SeaRox

Marine & Offshore Insulation

Acoustic Manual

ROCKWOOL®
TECHNICAL INSULATION

Insulation worldwide

Rockwool Marine & Offshore (RMO) has for many years been one of the leading suppliers of insulation within the shipbuilding industry. As part of a new strategy within the Rockwool Group and a more global strategic approach, world wide sales of insulation for marine and offshore is now part of Rockwool Technical Insulation (RTI). RTI is one of the biggest suppliers of thermal and fire-resistant insulation products for technical insulation, and an independent entity within the Rockwool Group. More than ever, we want to market a uniform and transparent product range throughout the world – from the United Kingdom to China.

In the ship building industry, this is crucial. It makes it easier for you to ensure the right material in your own country and for your international projects across borders.

Our focus: SeaRox and ProRox

Specifically, Rockwool Technical Insulation (RTI) will now focus on two key markets: marine and offshore and the process industry. To that end, we have subsumed our product range into two specialist categories. SeaRox comprises the full marine and offshore range. Our ProRox range covers all our thermal, fire-resistant and acoustic insulation solutions for technical installations in the process industry.

Introduction

Sound and Noise

In the modern life of today we are constantly surrounded by sound. But often these sounds are perceived as unwanted and therefore called noise.

In many aspects of engineering and design of products and solutions we are no longer satisfied with only the purpose, appearance, feel and design of a product. Further aspects have to be added so true value adding can be given to a product/solution. Sound design and noise control is this next level of value adding properties.

Rockwool stone wool is by its basic engineering the perfect material for the purpose of adding value for the customers. Very often installations of Rockwool products will supply an additional improvement in sound wellness. Within the Rockwool Group great focus and development is ongoing in the field of sound design and noise reduction. Rockwool Technical Insulation can supply the possibilities for true value adding for important markets as cruise liners and offshore living quarters.

Another increasing topic concerning noise is the health and safety aspect. Today several clinical studies have proven that people exposed to high noise levels will face increased risk of cardiac diseases and general stress threshold is significantly lowered. Fatigue problems, which are generally seen at sea and offshore, is also a serious safety issue for a large range of operators.

It is our hope that you will be inspired by this brochure

The brochure will contain a readable walk-trough in the theory of sound, noise and reduction, along with a section of more specific theory incl. some of the commonly used formulas. It will contain a section describing the possibilities of utilising Rockwool SeaRox products in solutions for excellent noise regulation. Hereafter an appendix with various references to rules, standard, textbooks. Finally the brochure will be completed by a range of our test results on material properties and some construction examples.

Construction and dynamic stiffness measurements have been performed by external acoustic specialist companies.

Content

Acoustic Knowledge

Noise is often discussed in many different forums, but we have to appreciate that the science behind is a rather complex world. A lot of physical laws, formulas and equations have been discovered over the years, and today a large range of specialist acoustic companies exists who are able to perform very complex and complicated computer simulations, physical measurements and calculations of an entire cruise liner or other vessels.

This compendium cannot cover all of this theory, but it is meant as a guideline to the basic sound theory and as guidance into principle solutions targeted towards the marine & offshore market.

Rules and regulations within noise control for the marine segments are still relatively limited, compared to the onshore building regulations in some countries. But it is expected that IMO and ILO will enhance the focus in this area in the near future. In the appendix a short guide to present rules and regulations is available.

Within the Rockwool Group several dedicated acoustic engineers are employed and the Group runs its own acoustic laboratory and testing facilities. Product and solutions testing along with new marine development projects are constantly ongoing.

Our product and marine engineers are also available for further support.

"SeaRox" the new family name

The SeaRox products have been given new names. This makes it even easier to find the exact product you need quickly, wherever you are working. Each product name is structured in the same clear way:

e.g.: **SeaRox WM 960 ALU SC**

- Product range: SeaRox
- As last part of the name you might find an abbreviation indicating local product specifications
- 2 last digits = refer to other product properties as stated by Rockwool Technical Insulation

■ Product identifier:

WM	= Wired Mats
SL	= Slab
PS	= Pipe Sections
LM	= Lamella Mats
MA	= Mats

■ Application code:

3	= acoustics, products mainly for sound absorption
4	= outfitting, products mainly as components of systems
6	= fire, products mainly for fire rated constructions
7	= comfort, products mainly for thermal insulation of accommodations
9	= thermal, products mainly for thermal insulation of technical installations

■ Product facings

ALU	= reinforced aluminium
GW	= glass cloth white
TB	= glass tissue black
GS	= glass scrim

SeaRox
Marine & Offshore Insulation

Under the SeaRox name we market a full range of fire-safe solutions for the ship building industry that also offer optimal acoustic, thermal insulation as well as solutions for insulation of technical installations on-board. The key property of all these products is outstanding thermal insulation, which helps keeping energy consumption under control. Naturally, they also meet the most stringent demands with respect to acoustic insulation and fire resistance. We have fine-tuned our marine and offshore range, too, bearing the increasing necessity for an efficient, clear product offering in mind.

