WHITE PAPER

Noise Control using Insulation

How to select the correct materials to get the best noise reduction on industrial and Energy facilities

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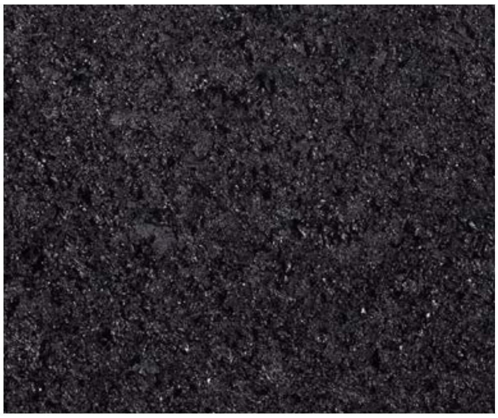

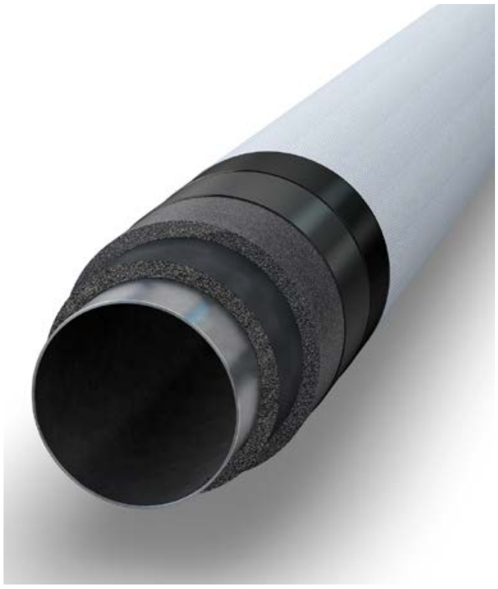

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MAKING A DIFFERENCE AROUND THE WORLD

How to select the correct materials to get the best noise reduction

The control of noise can be a significant requirement for many projects. Noise being a major hazard in the workplace and environment, or a disturbance in the built environment, low noise design can include buying quiet machinery or utilizing quiet technologies. This is particularly effective for new projects.

However, for existing facilities or buildings, this design strategy is not affordable or practicable making it necessary find other noise control solutions.

Noise Control

Noise control comprises three basic methods that disrupt either Noise Source, Noise Transmission Path, or Noise Receiver. The most effective solution is to remove the noise source. No noise, no problem. Noisy equipment should be designed out of a project, or the noisiest components should be replaced with quieter equivalents. Solutions could include changing operating conditions, (e.g., rotational speeds); modifying the design; or installing quieter equipment/ machinery/components. However, such solutions can be expensive or difficult to implement.

The next best solution is to disrupt the sound transmission path. Ideally a physical barrier to stop the noise travelling from the source to the receiver should be used. Depending on the situation/equipment, this could be for example, an actual barrier/fence/wall, machinery enclosure, duct silencer, or pipe insulation system such as the ArmaSound Industrial Systems.

Last resort should be to protect the noise receiver. This often takes the form of earmuffs or earplugs, or double/triple glazing/peace havens. But this solution impedes the person(s) being protected. Double or triple glazing used to reduce the noise at a property reduces the use of amenity. Similarly, ear defender protection is only as effective as claimed when based on the average person. Up to one-third of the workforce is not as effectively protected as they should be. Further, Personal Protective Equipment (PPE) is required to protect workers from a hazard. Employees are still exposed to the hazard, but the likelihood of harm– the risk – is reduced by wearing PPE. If the PPE fails, no protection is provided, and safety is compromised. If the hazard is removed, the danger is removed.

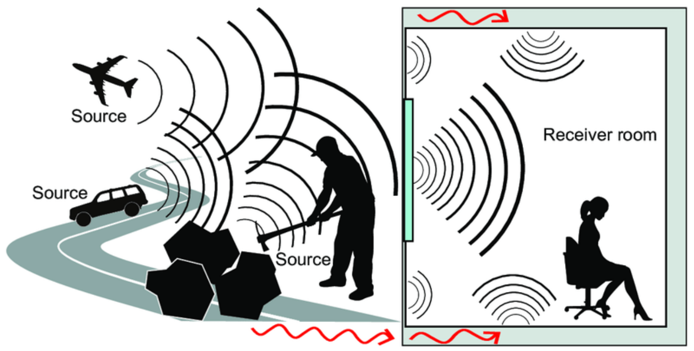
For the purposes of this white paper, we will look at the intermediate phase – the reduction of the transmission path – as it is most affected by insulation materials.

