

Technical Information Bulletin

Noise Attenuation of Ductwork using Thermobreak Acoustic

Introduction

Thermobreak Acoustic is a lightweight, crosslinked polyolefin foam. Its open cell nature combines excellent thermal insulation and sound absorption properties. It is non-fibrous, low VOC, formaldehyde free and PVC free. Thermobreak Acoustic has been specially designed for noise attenuation in internal HVAC duct lining by maximising acoustic performance in the appropriate noise frequency range. Figure 1 illustrates noise generation within HVAC systems as a function of frequency (Reference 1).

When combined with a high performance foil facing, it combines more targeted sound absorption properties with BS 476 Class 0 fire performance and inherent anti-mould properties. Table 1 provides an overview of performance criteria specific to the Thermobreak Acoustic product range.

Figure 1. Noise frequencies for different types of HVAC equipment.

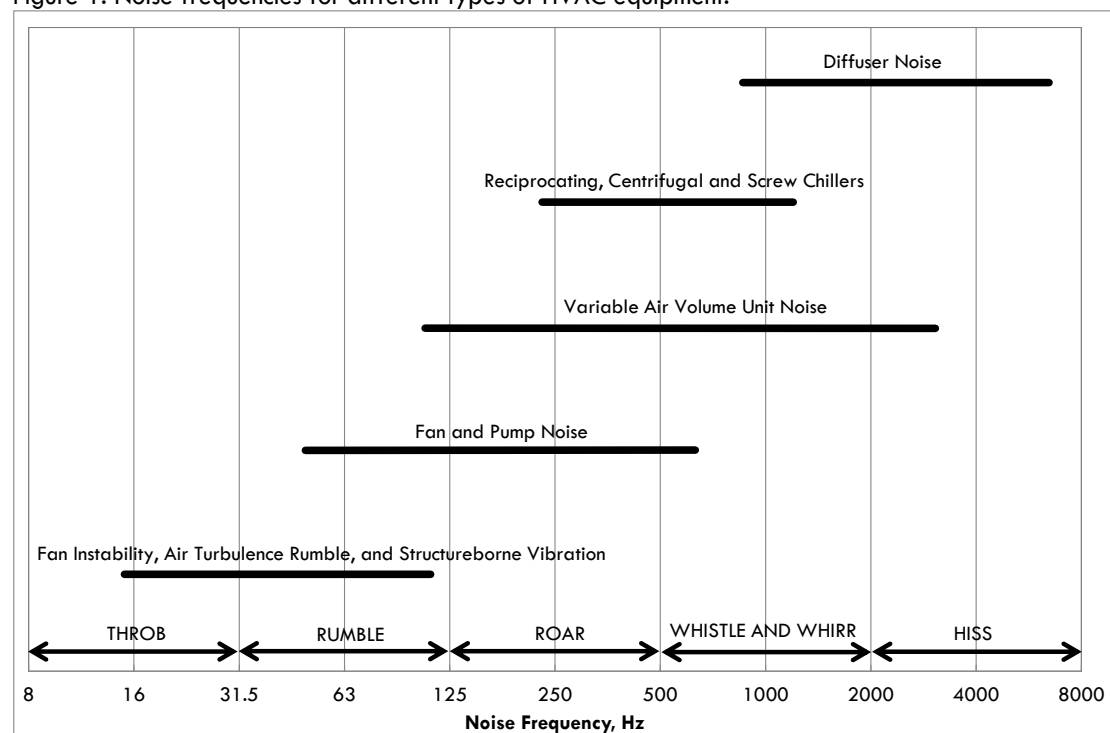


Table 1. Selection criteria for Thermobreak Acoustic insulation on ductwork.

Thermobreak Product	Criteria		
	Lower Frequency Noise Reduction (up to 1000 Hz)	Mid Frequency Noise Reduction (500 – 2000 Hz)	Higher Frequency Noise Reduction (more than 1000 Hz)
Acoustic 12mm			✓
Acoustic 14mm FF*		✓	
Acoustic 24mm	✓		

*Foil Faced.

