





SOUND MIND

FUNDAMENTALS OF ACOUSTIC DESIGN & AIRBORNE NOISE CONTROL

Acoustics are a fundamental aspect of everyday life. The way we experience sound in an indoor space can influence our health, comfort and wellbeing. It is particularly significant in spaces such as offices, classrooms, and shared communal areas where the quality of sound is critical to the functionality of the space.

Over the years there has been an overwhelming amount of research highlighting the negative impacts of poor acoustic environments. These impacts range from physical and mental health effects and extended recovery periods in hospitals¹, to reduced productivity in workplaces² and poor academic performance.³

Creating indoor environments with outstanding acoustic performance begins early in the project cycle, during the design and planning phase. The goal is to bring the acoustical properties of the space in line with its intended use. A solid grasp of acoustic design and methods for noise control is critical for delivering the right combination of acoustic solutions for any given space.

In this whitepaper we take a look at how we perceive sound, and the various rating options we use to define acoustic performance. We also consider common types of sound absorption and how they influence the acoustics of a space.

THE BASICS OF SOUND

How We Perceive Sound

The sound ratings used in acoustic design are based around a common understanding of how sound is perceived. Sound waves are vibrations carried through the air. Our brains interpret these vibrations as sound via a three-part process:

- collecting sound signals
- converting the airborne vibrations into mechanical energy
- relaying this energy into an electrical impulse that is interpreted as sound by the brain

Sound waves are funneled into the ear where vibrations are converted into mechanical energy. The ear drum is attached to the ossicular chain (small bones of the middle ear that form a chain for the transmission of sound). Sounds propel the chain sequentially, ultimately striking the oval window.

In the inner ear, the primary component in sound interpretation is the cochlear, a coiled chamber of fluid. The cochlear's oval window is the membranous barrier between the middle and inner ear. When the last bone in the middle ear strikes the oval window, the resonance is carried through the fluid. The movement of the fluid is relayed to the brain via the auditory nerve and interpreted as sound.

Decibels and Frequency

The decibel (dB) is a logarithmic unit used to measure sound level. In order for the human ear to detect a change in volume, the sound signal must change by 3dB, with little or no background noise. However, this change is slight, and most listeners can only distinguish that the volume has either increased or decreased when the signal changes by 5dB.

As a general rule of thumb, a change of 10dB results in sound being perceived as twice as loud or half as quiet, a change of 20dB results in sound being perceived four times louder or quieter, and so on.