Taking the above into account, noise control can depend on many elements such as cost, practicability, maintenance, and effectiveness. The primary consideration should be to determine the cause. Noise sources are not always obvious, particularly if you have a lot of noisy equipment in one area. Best practice should be a detailed noise assessment/survey of the area and problem. Specialists should undertake assessments to ensure a correct, detailed summary of the situation. General sound assessments can focus attention on noise sources. Detailed assessment of individual noise sources using either sound pressure, sound intensity, and/or vibration velocity techniques, provide a detailed picture of the problem. Such understanding leads to correct solutions. Armacell Consultancy Services can provide such assessments.

The Transmission Path

Noise is usually defined as unwanted sound. Sound is generated by structural vibrations (rotating equipment/ pipework, etc.) or aerodynamic flow (exhausts/vents, etc.) and propagates as a quickly varying pressure wave travelling through the surrounding medium (gas/liquid/solid). Understanding how to control this propagation can be defined by the type of sound generation and its medium and characteristics (e.g. sound level and frequencies).

Sound can travel in air either as an airborne pressure wave (air-borne sound), or via a structural vibration – pressure wave in a solid structure – which then re-radiates the sound into the air (structure-borne sound). What we hear is often a combination of both methods of travel – the key is to determine which is the most dominant path and subsequently which control method to use.



For air-borne sound propagation we need to either absorb the sound or block the sound. Therefore, sound absorption and acoustic barriers are most effective.

For structure-borne sound we need to either de-couple/ isolate the vibration source from the solid structure, or we need to dampen the structure to reduce its vibrational energy.

Air-borne Noise Control

Sound Absorption

Sound absorption is key when looking to reduce the sound level in an enclosed space. In a free-field environment, sound will continue to propagate away from the sound source, dissipating with distance using the inverse square law. In an enclosed space such as a room or enclosure, sound will propagate away from the sound source until it meets a barrier/wall. Depending on the materials and construction of the barrier, and the frequencies of the sound, sound will be transmitted, absorbed and reflected by the barrier to varying degrees. To reduce the reverberant sound level in a room/ enclosure the amount of sound reflected into that space can be reduced using sound absorption materials on the internal walls. Sound absorption materials in the wall can help absorb sound passing through the wall.

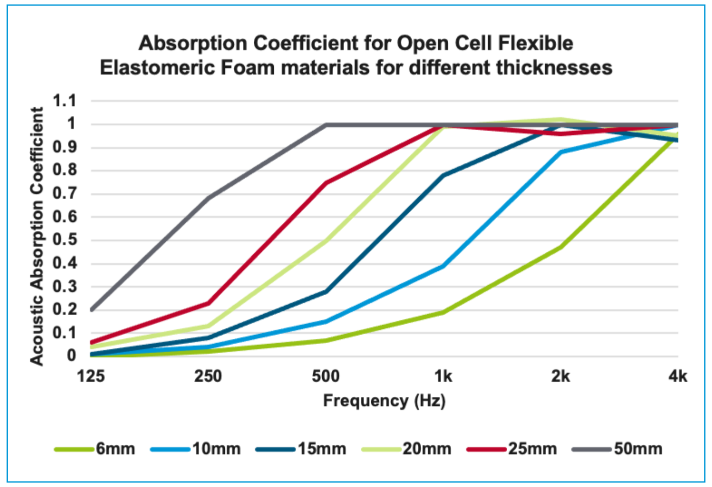
Applying sound absorbing materials to a wall of an enclosed space helps control the sound level inside the space. The amount of absorption required depends on the use of the enclosed space e.g. for speech intelligibility in schools, or for concert spaces or movie theaters. Additionally, reducing the reverberant sound level in an enclosure will also help to increase the overall noise reduction achieved by the enclosure.

Sound absorption materials are also a key part of reducing internal HVAC airborne sound transmission through ducts and within pipework acoustic insulation.

Within acoustic design, sound absorbers are classified as either (a) porous materials; (b) panel absorbers; or (c) cavity resonators.

Porous Materials

Porous materials are those most readily analogous to insulation materials. They are open cell in nature and often, though not exclusively, fibrous in design (e.g. open cell Flexible Elastomeric Foams [FEF] such as ArmaSound RD240). Such materials are characterized by a network of interconnected pores, creating small channels and cavities. As acoustic energy passes through these tortuous channels, the material creates viscous losses through conversion of the acoustic energy as heat. The absorption of acoustic energy is dependent on the frequency of the sound passing through the material. There is low absorption at low frequencies with absorption increasing as the material thickness increases relative to the wavelength of the sound. As frequency increases, wavelength decreases, and the thickness of the porous material becomes more effective. Generally, the thicker the porous material, the greater the degree of absorption across a wider range of frequencies.