■ Comfort Insulation

NEW NAME	OLD NAME
SeaRox MA 700 GS[d]	Shiprock Plus
SeaRox MA 700 ALU[d]	Shiprock Alu
SeaRox SL 720	Marine Batts 32
SeaRox MA 720 ALU	Marine Batts 32 RL
SeaRox SL 740	Marine Batts 45
SeaRox MA 740 ALU	Marine Batts 45 RL

■ Acoustic Insulation

NEW NAME	OLD NAME
SeaRox SL 320	Marine Slab 60
SeaRox SL 340	Marine Slab 80
SeaRox Acoustic Foil	Marine Acoustic Foil

■ Outfitting Insulation

NEW NAME	OLD NAME
SeaRox SL 436	Marine Slab 140
SeaRox SL 440	Marine Slab 150
SeaRox SL 470	Marine Slab 180
SeaRox SL 480	Marine Slab 200

■ Firesafe Insulation

NEW NAME	OLD NAME
SeaRox WM 620	Marine Wired Mat 90
SeaRox WM 640	Marine Wired Mat 105
SeaRox SL 620	Marine Firebatts 100
SeaRox SL 640	Marine Firebatts 130
SeaRox SL 660	HC Firebatts 150
SeaRox WM 660	HC Wired Mat 150
SeaRox PS 620 ALU[SC]	Marine Firebatts 100 PS

■ Thermal Insulation

NEW NAME	OLD NAME
SeaRox SL 970	Marine Firebatts 110
SeaRox LM 900 ALU	Marine Lamella Mat 32
SeaRox WM 950	Marine Wired Mat 80
ProRox PS 960 ALU	Rockwool 800*
ProRox PS 960	Pipe Sections 850*

Alternative facings may be available

* Part of Rockwool Technical Insulation assortment for process industry, ProRox

Sound and noise - Theory

1.0 What is sound?

In physical terms, sound is the mechanical vibration of a gaseous, liquid or solid elastic medium. Sound is a form of mechanical energy. It is produced, when particles oscillate around their equilibrium position.

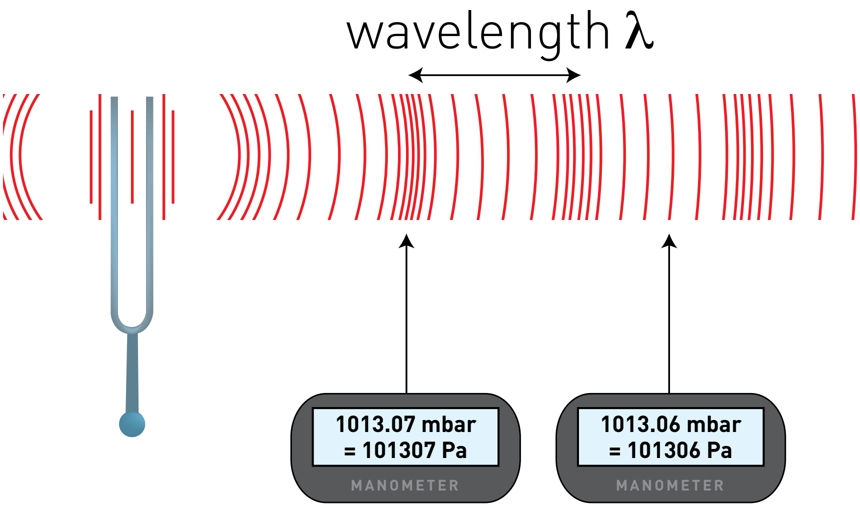
In this brochure, we will deal with sound in air (airborne sound) and sound/vibrations in solid medium as the steel construction of a vessel (structure-borne noise).

Propagation of sound in air happens, when a sound source, usually a vibrating object mechanically affected, makes the air molecules next to its surface oscillate around their equilibrium position in the stagnant air.

Due to the elasticity of the air the sound is propagated through the air by successive oscillations of the neighbouring elastic air particles, and we have a steadily progressing sound wave. If the sound source is vibrating harmonically, the fluctuations of the air particles will be harmonic too, and this in any arbitrary point. In a sound wave in air the particles will oscillate in the same direction as the wave front propagates (=longitudinal wave), and this creates areas with higher respectively lower pressure compared to the atmospheric pressure. Therefore sound waves can be treated as pressure waves.

Water waves

Sound waves



Type 2260 Investigater

1.0.1 Waves and speed

In opposite to the longitudinal sound waves in air, water waves are transversal waves, where the particle oscillation is perpendicular to the direction of wave propagation. The sound waves can be characterized by the frequency, wave length, wave propagation velocity and the amplitude from the oscillations.

The frequency f is the number of harmonic oscillations of a particle per second and is expressed in Hz (1Hz = 1/s) or kHz (kilo hertz; 1 kHz = 1000 Hz).

The wave length λ is the distance between particles oscillating in phase, e.g. between two maxima, and is expressed in m.

The propagation velocity of the wave front is called the speed of sound c and is expressed in m/s. The speed of sound must not be mistaken for the particle velocity u.

The speed of sound in air is independent of the frequency and can be calculated as a function of the temperature.

$$c = 331.4 + 0.607 \cdot t$$

(t – temperature in degree Celsius)

For a normal temperature range around 20°C you can calculate with a constant speed of air of about:

$$c \approx 340 \text{ m/s}$$

Between the wave length λ, the frequency f and the speed of sound c is the following relation:

$$c = f \cdot \lambda$$

$$f = \frac{c}{\lambda}$$

Frequency - Wavelength relation:

f (frequency)	λ (wavelenght)
(Hz)	(m)
63	5,40
125	2,72
250	1,36
500	0,68
1000	0,34
2000	0,17
4000	0,09
8000	0,04

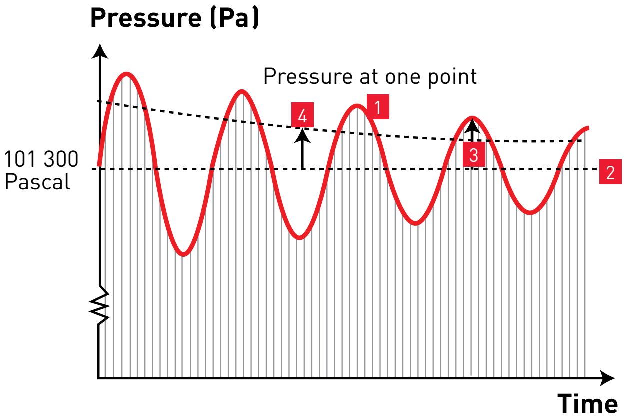
Temperature - Speed relation

t	c
(°C)	(m/s)
0	331
20	344
40	356
60	368

1.0.2 Sound pressure

The amplitude ("strength") of a sound wave in an arbitrary point can be described with the sound pressure P. In analogy to the voltage of an electric, alternating current, the amplitude is expressed with the effective value Peff

Because of the wide dynamic range of the human ears we have to deal with sound pressure values from about 0.000020 Pa =20 µPa to 200 Pa = 200000000 µPa. So independent of the used unit for the sound pressure (pascal Pa or micro Pascal µPa) we will get numbers with a lot of 0's, which are not easy to read and understand.