Insertion Losses and dB Reduction in Ductwork

The Insertion Loss (IL) of an insulation material relates to the reduction of sound intensity at the receiving point after the insulation component is installed ("inserted") into the system. Insertion loss is evaluated as a function of frequency, and is measured in dB/m (lengths of duct) or dB (other duct components such as bends). Although some ductwork components generate noise as a function of air velocity, the same components also have an insertion loss (with or without insulation), which in most cases is independent of air velocity (therefore it is commonly referred to as 'static' insertion loss).

Bare (unlined) duct components also have an insertion loss, and the improvement insulation can provide on the overall insertion loss depends on component type and sound frequency (Table 2).

The following tables can be used as a guide to quantify duct insertion losses for duct components, both unlined (Table 2) and lined with Thermobreak Acoustic (Tables 3 – 5), from the fan to the receiving room. Note that these calculations should only be completed after reading this whole document, noting the relevant noise criteria for a particular receiving room, so the optimal level of lining in a ductwork can be established.

Insertion losses attributable to duct components can be calculated as follows, for straight lengths and bends:

1. Evaluate duct bends and straight lengths as a function of shape and dimension.
2. Referring to Table 2, tabulate the insertion losses for each unlined component as a function of frequency.
3. Sum these components to work out IL from fan to receiving room:

$$\text{Total IL as a function of frequency} = \text{IL due to straight lengths} + \text{IL due to bends}$$

$$= \sum (\text{IL}_{\text{straight lengths per unit length}} \times \text{length}) + \sum \text{IL}_{\text{bends}}$$
4. Noting what additional attenuation is required and using most appropriate Thermobreak Acoustic product, repeat Steps 2 and 3.

An example calculation follows the insertion loss tables (Table 6).

Insertion Loss Tables for Straight Duct Lengths and Bends

Table 2. Insertion losses for unlined duct components (Reference 2).

Rectangular sheet metal ducts (dB/m)								
Duct Dimensions (mm)		Frequency (Hz)						
Height	Width	63	125	250	500	1000	2000	4000
300	300	1.1	0.7	0.3	0.2	0.2	0.2	0.2
300	600	1.3	0.7	0.3	0.2	0.2	0.2	0.2
600	600	0.8	0.3	0.3	0.1	0.1	0.1	0.1
900	900	0.7	0.3	0.2	0.1	0.1	0.1	0.1
Straight round ducts (dB/m)								
Duct Diameter (mm)		Frequency (Hz)						
		63	125	250	500	1000	2000	4000
<450		0.1	0.1	0.1	0.2	0.2	0.2	0.2
450 – 750		0.1	0.1	0.1	0.1	0.2	0.2	0.2
>750		0.0	0.0	0.0	0.1	0.1	0.1	0.1
Mitre bends without turning vanes (dB)								
Duct Width (mm)		Frequency (Hz)						
		63	125	250	500	1000	2000	4000
300		0	0	1	5	8	4	3
600		0	1	5	8	4	3	3
900		1	5	8	4	3	3	3
Round bends (dB)								
Duct Diameter (mm)		Frequency (Hz)						
		63	125	250	500	1000	2000	4000
300		0	0	1	2	3	3	3
600		0	1	2	3	3	3	3
900		1	2	3	3	3	3	3

Table 3. Insertion losses for duct components lined with Thermobreak Acoustic 12mm.

