New Zealand Acoustics

Volume 30, 2017 / # 1

International Noise Awareness Day

International Noise Awareness Day Wednesday 27th April 2017: International Noise Awareness Day is a global campaign, founded in 1996 by the Center of Hearing and Communication (CHC), aiming to raise awareness of noise on the welfare and health of people. https://euracoustics.org/INAD2017/

Forgotten linear behaviours in the sound field

Two recent sound insulation test results

Overview of developments in the description and assessment of high intensity impulse noise exposure

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Features

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From the President and the Editor's

President's Column

Dear ASNZ Members, Associates and Fellows,

Welcome to Volume 1 of the Journal for 2017, and what a great volume it is. Once again the editors have done a great job, as have the Council and all the contributors. The Society has had a great start to the year with a couple of successful branch meetings in Auckland and Christchurch and an online survey of the membership. At the first Council meeting held this year we agreed on a commitment to promote engagement amongst the membership using a variety of methods, including provision of a fund to pay for or subsidise branch meetings, the use of online surveys and other online tools to get people talking and events happening. The branch meeting funding scheme looks like this:

(i) $300 +GST per event (but a higher amount may be applied for, with reasons given)
(ii) Allowance for two events per branch, per year (branches being Auckland, Wellington and Christchurch).
(iii) Funding rounds begin 1 January and 1 July each year

Applications for funding should be made to the Secretary and it will be looked at by the Council generally in each case. The funding can be used for any reasonable purpose, including paying a speaker, booking a room or making sure people don't go hungry.

There are still two lots of funding available for the Auckland and Wellington branches and one left for the Christchurch/South Island branch before the 1st of July 2017. So if you have any great ideas for a branch meeting, want extra CPD points and need some funding then drop James Whitlock an email and make it happen.

The South Island Branch and the Auckland Branch both ran popular and engaging branch meetings in March (on the same day in fact). George Van Hout has provided a great write-up of the SI meeting along with a few photos – I hear it was a good night. The Auckland Branch meeting was held at the Styles Group office where Dr Matt Pine presented on underwater acoustics and we played some sweet tunes through the speaker wall. The sound of the dolphins' sonar locking onto its target was fascinating! Just like Iceman, Goose and Maverick do in Top Gun but with a more evolutionary feel to it. We had just a bit less than two dozen people turn up to the Auckland meeting, each of whom scored 5 CPD points.

On a completely separate note, I have noticed a significant increase in the number of issues arising where residential encroachment on noise generating activities (predominantly in the rural zones) has not been well managed and conflict has arisen. This is resulting in some significant costs being incurred to determine who should bear the burden, often resulting in the noise maker curtailing their activities and the new home owner being perpetually upset, sensitised and out of pocket. There is no easy solution to this, but foresight can go an awful long way to avoid or minimise the fallout. If the noise maker has the opportunity to put in place the right planning controls, begin fundraising for noise mitigation or even purchase or lease neighbouring land around them to create a buffer before residential gets too close then they should be encouraged to do so. Reliance on '*Existing Use Rights*' and previous consents will not prevent significant legal, planning and consultancy expenses being incurred, and often will not solve the problem anyway. I encourage all those who are involved in such activities, whether professionally or privately to help the noise makers protect themselves. This is a particular issue in Auckland, the Waikato and Bay of Plenty as people move to the country for the 'quiet' life, seeking out their 2 hectares of retirement life. There are many cases where the demise of shooting clubs, motorsport tracks and other great recreational activities could have been avoided.

Best wishes,
Jon Styles

Editor's Column

Welcome to the first Journal of 2017 (Vol. 30, #1). In the '*News, Reviews, Profiles & Events*' column we publish a first, a poem on architectural acoustics, submitted as a letter to the editor. So come on you budding poets, see if you can do better and share it with the world.

This issue we have a broad mixture of papers drawn from recent conferences. The first is a technical paper that is well worth a read and don't be put off by all the equations. The second is a topical short paper on practical sound insulation measurements in relation the Clause G6 (we are still waiting to see the revised version move to public consultation). The final paper provides an excellent overview of current approaches to the description and assessment of high intensity impulse noise exposure (think gun fire, large calibre weapons fire and explosives). As well as having application to those in the armed forces, it is applicable to those in industries with very high peak sound pressure levels, especially if there is also exposure to ototoxic chemical agents.

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Letter to the Editor

The Acoustics of a Typical Concert Hall

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As far as the present author is aware, there is no poem in the literature with regard to architectural acoustics. This letter is a poem which addresses the acoustical condition in a typical concert hall.

It's a concert hall
Its volume is not large
Its shape is irregular
Its stage is not small
Its ceiling is not tall
Its windows are rectangular
Its ceiling is hard
Its doors are tall
Its walls are partially hard
Its floor consists of a hard material
Its curtains have absorption coefficient of 0.5
Its doors are made of metal
Its pews are occupied
Its sound reinforcement systems are off
Its average absorption coefficient is not high
Its Schroeder frequency is partially high
Its critical distance is not long
Its early decay time is long
Its reverberation time is higher than usual
It's therefore a poor concert hall

Obituary William (Bill) Warner Lang (1926-2016)

New Zealand Acoustics was saddened to learn of the passing of Bill Lang on October 23rd 2016. Bill was recognized for his contributions to noise control throughout his career with fellowships in the Audio Engineering Society, American Association for the Advancement of Science, Acoustical Society of America, and the Institute of Electrical and Electronics Engineers. He was a Fellow, Distinguished Noise Control Engineer, past President of INCE-USA, as well as an honorary member of the Institute of Acoustics (UK) and the National Council of Acoustical Consultants. (Adapted from the obituary published in the Poughkeepsie Journal on Oct. 30, 2016).

Journal Feedback and Comments

If you have any feedback on what you would like to see in future issues or even things you don't like to see, please share with us via email to **journal@acoustics.org**, we would like to hear from you! All comments and feedback is treated as confidential by the Editors.

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of New Zealand

www.acoustics.org.nz

The ASNZ webpage contains a host of information including information on Membership, Journal Information and Journal Articles, Continuing Professional Development, Cafe and Restaurant Acoustic Index, Standards Committees and Standards, the Latest News and Discussion and Contact details of the Society.

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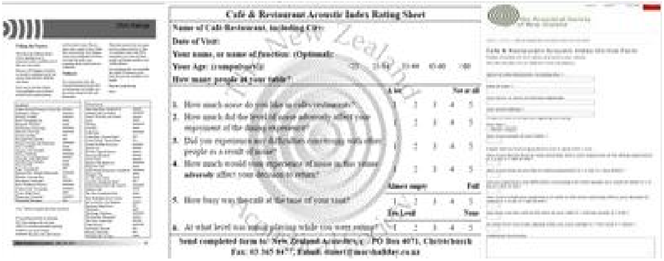
The Cafe and Restaurant Acoustic Index, C.R.A.I., is completely online with results and online forms able to be viewed and download from the acoustics.org.nz website under the C.R.A.I tab.



Lewis Hamilton: F1 cars sound terrible and the sport isn't winning

F1 superstar Lewis Hamilton has voiced major concerns ahead of the 2017 season. Speaking to the BBC ahead of the launch, the opinionated Hamilton didn't hold back about his concerns over the current state of international

...Continued on Page 15

Forgotten linear behaviours in the sound field

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Abstract

First reflections of a rigid panel, a rigid concave and convex panel, and a panel with reflection coefficient are reviewed as well as multiple reflections between them. Thus, early reflections in a scale model auditorium were calculated and compared with measured results. The transient response of human hearing system in the form of impulse response with 0.05ms rectangular pulse wave is reviewed. It has the absolutizing process after the linear response. Familiar impact sounds got pair comparison to arrange on the axis of loudness. When each impact sound was convolved with the dB (A) weight and the transient response of our hear-ing system, it was found that the latter convolution showed larger correlation to each loudness. And it was found that the time window of 40ms gives the largest correlation for its loudness among other time windows. The measurement of angle discrimina-tion was done with a 0.05ms rectangular pulse. It exists where the cross correlation of HRTF is 0.98. Acoustical information can be smoothed in this space. If it is expressed in the space using the stereoscopic view, temporal information is also obtained. It can be compared with the given estimation of a concert hall. Acoustical behaviours must be first arranged and established as the linear system on a 0.05ms rectangular pulse, then further steps can be clearer.

Originally published in the 22nd Biennial Conference of the Acoustical Society of New Zealand, November 2014

1. Introduction

The impulse response of a linear system is the output of the delta function input and it is the fundamental response of the system to be convolved to a practical input to find its output. This behaviour exists in our hearing system as well as in a sound field. The process of absolutization occurs after it. In this paper, the line-ar behaviours of a sound field and hearing system are reviewed first and the time window for the loudness of an impact sound and the angular discrimination for a 0.5ms rectangular pulse is mentioned.

2. The early reflections of th impulse respose in an auditorium

On the boundary in a sound field, the integral equations are formulated [1] to obtain the rigorous solution. At present it has to be solved numerically and it is difficult to find intuitively from the result how a sound field is formed and characterized. The successive substitution in one of the equations, however, gives the multiple integrations with known functions which correspond to multiple reflections between boundaries.

A velocity potential $\Phi(P)$ at a point P in an enclosure F is expressed by Helmholtz-Kirchhoff integral [2],

$$\Phi(P) = \Phi_D(P) + \int\int_F \left\{ \phi(q)\frac{\partial G}{\partial n} - \frac{\partial \phi(q)}{\partial n} G \right\} dS \tag{1}$$

where $\Phi_D(P)$ is a direct wave from an omnidirectional point source at P_s, G is $exp(-ikr)/4\pi r$, where r is a distance from a point q on the boundary to a receiving point P, n is an inward normal, and $\varnothing(q)$ and $\delta\varnothing(q)/\delta n$ take values at the boundary. But they are not given. When a receiving point P converges to a point p on the boundary, Eq. (1) turns into the integral equation jumping $1/2\,\varnothing(p)$ because of the discontinuity of the double layer term [1],

$$\Phi(p) = 2\Phi_D(p) + 2\int\int_F \left\{ \phi(q)\frac{\partial G}{\partial n} - \frac{\partial \phi(q)}{\partial n} G \right\} dS \tag{2}$$

where k is a wave number and an admittance A_j on a surface j is defined as,

$$\frac{\partial \phi}{\partial n} = ikA_j\phi \tag{3}$$

and the surface F is composed of N different parts, the successive substitution in Eq. (2) yields,

$$\begin{aligned}\Phi(p) = 2\Phi_D(p) &+ \sum_{j=1}^{N}\Big[2\int\int_{F_j}\Big\{2\phi_D(q)\frac{\partial G}{\partial n} \\ &-ikA_j 2\phi_D(q)G\Big\}dS_j\Big] \\ &+\sum_{k=1}^{N}2\int\int_{F_k}\Big[\sum_{j=1}^{N}2\int\int_{F_j}\Big\{\phi(q)\frac{\partial G}{\partial n} \\ &-ikA_j 2\phi_D(q)G\Big\}dS_j\frac{\partial G}{\partial n} \\ &-ikA_k\Big\{\sum_{j=1}^{N}2\int\int_{F_j}\Big(\phi(q)\frac{\partial G}{\partial n} \\ &-ikA_j\phi(q)G\Big)dS_j\Big\}\Big]dS_k + \cdots\end{aligned} \tag{4}$$

A velocity potential at a receiving point P is obtained by the substitution of Eq. (4) into Eq. (1),

$$\Phi(P) = \Phi_D(P) + \sum_{j=1}^{N} \int\int_{F_j} 2\phi_D \left\{ \frac{\partial G}{\partial n} - ikA_j G \right\} dS_j$$
$$+ \sum_{k=1}^{N} \int\int_{F_k} \sum_{j=1}^{N} \Big[2 \int\int_{F_j}$$
$$\cdot 2\phi_D \left\{ \frac{\partial G}{\partial n} - ikA_j G \right\} dS_j \Big]$$
$$\cdot \left\{ \frac{\partial G}{\partial n} - ikA_k G \right\} dS_k + \cdots \qquad (5)$$

or

$$\Phi(P) = \Phi_D(P) + \sum_{j=1}^{N} \int\int_{F_j} 2\phi_D \frac{\partial G}{\partial n} R_j dS_j$$
$$+ \sum_{k=1}^{N} \int\int_{F_k} \sum_{j=1}^{N} \Big[2 \int\int_{F_j} 2\phi_D \frac{\partial G}{\partial n} R_j dS_j \Big]$$
$$\cdot \frac{\partial G}{\partial n} R_k dS_k + \cdots \qquad (6)$$

where

$$R_j = 1 + \frac{ikA_j}{(ik + 1/r)\cos(n.r)} \qquad (7)$$

R_j is called a reflection coefficient. Each term in the right hand side shows a direct sound, the first and second reflections, respectively. When a surface is rigid and A_j is zero, R_j becomes unity. The second term in the right hand side of Eq. (6) in that case can be separated into two terms. Each of them can be transformed into the line integral [3] as is shown in Eq. (8). The multiple surface integrals between plane panels in Eq. (6) are then reduced to the line integrals. Practical calculations of multiple integrals, multiple reflections between different kinds of panels are mentioned as well.

2.1 First reflections of boundaries in an auditorium

1) The reflection of a rigid plane panel [4]

The first reflection of a rigid plane panel in Figure 1 corresponds to the second term in Eq. (6) when R_j is equal to unity. In the time domain, the reflection of the rigid plane panel, $h(P,t)$ is expressed

$$h(P,t) = \frac{\delta(t - d/C)}{d} + \frac{\delta(t - d'/C)}{d'}$$
$$+ \frac{1}{4\pi} \int_{\Gamma} \frac{\delta(t - (r + r_s)/C)}{rr_s}$$
$$\cdot \left\{ \frac{\boldsymbol{r} \times \boldsymbol{r}'_s}{rr'_s + \boldsymbol{r} \cdot \boldsymbol{r}'_s} + \frac{\boldsymbol{r} \times \boldsymbol{r}_s}{rr_s + \boldsymbol{r} \cdot \boldsymbol{r}_s} \right\} \cdot dg \qquad (8)$$

,where $\delta(t)$ is a delta function and C is a sound velocity. r_s, r_s' and r are vectors from a point source, an image source and a receiving point to the edge, respectively. dg is an element of a vector tangential to the edge. ε takes one, one half and zero, when a receiving point P is inside, on and outside the cone formed by P_s' and F in Figure 1, respectively. In the right hand side of Eq. (8), the first term is a direct sound from a point source, the second term is a geometrical wave from the image source P_s' and the third term is the edge waves from the image and real sources. The first term of the line integral corresponds to the diffracted wave from a complementary opening with the Kirchhoff's boundary condition which produced the direct sound from the image source. The equation shows that there is no reflection other than the geometrical wave until the wave front reaches the edges of the panel. Edge waves have a role to express the dimension of a panel and the ge-ometrical relation.

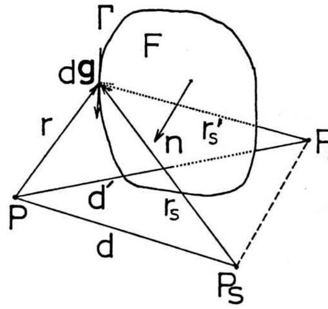

Figure 1: Sound reflection of a rigid plan panel by the in integral along Γ. A point source is at P_s and a receiving point is at P. P_s' is the image sources of P_s; n is the inward normal of the panel; d, d' are distances from the point source and the image source to the receiving point, respectively.

When the panel has a specular reflection point on it, they are negative. These negative waves becomes larger and closer to the specular reflection, as a panel become smaller. This explains our daily experience to hear only a small reflection from a small rigid panel even if it has a specular reflection. The next two points are very important for the later calculation of the multiple reflections between panels. The geometrical wave is the contribution of the singular point which is at a specular reflection point on a reflecting panel. A line element dg of the line integral, it is a secondary point source with directivity.

2) The reflection of a rigid curved panel [5]

If the rigid plane panel in Figure 1 is surrounded by other rigid panels, the last term of the line integrals in Eq. (8) vanishes on the common sides because of the counter line integral. Even at the free edges, it is less effective than the first term on the reflection side.

If a curved rigid panel in Figure 2 is parcelled into the partitions where an incident spherical wave can be regarded as a plane one and the curvature is estimated to be flat in comparison with a wavelength, and an asymptotic expansion, i.e. Fraunhofer diffraction, is applied to the surface integral corresponding to the remaining first term.

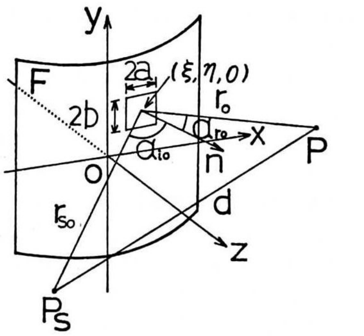

Figure 2: Sound reflection of a curved rigid panel. A point source P_s is at (x_0, y_0, z_0) and the receiving point P is at (x,y,z); side lengths of a division are $2a$ and $2b$; α_{i0} and α_{r0} are incident and reflection angles at the centre of division which is at (ξ,η,0), respectively; r_{s0} and r_0 are distances from the point source and the receiving point to the centre, respectively.