Total pressure = P_{atm} + $P_s(t)$

- 1 $P_s(t)$ - sound pressure
- 2 P_{atm} - atmospheric pressure
- 3 P_{peak} - peak value
- 4 P_{eff} - effective value

For sinus wave:

$$P_{eff} = \frac{P_{peak}}{\sqrt{2}} = 0.71 \times P_{peak}$$

Therefore the logarithmic unit decibel (dB) is introduced to express the sound pressure values with easy to handle numbers from about 0 to 140. To do that, a reference value Po is needed, and for the sound pressure this value Po=20 µPa represents the average threshold for hearing for young people. Sound pressure values expressed with the decibel unit [dB] are named:

Sound Pressure Level Lp (sometimes also SPL)

Sound Pressure Level (SPL)	Sound Pressure	
L_p	P	
dB ref 20 µPa	Pa	µPa
140	200.000000	200000000
130	63.245553	63245553
120	20.000000	20000000
110	6.324555	6324555
100	2.000000	20000000
90	0.632456	632456
80	0.200000	200000
70	0.063246	63246
60	0.020000	20000
50	0.006325	6325
40	0.002000	2000
30	0.000632	632
20	0.000200	200
10	0.000063	63
0	0.000020	20

The energy emitted from a sound source is called the sound power and is expressed in Watt (W). Due to the same reasons with a very large dynamic range, also here a logarithmic decibel definition is usually used:

Sound Power Level Lw = 10*log(Psource/Pref) dB with the reference value Pref = 10-12W

A sound source with a mechanical emitted sound effect of 1 W has a sound power level of

Lw = 10*log(1W/10-12W)dB = 120 dB

The energy flow in a sound wave can be expressed with the Sound intensity in W/m^2 or a similar dB definition with Io = 10-12W/m^2

Also other terms within vibration and acoustics are expressed with a dB unit using different reference values. Thus e.g. for vibration different dB definitions are used to describe the acceleration, the vibration velocity or the displacement of a vibrating point.

1.1 Sound and noise

Using a dB unit results in easy to handle numbers, but you have to ensure that you know which physical term and which reference value are used. Otherwise there is a risk of mixing values for e.g. sound power level emitted by a source and the sound pressure level, which can be heard (and measured) in a certain point in some distance.

Equally when measuring, there are several different standard methods seen. And also the surroundings/environment for the measurements are very determining for the outcome of the data material.

It is therefore impossible to compare measurement figures from different companies, without also looking at all the related parameters.

Comparing Sound Sources. Difference in Sound pressure. Human perception:

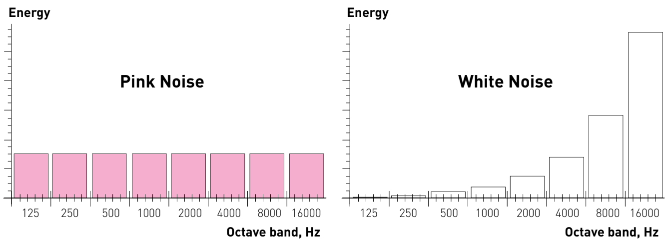
- 10 dB perceived as doubling
- 3 dB can just be heard
- 1 dB can't be heard

Physical: 2 x equal sources ⇒ + 3 dB

A simple definition for noise might be, that noise is unwanted sound.

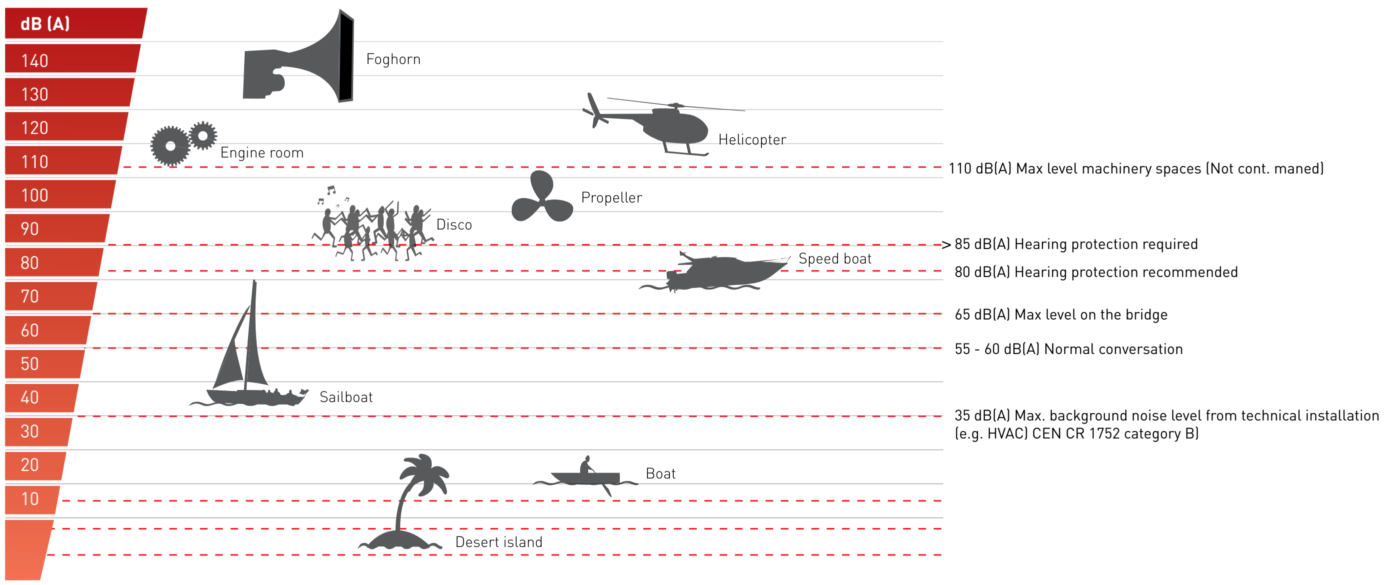
There are different kinds of sounds and noise. A pure sine tone consists of a single frequency. Tones from e.g. music instruments might consist of a mixture of different frequencies, typically the basic frequency and some harmonic frequencies with multiple frequency values of the basic tone.