When selecting the sound absorbing porous material, it is therefore key to understand the frequencies of sound that most need to be reduced, then select a material and thickness that will best provide such a reduction.

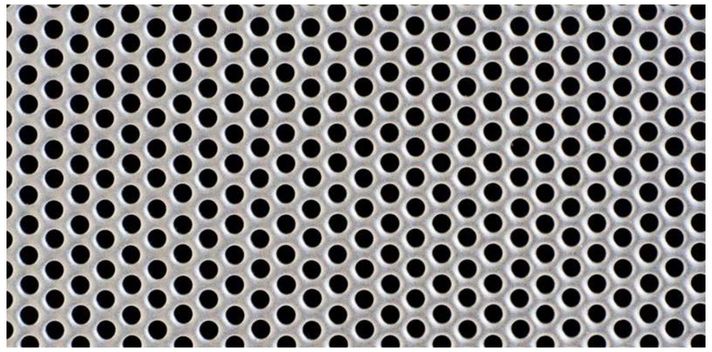
Determining the acoustic absorption of a porous material requires testing in a specialist laboratory to ISO354/ASTM C423-22. From the tests a variety of overall performance values can be derived, including the Sound Absorption Average (SAA) and Noise Reduction Coefficient (NRC) which are calculated from average material sound absorption coefficents between certain frequency ranges. These averages are a simple way to compare material performance with regards to sound absorption but for more detailed impact assessments of material performance the individual frequency sound absorption should be used.

Non-Porous Panel

Typically mounted away from a solid backing, non-porous panels such as gypsum, metal sheet, or plywood behave differently from porous materials. Sound incident upon non-porous panels causes the panel to vibrate. The dissipative mechanisms within the panels' material properties convert the acoustic energy into heat. Note, the addition of a porous material behind a non-porous panel can help to increase the lower frequency absorption.

Cavity Resonator

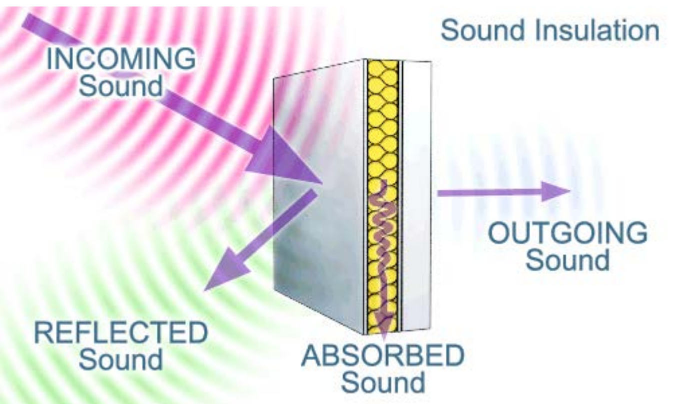
A non-porous panel located away from a solid backing, but with a narrow opening. This opening provides a connection between the volume of air behind the panel to the larger space/room/enclosure. This mechanism creates a 'Helmholtz Resonator' which absorbs acoustic energy, but only for a narrow band of frequencies near its resonance. It is possible to broaden these frequencies by increasing the number of openings – a perforated panel – and using porous materials between the panel and the solid backing.