The first reflection $h(P,t)$ of the curved rigid panel is approximately calculated by superposing the first reflections of the partitions as in the following,

$$h(P,t) = \frac{1}{4\pi}\sum_{j=1}^{N}[A_1\{U(t-T_1)+U(t-T_2) \\ -U(t-T_3)+U(t-T_4)\}+A_2\{R(t-T_1) \\ -R(t-T_2)+R(t-T_3)+R(t-T_4)\}], \qquad (9)$$

where

$$A_1 = Cr_{s0}r_0(\cos\alpha_{i0}+\cos\alpha_{r0}) \\ /[\{r_0(\eta-y_0)+r_{s0}(\eta-y)\}\cdot\{r_0(\xi-x_0)+r_{s0}(\xi-x)\}], \qquad (10)$$

$$A_2 = C^2(r_0\cos\alpha_{i0}+r_{s0}\cos\alpha_{r0}) \\ /[\{r_0(\eta-y_0)+r_{s0}(\eta-y)\}\cdot\{r_0(\xi-x_0)+r_{s0}(\xi-x)\}], \qquad (11)$$

and

$$T_1 = -D_1-D_2+D_3,\ \ T_2 = -D_1+D_2+D_3, \\ T_3 = D_1-D_2+D_3$$

and

$$T_4 = D_1+D_2+D_3, \qquad (12)$$

where

$$D_1 = \frac{a}{C}\{(\xi-x_0)/r_{s0}+(\xi-x)/r_0\}, \\ D_2 = \frac{b}{C}\{(\eta-y_0)/r_{s0}+(\eta-y)/r_0\}$$

and

$$D_3 = (r_{s0}+r_0)/C+d/C \qquad (13)$$

The far field term yields the step function $U(t)$ and the near field term yields the ramp functions $R(t)$. Figure 3 shows the reflection from a partition of the near and far field terms. When it is divided small, T_1,T_2,T_3 and $T4$ in Figure 3 come close each other and the height of the trapezoid wave becomes small. On the other hand, the far field term remains predominant having two rectangular waves with the opposite signs in the same height.

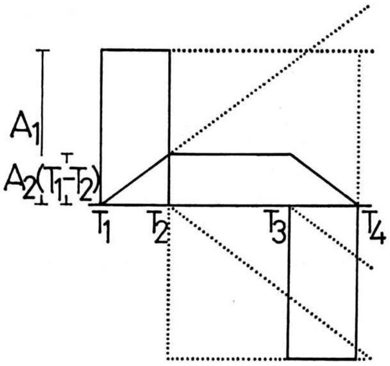

Figure 3: Reflection in the time domain from a rigid panel rectangular partition at a plane wave incidence. Far field terms: step functions, producer a pair of rectangular waves; near field terms: ramp functions, produce a trapezoid wave.

When the partition at the specular reflection on a rigid panel is surrounded by other partitions, the latter negative wave is cancelled completely in the case of a rigid plane panel, or almost completely in the case of a rigid convex panel, by the following positive waves from the other partitions (see Figure 4(a)). The partitions at the edges leaves boundary waves. When a panel is rigid and concave, positive and negative waves tend to be increased by those following in phase (see Figrue 4 (b)).

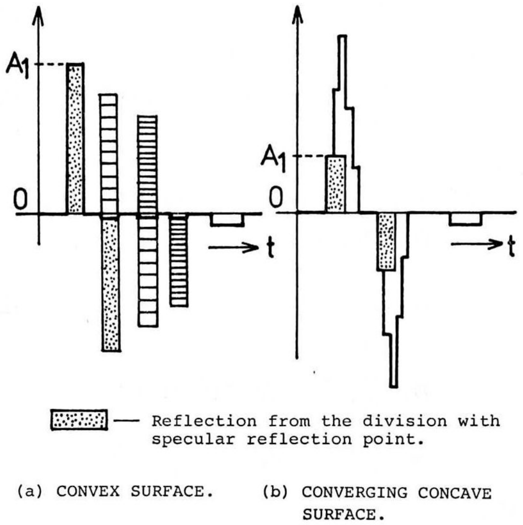

Figure 4: Formation of the specular reflections from a rigid concave or convex surface. A wave with a thick line shows the resultant.

3) The reflection of a plane panel covered with material having reflection coefficient [6].

The first reflection $h(P,t)$ of a plane panel covered with reflection coefficient in Figure 5 is practically obtained, substituting the reflection coefficient at the specular reflection $\gamma_0(t)$ for the other part of the surface,

$$h(P,t) = \gamma_0(t) * g(P,t), \qquad (14)$$

where, $\gamma_0(t)$ is the reflection coefficient in the time domain at the specular reflection point on the panel with large dimension, $g(P,t)$ is the reflection of a rigid plane panel at the same position as the panel. * shows the convolution product.

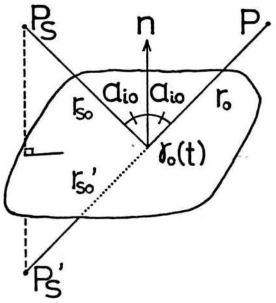

Figure 5: Sound reflection of a plane panel covered with reflection coefficient. $\gamma_0(t)$ is the reflection coefficient at the specular reflection where an incidence angle is α_{i0}.

Reflection coefficient at a specular reflection is obtained experimentally from the reflection of a sufficiently large plane panel covered with the material by de-convolving it from the direct sound of the image source. It shows the reflection of the surface when it is impinged by the impulsive spherical incident wave. Reflection coefficient in the time domain for punch-carpet and urethane form surface at different incident angles which are measured using spark pulses are shown in Figure 6. Unit in the ordinate corresponds to the reflection coefficient of a rigid surface, namely, the direct sound from the image source. Punch-carpet reflects more surface reflection because of harder surface, i.e., more impedance mismatching.

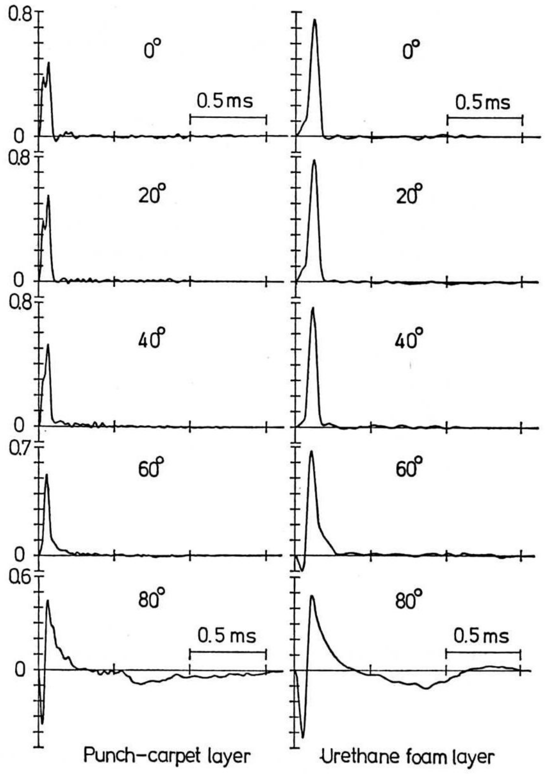

Figure 6: Reflection coefficients in the time domain of a punch-carpet layer of 4mm thickness and a urethane foam layer of 10mm thickness. An incidence angle is shown in each figure.

Reflection coefficient of a porous layer explains separately the amount of surface reflection and the reflection from its back with the amount decreased in the layer. It is interesting that at the grazing angle, both reflect negative surface reflections. This negative surface reflection can be imagined from the reflection coefficient for the plane wave incidence with the local reaction assumption.

When an incident angle is close to $\pi/2$, it becomes negative and its inverse Fourier transform yields negative reflection. Measured reflection coefficients for hard and soft real auditorium seats are reported [7]. They also have negative surface reflections at the grazing angles with the successive reflections among the seats. This negative reflection decreases the loudness of the direct sound from the stage. We have to notice the steep slope 26.3 degrees of auditorium seats at Greek amphitheatre [8] as shown in Figure 7.

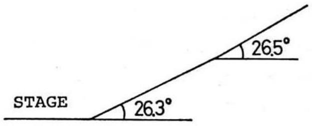

Figure 7: Steep slope of audience seats at a Greek ampitheatre

2.2 Multiple reflections between panels

1) Those between rigid plane panels [9]

The multiple reflection between rigid plane panels can be obtained from the interpretation of the first reflection mentioned in the earlier section.

When the projection of panel F_1 onto a panel F_2 from an image source P_s' covers F_2 as in Figure 8(a), the second reflection of a geometrical wave is obtained by the first reflection from F_2 of the image source P_s'. When it cuts F_2 by F_2' as in Figure 8(b), the second reflection is the first reflection from the area F_2'.

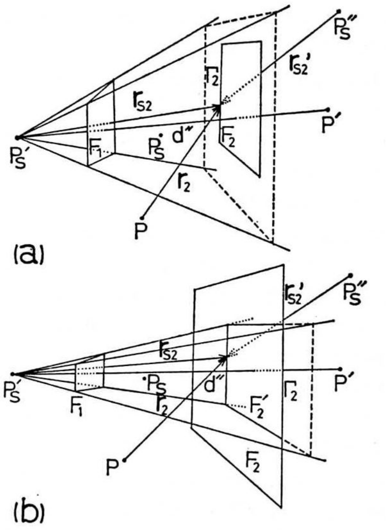

Figure 8: Second reflection of a geometrical wave having its boundary waves: (a) at the second panel F_2 and (b) on the projection F_2' of the first panel F_1 to the second panel F_2.

A higher order reflection of a geometrical wave can be estimated by the first reflection of the last image source from a panel or the area on the panel projected through the effective part of the preceding panel.

Since a geometrical wave is calculated as the contribution from the singular point on a second panel, the geometrical reflection of the edge wave at each element d_g is also obtained by finding the singular point on a second panel F_2 corresponding to it. Edge waves reflected at the edges of F_1 have such singular points on the lines $A'B'$, $B'C'$ and $C'D'$ on F_2 as shown in Figure 9. Geometrical reflection as the second reflection of edge waves is estimated by the line integrals Eq. (1) along AB, BC and CD of the panel F_1, when a point source is at P_s and a receiving point is at P' which is the image of a receiving point P. When the second edge reflection of edge waves at the first reflection is not negligible, it can be obtained by the double line integral.

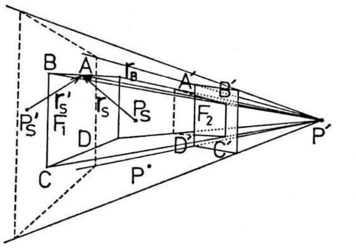

Figure 9: Geometrical reflecting of boundary waves. $A'B'$, $B'C'$ and $C'D'$ on F_2 have the specular reflections of the boundary waves at the first panel to the receiving point P'. r_s , r_s' and r_B are distances from the point source and its image sources, and the image receiving point on the edge, respectively.

2) Those between rigid curved panels [10]

2.1) Convex panels

Sound reflection from a rigid convex panel or concaved panel with small curvature is very similar to that from a rigid plane panel, when considered from the point of view that it produces a discrete specular reflection and a very slight reflection until a wave front reaches an edge. This suggests that the same treatment for calculating multiple reflection between rigid plane panels can be applied using an equivalent image point source as in Figure 10. The reflection at the specular reflection point on the second rigid curved panel from the first one is estimated by Eq.(9).

It has the magnitude of that from an equivalent image point source for the tangential plane at the specular reflection point of the first panel, as shown in Figures. 10(b) and (c). The second reflection between two rigid curved panels is approximated by the first reflection from one of them with the equivalent image point source thus obtained. This procedure corresponds to the calculation of the multiple reflection of a geometrical wave between rigid plane panels.

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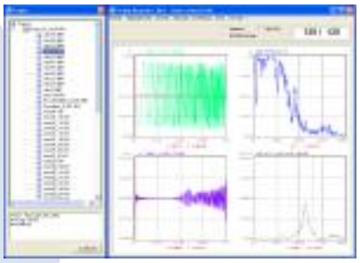

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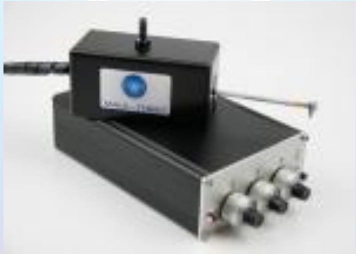

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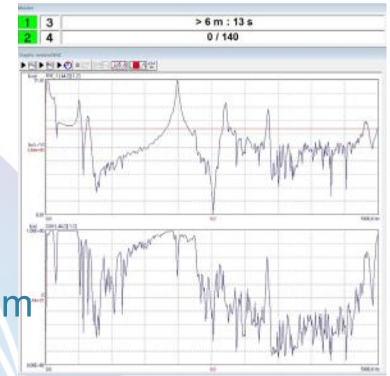

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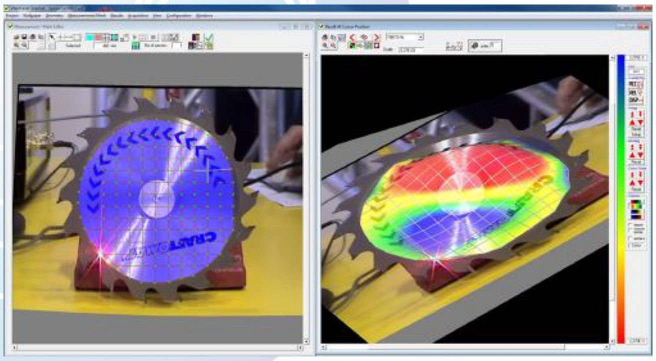

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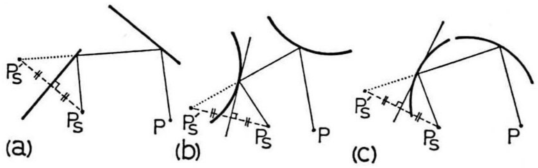

Figure 10: Multiple reflections between curved surfaces with equivalent image point sources for (b) a convex surface and (c) a concave surface.

2.2) Inside a concave panel with large curvature
At the second reflection inside the concave panel, the contribution from the division about the specular reflection point is still the most prominent, and the errors caused by the different incident angles of other partitions are decreased [10] by replacing them the incident angle of the specular reflection. For a second reflection, an image point source P_s' is obtained as for the tangential plane at the first specular reflection point as in Figure 11.

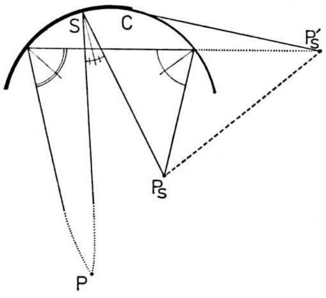

Figure 11: Multiple reflections inside a concave panel.

The plane of contact including the image P_s' limits an edge of the second reflecting concave panel, and the first reflection of the panel from the image source P_s' is convolved with the reflection from the point source to the second specular reflection point. The later continuous inter-reflection inside the curvature cannot be calculated with this method, but the calculation gives an approximate result to give good information. Its rigorous solution can be obtained by the integral equation methods.

3) Those between panels covered with materials having reflection coefficient other than unity [11]
The second reflections between two plane panels with reflection coefficients other than unity are also estimated by separating the first reflection of one of the panels. One is the contribution around the specular reflection point and another is lined point sources of edge waves at the edges (see Eqs. (8) and (14)). When two panels in Figure 12 are covered with reflection coefficients, both of them have specular reflection points, and the reflection of them as rigid surface is $g(P,t)$, their reflection is approximately estimated as,

$$h(P,t) = \gamma_{10}(t) * \gamma_{20}(t) * g(P,t), \qquad (15)$$

where $\gamma_{10}(t)$ and $\gamma_{20}(t)$ are reflection coefficients of two panels. Even if they do not have any specular reflection points on them, the reflection coefficients at the specular reflection points on their expanded surfaces are practically substituted.

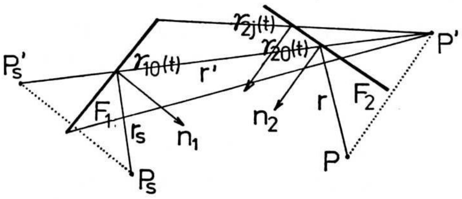

Figure 12: Multiple reflections between panels covered with reflections coefficients.

For the second reflection of the edge waves produced on the panel F_1 only their specular reflection on the panel F_2 is estimated. When the reflection coefficient at the incident angle of the edge waves on the panel F_1 which reflect specularly on the panel F_2 is $\gamma_{2j}(t)$ as shown in Figure 12, the reflection coefficient on the panel F_1 is $\gamma_{10}(t)$, and the specular reflection of the edge waves as the rigid surfaces is $g_{2j}(P,t)$, the specular reflection from the panel F_2 of the edge waves at the panel F_1, $h_2(P,t)$ is

$$h_2(P,t) = \sum_{j=1}^{m_2} \gamma_{10}(t) * \gamma_{2j}(t) * g_{2j}(P,t), \qquad (16)$$

where m_2 is the number of sides of the specular reflection on the panel F_2.

2.3 Early reflections in a scale model auditorium [12]

We are now ready to estimate the early reflections of the impulse response in an auditorium.

1) Experiments in the scale model auditorium
The scale model of an auditorium is made by the folded plane panels except the convex ceiling under the balcony as shown in Figure 13.