Rectangular sheet metal ducts (dB/m)								
Duct Dimensions (mm)		Frequency (Hz)						
Height	Width	125	250	500	1000	2000	4000	
300	300	0.8	0.5	0.5	2.2	9.9	4.1	
300	600	0.7	0.5	0.4	1.6	7.4	3.1	
600	600	0.4	0.4	0.3	1.1	4.9	2.0	

Straight round ducts (dB/m)						
Duct Diameter (mm)	Frequency (Hz)					
	125	250	500	1000	2000	4000
300	0.2	0.3	0.5	2.2	10.0	4.1
450	0.1	0.2	0.3	1.5	6.6	2.7
600	0.1	0.2	0.3	1.1	4.9	2.1
Mitre bends without turning vanes (dB)*						
Duct Width (mm)	Frequency (Hz)					
	125	250	500	1000	2000	4000
300	1	1	6	11	10	10
450	1	6	11	10	10	10
600	6	11	10	10	10	10
*Duct lining must extend at least two duct widths in each direction from the bend.						
Round bends (dB)						
There is no significant improvement in attenuation for lined round bends; refer to Table 2.						

Table 4. Insertion losses for duct components lined with Foil Faced Thermobreak Acoustic 14mm.

Rectangular sheet metal ducts (dB/m)							
Duct Dimensions (mm)		Frequency (Hz)					
Height	Width	125	250	500	1000	2000	4000
300	300	0.9	0.5	0.9	5.5	2.7	3.4
300	600	0.8	0.4	0.7	4.1	2.0	2.6
600	600	0.4	0.4	0.4	2.7	1.3	1.7
Straight round ducts (dB/m)							
Duct Diameter (mm)	Frequency (Hz)						
	125	250	500	1000	2000	4000	
300	0.3	0.3	0.8	5.5	2.7	3.5	
450	0.2	0.2	0.5	3.6	1.8	2.3	
600	0.2	0.1	0.4	2.7	1.4	1.7	
Mitre bends without turning vanes (dB)							
Refer to Table 3; the improvement in attenuation due to insulation is independent of its density/thickness (Reference 2).							
Round bends (dB)							
There is no significant improvement in attenuation for lined round bends; refer to Table 2.							

Table 5. Insertion losses for duct components lined with Thermobreak Acoustic 24mm.

Rectangular sheet metal ducts (dB/m)							
Duct Dimensions (mm)		Frequency (Hz)					
Height	Width	125	250	500	1000	2000	4000
300	300	0.9	0.9	2.5	7.8	6.0	7.3
300	600	0.8	0.8	1.9	5.8	4.4	5.4
600	600	0.4	0.6	1.2	3.7	2.9	3.5
Straight round ducts (dB/m)							
Duct Diameter (mm)	Frequency (Hz)						
	125	250	500	1000	2000	4000	
300	0.3	0.7	2.5	7.8	6.0	7.3	
450	0.2	0.5	1.6	5.1	3.9	4.8	
600	0.2	0.4	1.2	3.8	2.9	3.6	
Mitre bends without turning vanes (dB)							
Refer to Table 3; the improvement in attenuation due to insulation is independent of its density/thickness (Reference 2).							

Round bends (dB)
There is no significant improvement in attenuation for lined round bends; refer to Table 2.

Example Insertion Loss Calculation (Table 6)