Other kinds of sounds are a mixture of many frequencies in a given frequency range and we call this for broad band noise. Special broad band noises are used for measurements in acoustics, the "white noise" and the "pink noise". Both types have more or less all frequencies within the specified range (e.g. 50 Hz to 10000 Hz), the difference is the energy at each frequency.



1.0.3 Sound levels

Sound levels as seen within marine:



1.2 Sound propagation

In a free field (no reflecting surfaces) the sound power Lw emitted from a sound source (e.g. a chimney) generates a sound field with a sound pressure level Lp:

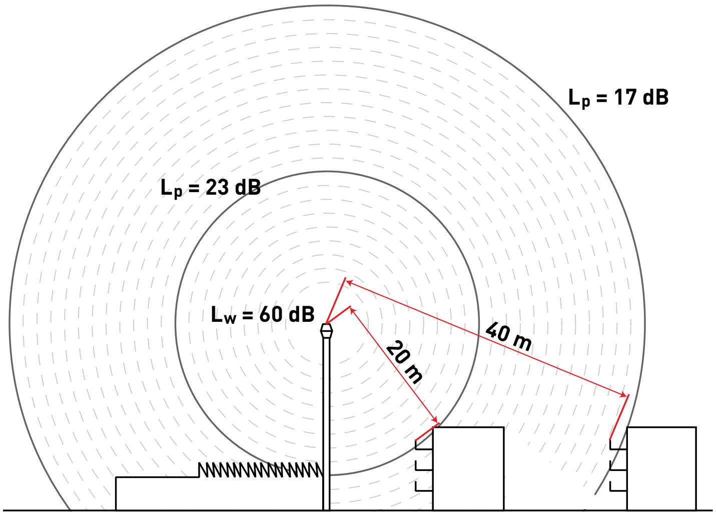
$$L_p = L_w + 10 \cdot \log \frac{1}{4 \cdot \pi \cdot r^2} \text{ (dB)}$$

Example:

$$L_p\,(20\,m) = 60 \text{ dB} + 10 \cdot \log \frac{1}{4 \cdot \pi \cdot 202} = 23 \text{ dB}$$

$$L_p\,(40\,m) = 60 \text{ dB} + 10 \cdot \log \frac{1}{4 \cdot \pi \cdot 402} = 17 \text{ dB}$$

According to this formula the sound pressure level decays in a free field with 6 db for doubling the distance.



1.3 Frequency analysis and octave bands

For more or less all technical evaluations, weighting, rating etc. of sound and noise, not only the total amount of energy in a noise is important but also the frequency distribution of the sound energy.

To analyze the sound in the relevant frequency range (e.g. from 20 Hz to 20000 Hz) this range must be divided in appropriate steps.

Two principle methods can be used to define these frequency steps:

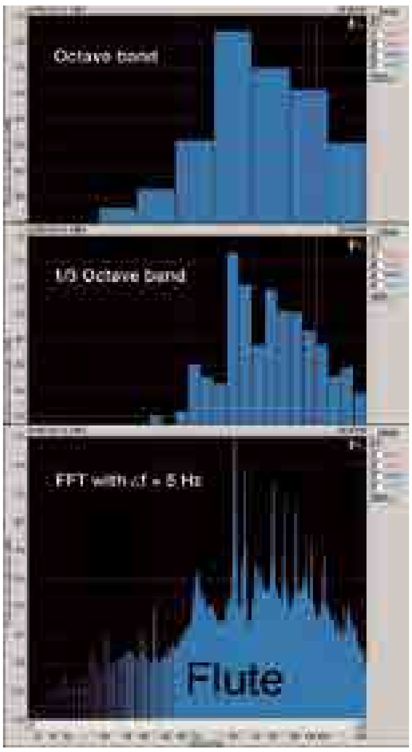
- A constant (absolute) bandwidth (e.g. 10 Hz, this means ranges from 10Hz ... 20 Hz; 20 Hz ...30 Hz; 30 Hz ...40 Hz ;...;19990 Hz ... 20000 Hz) or

- With constant relative bandwidth. The latter means, that the ratio between lowest and highest frequency in each interval is constant, e.g. 45 Hz...90 Hz (ratio=2); 90 Hz...180 Hz; 180 Hz ... 360 Hz; ... If the ratio as in the example is 2, we call these frequency bands for octave bands. Dividing the frequency range in bands with constant relative bandwidth corresponds best with the human perception of different frequencies also known from music.

For analyzing noise, octave bands and 1/3 octave bands (ratio $\sqrt[3]{2}$=1.26) are most common, but also 1/12 octave bands and 1/24 octave bands can be used.