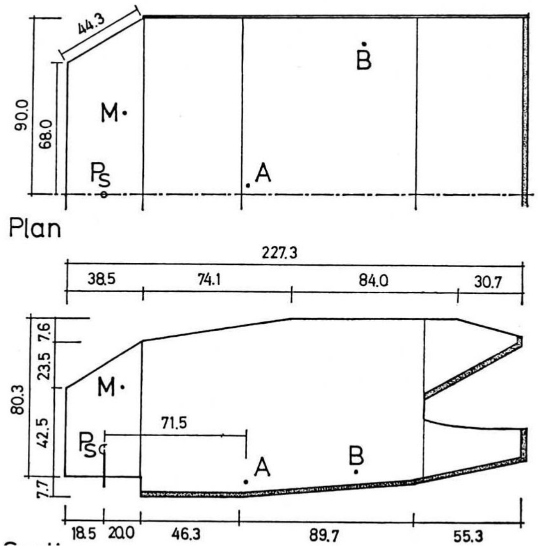

Figure 13: Scale model of an auditorium. A point source is a P_s and a reference microphone for simultaneous measuring of the direct sound is a M. Receiving points are A and B. Dimensions of the boundaries are shown in cm.

The convex ceiling is divided into three tangential rectangular plane panels in the calculation, then all the boundaries are calculated as rectangular plane panels.

Two parallel lateral walls are covered with punch-carpet layer of about 4mm thickness, the seat areas in the first floor and on the balcony, and rear walls are covered with urethane foam layer of 10mm thickness, whose reflection coefficients are shown in Figure 6. The other surfaces are made rigid. The spark pulse is generated at P_s on the stage. Wave forms were recorded on the digital memory with the sampling points 4,096 and sampling time of 10μs. For the anti- aliasing filter, low pass filter whose cut off frequency is 22.4 kHz with 24dB/oct and 28 kHz with 32dB/oct were used in series. Receiving points were at A and B in Figure 13. Receivers were two 1/4 inch condenser microphones which were recognized omni-directional below 15 kHz.

2) Comparison of measured and calculated results

Impulse responses at receiving points A and B were calculated. Discreteness of a geometrical wave was lost following the lapse of time at the calculated first reflec-tions, because edge waves become closer to it and negatively larger. It is also lost by the convolution of reflection coefficients. The second geometrical and specular reflections lost more discreteness. Because the first reflected edge waves are negative, their geometrical and most of their specular reflections are negative. They correspond to the modification of the overestimation at the second geometrical and specular reflections. The second geometrical and specular reflections of edge waves modified the overestimation at the third geometrical and specular reflections. The difference between receiving points A and B are noticed on the effect of the negative surface reflection at the ground floor. The direct sound at B is subtracted by it. In a real auditorium, such a negative surface reflection must decrease the loudness of the direct sound. The calculated impulse response up to the fourth reflections was convolved with the direct sound simultaneously measured and this is compared with the measured pulse response in Figure 14.

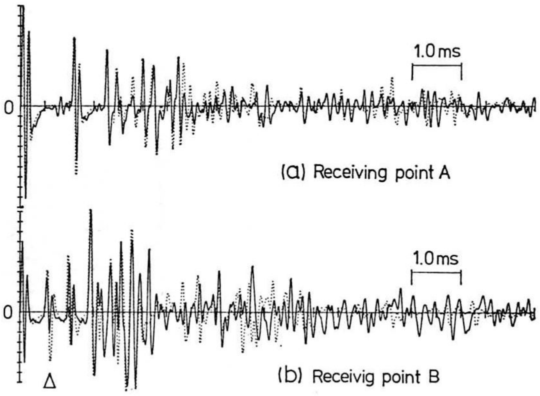

Figure 14: Pulse response of early reflections at the receiving point A and B. Solid curves are measured and dotted ones are calculated by the convolution of the first pulse wave and the calculated impulse response by sum up to the fourth reflection.

The amplitude of reflection in the ordinate is not shown, because it depends on the form and magnitude of a point source at the measurement. The disagreement, for instance, at Δ of the receiving point B in Figure 14 (b) is

caused by the excess attenuation at the edge of a panel with the thick layer of urethane foam, which cannot be predicted by Eq. (7). But it does not affect the total sound field so much. Their transfer function transformed from the pulse response until around 13ms after the direct sound is compared in Figure 15.

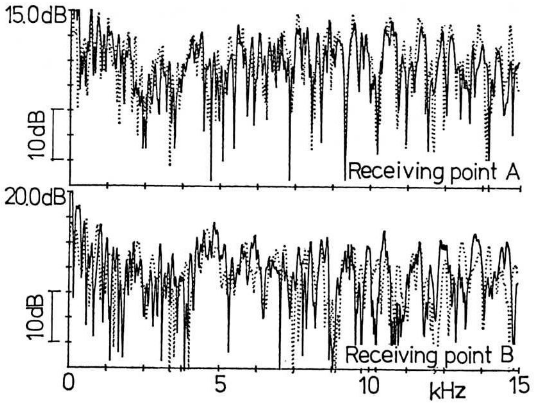

Figure 15: Measured transfer functions and the transfer functions calculated by sum up to the fourth reflection, shown by solid curve and dotted one respectively.

At a receiving point on or under the balcony, it has a few near boundaries which have specular reflection points. The decrease of the amplitude by distance from an image source is not much, in spite of the increase of the order of reflection. The early reflections such a receiving point include higher ordered reflections which are possible to be calculated by this method. These agreements show that the calculation of a sound field by geometrical acoustics is not sufficient, and that the introductions of edge waves, reflection coefficients and their multiple reflections give more precise estimation of the sound field in an auditorium.

When the sound field in an auditorium is understood as the distribution of the positive and negative image sources, the spatial information as well as the time sequence of them cannot be lost by the aid of stereo-scope expression. Then the sound field can be visualized [13].

2.4 Summary of this section

A method for calculating the early reflections of the impulse response in an auditorium is summarized based on the Terai's boundary integral equation, and on the calculation of the first reflections at boundaries and multiple reflections between them were reviewed. The result of the calculation by this method in a scale model auditorium is compared with the measured result in reasonable agreement. It is especially shown in the comparison that the multiple reflections of edge waves, which are caused by the limited dimension of the boundaries, give the effect of the modification of the overestimation caused by geometrical acoustical treatment and that reflection coefficients change incident wave forms depending on incident angles. In this way, the method on the successive substitution in the Terai's boundary integral equation shows clearly how a sound field is formed and characterized. These reflections seem to change the sound field into a diffused one and the definition of it seems to be newly discussed.

This method gives the more detailed spatial information as well as the time sequence.

3. Loudness of an impact sound

The linear part of our hearing system was found [14], having a pair comparison of the loudness of two rectangular pulses with that of a single rectangular pulse with changing their time intervals. The rectangular pulse had 0.05ms time duration, which covers our audio frequency, and had the amplitude of 93dB or 87dB.

This linear response, shown in Figure 16 is supposed to include the head related transfer function (HRTF), the elastic response of the eardrum to the three little bones, the lymph liquid in the cochlea, and the elastic movement of the basilar membrane. It might include even a part of peripheral nerve system.

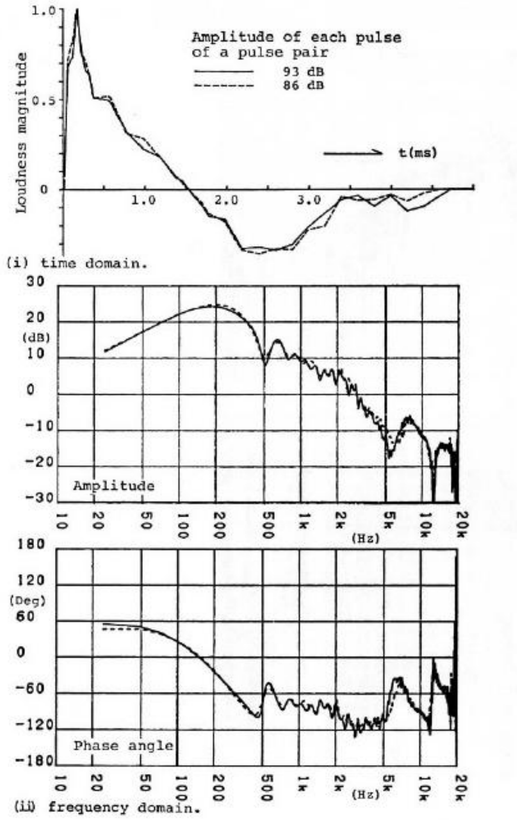

Figure 16: Impulse response of our hearing system and its frequency characteristics.

When a positive and a negative rectangular pulse of the same amplitude were given from opposite directions as in Figure 17, they were heard as the same loudness as if they were two positive rectangular pulses. It was shown that there is a process to make a sound absolutized [15] after the linear process.

It is discussed in this section how the loudness of an impact sound is decided at the higher level. It is tried to find how it weighs on frequency and forms a time window.

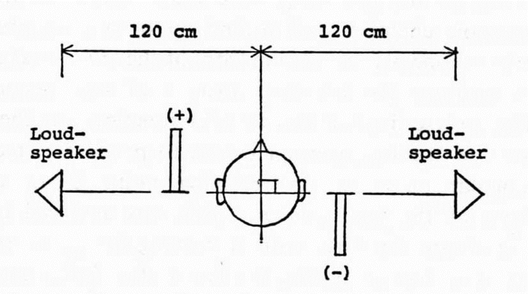

Figure 17: A positive and negative rectangular pulse from opposite directions.

1) The Thurston scale by pair comparison for various impact sounds

Firstly, eight kinds of impact noises were recorded with slight adjustment. They were the sounds of bottle tapping, concrete block hitting, tea cup tapping, aluminium bat impact, hand clapping, lighter clicking, sand-paper scrubbing and radio noise. Each impact noise got three different levels with an 8dB step and 24 impact noises were prepared. Pair comparison was done in the echoic chamber at Kansai University by 18 test persons. At pair comparison, the next pair was given at 3.5 seconds [14] after the first impact noise was ceased. The combination for a pair was not reversely done and it was the pairs of 24x23/2.

After 24 impact noises got the pair comparisons, they were arranged on the Thurston's scale in the case V and shown on one axis as in Figure18.

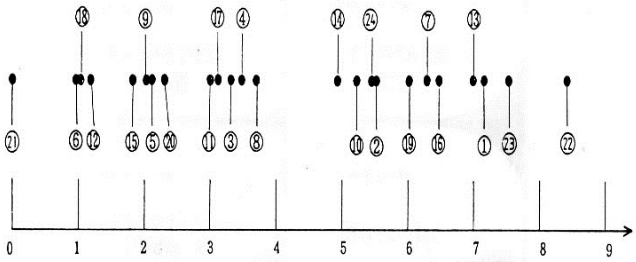

Figure 18: Loudness on the Thurston's scale for 24 impact sounds.

The next process after absolutization is supposed to have the integration in a time window. It is expressed as in the next equation (17) [16],

$$L = F\left\{\int_{t_1}^{t_2} \mid P(t) * R(t) \mid dt\right\} \tag{17}$$

where $P(t)$ is a given sound pressure which is an impact sound here. $R(t)$ is a transient response of hearing system to be convolved. * shows convolution product. From t_1 to t_2 is the interval of a time window for the integrand. $F\{\}$ is a function of power or logarithmic. Here the latter is used practically 20log10 to get a decibel value.

2) Time window with the application of the Theory of Quantification I

Having the Thurston's scale as an outsider and a variety of time window as a factor, Theory of Quantification I was applied to see how a multiple correlation coefficient changes. It was searched which time window shows the largest multiple-correlation coefficient. It must be the most proper time window.

An impact sound is convolved with: (a) unity to have a physical impact sound, (b) "A" weight without any phase angle and (c) the impulse response of our hearing system in Figure 16. After each convolution, it is absolutized and integrated with a variety of time windows.

Time window	Multiple Correlation Coef. (a)	(b)	(c)	Time window	Multiple Correlation Coef. (a)	(b)	(c)
10ms	0.8474	0.8399	0.9165	90ms	0.8286	0.8296	0.9181
20ms	0.8560	0.8545	0.9127	100ms	0.8211	0.8296	0.9003
30ms	0.8490	0.8500	0.9129	110ms	0.8211	0.8301	0.9003
40ms	0.8644	0.8764	0.9322	120ms	0.8216	0.8214	0.9003
50ms	0.8838	0.8855	0.9299	130ms	0.8216	0.8214	0.8957
60ms	0.8792	0.8940	0.9159	140ms	0.8216	0.8214	0.8931
70ms	0.8670	0.8291	0.9164	150ms	0.8488	0.8352	0.8931
80ms	0.8670	0.8222	0.9181	160ms	0.8488	0.8352	0.8931

Table 1: Multiple correlation coefficients by the Theory of Quantification I for three different convolution functions in the integral Eq. (17): (a) an impact sound itself; (b) "A" weight without any phase angle; and (c) the impulse response of our hearing system.

The integration with a time window was converted to the decibel value with 20log10. It was categorized with a 5dB step. Categories for convolutions (a) (b) and (c) in the above are varied 7 to 9. The result is shown in Table 1.

It shows that the largest multi-correlation coefficient among three convolving functions for every time window was with the impulse response of hearing system. Namely, it says that it is most proper weighing on our hearing attitude of an impact sound. And at the time window of 40ms the multiple-correlation coefficient is the largest for the outsider of the Thurston's scale. It must be the best time window for an impact sound.

A half of the selected impact sounds included pure tones. It was also quantified with Theory of Quantification I to have another factor for pure tone. At the time window 40ms the multiple-correlation coefficient changed only 0.9322 to 0.9357. It is not affected by the factor of pure tone. It might have been accepted as a part of the sound. There must exist a few other factors to make the coefficient larger.

3.1 Summary of this section

The loudness of an impact sound is estimated as follows:

- Firstly, the impulse response of our hearing system is convolved to a given impact noise. If it has an incident angle, its normalized directivity must be convolved.
- Before each signal comes to binaural hearing it is absolutized.
- Meantime, a path way is chosen for the signal; for instance, a pure tone from outside does not beat with a low pitch sound, the resonance frequencies at the ex-ternal ear are smoothed at the transient response for the rectangular pulse of 0.05ms. A rectangular pulse and a pure tone seem to be registered differently in brain.
- 40ms is the best time window for deciding the loudness of an impact sound.
- The non-linear function of power or logarithmic are supposed to be made with the saturation of excessive large input and the internal noise of our self, and the loudness level is given.
- A time window is supposed to be decided by the information and the auto-correlation of a given signal, and the integrand of Eq. (17) is integrated during the time window.

A sound field and the linear part of our hearing system have been solved for a rectangular pulse of 0.05ms. Accordingly, getting out somewhat confused expression of them in the frequency domain, the acoustical linear phenomena are properly arranged and grasped clearly. The above concept can be schematically expressed as in Figure.19.

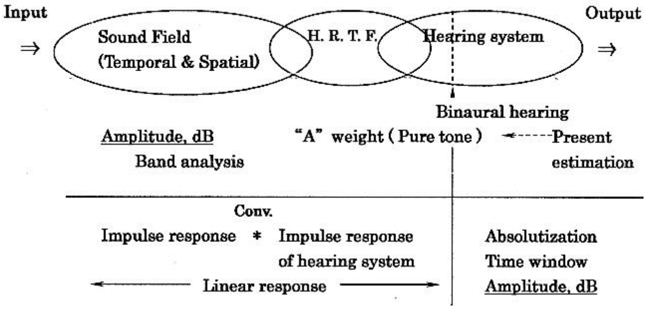

Figure 19: Sound field and hearing system

3.2 Additional comments

1) Absolutization in the hearing system and intensity

Acoustic signal travels in the linear form until it reaches to the process of absolutization of the hearing system. A diffusive sound field does not have any particular direction to hear. Energetic treatment with the amplitude of a microphone in a sound field explains a noise environment somewhat. But if a sound field is coherent or has dominant directions of incidence, it must be careful that the output of a level meter through an omni-directional microphone does not always decide the loudness. There the incident angle is important for the loudness because the HRTF is involved.

2) Temporal aspect of 0.05ms rectangular pulse

Looking back, experiments in the past with 0.05ms rectangular pulses, temporal aspect was as in the following:

0ms	Two pulses of the same amplitude are heard as one pulse with interference.

...Continued on Page 16

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sport's most glamourous scene. Asked about the lack of engine noise, Hamilton said: "*I've said time and time again that I think it's terrible. But most people are like 'oh, it's not that bad'. But my opinion is that I think it is*".

Hamilton said "*when I first went to a Grand Prix at Spa in 1996, got into the paddock and Michael (Schumacher) came past in the V10 (Ferrari) and it literally rumbled my ribcage. I was hooked even more than I was when I'd watched it on TV. It was like a fighter jet – I was like 'what the hell?*" Hamilton also stated that "*It's not the only thing the fans love, but it's an addition to smell, to the roar of awesomeness that Formula 1 is. Take that away and, jeez, it's just sad to see the cars come by now, sound-wise*".

World's largest study shows effects of long-term exposure to traffic noise on blood pressure

In a newly published study in the European Heart Journal, found that among adults, up to one extra person per 100 people of the same age group living in the most polluted areas of cities would develop high blood pressure (hypertension) compared to those living in the less polluted areas.

Professor Barbara Hoffmann, Professor of Environmental Epidemiology at the Centre for Health and Society at Heinrich-Heine-University of Düsseldorf, Germany, who led the analysis, said "*Exposure to traffic noise shares many of the same sources with air pollution and so has the potential to confound the estimates of the adverse effects of pollution on human health. However, this study controlled for traffic noise exposure and found that the associations of air pollution with hypertension did not vanish. This is important because preventive measures for air pollution and noise differ*". The researchers say that it is possible that air pollution and noise affect different, or not completely overlapping, pathways involved in disturbances in the way the body normally functions. Possible biological mechanisms for the adverse effect of air pollution on the functioning of the heart and blood vessels include local and systemic inflammation, oxidative stress [a build-up of damaging molecules in the body], and an imbalance in correct functioning of the nervous system. Noise is thought to affect the functioning of both the nervous and hormonal systems.