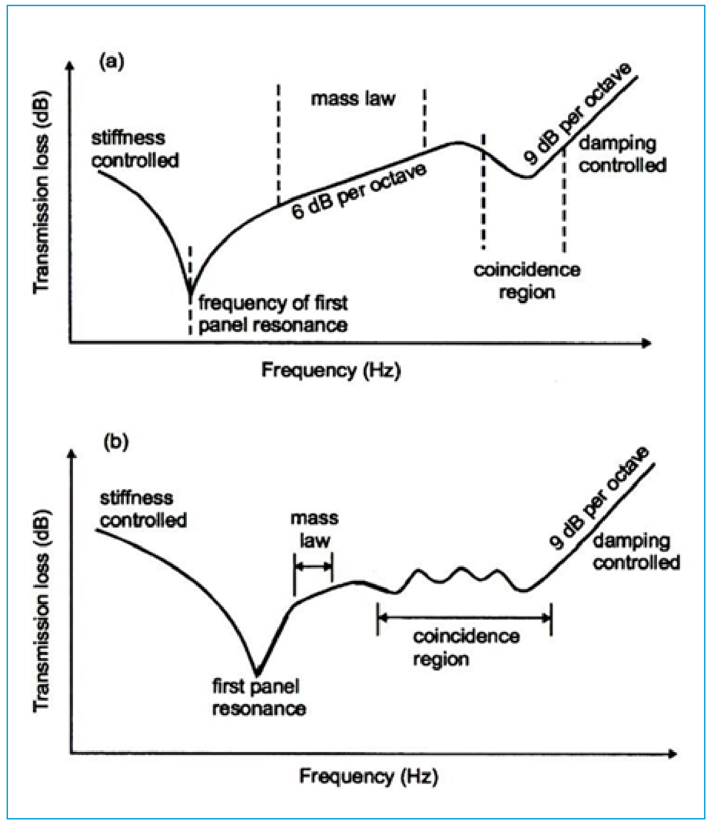
When trying to control the sound inside an enclosed room/space, any or a combination of the above systems can be effective. It is, however, necessary to ensure the source sound characteristics are known to select the correct system.

Barriers

Barriers prevent sound passing through them. They can be walls or fences, but a building/enclosure surrounding a noise source, or a machinery/valve jacket or a pipe or duct insulation covering also function as barriers. A barrier blocks sound getting from a sound source to a sound receiver. The noise source remains, the receiver is still there, but the sound transmission path is blocked. The basic performance of a barrier (transmission loss) for airborne sound is reflection, absorption, and transmission.



The acoustic transmission loss performance of a barrier depends on many factors. For simplicity, consider a basic incidence-absorption-transmission scenario. The ability of the barrier to impede the sound is defined by its physical material characteristics e.g. thickness, density, mass, stiffness, and damping.



The above diagram shows the behaviour of transmission loss for a single homogeneous material (a) and a composite multi-material sandwich construction (b)

Each barrier has a resonance. Below that resonance, stiffness controls transmission loss. At the resonance frequency, sound is transmitted through the barrier without much reflection or absorption. Around twice the lowest resonance frequency, the mass of the partition dominates the sound reduction. Transmission loss increases by 6dB per doubling of mass. Mass increase means the panel vibrates less in response to incident sound waves. Consequently, less sound energy radiates on the other side.

However, mass is not the only factor to consider in a barriers' acoustic transmission loss.

Mass loaded vinyl (MLV)	STC	Octave band frequency transmission loss (dB)					
		125Hz	250Hz	500Hz	100Hz	2000Hz	4000Hz
ArmaSound Barrier E	**28**	15	18	23	29	33	38
Non - Armacell MLV #2	**26**	14	17	21	26	32	37
Non - Armacell MLV #3	**27**	14	17	21	28	32	37
Non - Armacell MLV #4	**26**	23	18	22	26	32	37
Non - Armacell MLV #5	**26**	16	17	22	27	31	36
Non - Armacell MLV #5	**26**	13	17	22	26	32	37

Shown here (above) are six different Mass Loaded Vinyl (MLV) products from six different manufacturers. All have the same mass and produce similar Sound Transmission Class (STC), but the actual performance can vary. When selecting an MLV, or any barrier, matching the barrier to the noise source characteristics (e.g., frequency) ensures the most effective solution.

At higher frequencies there is a coincidence region where bending waves occur through the barrier. As the bending wave velocity increases with frequency, the wavelength of the bending wave differs from the incident sound wave which created it, except where the bending wave speed in the material equals the speed of sound in the air. Here all the waves coincide, and reinforce each other, in phase. This reduces the sound reduction performance of the panel around this frequency. Every material has a coincidence frequency where the transmission loss reduces considerably. For more complex barriers made of several materials (sandwich panel) the coincidence region is often wider than for a single homogeneous material.

Generally, the best acoustic barriers tend to be high mass, limp, highly damped materials with a high weight to stiffness ratio.

Structure-Borne Noise Control

Isolation

At its most basic, anything that vibrates can produce sound waves. Depending on the material and the size of the vibrating object, the amount of sound generated differs. Exciting a tuning fork, causing it to vibrate, and holding it in the air, it is audible but quiet. However, placing the base of the fork on a desktop for example, the loudness increases significantly. The tuning fork is vibration coupled with the desktop and forces the desk to re-radiate the excitation vibration of the fork as sound. Because the desk has a larger surface area, the loudness increases. This process of vibration coupling is important when considering industrial equipment such as rotating machinery on a metal skid, or an HVAC Air Handling Unit (AHU) connected to HVAC ducting. Treating the item of equipment alone is insufficient, isolating the equipment from connected structures can be equally, if not more, important. Similarly, a washing machine on spin cycle can couple with a building structure and cause other structures in the building (walls/floors/ceilings etc.) to vibrate and re-radiate the sound of the washing machine. This causes issues of disturbance in other parts of the building and is extremely hard to treat without reducing the noise at source.