1. 12 metres length and 2 mitre bends in 600mm x 600mm square primary duct, 2 metres length in 300mm x 300mm square terminal branch; line the first 6 metres of straight duct and both mitre bends with Thermobreak Acoustic 24mm.							
2. Unlined insertion loss data:							
Duct Component	Frequency (Hz)						
	63	125	250	500	1000	2000	4000
600 x 600mm straight duct (dB/m)	0.8	0.3	0.3	0.1	0.1	0.1	0.1
300 x 300mm straight duct (dB/m)	1.1	0.7	0.3	0.2	0.2	0.2	0.2
600 x 600mm mitre bend (dB)	0	1	5	8	4	3	3
3. Summation of Insertion Losses for unlined duct:							
Duct Component	Frequency (Hz)						
	63	125	250	500	1000	2000	4000
600 x 600mm straight duct (dB)	9.6	3.6	3.6	1.0	1.0	1.0	1.0
300 x 300mm straight duct (dB)	2.2	1.4	0.6	0.4	0.4	0.4	0.4
600 x 600mm mitre bend (dB)	0	2	10	16	8	6	6
Total	11.8	7.0	14.2	17.4	9.4	7.4	7.4
4. Insertion loss data for duct components lined with Thermobreak Acoustic 24mm:							
Duct Component	Frequency (Hz)						
	63	125	250	500	1000	2000	4000
600 x 600mm lined straight duct (dB/m)	0.8*	0.4	0.6	1.2	3.7	2.9	3.5
600 x 600mm lined mitre bend (dB)	0*	6	11	10	10	10	10
*Use data from unlined duct components.							
5. Summation of Insertion Losses for duct including internal lining.							
Duct Component	Frequency (Hz)						
	63	125	250	500	1000	2000	4000
6 metres x 600 x 600mm unlined straight duct (dB)	4.8	1.8	1.0	0.5	0.5	0.5	0.5
2 metres x 300 x 300mm unlined straight duct (dB)	2.2	1.4	0.6	0.4	0.4	0.4	0.4
6 metres x 600 x 600mm lined straight duct (dB)	4.8	2.4	3.6	7.2	22.2	17.6	21.0
600 x 600mm lined mitre bend (dB)	0	12	22	20	20	20	20
Total	11.8	18.6	27.2	28.1	43.1	38.5	41.0
Improvement due to internal lining	0[#]	11.6	13.0	10.7	33.7	31.1	33.6
[#] Improvements can be obtained by using external lining. Refer to Reference 3 for more information.							

Insertion Loss Calculations for Other Straight Duct Dimensions and Plenums

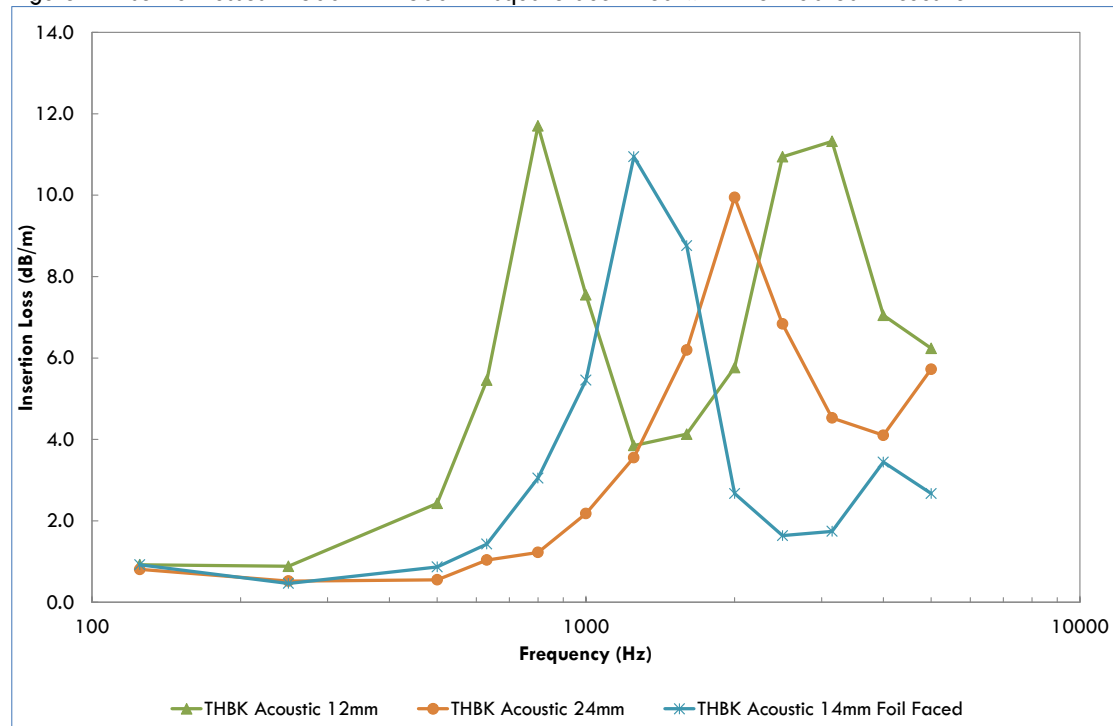
The insertion losses attributable to lined straight ductwork have been derived from the Sabine equation, detailed below (Reference 4). Use this equation to determine insertion losses for straight duct dimensions other than those provided in the above tables. Absorption values for Thermobreak are provided in Table 5. Note the quoted accuracy is $\pm 10\%$ for duct dimensions between 225mm and 450mm width/height, dimension ratios up to 2:1, frequencies between 125 Hz and 2000 Hz, and absorption values between 0.20 and 0.80.