Gillies Ave braking noise to be curbed thanks to camera installation

It has been reported that the a noise detection camera has been installed on a busy Auckland road to help residents sleep better at night. Epsom MP David Seymour and the Minister of Transport Simon Bridges unveiled a noise camera to be installed near the Gillies Avenue off-ramp on Wednesday to help crack down on trucks engine braking illegally as they exit the off-ramp, but one resident believes it won't be effective. Greg Bunkall, who has lived in the area for six years and initially approached Seymour about the problem, said while the noise camera was a step in the right direction it wasn't going to stop the noise. Bunkall said the only thing to fix noise pollution would be sound barriers.

Building site work starts at 'ridiculous' time of day

Residents in a quiet Auckland neighbourhood had a rude awakening recently when work on a building site started before the crack of dawn. Housing New Zealand is developing a site in Mount Albert for social housing, and construction got under way late last year. But, on Wednesday morning, sub-contractors tasked with pouring concrete arrived well before the scheduled start time. Before construction started, neighbors' were sent letters outlining the work, including the time each day building would start and finish. Grant Millar the principal contractor for the

...Continued on Page 36

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1.4ms	Two positive pulses of the same ampli-tude start to be heard split.
1.7ms	Two pulses in positive and negative signs of the same amplitude start to be heard split.
3.5-3.8ms	Each of two pulses of the same amplitude is heard equal. Slightly larger than that of a single pulse.
4-5ms	Two pulses are heard completely separated, but its loudness is still slightly larger.

The discrimination time of 1-3ms by Hirsh [17] is referred to papers by Wallach, Newman and Rosenzueing and it was found at different directions. On the other hand, our results in the above were obtained at the median plane.

We learnt that two rectangular pulses of 0.05ms are heard as the same loudness at the time interval of 3.5-3.8ms [14]. It means that the time window for non-correlated two pulses is finished to have integration. This must be the shortest time window. It starts to be separated at 1.4 to 1.7ms but it is not yet done by a time window. Even after this shortest time window, it is not enough long to understand the meaning of signals. They are not yet autocorrelated for that.

3) Gestalt psychology by two 0.05ms rectangular puls-es

Two successive rectangular pulses were heard three or more continuous sounds when their time interval was 50m-80ms. Two non-correlated signals make Gestalt psychology. It is interesting too because it was different at each test person. A few other persons heard them just as two pulses. This different response might tell one's musical favorite and/or talent. The inverse frequency of this range is 12-20Hz. α brain wave (EEG) has 8-13Hz, the lowest frequency of a pipe organ is 16Hz.

4) A few other things around 40ms time difference

A singer at a choir does not like the delay of 40ms from surrounding reflectors on the stage (Harold Marshall, personal communication)

The path difference with 40ms is 13.6m. For 50ms it's 17m. It is often referred this path difference to have the disturbance by an echo especially on speech.

4. Method of acoustical estimation of an Auditorium

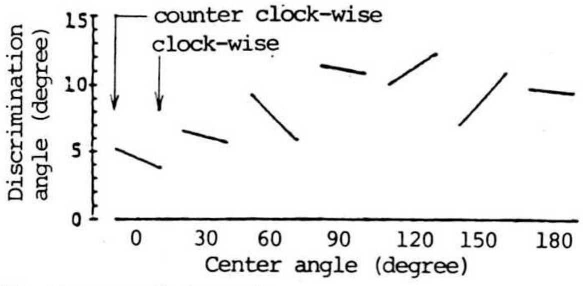
The impulse response calculation of the early reflection in an auditorium has been established as well as its transfer function. The linear response of human hearing system was measured in the form of impulse response with a rectangular pulse of 0.05ms. When a positive and a negative pulse were given from the opposite direction, they were heard on loudness as if two positive pulses were given. It is found that they are absolutized after the linear response.

The discrimination angle for the 0.05ms rectangular pulse was measured, and it happened with the cross-correlation 0.98 of the head related transfer function (HRTF) [18]. Acoustical information can be smoothed spatially and temporally in that region, being convolved with the impulse response of our hearing system which is modified by the directivity. To find its loudness, it must be integrated in a time window.

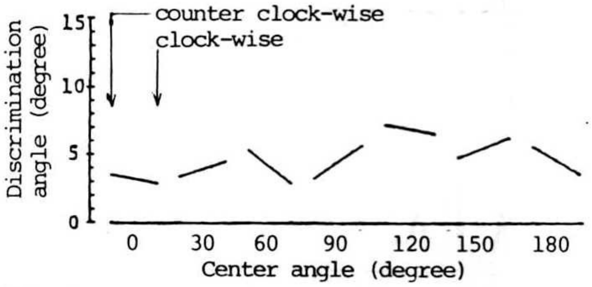
The above information can be expressed using the stereo-scopes. It is called visual sound field [13]. One of the authors got acoustic measurements of world famous concert halls to relate such information of the early reflections of them and their reputations.

4.1 Spatial discrimination for sound field estimation

A rectangular pulse of 0.05ms was generated every one second in the anechoic chamber at Kansai University. A test person was on a rotary chair and asked when he felt that coming direction was changed. Seven centre angles were chosen from 0 degree to 180 degrees at every 30 degrees. The chair was rotated clockwise and anticlockwise. The median plane was at 0 degree and the loud speaker was rotated at 1.2 metres away from a test person.



(i) Monaural hearing.



(ii) Binaural hearing.

Figure 20: Threshold angle of direction discrimination to a rectangular pulse of 0.05ms at monaural and binaural hearing.

Eight male students were tested twice for each and its average was obtained. A discrimination angle is for the clockwise and anticlockwise. Threshold angle of dis-crimination for monaural hearing is given for each centre angle in Figure 20 (i), and that for binaural hearing in Figure 20 (ii). It is very interesting that the binaural hearing shows much more sensitive. The cross talk between both ears should be possible to explain it.

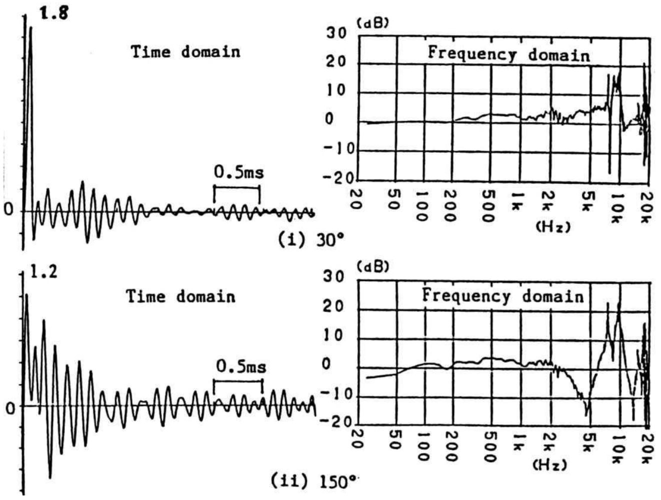


Figure 21: Directivity of head-related transfer function normalised by the one at normal incidence for the incident angle 30 degrees above and 150 degrees below.

The monaural discrimination threshold is supposed to be given by the change of head-related transfer function (HRTF). Namely, it was caused by the cross-correlation function between the HRTF at the centre angle and the discriminated angle. HRTF was measured at the eardrum of a dummy head at a different incident angle with the rectangular pulse of 0.05ms.

The directivity of the HRTF at 30 degrees and 150 degrees is shown in Figure 21 as examples after it was de-convolved or normalized with the one at the front incidence. They are shown for the time domain in the left and the frequency domain in the right.

The transient response of our hearing system, usually written by $R(t)$, was measured at the front. If $R(t)$ is convolved with the directivity at an incident angle, the transient response of our hearing system of the angle is obtained. When directivity is expressed in the time domain being de-convolved with the front one, it can be clearer to understand its feature and it is the information enough for the direction.

As the angle discrimination was supposed to be caused by the directivity of HRTF, the maximum value of the cross correlation function between the directivity at a centre angle and the one at the angle when it was felt changed, was discussed. It was normalized by the auto-correlation function of the two functions.

The maximum cross correlation for each centre angle is shown in Figure 22 for clockwise with ‘o’ and counter clockwise with ‘x’. It deviates around 0.98. The result in Figure 22 was obtained from the experiment in the horizontal level. It is evident that the discrimination is strongly depending on the directivity of the HRTF. If the directivity of a dummy head for a different angle is obtained and the space is divided with angles where cross correlation is 0.98, the spatial discrimination angle will be found for the whole space.

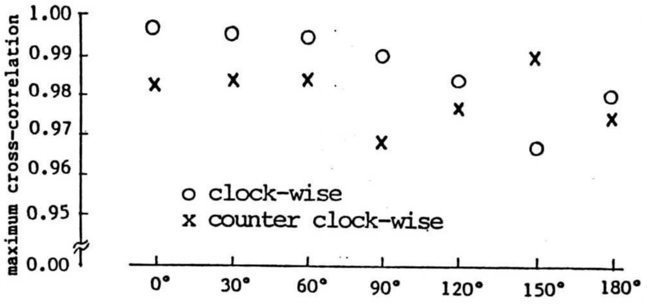


Figure 22: Relation between the threshold of angle discrimination with the maximum cross-correlation of the head-related transfer function.

The sound field information on the impulse response is separated in the angle and then the transient response of hearing system modified to the angle is convolved to it. The acoustic information is smoothed and easier to discuss with.

Not only in the time domain for the evaluation of an auditorium, must it be discussed with the spatial information together. A visual sound field was introduced with stereoscopic expression [13].

4.2 Summary of this section

- Calculation of the impulse response of an auditorium to see it spatially in the time domain.
- Convolution to it of the impulse response of hearing system with the directivity-modified HRTF in a discrimination angle: The space must have 0.98 on the cross correlation of HRTF.
- Integration of its absolute value in the time window 40ms for loudness as a temporary time window.
- The loudness in each discrimination angle is calculated in every time window. This loudness of reflections is expressed in the time sequence through the auditorium space.
- Using visual sound field to see the reflections in loudness, its change can be observed from one seat to another. Reputation of each seat is referred to the visual sound field to find the common Acoustical characters.

When one of the authors got sabbatical leave in 1985 to 1986, he visited world famous concert halls for acoustical measurements. They were done with impulsive sound sources on the stage to a several audience seats. Their impulse responses will be obtained with their Architectural drawings.

Acknowledgements

The authors appreciate Ms Fumiko Nantani for her help of copying some materials from our past papers to MSWord.

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Firstly, Happy New Year to you all, we hope you had a relaxing Christmas break and 2017 has started well. This issue we have details of an Environment Court decision in December 2016 concerning Windflow Technologies' application for the re-consent of the Geddies Pass turbine, Banks Peninsula. Also, a significant decision by the Court of Appeal regarding the confirmation of a District Plan rule which required compliance with specific noise limits at the notional boundary of any dwelling house in the Rural Zone notwithstanding that the dwelling house was not in existence at the time the permitted activity was established.

Following are brief summaries of these proceedings but full copies of these decisions can be found on the RMA Net website at www.rma.net.

In the Environment Court

LUKE PICKERING - Appellant
CHRISTCHURCH CITY COUNCIL - Respondent
WINDFLOW TECHNOLOGY LTD - Applicant

[2016] NZEnvC 237, 44p, [165] paras, 1 December 2016

Summary of Facts

The Council granted Windflow Technology's application for the re-consent of a wind turbine at Gebbies Pass, Banks Peninsula. Under the Replacement District Plan the activity consent status was non-complying. Mr Pickering, a resident of McQueen's Valley, joined by several other residents, appealed the decision on the grounds that the residents of the valley had experienced noise from the turbine which had intruded upon the general enjoyment of their properties and for some, disturbed their sleep. Mr Pickering sought the consent be refused.

McQueen's Valley was described as a low sound environment and the primary issue was whether the valley was adversely affected by noise generated by the wind turbine. The most applicable noise standard was held to be NZS 6808:2010 and the experts agreed that the noise level from the turbine was below the high amenity noise level standard and that measurements did not show the turbine exhibiting any special audible characteristics (SAC).

However, the experts disagreed on whether the character of the receiving environment was sufficiently out of the ordinary and the character of the wind turbine noise sufficiently annoying that the noise limits in NZS 6808 did not, by themselves, maintain residents' amenity. It was agreed that the turbine should not warrant a penalty for SAC's in the valley. However, the primary issue arose from the low frequency sounds resulting in amplitude modulation, which was attributed to the motion of the blades passing in front of the support tower creating an impulsive sound.

Based on the measurements taken by the applicant, the Court found that the turbine could operate within the noise limits in NZS 6808 including the high amenity area limit at the notional boundaries of the residences of the valley and that penalties for SACs would not apply. The Court then went on to consider the proposal's benefits and adverse effects on the environment in the context of the planning documents. Having regard to the character and amenity value of the receiving environment the Court was satisfied that the proposal was not contrary, but gave effect to, the Replacement District Plans' objectives and policies. The proposal would have a more than minor effect on the views from three dwellings, however the scale and extent of this effect would still maintain the rural character and amenity of the valley.

Court held:

Appeal allowed to the extent that the application for consent was granted, subject to further amendments to conditions.

Costs reserved.

In the Court of Appeal

NORTH CANTERBURY CLAY TARGET ASSOCIATION INCORPORATED - Appellant
WAIMAKARIRI COUNCIL - Respondent

[2016] NZCA 305, 17p, [51] paras, 15 July 2016

Summary of Facts

The Association conducted clay target shooting practices at 269 Boundary Road, Cust for many years. Previously operating under a consent, in 2008 the Association was given a certificate of compliance after having satisfied the Council that its activities complied with applicable noise limits at the notional boundary of any dwelling house in the vicinity. Since 2008, houses had been built much closer to the Association's property resulting in noise complaints from the residents. In decision [2014] NZEnvC 114 the Environment Court held that the noise rule in the District Plan required continuing compliance with noise standards in a receiving environment that could be expected to change over time. The Association appealed, however in decision [2014] NZHC 3021 the High Court dismissed the Association's appeal. With the Association at risk of having its long-established and permitted activities curtailed it applied and was given leave to appeal ([2015] NZCA 225) on two questions of law:

Does rule 31.11.12 of the Waimakariri District Plan require compliance with specified noise limits at the notional boundary of any dwelling house in the Rural Zone in existence from time to time, notwithstanding that the dwelling house was not in existence at the time of the permitted activity was established?

Where a certificate of compliance has been issued under s 139 of the RMA, is the holder of the certificate subject to a continuing obligation to abide by the noise limitation specified in rule 31.11.12, notwithstanding the changing surrounding physical environment?

The Court discussed the District Plan in relation to permitted activities and noise constraints, and the certificate of compliance and Section 139, before reviewing the Environment Court and High Court decisions. Starting with the second question of law, whether post-certificate changes in the receiving environment affected the holder's obligation to abide by noise limits, the Court noted a certificate was subject to s 10 and the Association's activities appeared to now be significantly more intensive than it once was. The heart of Association's case lay in the proposition that the certificate added to its existing use rights by exempting it from compliance with a rule that was already in effect. The Court held that the Association's argument was positively inconsistent with s 10, to which certificates were expressly subject. Under s 10 a given use was not protected from a rule that became operative before the use was established.

The Court highlighted the Association's appeal turned on the meaning of the noise rule; specifically, whether it was ambulatory in the sense that it required compliance at dwellings built since the use was established. The certificate only established that the use complied in fact at a given date, in the environment as it was at that time. The Court felt the first question was to be answered by interpreting the Plan as a whole, noting the noise rule existed to regulate noise that adversely affected the amenity values and health and safety of people on neighbouring sites, the focus being on dwelling houses. While farming activities were exempt, the Association's use was not. The Plan recognised that the receiving environment may change because of new dwellings erected in the Zone. Against that background the Court agreed with the other Courts that the certificate did not protect the Association from changes in the receiving environment.

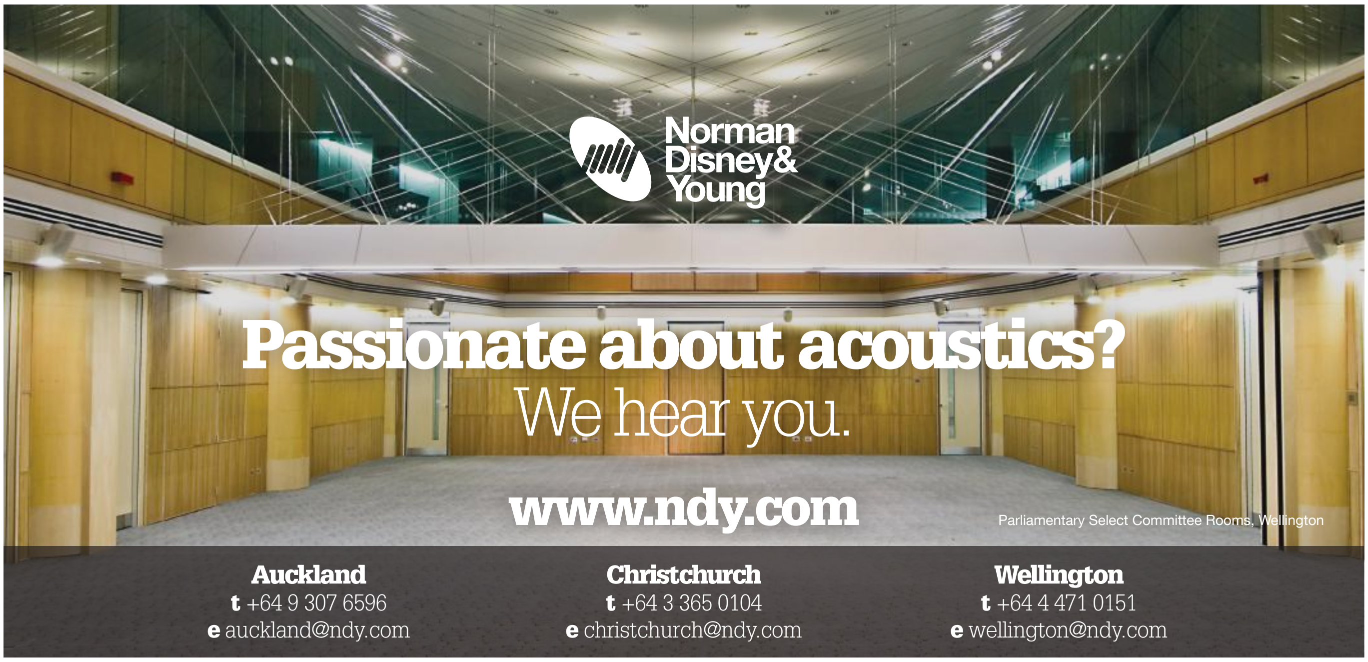
Court held:

The answer to both questions of law was yes.