If a more detailed frequency information is required, a frequency analysis with constant absolute bandwidth (e.g. 1 Hz or 2 Hz or 10 Hz or xx Hz) can be used. The most frequently used mathematical method mostly used is called FFT (Fast Fourier Transformation).

1/3 octave band		1/1 octave band	
Centre frequency (Hz)	Frequency range (Hz)	Centre frequency (Hz)	Frequency range (Hz)
50	45 - 56		
63	56 - 71	63	45 - 90
80	71 - 90		
10	90 - 112		
125	112 - 140	125	90 - 180
160	140 - 180		
200	180 - 224		
250	224 - 280	250	180 - 355
315	280 - 355		
400	355 - 450		
500	450 - 560	500	355 - 710
630	560 - 710		
800	710 - 890		
1000	890 - 1120	1000	710 - 1410
1250	1120 - 1410		
1600	1410 - 1800		
2000	1800 - 2240	2000	1410 - 2800
2500	2240 - 2800		
3150	2800 - 3550		
4000	3550 - 4500	4000	2800 - 5600
5000	4500 - 5600		
6300	5600 - 7100		
8000	7100 - 9000	8000	5600 - 11200
10000	9000 - 11200		



Frequency analysis of a tone played on a flute

1.4 Sound perception and A-weighting

Humans can hear sound from about 20 Hz up to about 20000 Hz. In the diagram the total audible range and the typical ranges for music and speech are indicted. Sound with frequencies below 20 Hz is called infra sound, sound above 20000 Hz = 20 kHz is called ultra sound.

The human ear perceives sound with different frequencies differently. The following diagram shows curves (called Phon-curves) for sinus tones, which results in the same perception as a 1000 Hz sinus tone at the given level (= Phon value) (here the simplyfied Fletcher-Munson curves from 1933 are shown).

To adjust the perception of noises with different frequency distribution to the human ear response, a frequency weighting with the A-filter can be performed. This is usually done in octave bands or 1/3 octave bands. A similar weighting with the C-filter is some times used to emphasize low frequent noise components.

The measured dB-values (either in octave bands or 1/3 octave bands) are corrected with the filter values according to the table, before the sum (logarithmic addition) is calculated.

Example for comparison of total sound energy, with human perception.

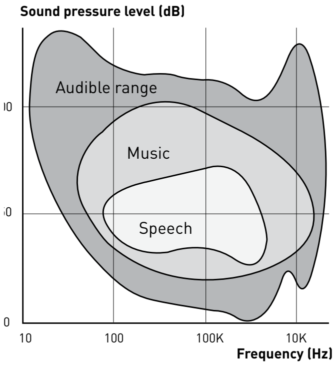
Hz	63	125	250	500	1000	2000	4000	8000
A-filter	-26	-16	-19	-3	0	1	1	-1
dB (measured)	67	76	73	70	65	66	62	52
dB (A-weigthed)	41	60	64	67	65	67	63	51

$$L_{pA} = 10 \cdot \log\left(10^{\frac{41}{10}} + 10^{\frac{60}{10}} + ..\right) = 73\ dB(A)$$

(human response)

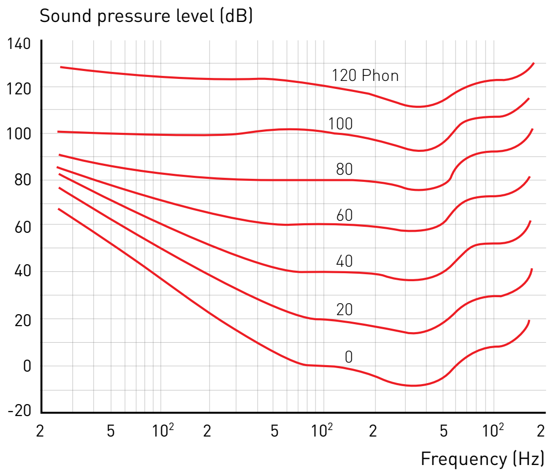
$$L_{pA} = 10 \cdot \log\left(10^{\frac{41}{10}} + 10^{\frac{60}{10}} + ..\right) = 73\ dB(A)$$

(human response)