$$\text{Lined Insertion Loss (dB/m):} \quad 1.05 \alpha^{1.4} P/A + \text{Unlined Duct Insertion Loss}$$

Where α = Sound Absorption Coefficient as a function of frequency
 P = Internal lined duct perimeter, m
 A = Internal lined duct cross-sectional area, m²

Figure 2 provides a comparison for insertion losses across the Thermobreak Acoustic product range.

Figure 2. Insertion losses in 300mm x 300mm square duct lined with Thermobreak Acoustic.



Note that the direct measurement of insertion losses for insulation materials is a complex field and is highly dependent on several variables including test method, duct dimensions, duct wall thickness, number and position of bends and other fittings. These measurements are also dependent on the insulation material (density, thickness, composition). Given the wide range of duct applications where Thermobreak Acoustic can be used, it is impossible to measure insertion loss data for all possible scenarios.

The lining of any plenums in the duct network provides a further economical method to further attenuate noise. The benefits are due to all four walls of the plenum chamber being lined, and sound waves above a cut-off frequency tend to reflect internally within the chamber rather than propagate down the ductwork. The cut-off frequency is calculated thus:

$$f_{co} = 173/a \text{ (rectangular ducts);} \quad f_{co} = 202/D \text{ (round ducts);}$$

where a = larger cross-sectional dimension of rectangular duct, m
 D = diameter of round duct, m

If the duct perimeter or diameter is relatively large, then lining the plenum can provide significant acoustic benefits over a broad frequency range. Detailed calculations of insertion losses due to a lined plenum are available in ASHRAE (Reference 2).

Analysis of noise in the HVAC network

Quantifying noise attenuation through lengths of ducting is only one part of a full analysis of noise generation and control within a duct network, detailing noise levels as a function of frequency. The analysis generally requires an iterative process. Firstly, all the noise generation and attenuation within a network is worked out before the addition of insulation lining, silencers or other attenuators.

The noise generation in a network is primarily due to the fan, either directly from the blades or indirectly from the motor/plant room. Fan manufacturer sound power spectra should always be used to establish the starting point for noise control evaluation; otherwise it can be calculated using the likes of ASHRAE, FESI or using online links (Reference 5).

Noise is also generated due to turbulent airflow through the ductwork and particularly through restrictions such as grilles, dampers, orifice plates etc. The level of regenerated noise is a function of air velocity and needs to be added to the fan noise output. Refer to publications such as ASHRAE, FESI or AIRAH to determine the level of regenerated noise.

Noise attenuation in a network can be derived from several sources. Only noise attenuation due to straight ducts, bends and plenums are described here. The suitably trained engineer needs also to quantify attenuation in the network due to the following:

- Duct splitting – main duct to branches, and branches to terminals.
- Room and terminal effects (smaller rooms and walls/floors/ceilings lined with sound absorbers both increase attenuation).
- End reflection. Some low frequency noise reaching the end terminals reflects back into the duct (smaller ducts increase end reflection).