Council succeeded in the result.

No costs sought.

Disclaimer - *This article has been provided to help raise an initial awareness of some recent cases involving acoustic issues. It does not purport to be a full listing of all decisions which have acoustic issues, nor does it replace proper professional advice.*



Two recent sound insulation test results

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Abstract

A minimum level of inter-tenancy sound insulation is specified in Clause G6 of the current New Zealand Building Code. The clause was first introduced in July 1992, and despite a number of proposed revisions, has not been significantly revised since its introduction. A paper published in 2011 noted that Clause G6 had the lowest "estimated equivalent R'_w" rating amongst the 26 (predominantly European) countries considered. This brief paper discusses two recent sound insulation test results in light of a recent determination regarding the applicability of Clause G6, and in light of a proposed.

Originally published in the Proceedings of ACOUSTICS 2016, 9-11 November, Brisbane, Australia.

1. Introduction

In 2014 Design Acoustics Auckland Ltd (DAAL) carried out airborne and impact sound insulation tests between two recently completed adjoining terrace houses. The internal layouts were the same for both residences:

- Ground floor; entry, open plan kitchen/dining/living area, bedroom, bathroom.
- First floor; two bedrooms, one bathroom.

The separating inter-tenancy wall was full height double timber frame construction, with a published rating of STC 63. The mid-floors were timber frame construction. The ground floor was slab on grade construction and ground floor was finished in polished concrete. There was a 300 mm deep ground floor slab thickening centered under the inter-tenancy wall.

Two tests were carried out between the adjacent ground floor kitchen/dining/living areas. The test arrangement is shown in Figure 1.

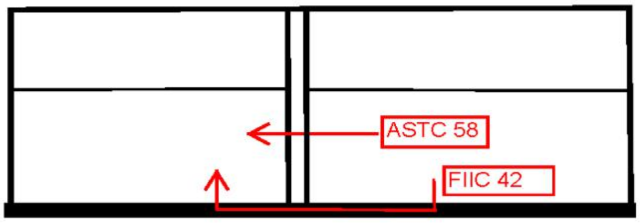

Figure 1: Test arrangement

The calculated test results are shown in Table 1.

Table 1: Test results

Test type	Result
Airborne	ASTC 58
Impact	FIIC 42

The following ISO stndard metrics were calculated from the test measurements: R'_w 57, $L_{n,w}$ 67.

Clause G6 of the New Zealand Bulding Code [1] has minimum on-site allowable results of ASTC 50 and FIIC 50. The test result of ASTC 58 is comfortably above the minimum requirement and shows there were no significant airborne flanking paths between the rooms. However, the impact test result of FIIC 42 is significantly less than the minimum requirement – if the test is required as part of compliance testing.

2. Determination of 2015/007

The impact test described above is an example of "horizontal impact noise", that is, the source room and the receive room are on the same floor level and are not vertically separated.

The applicability of horizontal impact testing has been the subject of some debate over recent years, and '*Determination 2015/007*' [2] was intended to provide direction in this regard. 'Determination 2015/007' was principally concerned with applicability of the general building code sound insulation requirements to apartment-style accommodation within a retirement home complex. Within this determination, the consideration of horizontal impact noise was an "extra" and was not limited to a retirement home context. In reaching a conclusion, the author of '*Determination 2015/007*' took the wording of Clause G6 into account, but also considered invited submissions.

The text of Clause G6 is silent on the "directionality" of testing, however the clause applies to "building elements which are common between occupancies", and the testing standard cited for calculation of IIC applies to "floor-ceiling assemblies". The author of '*Determination 2015/007*' also acknowledged a submission that pointed out "there is currently no known acoustic laboratories world-wide where any horizontal impact testing has been carried out on concrete structures".

'Determination 2015/007' found that compliance with the impact noise requirements of Clause G6 is required vertically, but is not required horizontally. Therefore, the impact test described above need not be carried out, nor reported on, as part of compliance testing. Provided other test results were satisfactory, the building would meet the requirements of Clause G6.

3. Proposed code revision

Despite there having been no substantial changes to Clause G6 since its introduction, there have been a number of proposed revisions over the years.

In 2014 a revision to Clause G6 was developed and submitted that proposed: ISO stndard airborne and impact sound insulation requirements; consideration of noise from building services; and consideration of environmental sound.

At the time of writing (July 2016), this revision is still "live" but has not been made public. By the time of the ACOUSTICS 2016 conference in November, it may or may not have been formerly accepted for review and progressed to the public consultation phase. As at July 2016 this proposed code revision does specify that impact noise in a horizontal direction be assessed as part of code requirements.

4. Conclusion

The test results given above, '*Determination 2015/007*', and the proposed revision to Clause G6, raise a number of questions:

1. If the technical issues regarding the assessment of horizontal impact noise were considered in New Zealand as recently as 2015, and if the assessment of such noise is not the standard or accepted practice overseas, is there a sound basis for including the assessment of horizontal impact noise in future Clause G6 code revisions? Should the New Zealand Building Code "lead the world" in this regard?
2. Putting aside technical arguments and justifications, is the on-site test result of FIIC 42 described above, measured between what are two high-traffic ground floor areas of abutting dwellings, adequate and acceptable to residents in practice?

Consideration of these questions could help inform and shape the development of the next Clause G6.

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Overview of developments in the description and assessment of high intensity impulse noise exposure

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Abstract

The precise description and assessment of high intensity impulse noise can be difficult due to the rapid onset-rates, short durations, very high peak noise levels (and overpressures) and the non-linear acoustic behaviour in the near-field of the source. Furthermore, determining the likely impact on hearing is limited by the current tools available for assessing the actual noise exposure/dose, auditory hazard risk and potential (irreversible) hearing damage. This paper provides insight to the recent developments in the measurement, prediction and assessment of impulsive noise exposure. Guidance is given on the relevant standards and guidelines, the range of measurement and prediction methods, impulse waveform pressure-time characteristics, relevant noise metrics/descriptors, models of impulsive noise exposure and hearing damage mechanisms. Recently developed electroacoustic hearing models are explored, including the Auditory Hazard Assessment Algorithm for Humans (AHAAH) and exposure metrics such as Auditory Risk Units (ARU). Other emerging influences and synergistic effects due to ototoxic substances, human vibration and extended work-shifts are investigated. Real-world examples and the mitigation of high intensity impulse noise are explored along with the need for further research and innovation.

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1. Introduction

Exposure to high intensity impulse noise represents a significant occupational noise hazard, especially in certain industries such as defence, mining, trades and industrial plants. Noise Induced Hearing Loss (NIHL) is one of the most prevalent and serious occupational health conditions and is a consequence of being subjected to long term exposure to high noise levels, and exposure to very high peak noise. Compensation claims paid to employees who suffer from some form of hearing loss is estimated to be well into the hundreds of millions globally, and assessing and understanding the health risks to a workers' health have become a key responsibility for employers.

In relation to the description and assessment of high intensity impulse noise, problematic issues are associated with the accurate measurement and prediction of impulsive noise events due to the very short durations, rapid onset-rates, large amplitudes (high peak noise levels/ overpressures) and the non-linear acoustic behaviour close to the source. In addition, the previous tools available for assessing the actual noise exposure, auditory hazard risk and potential hearing loss are limited. For impulse noise, there is a need for determining the number of peak events above a certain threshold that is allowable before the risk of permanent NIHL becomes too high.

Recent developments in the description and assessment of impulsive noise exposure provide improved guidance in the areas of impulse measurement and prediction methods, applicable noise exposure descriptors and criteria, models of hearing damage mechanisms and new methods for determining impulsive noise exposure.

2. Relevant Standards and Guidelines

A brief overview is provided of the relevant standards, legislation and guidelines within Australia and internationally. There have been recent developments in the methods of measurement, prediction and assessment of impulsive noise exposure. The primary standards that relate to impulse noise, with a brief summary, include:

1. AS/NZS 1269, Occupational Noise Management (comprising 5 parts, 0 to 4; latest version: 2005)

AS/NZS 1269.1 (Part 1: Measurement and assessment of noise immission and exposure) stipulates the preferred measurement quantities and metrics for occupational exposure of $L_{Aeq,T}$ (or $E_{A,T}$) and L_{peak}. The L_{peak} level is used to determine impulse noise exposure. AS/NZS 1269.3 (Part 3: Hearing protector program) Appendix B provides a normative method for selecting a hearing protector for when Lpeak exceeds L(crit)peak: for impulse noise from small-calibre weapons and tools, use Class 5 hearing protection (HP); and for impulse noise from large-calibre weapons and blasting, use double HP with at least Class 3 earplugs and earmuffs of any classification.

2. ISO 1999, Acoustics – Estimation of noise induced hearing loss

ISO 1999:2013 specifies a method for calculating the expected noise-induced permanent threshold shift in the hearing threshold levels of adult populations due to various levels and durations of noise exposure. It provides the basis for calculating hearing disability when hearing threshold levels at measured audiometric frequencies exceed a certain value. Estimates of NIHL are based on time-varying exposures to steady-state noise and may not be reliable for impulse noise (sound levels greater than

140 dB); the standard therefore may not provide valid estimates of hearing loss for impulse noise. Note: AS ISO 1999:2003 (based on old ISO 1999:1990 version, including noise exposure estimation) has been superseded and the new version, ISO 1999:2013, now applies.

3. ISO 9612, Acoustics – Determination of occupational noise exposure – Engineering method

ISO 9612 :2009 provides an engineering method and equations to calculate time-averaged sound exposure levels. Like ISO 1999, the standard does not adequately address impulse noise, apart from noting highest L_{Cpeak} levels, and the standard is therefore less likely to provide valid estimates of noise exposure for impulse noise.

4. AS/NZS 3817, Acoustics – Methods for the description and physical measurement of single impulses or series of impulses

AS/NZS 3817 :1998 is a direct text adoption (DTA) of the international ISO 10843 :1997 standard, described below. This standard is likely to be reconfirmed as a DTA of the latest version of ISO 10843; if this is the case then AS/NZS 3817 will be withdrawn and the new standard will be AS ISO 10843.

5. ISO 10843, Acoustics – Methods for the description and physical measurement of single impulses or series of impulses

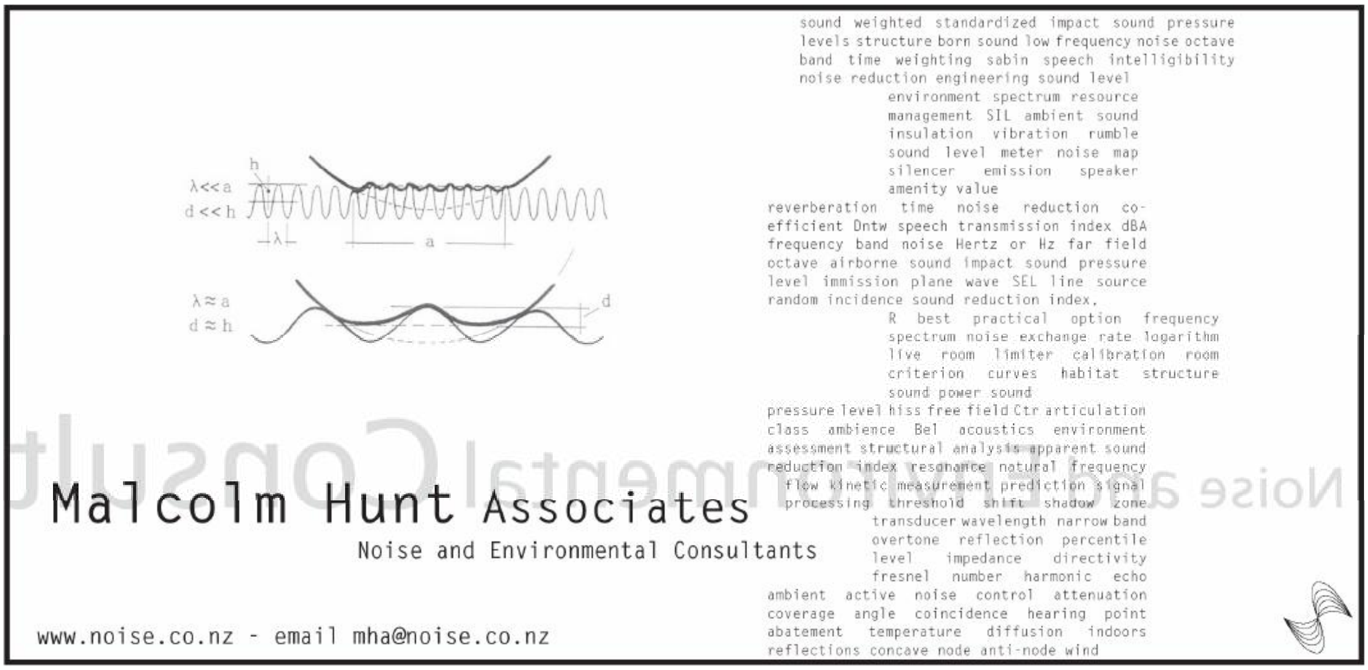
ISO 10843:1997 (with Technical Corrigendum 1 :2009) describes preferred methods for the description and the physical measurement of single impulsive sounds or short series of impulsive sounds and for the presentation of the data. It does not provide methods for interpreting the potential effects of series of impulses of noise on hearing and receiver points. ISO 10843 provides the range of parameters and metrics that define impulse noise characteristics, and methods for measurement of phase-sensitive parameters and time-integrated quantities.

6. ISO 13474, Acoustics – Framework for calculating a distribution of sound exposure levels for impulsive sound events for the purposes of environmental noise assessment

ISO 13474:2009 provides an engineering method for calculating a statistical distribution of event sound exposure levels at locations which are some distance from high-energy impulsive sound sources. Hence, it is specifically intended for environmental noise assessment at distance and not for the assessment of the risk of occupational noise exposure. However, the standard does provide guidance on the determination of impulse source characteristics such as the measurement and estimation of sound emission properties of muzzle blast and projectile sound. It generally uses the methods defined in ISO 17201 with some modifications.

7. ISO 17201, Acoustics – Noise from shooting ranges (comprising 5 parts, 1 to 5)

ISO 17201 provides guidance for calculating the sound propagation of shooting sound from shooting ranges, primarily for environmental noise assessment purposes. The standard applies to firearm calibres of less than 20 mm or explosive charges of less than 50g TNT equivalent. The five parts of the standard include: ISO 17201-1 (*Part 1: Determination of muzzle blast by measurement*), ISO 17201-2 (*Part 2: Estimation of muzzle blast and projectile sound by calculation*), ISO 17201-3 (*Part 3: Guidelines for sound propagation calculations*), ISO 17201-4 (*Part 4: Prediction of projectile sound*), ISO 17201-5 (*Part 5: Noise management*). These parts are described further in section 4 of this paper. A new Part 6 has been proposed for guidance on occupational noise exposure from impulsive shooting or blast noise at close range to the source, and is currently under preparation.



8. MIL-STD-1474, US Military Standard

The United States' Department of Defence has developed a Design Criteria Standard, MIL-STD-1474 (latest version: MIL-STD-1474E, issued 15th April 2015), for Impulsive and Continuous Noise of Platforms and Weapons Systems (Design Criteria – Noise Limits). It provides noise criteria for designing defence materiel having noise levels that minimise the risk of permanent noise induced hearing loss. While this standard is not enforceable in Australia, it is a useful guideline for the impact of high intensity impulsive noise, in lieu of a suitable AS. The MIL-STD-1474E (Appendix B – Impulsive Noise) uses two methods to determine the noise risk associated with impulsive noise that exceeds an L_{Cpeak} of 140 dB, including a new exposure metric, the Auditory Risk Unit (ARU). The MIL-STD-1474E recommends noise criteria, based on the ARU metric, to minimise the likelihood of permanent hearing loss; which is described further in section 5 of this paper.

9. Other relevant standards and guidelines include: European Union (EU) Directive 2003/10/EC, NORDTEST Method NT ACOU 112 (2002-05), American standard ANSI S3.44, US OSHA standard 1910, US NIOSH Standard (Criteria for a Recommended Standard – Occupational Noise Exposure), UK Control of Noise at Work Regulations L108 and the World Health Organization (WHO) Occupational Noise Exposure Criteria

National legislation in Australia (WHS Act 2011, WHS Regulations 2011, WHS Code of Practice) states that employers must ensure employees are not exposed to noise levels within the workplace that exceed the national exposure standard (NES) for noise; i.e. $L_{Aeq,8h}$ of 85 dB and L_{Cpeak} of 140 dB.