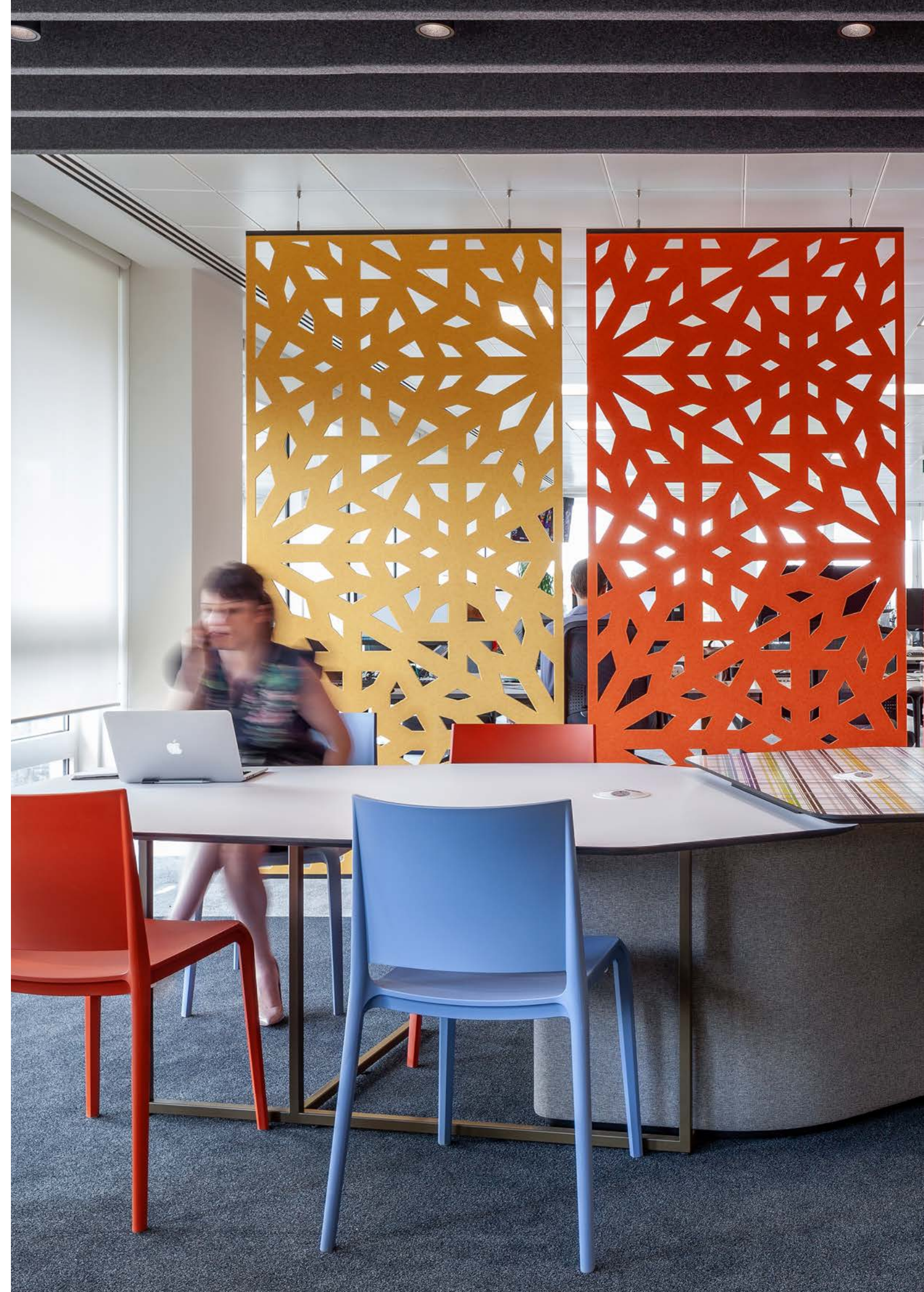
Sound frequency is another key component of sound. Frequency is measured in hertz (Hz), referring to the number of wave cycles per second. Humans are more sensitive to sound at differing frequencies; generally, the higher the frequency of the sound, the easier it is for us to detect it.

A-Weighting

A series of corrections are applied to measured sound levels to mimic the way humans perceive sound at different frequencies. This is expressed as an "A-weighting" (dB(A)). A-weighting adjusts the measured levels to account for the human perception of sound across the audible frequency range.⁴ This is because the human ear doesn't hear all frequencies equally.

If we had a sound measuring at 100Hz, we would need approximately 30dB to hear this signal whereas for a 1000Hz signal only a few dB would be needed. As the volume increases, our hearing response flattens. For acoustic engineers, controlling noise across the frequency range is critical to ensuring sound quality and intelligibility is maintained within an indoor space.

Excessive noise, especially in the lower frequency range, means speech intelligibility can be easily compromised. The frequency of vowels is generally around the 250 - 2000Hz range, while voiced consonants are within 250 - 4,000Hz. Speech intelligibility is dependent on hearing the entire range of frequencies. Excessive low frequency noise has a "masking" effect on higher frequency signals as they become closer in their perceived loudness.





CONTROLLING NOISE

Sound Absorption

Acoustic design involves controlling noise transmission as well as the characteristics of sound—such as frequency and loudness—within the space itself. Noise or sound absorption is one of the primary methods of controlling building acoustics.