The noise attenuations are summed and subtracted from the sum of generated noise. The resultant sound power level represents the noise reaching the receiver in the conditioned room/building.

The sound power is compared to the design requirements for the space based on the selected noise rating criterion. If the design goals have not been achieved, the additional attenuation needed at each frequency band must be designed into the system. Duct silencers can be used, however the most economical approach where space permits is using duct liners.

Table 7 describes an example summary of a noise analysis of a duct network showing noise generated and attenuated, the required Noise Rating (NR) in the receiving room, and the shortfall. The shortfall can be compensated for by recalculating the noise attenuation by using lined duct components or lining particular lengths of straight duct (using Tables 3 – 5). If noise attenuation contributed only from the lining insulation is required, then follow the Table 6 example.

For this example, the minimum length of duct that requires lining to attenuate the appropriate amount of noise across all frequencies is 10 metres. Note that in this scenario no bends or plenums require lining, but it makes economic sense to do so and provides an extra safety factor. The recommended location to line straight lengths of duct is to start immediately downstream of the fan.

Table 7. Example summary duct network noise analysis (values in dB).

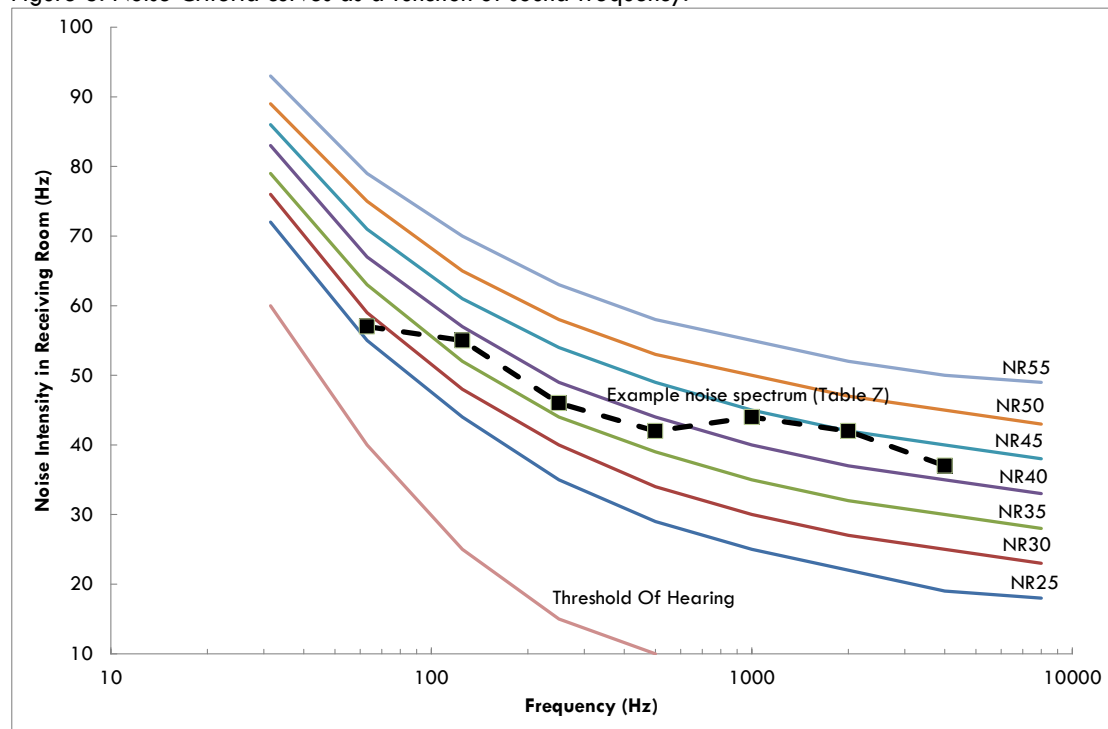
Noise Factor	Frequency (Hz)						
	63	125	250	500	1000	2000	4000
Total noise generation	97	94	93	90	86	80	77
Total noise attenuation	40	39	47	48	42	38	35
Noise spectrum at receiver	57	55	46	42	44	42	37
Required NR Curve (NR 35)	63	52	44	39	35	32	30
Shortfall	0	0	2	3	9	10	7
Required lined duct length*	0	0	10.0	10.0	3.5	8.3	4.4