3. Impulse characteristic and descriptors

The sudden onset of a sound is defined as an impulse. High-level, short-duration noise can arbitrarily be categorized as impulse noise, which is the product of explosive devices (e.g. gunfire), or impact noise, which is generated by the forceful meeting of two hard surfaces (e.g. hammering, impact wrenches).

Impulse noise is typically characterized as having the following main properties:

- rapid onset-rates – the onset rate is the slope in dB/second of the straight line approximation between the starting point and end point of the impulse waveform time history (typically greater than 10 dB/s).
- very short durations – the first positive pulse duration can be of the order 1 to 5 ms for weapon firing and a pulse width of up to 10 ms for some sources.
- large amplitudes for high intensity sources, i.e. very high peak noise levels (greater than 130 dB and up to 180-190 dB).
- extreme overpressures for high energy sources (greater than 1 kPa and up to 100 kPa).
- high-energy impulsive sound sources comprise prominent low-frequency components.

The typical descriptive measures of impulse noise are the initial peak level and the duration of the first overpressure. This is the A-duration and is typically less than 1 millisecond (ms) for small-medium calibre firearms (e.g. rifles, machine guns) and several milliseconds for large calibre weapons (e.g. cannons). For impact noise, the two principal descriptors are the highest peak in a series of successive peaks (i.e. reverberations) and the so-called B-duration, the duration from the highest peak level to a point in time when the reverberations have decayed by either 10 or 20 dB. B-durations typically are 50 - 300+ ms.

The character and prominence of the impulse at an immission or receiver point depends on the character of the emitted sound, the distance and propagation path from the sound source and the background noise.

In the near-field of impulse sources (within about 20m to 30m for large calibre weapons, depending on source) the acoustic field exhibits non-linear behaviour, and presents difficulties for accurately measuring or predicting noise levels in this region. Many studies have found that non-linear effects can occur in high pressure wave propagation, and as a result, application of non-linear mathematical methods (e.g. Hilbert transform, causality indices) are employed to describe high intensity sound waves and are justified by the fact that linear approaches do not provide accurate solutions for high pressure acoustics [1].

The region within which non-linear acoustics applies is above 154 dB (1 kPa) – this is where strongly non-linear waves and shock waves are generated (where dynamic pressure is close to static pressure of 100 kPa or 194 dB), leading to different sound speeds in different parts of the wave and causing additional/non-linear attenuation. Distances should be 2–3 times longer than the longest wavelength in order for lowest frequencies to fully develop.

The two primary sound generating sources from firearm/weapon firing are the muzzle blast (sound from explosion inside gun barrel, rapid directional volume expansion of gases and resulting pressure waves) and the projectile sound (non-linear sonic boom of supersonic projectiles plus any turbulence, scattering, reflection).

4. Measurement and prediction methods of impulse propagation

4.1 Measurement methods

ISO 10843 describes preferred methods for the physical measurement of single impulsive sounds or series of impulsive sounds. It provides the range of parameters and metrics that define impulse noise characteristics, and specifies methods for: 1) measurements of phase-sensitive parameters (such as peak sound pressure level and duration, which characterises the variation of

sound pressure with time) and 2) measurements of time-integrated quantities (such as frequency-weighted sound exposure level or sound energy level). However, it does not provide methods for interpreting the potential effects of series of impulses of noise on hearing and receiver points.

ISO 17201 provides guidance for calculating the sound propagation of shooting sound from shooting ranges. The standard applies to firearm calibres of less than 20mm or explosive charges of less than 50g TNT equivalent, and applies at distances where peak pressures are below 1 kPa (154 dB), outside the non-linear acoustic region. Energy-based levels (L_{AE}, L_{CE}) are used to describe or assess annoyance due to impulse noise (for environmental noise assessment purposes) and maximum or peak levels (e.g. L_{IAmax}) may not be considered valid.

ISO 17201-1 (*Part 1: Determination of muzzle blast by measurement*) provides an engineering method for determining the angular source energy distribution of a firearm muzzle blast from measurements. The source energy, its directivity and spectral structure can be used as input for sound propagation models for environmental noise assessment. The angular source energy distribution levels, $L_q(\alpha_n)$, are estimated on the basis of the sound exposure level measurements, $L_E(r_m, \alpha_n)$, at N discrete angles α_n at the distance r_m (assuming rotational symmetry). Due to ground reflections when measuring above ground, the sound exposure level $L_E(r_m, \alpha_n)$ will also depend on rotational angle β; however, corrections are provided to remove ground reflections. In order to calculate the total source energy and to provide a continuous directivity function, a curve fitting for the angular source energy distribution level is needed, and curve-fitting methods describe the periodic behaviour of the directivity function.

Detailed measurement procedures and sound data requirements are provided in ISO 17201-1. At least five measurements of the sound exposure, $E(\alpha, r_m)$, are required to be made at each microphone position (and angular increment step should not exceed 45°). Simultaneous measurements should be made at all microphone positions; however, measurements may be made sequentially but two microphones should be used with one microphone remaining at the same position. If the peak sound pressure level exceeds 154 dB at any of the microphone positions, the measurement distance shall be increased. Peak pressures should preferably be read from the time/pressure signal, where the error due to limited equipment high-frequency response can be corrected.

Aside from detailed sound level meter measurements of impulse noise, one common method used to assess occupational noise exposure is that of personal noise dosimetry sampling. However, there are serious limitations to obtaining accurate and reliable measurements of impulsive noise levels using dosimeters. This is due primarily to the limitations of most standard dosimeters to maximum peak levels of 140 dB (high impulse levels often exceed this range) and the occurrence of extraneous peak events due to accidental or intentional tapping/knocking the dosimeter while being worn.

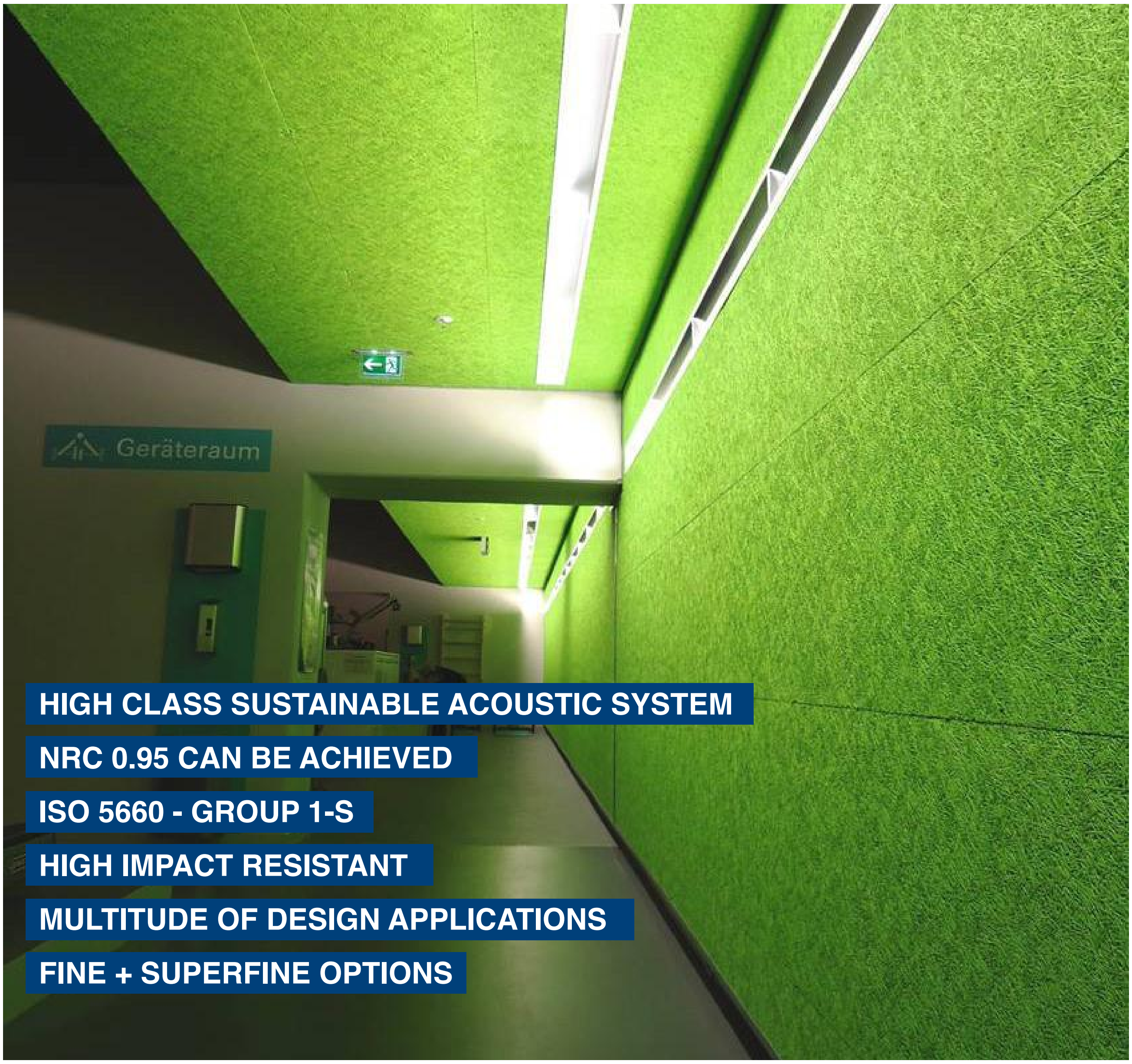
4.2 Prediction methods

ISO 17201-2 (*Part 2: Estimation of muzzle blast and projectile sound by calculation*) provides methods for estimating the acoustic source data (i.e. spectral angular source energy distribution) of muzzle blast and explosions and the source data of projectile sound on the basis of non-acoustic data for firearms. This part effectively provides an interpolation method between measurements of muzzle blast. Firearm muzzle blast is highly directive, and both the angular source energy distribution and spectrum vary with angle from the line of fire.

The method is separated in two parts: firstly, the acoustic energy of the shot is estimated; secondly, the directional pattern of the source is applied and the spectrum calculated. The procedure allows the use of very general data or, if available, specific data to provide a more accurate result. Therefore, the procedure allows the use of alternatives such as default values or specific values for certain parameters. The estimate of the muzzle source energy (from estimating chemical energy, energy conversion efficiency, acoustic energy and Weber propellant energy density parameters) is used to determine the acoustical source data, including blast source directivity, spectrum and projectile sound source energy. This allows the sound exposure to be determined at a reception point, depending on the path length from the source position.

ISO 17201-3 (*Part 3: Guidelines for sound propagation calculations*) provides an engineering method for predicting sound exposure levels of shooting sounds for single shots at a certain receiver point, for open field and non-open field situations. This part uses a modification of the ISO 9613-2 method and provides guidance on how to calculate other acoustic measures from sound exposure level. Modelling of projectile sound is specified in ISO 17201-2 and ISO 17201-4. ISO 17201-4 (*Part 4: Prediction of projectile sound*) also gives guidelines for the calculation of the propagation of projectile sound (as far as it deviates from the propagation of other sound) such that for the attenuation for projectile noise, A_{excess}, ISO 9613-2 can also be used. Other attenuation parameters such as divergence, air absorption and non-linear attenuation are specified in ISO 17201-4.

In open field situations, especially in front of the firearm when the distance to the trajectory is short, projectile sound can be a relevant source for the sound exposure level of shooting sound. If a shot is fired in a shooting range, projectile sound is in general of minor importance in the estimation of the sound exposure level at a reception point. However, if measures are taken to reduce the sound emission of the muzzle blast, projectile sound can then become a dominant factor.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The propagation calculation may be performed using ray-tracing or more sophisticated models, which take specific weather conditions into account. To calculate a long-term L_{eq}, the results are weighted with respect to the frequency of occurrence of weather conditions pertinent to the time periods of interest. ISO 17201-3 also provides estimate relations for the conversion of sound exposure level to various L_{max} metrics.

5. Models of hearing damage and noise exposure

5.1 Effects of noise and hearing damage

The effects of impulse noise on the auditory system and likely hearing damage mechanisms are briefly described. Impulse noise creates several special hazards to the human auditory system.

First, the high peak levels associated with gunfire (140 –190dB) may damage the cochlea by causing rapid mechanical failure and injury [2] [3]. A series of rapidly occurring impulses can be partially attenuated by the acoustic reflex, a reflexive contraction of the middle-ear muscles, while isolated impulses reach the cochlea before the activation of the acoustic reflex. Thus, intense explosions may result in large cochlear lesions and significant hearing losses. This damage is termed “acoustic trauma”, and hearing at most frequencies may be affected. Additional symptoms include a sense of fullness in the ears, speech sounding muffled and a ringing in the ears (i.e. tinnitus). Although some recovery of hearing takes place after an acoustic trauma episode, the individual is often left with a severe, permanent hearing loss [2].

The relationship between noise-induced hearing loss and the peak amplitude of an impulse or impact noise is complex. Systematic research has shown that at the lower range of exposure to impulse noise (< 140 dB) or impact noise (< 115 dB), the hearing loss is likely to be proportional to the total energy of the exposure (peak level × number of impulses). However, above these peak sound pressure levels, the auditory system is damaged primarily by the large displacements caused by high peak levels. The dividing line between the “*energy*” and “*peak-level*” behaviour is referred to as the “*critical level*”, taken to be 140 dB but is dependent on the impulse waveform.

Humans experiencing blasts at very high sound levels (> 170-180 dB) may suffer damage to the middle ear, including haemorrhage in or perforation of the eardrum and fracture of the malleus. If the eardrum does not rupture during such an intense exposure, the organ of Corti is likely to rupture off the basilar membrane. When a portion of the organ of Corti ruptures, it does not reattach to the basilar membrane and it eventually degenerates. Individuals with mild or moderate permanent NIHL typically have some structural damage in their cochleas. The damage may initially involve scattered loss of sensory cells, primarily outer hair cells, in the organ of Corti. NIHL may also result in damage to, or destruction of, other important structures in the cochlea, including fibrocytes in the spiral ligament and limbus and cells of the stria vascularis [2].

For high-intensity low frequency sounds, good consistency has been observed in human and animal studies between the frequency content of the exposure stimulus and the location in the cochlea experiencing the greatest damage or injury. For narrow-band stimuli, the maximum cochlear insult is often one-half to one octave higher in frequency than the exposure stimulus. For broad-band noises and impulses, more commonly at military and industrial sites, the damage is greatest in the high-frequency (i.e. basal) portion of the cochlea. Also, the differences in location of the greatest cochlear damage are accurately reflected in the pattern of hearing loss.

Hearing damage mechanisms relating to impulse noise are difficult to establish with certainty and further research is required. There is a well-defined need for better tools and models for simulating and estimating the hearing damage resulting from impulse noise exposure.

5.2 Noise exposure and hearing models

The accurate determination of the likely impact of impulse noise on hearing and the auditory system is limited by the previous tools available for estimating and assessing the actual noise exposure, auditory hazard risk and potential hearing loss. Theoretical and semi-empirical hearing models provide predictive methods for the estimation of hearing damage mechanisms, damage risk criteria (DRC) and resultant noise exposure. In general, for noise exposure, one can add 10logN to the one shot exposure to determine the noise exposure from N shots.

Advanced electroacoustic, biomechanical and dynamic hearing models have been recently developed and tested. One such model is the Auditory Hazard Assessment Algorithm for Humans (AHAAH) mathematical software model (www.arl.army.mil/ahaah), which represents an advance in the evaluation of hearing damage risk associated with impulsive noise [4]. The AHAAH algorithms apply pressure response dynamics measured for the external, middle, and inner ear, to biomechanically model the ear’s non-linear physical response to impulsive sound and accurately determine the strain-induced fatigue occurring in the cochlea’s organ of Corti. It models the 95th percentile (most susceptible) human ear. It also applies a user-selected direction from which sound is incident on the ear; sound traveling toward the head along the inter-aural axis is a worst-case condition.

The AHAAH Model calculates the auditory hazard of impulsive sounds by dynamically modelling their transmission from the free field, through hearing protection (if used), through the middle ear, into the inner ear, where noise-induced hearing damage typically occurs. The model includes an active auditory reflex, involving middle ear muscle contractions, which can occur in response to the arrival of an intense sound or in anticipation of the arrival of such a sound. The output of the model is given in Auditory Risk Units (ARUs), which are physically related to damage resulting from displacements of the basilar membrane in the inner ear. The AHAAH model was developed based on the mechanical and fluid dynamic properties of the ear, and includes wave motion analysis of the basilar membrane in the cochlea based on the Wentzel–Kramers–Brillouin wave dynamics method.

The US standard MIL-STD-1474E (*Appendix B – Impulsive Noise*) uses two methods to determine the noise risk associated with impulsive noise that exceeds L_{Cpeak} of 140 dB. Note that these new methods supersede the previous MIL-STD-1474D method and the Free-field Exception (FFE) and Proportional Dose (PD) methods. The two methods in MIL-STD-1474E employ the following two metrics for assessing noise exposure:

- $L_{IAeq,100ms}$ metric (equal energy model), and
- Auditory Risk Unit (ARU) metric, calculated from the AHAAH model.