Human perception

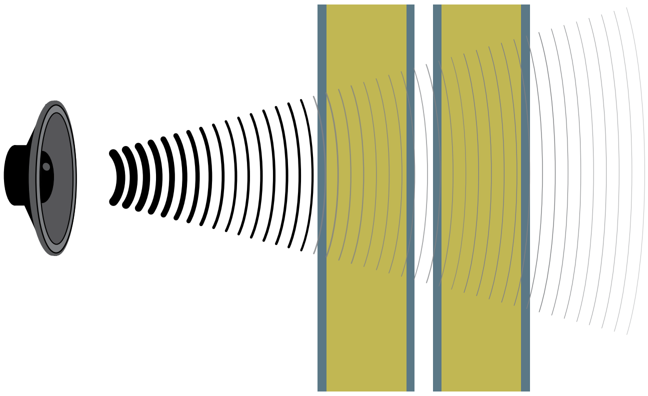
Fletcher Munson Phon Curves



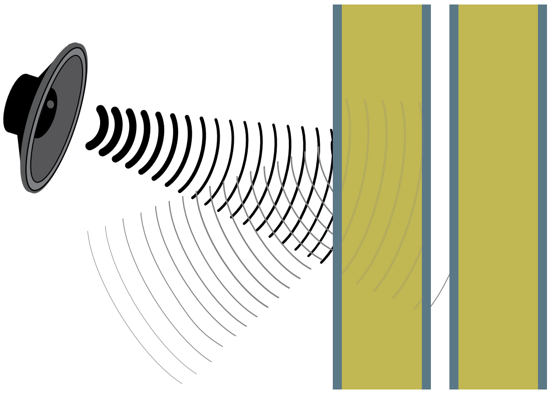
dB filtervalues

Center frequency	A-Filter		C-Filter
	1/3 octave band	octave band	1/3 octave band
(Hz)	(dB)	(dB)	(dB)
10	-70.4		-14.3
12.5	-63.4		-11.2
16	-56.7	-56.7	-8.5
20	-50.5		-6.2
25	-44.7		-4.4
31.5	-39.4	-39.4	-3.0
40	-34.6		-2.0
50	-30.2		-1.3
63	-26.2	-26.2	-0.8
80	-22.5		-0.5
100	-19.1		-0.3
125	-16.1	-16.1	-0.2
160	-13.4		-0.1
200	-10.9		0.0
250	-8.6	-8.6	0.0
315	-6.6		0.0
400	-4.8		0.0
500	-3.2	-3.2	0.0
630	-1.9		0.0
800	-0.8		0.0
1000	0.0	0.0	0.0
1250	0.6		0.0
1600	1.0		-0.1
2000	1.2	1.2	-0.2
2500	1.3		-0.3
3150	1.2		-0.5
4000	1.0	1.0	-0.8
5000	0.5		-1.3
6300	-0.1		-2.0
8000	-1.1	-1.1	-3.0
10000	-2.5		-4.4

1.5 Sound absorption and sound reduction



Sound absorption



Sound reduction

Sound absorption coefficient:

$$\alpha = \frac{\text{absorbed + transmitted energy}}{\text{incident energy}} = \frac{I_a + I_{tr}}{I_i}$$

Sound transmission factor:

$$\tau = \frac{\text{transmitted energy}}{\text{incident energy}} = \frac{I_{tr}}{I_i}$$

Due to the very small values for the sound transmission factor, the sound transmission is usually described with the sound reduction index R (also called transmission loss TR) expressed in dB.

$$R = 10 \cdot \log \left(\frac{1}{\tau} \right) = 10 \cdot \log \left(\frac{I_i}{I_{tr}} \right) \text{(dB)}$$

I_i = Incident wave with intensity

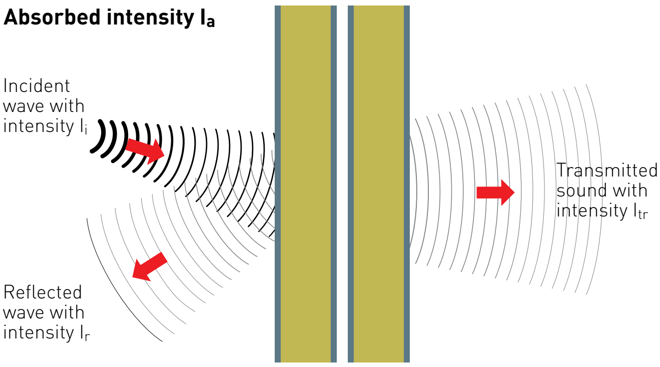
I_a = Absorbed intensity

I_{tr} = Transmitted sound intensity

I_r = Reflected wave with intensity

If a sound wave hits a wall a part of the energy will be reflected, another part will be absorbed in the wall and a third fraction will be transmitted. According to the sketch the sound absorption and the sound transmission can be defined as following:

Absorbed intensity I_a



1.6 Airborne sound Insulation

The sound insulation is normally expressed with the sound reduction index R. R depends on the frequency of the sound passing through the element and is measured in 1/3 octave bands according to ISO 140.

According to ISO 717 a rating of the frequency depending sound insulation results in a single number value Rw and adaption terms C and Ctr can be performed.

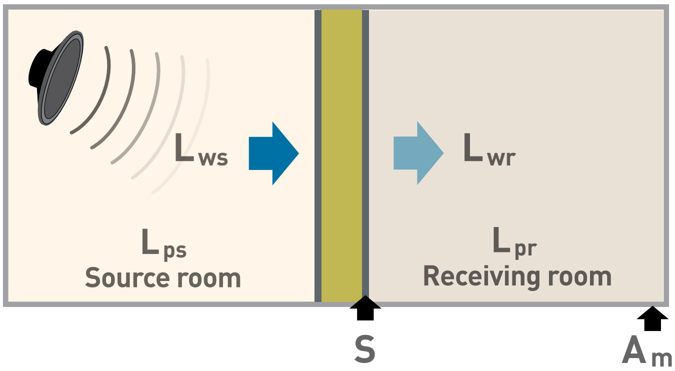
Definition:
Reduction index (but difficult to measure)

$$R = L_{ws} - L_{wr} \text{ (dB)}$$

Meassurement (laboratory):
Reduction index

$$R = L_{ps} - L_{pr} + 10 \cdot \log \left(\frac{S}{A_r} \right)$$

The sound rating according ISO 717 uses a reference curve, which is shifted up or down until the sum of the unfavourable deviations between measurement result and shifted reference curve is a maximum, but still less or equal 32 dB. The single number value Rw is the value of the shifted reference curve at 500 Hz.

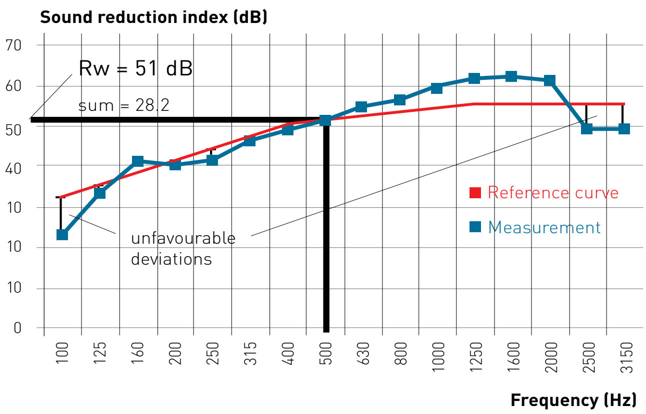


- L_{ps} = Sound pressure level (Source room)
- L_{pr} = Sound pressure level (Receiving room)
- L_{ws} = Sound power levels (Source room)
- L_{wr} = Sound power levels (Receiving room)
- S = Area of the partition wall of the test speciment
- A_m = Equivalent sound absorption area in receiving room
- C = Adaptation term for pink noise
- C_{tr} = Adaptation term for typical trafficnoise