* Length of 300mm x 300mm straight rectangular duct lined with Foil Faced Thermobreak Acoustic 14mm to achieve NR 35 curve at a given frequency, as shown in Figure 3.

Noise Criteria Guides

There are various methods used to determine what is an acceptable noise level rating inside buildings. ASHRAE details Noise Criteria (NC), Balanced Noise Criteria (NCB), Room Criterion (RC) and Room Criterion (RC) Mark II Methods, while AIRAH recommends a Noise Rating (NR) Method. All methods are based on a family of criterion curves plotting sound intensity (dB) as a function of frequency (Hz), adjusted for human threshold of hearing. Figure 3 illustrates the NR concept, showing NR curves as a function of frequency as well as the hearing threshold. The noise intensity in the receiving room must not exceed the required NR curve at any frequency.

Figure 3. Noise Criteria curves as a function of sound frequency.



The NC and NR methods are relatively simple to use but tend to underestimate HVAC noise generated in certain frequency ranges known to cause discomfort:

- 'Rumble' (16 – 63 Hz)
- 'Roar' (125 – 500 Hz)
- 'Hiss' (1000 – 4000 Hz)

However appropriate design of the HVAC network (including the use of insulation lining) can alter the noise spectrum to more closely align the calculated noise spectrum in the receiving room with the criterion curve.

The NC and NR methods are also well established in HVAC textbooks and are widely used for noise control design. Furthermore, there are many published guides for acceptable NR values for various buildings and rooms. Table 8 provides a guide for NR for various buildings and rooms (Reference 6).

Table 8. Noise Criteria curves for various building or room functions.

Building or room function	NR Curve
Recording studios, concert halls	25
Private dwellings, libraries, lecture theatres, private wards	30
Hotel rooms, apartments, classrooms	35
Open offices, control rooms, restaurants, small shops	40
General public areas, washrooms, toilets, small shops	45
Gymnasias, light machinery areas, supermarkets	50
General factory areas	60

The modified Noise Criteria (NCB) and Room Criterion (RC Mark II) methods better compensate for undesirable noise frequencies but are more complicated to use. Furthermore, there is very limited information available on what are acceptable NCB and RC Mark II values for buildings.

