (1915-2015)

Obituary

Peter Tucker (1937-2015): a founder member of the IOA and of Hann Tucker Associates

Peter Tucker, a member of the British Acoustical Society and subsequently a founder member of the Institute of Acoustics, has died. He was 77.

John Lesser, a colleague at Impulse Acoustics, where he worked in later years, paid this tribute to him:

"A founder of Hann Tucker Associates in 1971, he wrote numerous papers and given many lectures on acoustics.

He served on many learned committees, most recently the C.I.B.S.E. committee to review and rewrite Chapter 5 'Noise and Vibration Control' of their guide, where he made a major contribution to the vibration section.

He was a pioneer of the thin wall, stainless steel acoustic enclosure system, for North Sea Applications, and became a specialist in ordnance and earthquake shock applications, designing the existing application to RNAD Coulport (nuclear submarine warhead base).

Peter resigned his membership in his later years, anticipating a quieter life, although he maintained an interest in acoustics as a partner with Impulse Acoustics Ltd, where his technical input has been inestimable."

Obituary

Ian Thompson (1961-2015): accomplished acoustician, terrific mentor and keen jazz drummer

It is with great sadness that we mark the passing of our friend and colleague, Ian Thompson, or Thommo, as he was often known, *writes Rory Huston with Gavin Irvine.*

Ian started out as a technician at Acoustic Technology in Southampton, and then spent 20 years at Arup Acoustics. During his time at Arup he worked on many projects including theatres and cinemas and was remembered by colleagues knee-deep in construction site mud setting up accelerometers (not easy in mud) and crawling around in basements trying to inspect the vibration isolation. Outside work he was remembered for his good company, enthusiasm, drumming, cars, motor bikes and his fondness for tea, real ale and curry. He would also be seen at the IOA London Branch meetings, not least in the pub afterwards holding forth on any subject relating to acoustics, vibration or indeed anything else. He was never boring and the conversation would happily wander off-topic.

Ian moved to set up the acoustics team at Buro Happold in 2006, where he built up a team of 10 acousticians. Ian was a terrific mentor, and colleagues have resoundingly said that he was great at getting the best out of them, in a calm, patient manner. Ian also lectured at NESCOT, so probably supported many at the beginning of their careers.

He was a bit of an arts and culture specialist, with a vibration pedigree too, as you might expect from someone from Southampton. He worked on a variety of iconic projects, which included Hampstead Theatre, Birmingham Symphony Hall, Hull Truck Theatre and the Olympic Media Centre, as well as international projects such as the Louvre II in Abu Dhabi, offices, education buildings, the list goes on. As someone who had been there, done that, he was excellent at knowing exactly how everything could and should be built. Ian was great at not only telling you how to do something, he also showed you, and then encouraged you have a go, and was on hand when you got it wrong. He always seemed to have time to help, and in all those years I can't think of a single occasion that he ever asked me to do something that wasn't fully prepared to do himself.

Ian looked after his team with great kindness and sensitivity to feelings, whilst driving hard to keep standards very high. Being such a good person is not easy in business, but this was always a high priority for him. Sometimes I could see that he suffered for this, taking our burden on his shoulders and absorbing the flak that came our way. We certainly appreciated it. Serafino di Rosario, who worked for Ian throughout his time at Buro Happold, was part of the team which recently won the IOA's Peter Lord Award for the RES acoustic shell. Serafino said it was Ian's mentorship and encouragement that helped him believe projects such as this were possible.

As with many acousticians, music was very import to him; before his time as an acoustic team leader, Ian was a jazz drummer, and even in an acoustician band! He was happiest in a pub, sipping his pint, talking about Tracy (his wife) and Oliver (his son), both of whom meant the world to him. I can picture him sitting in the sunshine in the beer garden of the Castle pub in Cambridge on a Friday lunchtime, relaxed and smiling, or striding out of the office at the end of the day, folding himself into what was really a very small car for a very tall man to drive home across the Fens.

Ian put up a brave fight against cancer for two years. Knowing he had terminal cancer from the beginning, Ian and Tracy decided to take their retirement together while they could. That meant trading in the very small smart car for a very fast Audi TT. I like to imagine him roaring around the Fens grinning from ear to ear. His memory will always be an inspiration to those who knew him, in guiding our professional standards, in reminding us how people should be treated, and to keep a smile on your face. And many will so miss the fun we had working together.

Ian, I hope you can find your drums and your passion for applied acoustics wherever you are now.

Ian Thompson (1961-2015)

Looking to make waves: CD-adapco launches new vibro-acoustic software

CD-adapco has unveiled wave⁶, a new software product line for vibro-acoustic and aero-vibro-acoustic simulation.

The new products will complement and extend the functionality of the company's flagship simulation tool, STAR-CCM+®, to address flow-induced noise and vibration problems.

"Solving problems that involve flow-induced noise and vibration is of increasing importance to our customers. It is an application that crosses multiple disciplines and requires accurate simulation of both unsteady flow and the transmission of noise and vibration through large complex systems across a broad frequency range," said Phil Shorter, Vice President, CD-adapco. "We developed wave⁶ from the ground up with a group of experts who truly understand the problems engineers face trying to work with older legacy codes."

The wave⁶ product line also focuses on usability and introduces new automated workflows to make advanced aero-vibro-acoustic analysis methods more readily accessible.