Sound reduction index:

- **Results according to ISO 717-1: R_w (C ; C_{tr})**
  R_w + C is the reduction of A-weigthed sound pressure level for pink noise, R_w + C_{tr} for traffic noise
- **In some countries the following definition for RA1 is used:**
  R_{A1} = R_w + C

Example - facade:
R_w (C ; C_{tr}) = 41 (0 ; -5) dB
External traffic noise with 65 dB(A) will be reduced with
41 + (-5) = 36 dB to 65-36 = 29 dB(A) behind the facade.



Reference shifting curve for determening R_w

1.7 Sound pressure calculation in a room

In a room with reflecting walls and objects the sound pressure does not decay that much and the sound field in a certain distance from the source becomes more or less diffuse, that means that due to the many reflections the sound waves come from all directions.

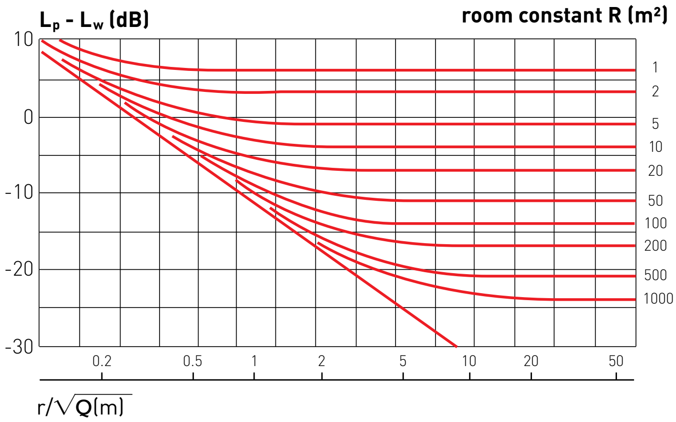
A simple model for calculating the sound pressure level in a closed space is using:

Sound pressure level:

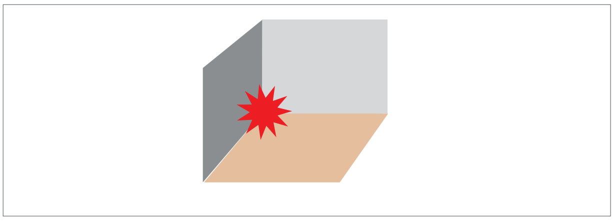
$$L_p = L_w + 10 \cdot \log \left(\frac{Q}{4 \cdot \pi \cdot r^2} + \frac{4}{R} \right)$$

Room constant:

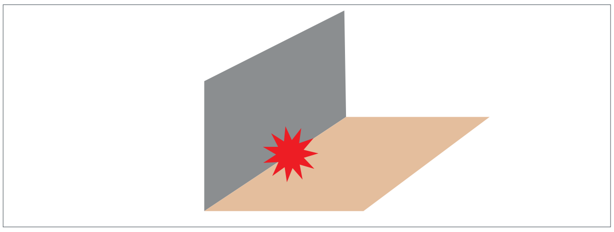
$$R = \frac{A}{1 - \alpha_m} = \frac{S \cdot \alpha_m}{1 - \alpha_m}$$



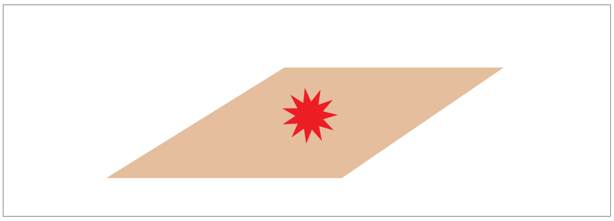
More advanced calculations can be performed with acoustical programs using e.g. ray tracing and mirror source techniques. Those programs need detailed information about the room geometry and sound absorbing and reflecting properties of all surfaces. Normally those programs will only be used by qualified acoustic engineers.



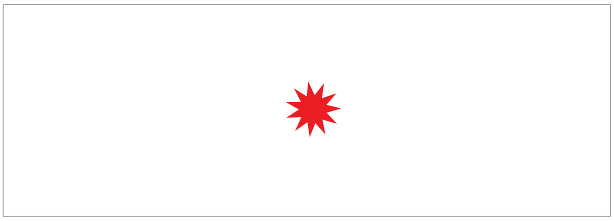
Q = 8 (source in a corner)



Q = 4 (source close to an edge)



Q = 2 (source close to one surface)



Q = 1 (source in the room)

L_w = Sound power level, source

L_p = Sound pressure level

Q = Constant, source position

R = Room constant

A = Equivalent sound absorption area (m²)

S = Total room surface

α_m = Mean absorption coefficient

V = **Room volume**

S = **Total room surface**

A = **Equivalent sound absorption area (m²)**

α_m = **Mean absorption coefficient**

1.8 Room acoustics

The sound propagation within a room depends on the reflection, absorption and spreading of sound waves on all surfaces and objects in the room. The most important parameter describing the room acoustics is the reverberation time. The reverberation time describes, how long time it takes for a sound to decay 60 dB after the source has stopped. Depending on the measurement procedure, the reverberation time is called T20 (measured decay from -5 dB to -25 dB and extrapolated to 60 dB decay), T30 (measured from -5 dB to -35 dB and extrapolated) or EDT (Early Decay Time, the initial 10 dB decay extrapolated to 60 dB).