The most effective way to control these situations is to "vibration isolate" the excitation source from its surrounding structure. Various techniques achieve this, usually through rubber mounts or spring connections.

Selection of the correct anti-vibration mount(s) should be undertaken by an expert or supplier as selection of the correct system and materials must allow for the operation of the machinery, frequencies, weight, balance, etc.

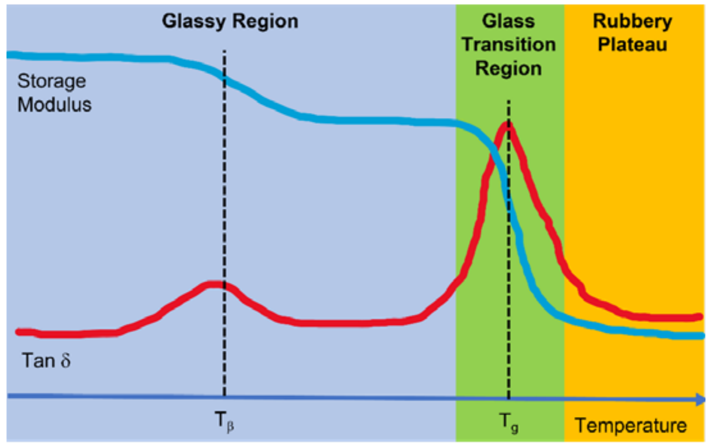
A good example of a vibration isolation system would be to consider the Air Handling Unit for HVAC systems – the AHU has a rubber type collar separating the unit from the ductwork. The collar reduces the machinery vibration of the AHU coupling to the duct work. The duct work is thin steel with a high surface area – it would very easily re-radiate the AHU machinery vibration throughout the building. Note that the noise from HVAC systems is primarily, though not only, generated by the fan as airborne sound that travels through the duct. Consequently, acoustic absorbing insulation materials are used as a possible solution. These would not work if the sound propagation path was mechanical vibration of the duct itself.

Process pipework acoustic insulation systems reduce the sound emitted from the pipe surface. If the pipe is physically attached to a steel pipe rack, the pipe wall vibration is coupled directly to the pipe rack. The pipe rack is often steel and easily re-radiates the pipe noise. When treating pipework noise, it is important to insulate the pipe with suitable acoustic insulation but also to vibration isolate the pipe from the supporting structure.

For a vibrating sound source – vibration isolate it from its supporting structure if that structure is likely to re-radiate the noise.

Damping

If isolation is not possible, it becomes necessary to try to reduce the amount of vibration energy in the coupled structure using damping. Damping materials reduce the amount of resonant vibrational energy in a structure, minimizing transmitted vibration. Subsequently the amount of radiated noise is reduced by the damping out of these structural bending waves. Damping materials reduce the kinetic energy present in a system by transformation into thermal energy. The degree to which a material can provide damping is presented as the Loss Factor. The loss factor (η or Tan δ)of a material is the ratio of a material loss modulus and the storage modulus and varies with frequency and temperature. The highest loss factor and therefore damping occurs within the glass transition region of a material. Selecting the correct damping material, aside from the damping system used, should be a function of the operating temperature and frequency.



For non-porous material panels, damping is an important parameter, especially below first resonance and above the coincidence frequency. However, for porous insulation materials, damping is a key factor in reducing the thickness of pipework acoustic insulation systems. Within ArmaGel blankets, the embedded aerogel within the blanket damps the blanket fibers. This has a dual effect.The sound wave passing through the damped blanket must work harder as the energy is better dissipated by the blanket fibers. Additionally, the ArmaGel material acts as a spring in a mass spring system.