Comparison between the two methodologies is presented in Table B-11 of the standard. MIL-STD-1474E recommends the following noise damage risk criteria (DRC) to minimise likelihood of permanent hearing loss:

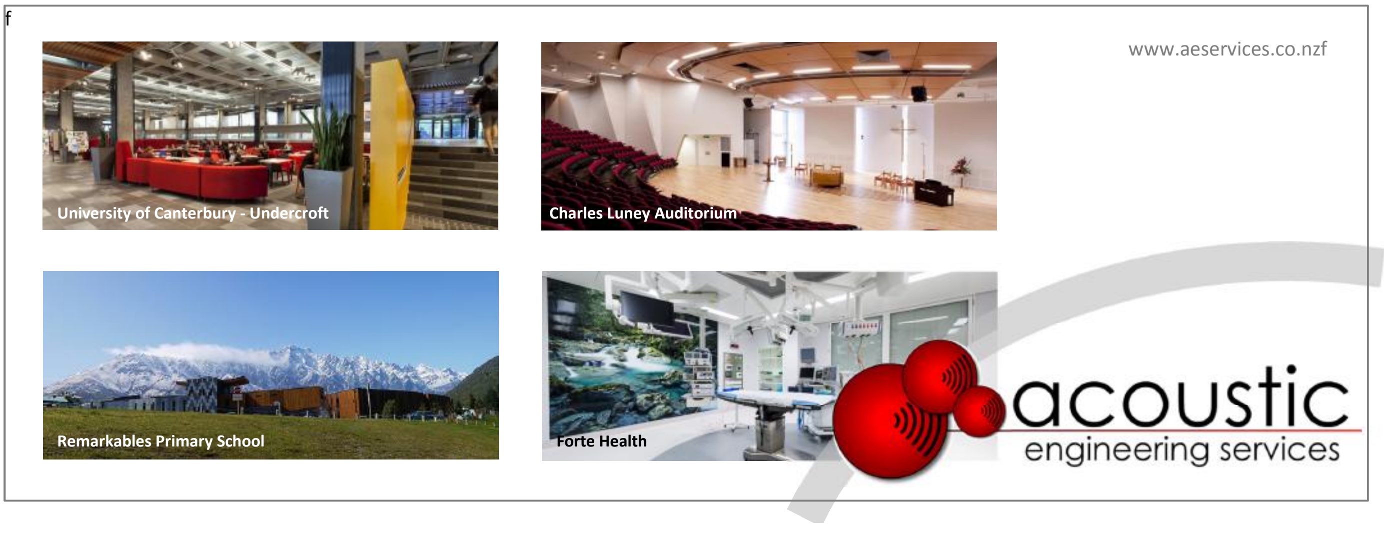
- a total of 500 ARUs is the maximum allowable 'dose' (within a 24 hour period) for occasional exposures (e.g. less than once per week on average), noting that doses greater than 500 ARUs are predicted to produce permanent hearing loss; and
- for occupational exposures occurring more regularly (i.e. on average, daily or near daily), the limit should be reduced to 200 ARUs (within a 24 hour period) to reduce the likelihood of permanent hearing loss.

This prescription is based on the direct relation between ARUs, temporary changes in hearing sensitivity and the probability of permanent hearing loss. A dose of 500 ARUs is barely safe, a dose of 200 ARUs is more reasonable as an occupational dose limit where daily exposures could occur. The allowable number of rounds (ANOR) of weapon fire is determined based on noise exposure limits of 200 and 500 ARU.

Inputs to the AHAAH model include the high resolution pressure-time history of the impulse waveform, and the model predicts the resultant transfer functions and in-ear displacements. The AHAAH model and MIL-STD-1474E allow the calculation of the attenuation of different default hearing protection configurations (for both "*warned*" and "*unwarned*" scenarios). The Hearing Protector Module (HPM) of the AHAAH software models all hearing protectors as passive level independent linear (LIL) devices. The model includes several level dependent non-linear (LDNL) hearing protector devices (HPDs). These LDNL HPDs are modelled linearly, based on Real Ear Attenuation at Threshold (REAT) measurements performed with the HPDs worn in the closed and the open modes.

Other models have been investigated and include: 1) MIL-STD-1474D; 2) NATO Models; 3) L_{Aeq8} Model. The previously used MIL-STD-1474D standard model has shown to be inaccurate for determining impulse noise injury. The other models have their merits but have generally been shown to be deficient in the prediction of impulse noise impacts compared to the AHAAH Model in a recent review [11]. The AHAAH Model has been extensively evaluated, peer-reviewed and fully vetted and is the new standard (as is the case with the current MIL-STD-1474E). Even though the AHAAH Model is the best model currently available, it still requires further refinement in the areas of stapes non-linearity, basilar membrane displacements, reflexes and metabolic exhaustion.

Notwithstanding the advances in hearing models for impulse noise, the correlation between model predictions and actual hearing damage can be deficient or inconsistent. There is a need for extensive comparisons with real-world measurements of impulse noise levels (field and laboratory) and measurements of actual hearing damage extent, which will inform future improvements to noise injury models and hearing protection requirements.



6. Other influencing effects

Other emerging influences and synergistic effects due to ototoxic substances, human vibration and extended work-shift periods can increase the risk of hearing loss in combination with noise and impulse noise.

Exposure to ototoxic substances and chemicals such as Volatile Organic Compounds (VOCs) can lead to hearing loss. The extent of hearing loss can be exacerbated through combined exposure to both noise and ototoxic agents. There are three major classes of ototoxic substances: solvents, heavy metals and asphyxiates. Activities where these substances may become an issue include painting, construction, fuelling, degreasing, weapons firing and fire-fighting. Ototoxic substances are often present in marine, mining, vehicle and defence industries, specifically fuels and carbon monoxide in engine spaces and maintenance personnel who are exposed to fuels, metals and solvents. Recent review papers provide an overview of ototoxic agents and effects [5] [6].

Live weapon firing (large and small-medium calibre) is known to generate ototoxic chemicals, including lead, manganese, arsenic, hydrogen cyanide and carbon monoxide (and toluene compounds), via airborne inhalation and dermal contact [7]. The airborne concentration and total exposure levels (and the combined effects of different ototoxic agents) will vary depending on a range of factors such as weapon type, propellant charge types, firing scenarios, number/frequency of firing rounds, local weather conditions etc.

The WHS Code of Practice (COP) recommends that monitoring hearing with regular audiometric testing should be conducted where workers are exposed to:

- any of the ototoxic substances (listed in the COP Appendix A) where the airborne exposure (without regard to respiratory protection worn) is greater than 50 per cent of the national exposure standard for the substance, regardless of the noise level; or
- ototoxic substances at any level and noise with $L_{Aeq,8h}$ greater than 80 dB or L_{Cpeak} greater than 135 dB.

The COP also recommends reduced noise criteria of 80 dB (and L_{Cpeak} <= 135 dB) in situations where personnel may be exposed to ototoxic substances in addition to noise.

It is also widely recognised throughout industry that there is a link between exposure to hand-arm vibration (HAV) and hearing loss [7] [9]. Note that significant levels of HAV in conjunction with noise may occur with the use of a range of hand tools, pneumatic tools, machinery/ vehicles and small to medium calibre automatic firearms. It is suggested that vibration exposure from hand-held tools reduces the blood flow in the cochlea by activating the sympathetic nervous system, leading to increased risk of hearing loss [8]. Longitudinal and case-control studies on subjects who have contracted vibration-related disorders found that subjects with vibration white fingers (VWF) have an increased risk of developing hearing loss. The risk of hearing loss is confounded by several factors such as age, medical, chemical and genetic factors. It is also suggested that whole body vibration (WBV) from operating machinery and vehicles may also increase the risk further.

Work shift durations greater than 8 hours impose a higher health risk to exposed workers. The increased health risk occurs from the additional damaging effect that continued exposure to noise has, once the maximum temporary threshold shift is reached. Risk may be further increased if there is a reduced recovery time between successive working shifts. To compare the effect of noise exposure during a workday other than 8 hours, one needs to normalise this exposure to an equivalent 8 hour exposure $L_{Aeq,8h}$ using equation 9(4) in AS/NZS 1269. In addition, AS/NZS 1269 suggests an additional penalty adjustment to the 8-hour normalised level according to shift length.

A combination of the described effects above can occur in some workplaces which increases the risk of excessive exposure. For example, trades such as aircraft refuellers and vehicle/workshop mechanics can be exposed to high peak levels, extended work-shift noise exposure, ototoxic substances (e.g. fuels, solvents) and HAV, often during the same work-shift. Such situations require careful exposure assessment (including a lower noise exposure standard or additional adjustments) and application of a range of specific control practices.

7. Real-world examples and mitigation

7.1 Examples of real-word situations

A subset of real-world examples of the measurement and estimation of noise exposure from a sample of high energy impulse sources is summarised for a range of exposure metrics and criteria.

Noise exposure data was determined for small calibre firearms (SCF, calibre < 10mm) and large calibre weapons (LCW, calibre > 100mm) from high-resolution measurements (sample rate of 200 kHz; time resolution of 0.005 ms; at a range of distances/angles with high-pressure microphones) and calculations conducted in accordance with MIL-STD-1474E (and the AHAAH Model). Exposure calculations were performed for actual near-field operator scenarios (e.g. at or near gun firing position; for cases with and without hearing protection) to determine:

- Calculated in-ear peak pressure level;
- Auditory Risk Unit (ARU) exposure;
- $L_{IAeq,100ms}$ per impulse;
- Calculated $L_{Aeq,8h}$ for a number of impulses;
- Allowable number of rounds (ANOR), based on an ARU of 500 limit;
- Allowable number of rounds (ANOR), based on an ARU of 200 limit.

Table 1: Allowable number of rounds for a large-calibre weapon based on different noise criteria

	Allowed Number of Rounds (ANOR), AHAAH Model			
	No HPD	Ear Plugs	Ear Muffs	Plugs & Muffs
		(Default 02)*	(Default 04)*	(Default 06)*
$L_{Aeq,8h}$ WHS adjusted NES, 80 dB	0.1 – 0.2	4 – 6	21	43 – 53
$L_{Aeq,8h}$ WHS standard NES, 85 dB	0.3 – 0.7	13 – 20	70	142 – 178
MIL-STD-1474E Assessment (200 ARU)	0.3 – 0.5	19 – 28	272 – 355	283 – 389

*The Default 02 Ear Plug (within AHAAH model) closely matches the attenuation levels provided by the Class 4 EAR Classic plug, the Default 04 Ear Muff closely matches a Comtec Noise Cancelling Headset, and Default 06 represents double hearing protection.

In terms of hearing protection (see also section 6.2), MIL-STD-1474E and the AHAAH model allow the calculation of the attenuation of different hearing protection device (HPD) configurations (for various scenarios). A range of default HPD options includes earplugs only, ear muffs only and double hearing protection (earplugs plus ear muffs), based on actual Real Ear Attenuation at Threshold (REAT) measurements for a range of available HPDs.

Based on the measured noise levels and the AHAAH model outputs, the ANOR for unprotected exposure and various HPD (at or near gun firing position) is presented in Table 1. An assessment was conducted against the:

1. WHS Legislation with consideration of ototoxic substances ($L_{Aeq,8h}$ NES of 80 dB);
2. WHS Legislation without presence of ototoxic substances ($L_{Aeq,8h}$ NES of 85 dB); and
3. MIL-STD-1474E ANOR using 200 ARU criterion.

Table 1 indicates that *unprotected* exposure will result in hearing loss, as the allowable number of rounds is significantly less than 1. The allowable number of rounds provided is based on an in-ear noise level calculation. When considering all assessment methods, the standard WHS Assessment (using $L_{Aeq,8h}$ criteria) is more conservative than the MIL-STD1474E/AHAAH method and thus allows the least number of rounds per 24 hour period (13 to 20 shots with ear plugs, and 70 shots with ear muffs). When fitting double hearing protection (as is the requirement in the near-field of the LCW), 140 to 180 rounds can be fired per 24 hour period.

In the presence of ototoxic substances and with double hearing protection (within 20m to rear and 40m to side of the LCW, using a particular propellant charge), up to approximately 40 rounds can be fired per 24 hour period. If further research shows that no significant ototoxic chemicals are produced from LCW firing, then up to approximately 140 rounds could be fired per 24 hour period. Note that, at the gun operator positions, peak levels of up to 170 dB L_{Cpeak} were measured and $L_{IAeq,100ms}$ levels of up to 140 dB were measured per impulse.

Table 2 provides the current requirements and the recommended updated requirements (for up to 40 rounds in a day) in the near-field of a Large-Calibre Weapon (LCW), noting the high directivity of noise emission. Note that this assessment is only for LCW firing with a certain propellant charge, and that stricter requirements will probably apply for LCW use with other (larger/noisier) charge types, after confirmation from further noise testing. For small calibre firearms (SCF), it was found that Class 4 ear plugs do not provide satisfactory attenuation for more than 6 rounds in a day, assuming that ototoxic substances are present – hence, a new requirement of at least Class 5 ear muffs (or ideally double HP for up to 200 rounds/day) would be required for SCF.

7.2 Noise Exposure Controls

Where noise exposure controls are required from the measurement data and subsequent exposure risk assessment, the hierarchy of noise control should be applied. Engineering noise control is the preferred method of initial noise reduction, however this is not always practicable. As such, the implementation of mandatory personal protective equipment (PPE) usage and administrative controls are normally applied and used widely within industry.

Administrative control measures recommended and applied throughout industry include job rotation, work scheduling, changing work processes, limiting exposure times for high noise tasks, minimum rest periods, limiting distances from noise hazards, limiting exposure to ototoxic substances and hand-arm vibration, and ensuring equipment is maintained. In particular, for impulse noise from weapon firing, minimum safe distances and the allowable number of rounds (ANOR) should be specified

Table 2: Current and proposed hearing protection requirements in the near-field of a large-calibre weapon

Current Requirements	Proposed Requirements
• Double Hearing Protection (ear plugs + muffs) required within 5 metres of LCW; and • Single Hearing Protection (ear plugs or muffs) required between 5 and 100 metres of LCW.	At side of LCW (e.g. 90 or 270 degrees): • Double Hearing Protection (ear plugs + muffs) required within 40 metres of LCW; and • Single Hearing Protection (ear plugs or muffs) required 40-200 metres of LCW.
	At rear of LCW (e.g. 180 degrees): • Double Hearing Protection (ear plugs + muffs) required within 20 metres of LCW; and • Single Hearing Protection (ear plugs or muffs) required 20-100 metres of LCW.

(as described in the last section). For high intensity impulse noise (e.g. from large calibre weapons), double hearing protection is required, i.e. ear plugs and ear muffs. As an example, the combination of a Peltor COMTEC Noise Cancelling Headset (Class 3, 21 SLC_{80}) with either EAR Classic Platinum or HL Bilsom 303L ear plugs (Class 4, 23 SLC_{80}) would meet the primary requirement (selection rule) in AS/NZS 1269.3 (Appendix B) for impulse noise.

Observations made throughout most site surveys showed improper fitting of HPDs. Improper fitting means that the HPD will not achieve the attenuation it is designed to provide, and that wearers could be under-attenuating noise levels by up to 10-15 dB. Therefore incorrect fitting of HPDs has the potential for workers to be exposed unknowingly to unacceptably high noise levels and subsequent health risks. As such, a recommended action is for training on the use and proper fitting of HPDs for all workers. Personal hearing protectors should be selected and maintained in accordance with WHS Regulation 44, the COP and AS/NZS 1269.3. Employers should involve workers in the HPD selection process and ensure that workers are comfortable with the HPD of choice.

It is important to note that workers exposed to ototoxic substances may require additional PPE in the form of respiratory protection as well as suitable hearing protection. This would depend on the number of ototoxic agents exposed to, the exposure levels (specific ototoxic agents relative to standard exposure criteria for each agent) and the combination with the level of noise exposure.

Noise controls applied within industry for work processes include: buying quiet equipment, acoustic screens in high noise areas (e.g. workshops), silencers and low noise fittings to specific tools, HPDs etc. These solutions have proven effective in reducing occupational noise exposure for high noise areas within Defence [6].

WHS legislation requires that workers exposed to high noise levels must have regular audiometric testing. In the area of the measurement of hearing damage, advances in audiometric testing are being made. For example, the measurement of evoked otoacoustic emissions (OAE), such as DP (Distortion Product) and TE (Transient Evoked) testing, could provide a more objective, sensitive and accurate clinical determination of hearing damage (to auditory stimuli in real-time) than standard pure-tone threshold-shift audiometry [10]. However, there are limitations in this area given that there are currently no accepted normative values available that can be used in relation to hearing health; and, as such, further research in this area is required.

8. Conclusions

Recent developments have been made in the description and assessment of impulsive noise exposure. This paper has summarised the relevant standards and guidelines, and has provided an overview of the previous work and applicable methods for impulse measurement and prediction, noise exposure metrics, models of hearing damage mechanisms and approaches to determining the resultant impulsive noise exposure. A discussion on the control of noise exposure highlights the hearing protection and other measures required to mitigate impulse noise.

Recently advanced electroacoustic/biomechanical hearing and noise injury models (such as the AHAAH Model) provide a more robust estimation of likely hearing impact from impulse noise and applicable damage risk criteria. However, there remain limitations to the accuracy and coverage of such models, which require further work including comparisons with real-world measurement data and subsequent verification/validation. Looking forward, in order to minimise severe health risk and injury to workers' hearing from impulse noise, this demonstrates the need to apply a conservative approach and the need for further research and innovation.

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Housing New Zealand project - said the sub-contractors doing the concrete pumping turned up early without permission. He said the company was putting in place extra measures to ensure everyone working on the site - sub-contractors and their employees - was aware of those conditions.