Sound absorption refers to the loss of sound energy when sound waves come into contact with an absorbent material on interior surfaces including ceiling, walls and floors.⁵

Reverberation Time

“Reverberation time” is the time it takes for sound to decay by 60dB.⁶ If the surface is not sound absorbent, the sound is reflected back into the space, creating an echo or reverberant sound. As sound is reflected off surfaces, some energy will be reduced⁷ but much will persist, contributing to the reverberation time.

Reverberation time of a space directly impacts the intelligibility of sound information—too much reverberation can make speech sound muffled if reflections arrive the same time a new word is spoken.⁸ Conversely, too little reverberation may make a room sound “dead”. Achieving the appropriate reverberation time for the intended use of the space is critical.

Controlling reverberation time can also reduce the build up of reverberant noise (i.e. sound levels being sustained by reflecting off multiple surfaces with minimal energy loss) and limit the “Lombard Effect”,⁹ which refers to the tendency of speakers to raise their voice in a noisy room.

As controlling reverberation time is a critical component to creating a comfortable and productive space, it has been recognised in many building design guidelines. For example, every state and territory has their own requirements for reverberation time and noise levels for education spaces, as set out in their respective guidance documents.

Most of these documents reference the levels published in AS/NZS 2107:2016 Acoustics - Recommended design sound levels and reverberation times for building interiors.

DESIGNING FOR GOOD ACOUSTICS

Room Layout and Configuration

Room configuration, layout, and effective sound absorption can be used to control the flow of noise throughout a space, and lower the reverberation time. The correct placement of absorption will improve the effectiveness of sound absorbing products. Where possible, it is advisable to configure spaces to avoid parallel hard surfaces. When constructed parallel, hard surfaces increase echo and reverberation.

Hard surfaces can also direct unwanted noise to other areas. If left untreated these surfaces become acoustic reflectors that increase noise and lower speech privacy. Careful selection of absorbers is recommended, as some types lose efficiency when the angle of incidence moves away from normal. Concave walls that can focus acoustic energy should have absorptive treatments applied.

Reducing hard surfaces near sound sources should also be considered. This will reduce strong, early reflections forming near the original signal.

Selecting Acoustic Solutions

Absorption Coefficient, Sabins, and Noise Reduction Coefficient

In the acoustic design industry, three units of measurement are used to demonstrate acoustic performance:

- **Absorption Coefficient** measures how effective a planar absorber—such as a wall, ceiling, or floor lining—is at absorbing sound energy. Ratings range between 0 (no sound absorption at all) to 1.0 (100% of measured sound is absorbed by the material). It is frequency specific.
- **Sabins** are a unit of sound measurement that quantify how well one square metre of any surface material in a room is able to absorb sound reflections. A surface that absorbs 100% of sound is equal to 1 sabin/m². If sound is partially absorbed, this is shown as a fraction of a sabin/m². It is frequency specific.
- **Noise Reduction Coefficient (NRC)** is the mathematical average of the sound absorption coefficient across the middle audible range (i.e. 250 - 2000Hz).

While useful, NRC ratings are outdated and do not necessarily provide a true indication of acoustic performance. NRC ratings ignore much of the vowel region and many of the consonants that carry much of the information required for speech intelligibility.¹⁰

It is advisable to compare performance across the frequency range rather than relying on a single number rating. Two different surfaces and material combinations can deliver very different acoustic performance, even if the calculated average within 250 - 2000Hz is the same.

More modern rating systems, such as the weighted sound absorption coefficient, have shape indicators to inform of spikes or dips in acoustic performance over different frequencies. This can enable engineers to provide a more tailored performance rating to the designer or client, ensuring better products or configuration are selected for a specific application. This goes a long way in creating a balanced acoustic environment.