Comparison with Alternative Insulation Materials

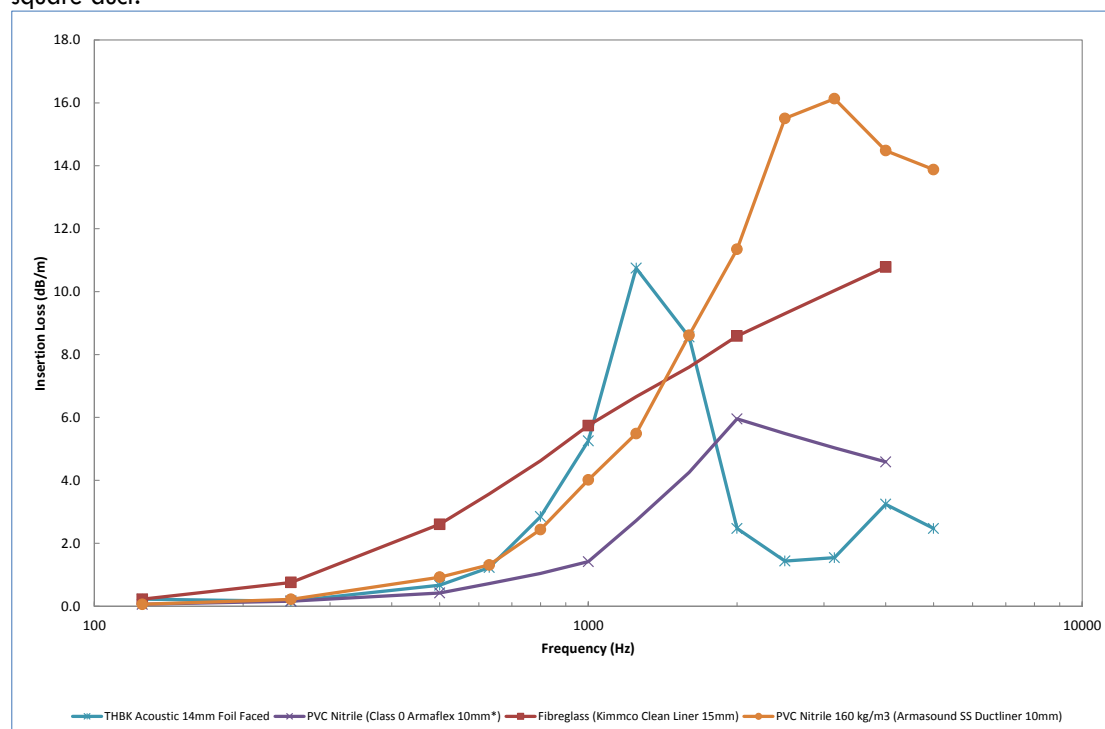
Table 2 provides important selection criteria for Thermobreak Acoustic FF compared to alternative insulation materials. It shows that Thermobreak Acoustic FF is the ideal all-purpose sound absorption insulation.

Table 2. Selection criteria for Thermobreak Acoustic insulation versus other insulation materials.

Product	Criteria				
	Fibre Free?	PVC Free?	Formaldehyde Free?	Vapour Barrier?	Inherently Anti-Mould?
Thermobreak Acoustic FF	✓	✓	✓	✓	✓
PVC Nitrile Elastomer	✓	✗	✓	✓	✗
Fibreglass/Rockwool	✗	✓	✗	✗	✗

Figure 4 graphically illustrates that Thermobreak Acoustic 14mm FF has overall superior insertion loss performance compared to PVC Nitrile insulation in the frequency range most relevant to HVAC generated noise (<2000 Hz). It also provides targeted performance in the 1000 Hz – 1600 Hz frequency range to exceed the performance of equivalent thickness fibreglass insulation.

Figure 4. Insertion Losses for 10 – 15mm lining materials as a function of frequency in 300mm x 300mm square duct.



*Derived from online software (Reference 7) that calculates insertion losses from absorption coefficients using the Sabine equation.

References

1. ASHRAE Handbook (2009) – Fundamentals, Chapter 8.
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5. Engineering Toolbox, Acoustic Calculation of Ventilation Systems (http://www.engineeringtoolbox.com/acoustic-calculation-ventilation-d_70.html).
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7. Armacell - FESI Ductwork Acoustic Lining Calculator ([http://www.armacell.com/www/armacell/ACwwwAttach.nsf/ansFiles/keytecLiningDuctworkArmacellUK.pdf/\\$File/keytecLiningDuctworkArmacellUK.pdf](http://www.armacell.com/www/armacell/ACwwwAttach.nsf/ansFiles/keytecLiningDuctworkArmacellUK.pdf/$File/keytecLiningDuctworkArmacellUK.pdf)).

Enquiries

All Test Reports and Certificates are included in our *Thermobreak*™ Information Kit. If you require any further information, please consult your local distributor or contact us at

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This information on Sekisui Pilon products is presented to the best of our knowledge. All product data is based on average values and is for guidance only. As these products are subject to constant research and development, we reserve the right to update the contents without notice. Date of Publication: November 2011.

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