For more details go to **www.cd-adapco.com**

Svantek UK aims to dig deep with MOLES

Svantek UK has launched a new outdoor noise monitoring system called MOLES (Miniature Outdoor Logging of Environmental Sound), which can operate for up to four weeks on a single charge.

Using Svantek's Class 1 SVAN 971 sound level meter and featuring a weatherproof design with IP65 protection level, MOLES is a fully autonomous environmental noise monitoring system.

It is available with options for 1/1 and 1/3 octave real-time analysis and triggered audio recording. It also offers two in 10 audio recording making it ideal, says Svantek, for measuring levels of noise from wind turbines.

It is also available with free SvanPC++ software with the option of environmental calculations / tonal assessment. MOLES provides 4GB storage capacity and data.

For more information contact Paul Rubens on **01296 682040** or **07815 087905** or **paulrubens@svantek.co.uk** or go to **www.svantek.co.uk**

The new MOLES system

Ecophon goes green by turning to plant-based solution

Ecophon has converted its entire range of acoustic solutions to a plant-based binder, taking 24,000 barrels of crude oil out of the production a year and reducing emissions accordingly.

It is also now able to introduce guaranteed recycling of all products manufactured from third generation glasswool.

Company spokesman Will Jones said: "Our ambition is to have a 'sound' effect on people, in everything we do. To do this. we always strive to stay ahead of market and regulatory demands. The plant-based binder is a major development."

Environmentally friendly: acoustic products from the Ecophon range

New SV104 dosimeter set for 'explosive' future

The new SV104 personal noise dosimeter

Svantek has launched a new version of the SV104 personal noise dosimeter, which, thanks to ATEX and IECEx approval, means it can be used in potentially explosive work environments including mines and petrochemical plants.

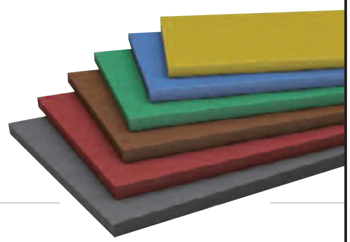
The company says the IS (Intrinsically Safe) device sets a new benchmark in personal noise measurement by offering a wide range of unrivalled features including octave band analysis for helping to select hearing protection and audio recording.

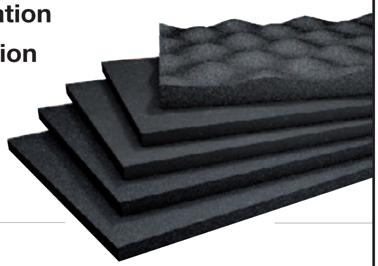
The full-colour OLED screen displays information in both text and graphical form plus offers visibility even in full daylight. It also incorporates a MEMS microphone enabling easy calibration using most commonly available acoustic calibrators and inbuilt tri-axial accelerometer for vibration shock detection.

Measurement data is stored in the eight GB memory and the instrument works with Svantek's Supervisor health and safety software package. It is powered using built-in rechargeable batteries or through the USB interface which also enables easy connection between the SV104 and a PC.

John Shelton, Svantek Managing Director, said: "Getting ATEX and IECEx approval for the SV104 was the obvious next step and will help open up previously untapped business in global markets such as petrochemical, oil and gas and mining."

For product information contact Paul Rubens on **01296 682040** or **07815 087905** or **paulrubens@svantek.co.uk** or visit **www.svantek.co.uk**





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Committee meetings 2015

DAY	DATE	TIME	MEETING
Thursday	14 May	11.00	Publications
Tuesday	19 May	10.30	CCHAV Examiners
Tuesday	19 May	1.30	CCHAV Committee
Monday	8 June	10.30	ASBA Examiners
Monday	8 June	1.30	ASBA Committee
Thursday	11 June	10.30	Executive
Tuesday	**16 June**	**10.30**	**Council**
Wednesday	24 June	10.30	CCENM Examiners
Wednesday	24 June	1.30	CCENM Committee
Wednesday	24 June	10.30	CCBAM
Thursday	25 June	10.30	Distance Learning Tutors WG
Thursday	25 June	1.30	Education
Thursday	16 July	10.30	Meetings
Thursday	30 July	10.30	Diploma Moderators Meeting
Thursday	13 August	10.30	Membership
Tuesday	8 September	10.30	Executive
Tuesday	**15 September**	**10.30**	**Council**
Thursday	24 September	10.30	Engineering Division
Monday	28 September	11.00	Research Co-ordination
Thursday	22 October	11.00	Publications
Tuesday	27 October	10.30	Diploma Tutors and Examiners
Wednesday	28 October	TBA	CCWPNA Examiners
Wednesday	28 October	TBA	CCWPNA Committee
Wednesday	28 October	TBA	CCENM Examiners
Wednesday	28 October	TBA	CCENM Committee
Wednesday	28 October	TBA	CCBAM
Thursday	29 October	10.30	Membership
Wednesday	4 November	1.30	Education
Tuesday	10 November	10.30	ASBA Examiners
Tuesday	10 November	1.30	ASBA Committee
Tuesday	17 November	10.30	Executive
Thursday	19 November	11.30	Meetings
Tuesday	**1 December**	**10.30**	**Council**

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

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