Absorption coefficients consider only one face of the product, whereas sabins will typically be used to represent the value of an object in a space. Suspended rafts, clouds, acoustic lighting, and acoustic dividing screens should ideally have the acoustic data declared as sabins. For clusters or groupings of objects, such as a fin ceiling system used in standard configurations, then absorption coefficients can be more accurate to understand the absorption added for every square metre of the specific configuration installed. This is due to the acoustic efficiency of each individual fin changing based on proximity to other fins.

Most acoustic reporting and performance specifications for building interiors considers the range between 125 - 4000Hz. As noted above, NRC ratings consider the 250 - 2000Hz range. Where a supplier publishes single number ratings for sabins or absorption per object, extreme care should be taken as the range considered to obtain this value can differ.

Types of Sound Absorbers

By considering the type of materials and finishes in a space, we can create an acoustic environment that meets performance requirements. The different types of absorbers and their performance properties are discussed below.

- Panel-membrane absorbers refer to common surfaces like plasterboard and plywood-lined structures that can provide some lower frequency absorption. Specialist options can be designed to target a specific range of unwanted noise. As pressure waves impact on the surface, this sets the lining into vibration at the frequencies it has been tuned to absorb. These types of absorbers are typically used where low frequency absorption is a concern, such as in concert halls and auditoriums or specialist recording spaces.
- Resonant absorbers typically resemble perforated or slotted-type linings that dissipate energy by frictional losses around the aperture. Many tend to offer mid-frequency performance. This solution requires an air space behind, ideally with porous absorption in the air space, to improve and widen the absorption range.

- Porous absorbers include materials such as polyester panels, carpets, foams, and mineral wool. The level of sound absorption differs depending on the density and thickness of the material; the thicker the absorber, the lower the frequency it can absorb. Multi-density configurations and air gaps can be used to increase lower frequency performance. Porous absorbers can offer more consistent absorption levels as the angle of incidence shifts away from normal incidence.

Air Gaps

Introducing air spaces or increasing cavity depth will typically result in improving absorption at lower frequency ranges. For panel-membrane and resonant types, this typically shifts their point of maximum efficiency to a lower frequency. For porous-type absorbers, it widens their efficiency, increasing lower frequency absorption while maintaining the levels of efficiency in the higher range.