As a damped mass spring is more effective at reducing the vibration energy, so a damped porous material is better at removing vibrational energy from the system. This is particularly important in pipework insulation systems and one of the reasons why an ArmaGel acoustic pipe insulation system can be much thinner than a standard mineral wool acoustic system. In ArmaFlex-based acoustic insulation systems, the closed cell ArmaFlex acts as a spring to reduce vibration transmission. The addition of an open cell ArmaSound RD240 acts as a damped airborne acoustic absorber and the ArmaSound Barrier E/H/HC function as a mass barrier. For metal clad systems, the use of a viscoelastic barrier can be even more efficient than an ArmaSound Barrier E/H/HC. This is due to the higher loss factor (damping) of the ArmaSound Barrier D which reduces the ability of the metal cladding to radiate sound.

Which Noise Control Method to Use?

Example: Machinery Enclosures

Where there is a high noise generating item of equipment, e.g. a pump package, it can be possible to enclose the package. The best practice solution for an enclosure could be considered a steel enclosure with ArmaSound Barrier E on the inside of the box, a porous sound absorbing material such as open cell ArmaSound RD240, a thin (25 micron) polyurethane sheet to reduce moisture/chemical ingress and a perforated metal sheet. This type of design provides both sound absorption inside the enclosure, reducing the reverberant sound energy, and a physical, damped barrier.

The choice of material thickness depends on the sound source characteristics/frequencies and the level of reduction required. For example, if a 50mm (2") sound absorption material was required, selecting the open cell ArmaSound RD240 option is likely to add more mass and damping to the enclosure system than may be achieved with the same thickness of mineral wool. Using the ArmaSound RD240 would therefore improve the barrier transmission loss.

Additionally, care should be taken to avoid any physical connections from the noisy equipment in the enclosure to the enclosure itself (e.g. pipe penetrations). This could allow structure-borne noise transmission.

Example: Pipework Acoustic Insulation

Effective pipework insulation must incorporate all the above noise control elements. The vibrating pipe-wall radiates airborne sound. When attaching an insulation system to the pipe, the pipe-wall vibration can be transmitted to the insulation cladding and re-radiated by the cladding as airborne sound. Acoustic insulation must reduce both air-borne and structure-borne contributions.

The 'porous' layers provide acoustic absorption and provide structure-borne vibration isolation between the pipe wall and cladding system. The cladding system requires sufficient mass and suitable low stiffness to function as an airborne acoustic barrier and enough damping to reduce re-radiation from the external cladding material.

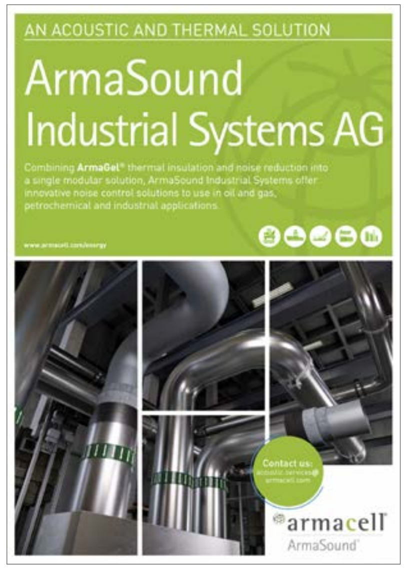
Additionally, care should be taken to use anti-vibration mounts to support the pipe on the pipe support structure to avoid structure-borne noise.

Summary

The use of insulation materials to reduce noise is highly dependent on the nature of the noise source, the path the noise takes to get from the source to the receiver, and the amount of noise that is needed to be reduced. Proper assessment of the nature of the noise problem should be sought to ensure the correct control methods are selected. To reduce air-borne noise, the use of suitable sound absorbing and/or barrier materials is required. For structure-borne noise control, the use of vibration isolation or structural damping would be required.

Armacell offer superior noise control insulation materials that can be used to form highly effective noise control systems. Further, Armacell's technical services group can provide the necessary assessments required to determine the cause of any noise issues and subsequently the correct noise control solutions.

Armacell Acoustic Solutions



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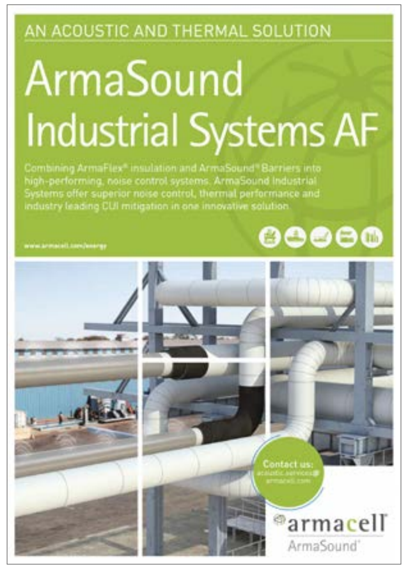

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