Noise sensitivity traced to changes in brain functions

In a newly published report researchers from the University of Helsinki and Aarhus University addressed whether noise sensitivity is manifested in the way the brain processes sounds. The report showed that the auditory system of noise sensitive individuals is less responsive to new sound features introduced among repetitive sounds, especially if the novel sound is noisier than the rest and that he degree to which one is disturbed by noises of everyday life may be related to how the brain processes variations in the sound stream. The contribution of this study crosses boundaries of the brain science and reaches to public and occupational healthcare. The researchers hope that their work will highlight that noise sensitivity is an important issue to be recognized in planning noise control in living and working environments.

Electric Avenue Music Festival Attracts 105 Noise Complaints

The Press has reported that a Christchurch music festival sparked more than 100 noise complaints but did not breach permitted noise limits, the Christchurch City Council says. Electric Avenue, a 12-hour festival, attracted 11,000 people who watched more than 30 international and national acts across multiple stages in Hagley Park on Saturday.

Christchurch City Council fielded 105 noise complaints from residents during the festival, which finished at 11.00pm. Council recreation and sports head said permitted noise levels were not breached throughout the event. A staff member was regularly carrying out sound level assessments during the festival. Christchurch City Council Team Event director said he was concerned about the high number of complaints.

Acoustical Society of NZ Member Profile - Tracey Hilliker

Location:	Christchurch
Position:	Senior Acoustic Engineer
Expertise:	Acoustics – Building services, environmental
Qualifications:	BE Hons (Mech), MASNZ

Work Questions

1. What initially drew you to the field of acoustics? *After finishing my degree in 2001, I worked as a Mechanical & Hydraulics consulting engineer. During this time I remember having to look at external façade sound insulation requirements and passive ventilation techniques for compliance with NZBC G4 - Ventilation. I attended the Wellington Acoustics Conference in 2004, where this was discussed further, as was the growing issue of increasing inner city living and noise conflicts with mixed-use urban environments - I guess my interest grew from there! When I then had the opportunity to change career direction and join Jeremy Trevathan at Acoustic Engineering Services in early 2007, it was the right step.*

2. Why do you do what you do? *It is important to have a good work-life balance, and being an Acoustic Engineer allows this for me. As an Engineer, I spend time in the office but also get the opportunity to get out on site and connect with others from differing industries which I find very rewarding. As a mother and wife, I also want to focus on my family when not in the office, which again, my role allows me enough downtime for these most important things.*

3. What is the one key skill you most need to be successful in your day to day work? *Clear communication! Whether liaising with Clients or other professionals, mentoring other acoustic engineers or just sorting our resourcing for the week, the ability to clearly communicate ideas, solutions and intentions (both in written form and verbally) is critical to a smooth working environment and for building long-term relationships.*

4. What is the most satisfying project you have worked on and why? *Hagley Oval. It was more controversial that I thought it would be, with many of the public rejecting the use of recreational land for what was seen as commercial purposes. However, the end result is such an asset for Christchurch, and it is great to have a world-class sporting facility in the centre of our city that anyone can use. AES had a great client function in the Pavilion on site not long after it opened, and I have enjoyed sitting on the embankment watching cricket, especially the Black Caps during the World Cup where the atmosphere was fantastic.*

5. What are your favourite and least favourite sounds? *My daughters' laughter is a favourite - always brings a smile to my face and laughter is definitely the best medicine. I'm not a big fan of dogs barking, microphone feedback, and kids screaming (unless they're in trouble or hurt of course)!*

6. What was the last project you did? *Ao Tawhiti Unlimited Discovery, which is here in Christchurch. It is work in progress, but I am enjoying undertaking both the building acoustic review and assessment of environmental noise effects for this School to be relocated back into the Central City. The School is designated Special Character under the Education Act, and its fundamental belief is student-directed learning. The design is very open plan, with co-ordinated flexible learning spaces connected over four levels. With both primary and secondary students to be accommodated there is an array of acoustic considerations and challenges to overcome.*

7. What was the most 'quirky' job you ever worked on? *Undertaking an occupational noise assessment for a commercial cleaning company, where workers were concerned about hearing damage from the back-pack vacuum cleaners.*

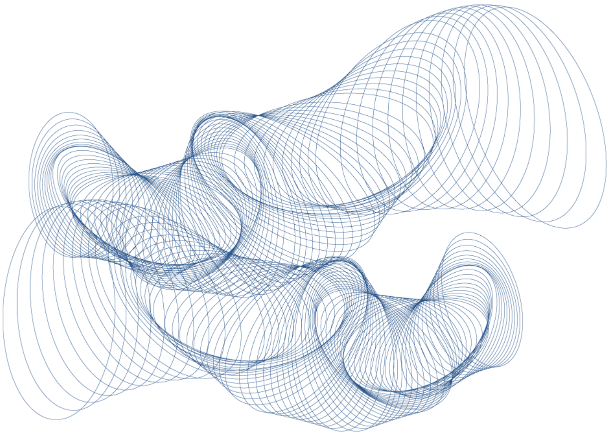
8. What is one unexpected outcome you have had on a project you're worked on and why? *We just received a box of chocolates and bottle of bubbly from a very happy client for some Green Star IEQ-13 verification testing we completed. It was a difficult project in terms of liaison with all parties involved (commercial agent, tenants, project manager, mechanical sub-contractor etc.) and a short timeframe for the work to be undertaken, but we got there in the end. Was a lovely gesture by the Client - very unexpected, but nice to feel appreciated and have some recognition when*

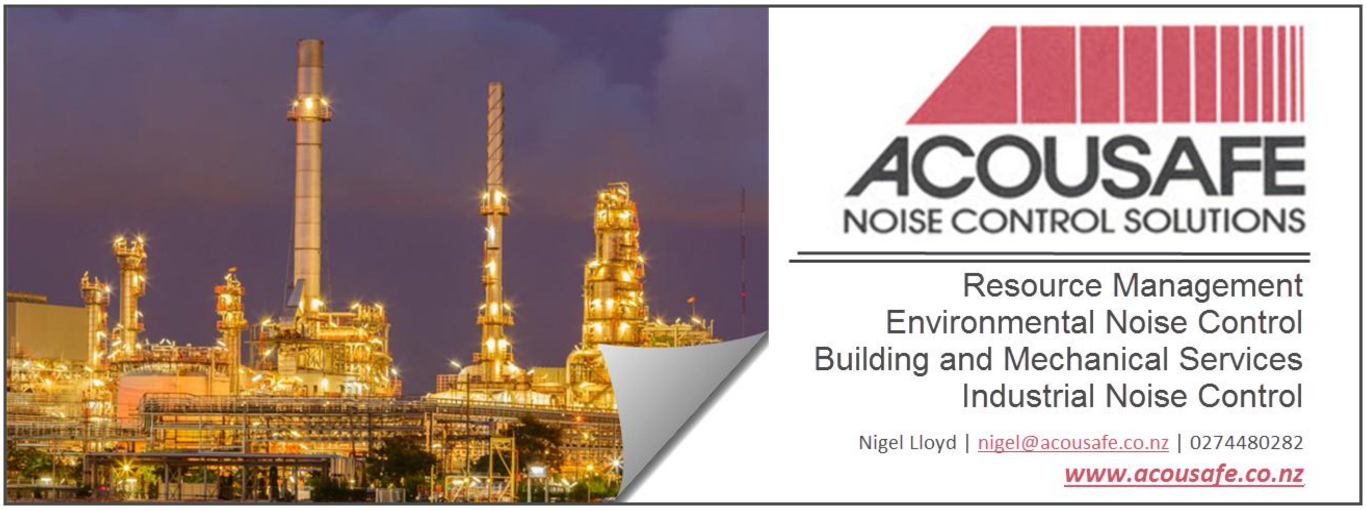
we have gone above and beyond their expectations.

9. What's your definition of success in your role? *espect from your fellow colleagues and peers. That, and the ability to sleep at night with a clear conscience!*
10. What are the challenges that are also rewards for your work? *Mentoring the younger staff and seeing their progression.*

Personnel Questions

1. How has being in Christchurch over the last few years with the aftermath of the 'Christchurch earthquakes' affected your work? *We lost our office building which was located on Kilmore Street due to the shakes in Feb 2011. Since then, we've endured four temporary work locations before finally moving into long-term accommodation back in the Central City. Personally, I have learnt to be resilient and self-sufficient and not to take things for granted. That, and to always have half a tank of gas in the car! Our work has seen a significant shift from environmental projects to building acoustics with the rebuild of our City and in particular for me, I have enjoyed being involved with a number of local School rebuilds and refurbishments commissioned by the MOE.*
2. Other than acoustics what are you passionate about? *Rugby, motorbikes, rock music and whisky (in addition to my family of course)!*
3. What's your favourite band or musician and why? *Slash – he is one talented musician, and I love listening to his guitar riffs. I was fortunate enough to see him live in Wellington as part of Guns N' Roses just the other week.*
4. If you were not an acoustic engineer what would you be doing? *Hard question! Lots of things I'd like to be doing, like being a lady of leisure, or racing motorcycles (not very sensible for a mother though). Growing up I was going to first be a Physiotherapist, then Accountant, then Astronomer – so maybe one of these?*
5. How would you describe sound to someone who is deaf? *This is a harder question! Vibrations? Waves? Interpretive dance? Since they can't hear me explain, maybe I'd try to show them? On the tele just the other night as part of Nigel Latta's Blow Stuff Up series was an episode on sound. He went about trying to 'break' the sound barrier, and had several experiments along the way to demonstrate the fundamentals of sound (nice cameo Gian Schmid). I particularly liked the differences in sound waves shown by sprinkling salt onto a speaker which was played at various frequencies.*
6. If you had a time machine where would you go? *Back to 1999. I would love to go home, and have one more dram with my Dad and sister Leanne (whom both passed away too many years ago).*





Future Events

2017

18-22 June: Zurich, Switzerland, 12th. ICBEN Congress on Noise as a Public Health Problem
www.icben.org/ICBEN2017.html

25-29 June: Boston, USA, Acoustics 2017 Joint meeting of the Acoustical Society of America and the European Acoustics Association
www.acousticalsociety.org

23-27 July: London, UK, 24th International Congress on Sound and Vibration [ICSV24]
www.icsv24.org

27-30 August: Hong Kong. 46th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2017)
www.internoise2017.org

3-8 September: Skiathos Island, Western Aegean, Greece. 4th Underwater Acoustics Conference and Exhibition (UACE2017)
www.uaconferences.org

19-22 November: Perth, Australia, The annual conference of the Australian Acoustical Society
www.acoustics2017.com

4-8 December: New Orleans, Louisiana, USA. 174th Meeting of the Acoustical Society of America
www.acousticalsociety.org

18-20 December: Honolulu, Hawaii, USA , 2017 International Congress on Ultrasonics
http://www4.eng.hawaii.edu/~icu2017

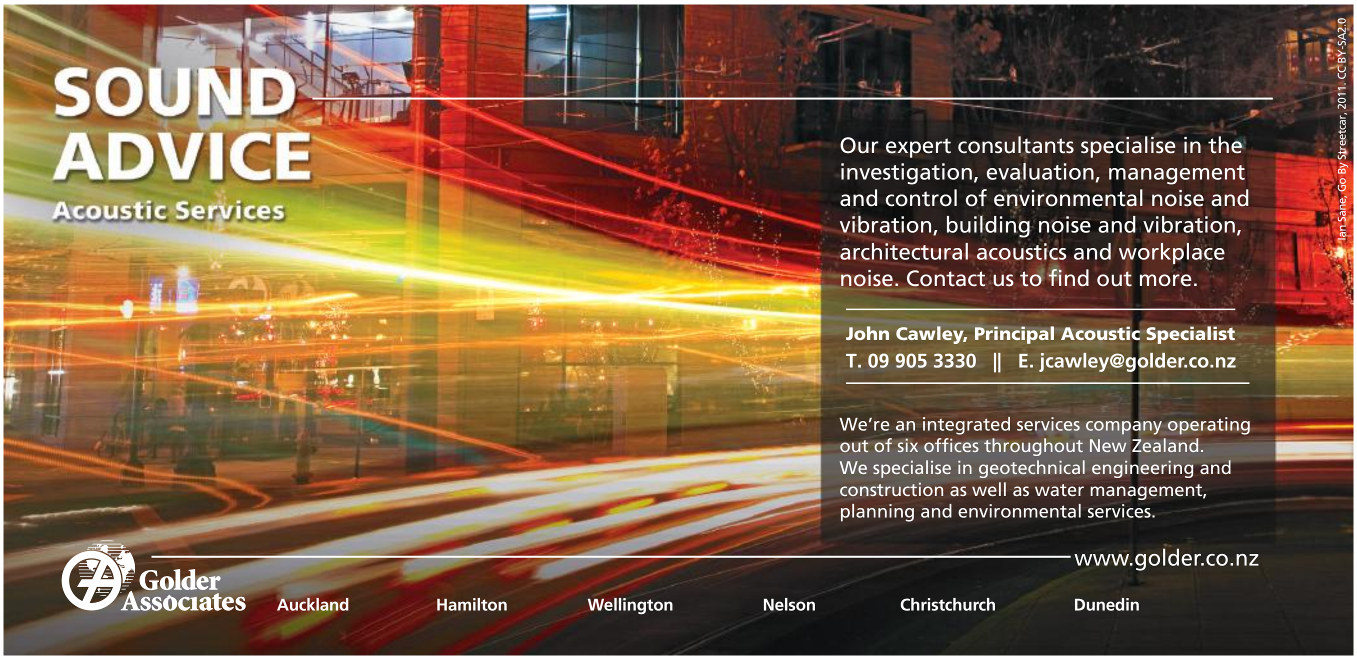
2018

7-11 May: Minneapolis, USA , 175th Meeting of the Acoustical Society of America
www.acousticalsociety.org

27-31 May: Heraklion, Crete, Greece , EURONOISE 2018
. www.euracoustics.org/events/eaa-conferences

26-29 August: Chicago, USA, 47th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2018)
www.i-ince.org

5-9 November: Victoria, Canada, 176th Meeting of the Acoustical Society of America
www.acousticalsociety.org



The AAAC is a not for profit peak body representing professionals who are involved in providing comprehensive noise and vibration services to a wide range of clients and the community. www.aaac.org.au

SEEKING APPLICATIONS

Following enquiries from member consultancy practices who had offices in both New Zealand and Australia, in 2016 the members voted to allow expansion of our organisation to welcome likeminded professional firms from New Zealand, with a renaming from Australian to Australasian and associated constitutional changes. The intention is to bring the benefits of the AAAC to NZ; such as peer collaboration, member only discussion forum and networking events.

The AAAC is now seeking NZ based consultancy practices. A membership application form will be provided by contacting info@aaac.org.au.

ROLE OF THE AAAC

While the Australian and New Zealand Acoustical Societies (AAS and ASNZ) provide a platform for any individual involved in acoustics to improve their technical and professional skills through collaboration, comradery and organised events, the AAAC is for Acoustical Consulting firms who nominate a representative from each of their regional offices (if they wish). The AAAC focus is on practice and business matters. It doesn't represent individuals, and works with the Societies for the overall benefit of the Australasian Acoustics community.

NZ MEETING

The AAAC is planning to hold our AGM in Queenstown New Zealand in July 2017. Any firm interested in joining is welcome to attend a special meeting associated with the AGM. The AGM normally involves a meeting on Saturday, a dinner with partners on Saturday evening and a social function on Sunday morning.

HISTORY OF THE AAAC

The AAAC was officially formed in 1978. In 2016, the AAAC comprises some 56 member firms across Australia. They provide a wide range of Consulting, Testing and Research facilities to Community, Industry, Commercial and Government organisations as well as to individual projects and programs.

BENEFITS AND OBJECTIVES OF THE AAAC

The objects for which the Association is established are:
(a) To inform the public of the role and responsibilities of Acoustical Consultants and in particular the services which such consultants provide.
(b) To establish and encourage adherence to standards of professional behaviour and conduct for acoustical consultants.
(c) To provide members with a forum for exchange of information on matters relating to acoustics.
(d) To cooperate and liaise with other Associations and bodies with respect to matters of mutual acoustical interest.
(e) To inform and protect the community by discouraging, clarifying, negating or questioning unclear inaccurate or unproven representations of an acoustical nature.
(f) To cooperate and liaise with authorities and associations having similar or analogous interests and in so doing, to contribute to the establishment, maintenance and application of standards, laws and registrations.
(g) To encourage amongst the members of the association a high professional standard in all matters of practice including the calibration and use of instruments, measuring techniques and data processing employed by acoustical consultants.
(h) To promote the welfare of acoustical consultants and the common interests of the members of the association and to do all such things as may be meaningful and lawful from time to time.

For more information contact: info@aaac.org.au **or AAAC Chairman (Matthew Stead) on +61 408 805 293**

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Publication Dates and Deadlines

New Zealand Acoustics aims at least three times per year, in April, August and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 4 weeks prior to this.

The opinions expressed in this journal are those of the writers and do not necessarily represent the policy or views of the Acoustical Society of New Zealand. Unless indicated with a © symbol or stated otherwise within the articles themselves, any articles appearing in this journal may be reproduced provided New Zealand Acoustics and the author are acknowledged.

Advertising

Enquiries regarding advertising are welcome. For a list of current prices and any further information please contact: advertising@acoustics.org.nz

Society Membership

Associate Membership of the Acoustical Society of New Zealand is open to anybody interested in acoustics. Members receive benefits including;

- Direct notification of upcoming local events
- Regular mailing of Noise News International
- Reduced charges for local and national Society events
- Priority space allocation for trade stands at society events
- Discounted rates on selected acoustic products

To join the society, visit www.acoustics.ac.nz or contact the Secretary; secretary@acoustics.org.nz