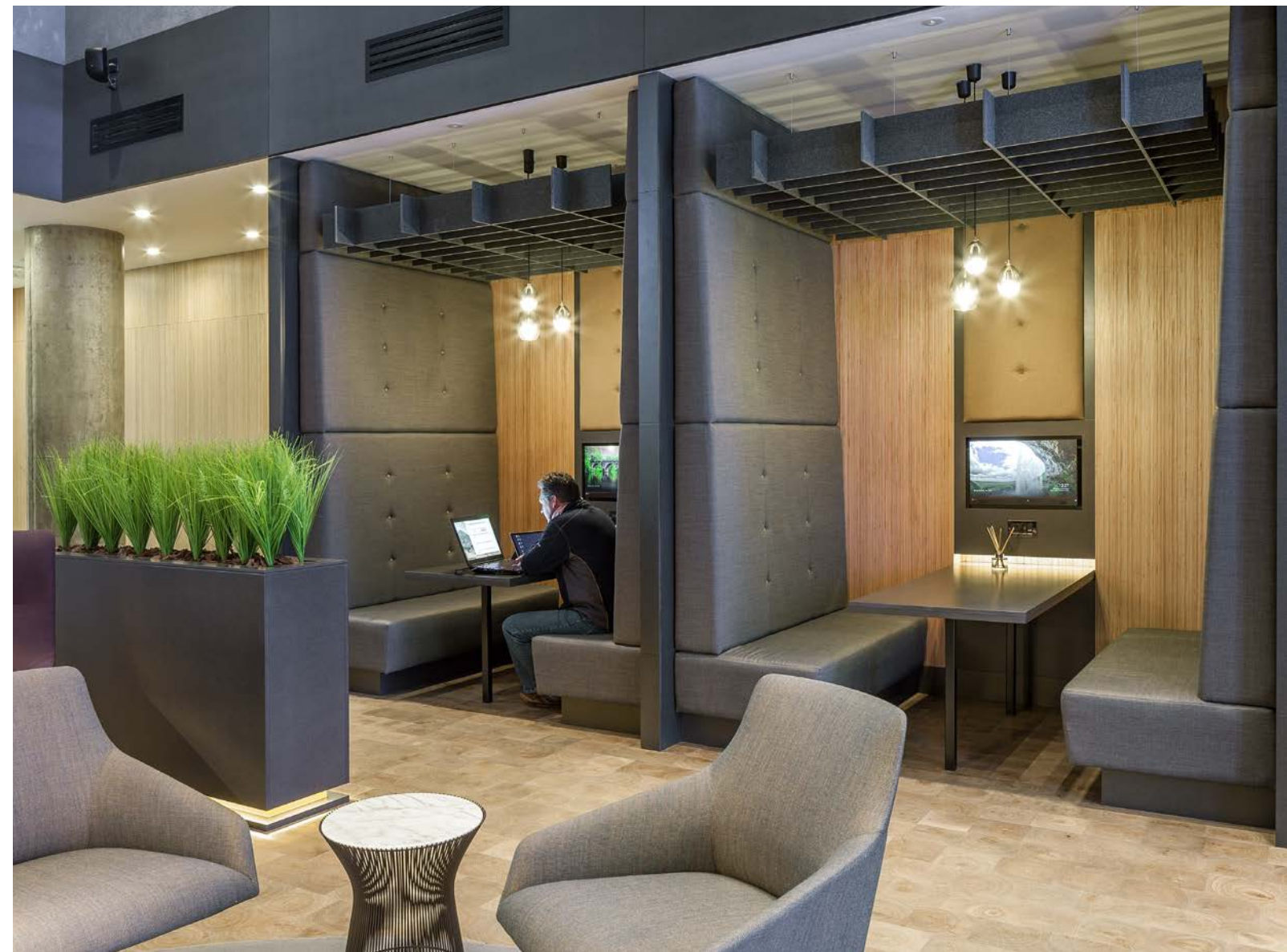
Adding a highly compressed facing on the front of a lower density panel increases product efficiency, without increasing mass and thickness. Much like the addition of an airgap, the highly compressed

facing of the product is in the area of highest particle motion. The greater the distance this compressed face is from the substrate, the more low-frequency noise will be attenuated.

Fins and Rafts

Acoustic fins and baffles can be configured to capture specific unwanted frequencies of sound. Absorption levels can be adjusted by modifying fin density, thickness, and suspension height. Unwanted noise is not only trapped within the physical product itself, but the depth and orientation can all be altered to tailor a solution to suit the space.

The acoustic performance of fins and rafts can be presented in both absorption coefficients and sabins of absorption. Both are useful—but as the physical dimensions and spacings between each fin or object are altered, as well as their proximity to other surfaces—the amount of absorption they add will differ, and changes in the amount of absorption provided will not be linear. Advice from experienced professionals in the field of acoustics should be obtained where deviations from tested configurations are required.





AUTEX

Founded in 1967 on the principles of innovation and outstanding customer service, Autex are the Australian leaders in designing, developing and manufacturing acoustics and industrial products made from thermally-bonded polyester.

The Autex team consists of highly-skilled and dedicated manufacturers, designers, engineers, creatives, and specification specialists working to transform commercial and education interiors into beautiful, functional and acoustically-sound spaces. With sustainability at the core of their practice, the team works hard to ensure every Autex product is contributing to a greener future.

The Autex range of acoustical solutions includes interior acoustic wall and ceiling panels, suspended ceiling systems, wallcoverings, and partitions. The company also offers Frontier™ Acoustic Fins, a wall and ceiling acoustic system that delivers targeted sound absorption, endless configurations, and stress-free installation without compromising acoustic performance.

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