The reverberation time for a room can be calculated according to Sabine's reverberation equation (Wallace C. Sabine, founder of modern acoustics; 1868-1919)

Calculation of reverberation time T:

Sabine: $$T_{rev} = 0{,}16 \cdot \frac{V}{A} \qquad \alpha_m = \frac{A}{S}$$

$$A = \alpha_1 \cdot S_1 + \alpha_2 \cdot S_2 + \dots \alpha_n \cdot S_n = \alpha_m \cdot S$$

The calculation has to be done for every octave band.

Reverberation is a very important factor for the quality or wellness of the sound, but within marine regulations this is an issue not dealt with.

Examples from building regulations seen below:

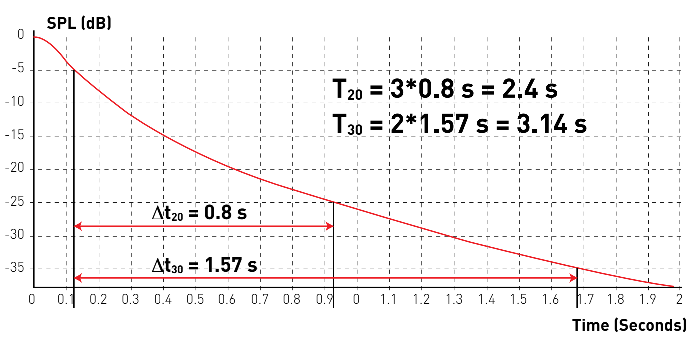
	Type of room	Max. Reverb. Time (sec)
Buildings for education Equivalent absorption (m²) Reverberation Time (s)	Stairway	1.3
	Classroom, music room for electric instruments ($V < 250$ m³), manual work room	0.6
	Common corridors	0.9
	Music room for acoustic instruments ($V < 250$ m³)	1.1
	Gymnasium ($V < 3500$ m³)	1.6
	Swimming pool ($V < 1500$ m³)	2.0
	Meeting room	0.4
Childrens day care institutions	Common room	0.4

1.9 Reverberation time

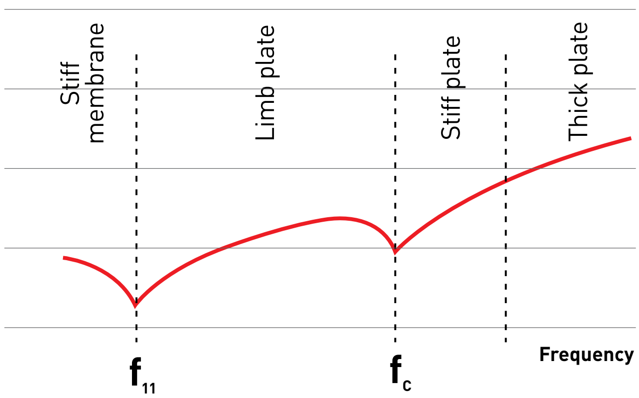
In an acoustic hard room with even distributed absorption areas, the sound decays with more or less constant slope, and the results of T30, T20 or EDT will be the same. In more irregular rooms the T20 might be less than the T30 value.

Reverberation time T20, T30

dB delay for reverberation time:



Sound reduction



1.10 Acoustic mass law

The first rough approach to calculate sound insulation for a single leaf panel is the so called acoustic mass law. According to this theoretical model the sound insulation increases with the surface density (kg / m²) and the frequency according to following formula:

Acoustical mass law for a single wall:

$$R \approx 20 \bullet \log(m) + 20 \log(f/100) - 7 \text{ dB}$$

$\Rightarrow$ doubling of density

= 6 dB increased reduction index

For a given material the mass law is valid in a limited frequency range, but other effects reduce the sound insulation at certain frequencies.

A principle diagram for the sound reduction index over the frequency is shown below:

The resonance frequencies depend on the size of the vibrating panel. In most cases the first resonance frequency f11 results in a clear dip in the sound reduction, while higher resonance frequencies do not become that visible in the sound reduction curve.

The critical frequency, where the speed of sound in air is equal to the propagation velocity of the bending waves in the panel, creates the second serious dip in the sound reduction curve.

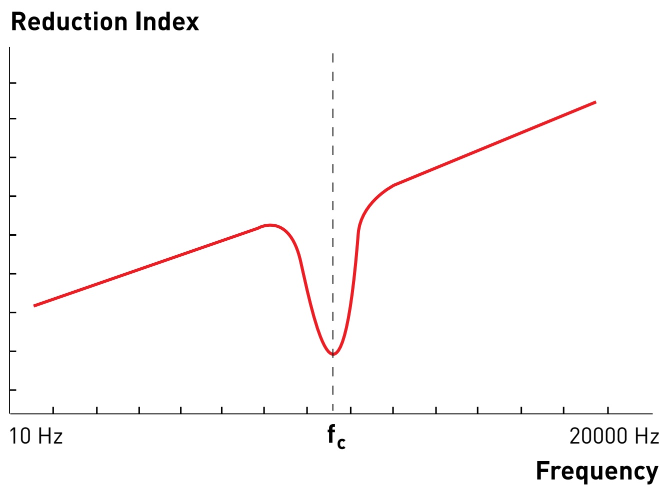
The two characteristic dips of the sound reduction, at the resonance frequency and at the critical frequency, can be very important when relating to the dominant frequencies from the source.

m = Surface density ("mass") (kg/m²)

f = Frequency (Hz)

f_{11} = Resonance frequency in plate

f_c = Critical frequency



1.11 Single wall - airborne sound reduction

When looking at a single homogeneous material, like a single steel plate (bulkhead or deck plate), following factors influence the sound reduction.

- Mass of the bulkhead/deck plate
- Bending stiffness
- Elasticity
- How it is restraint in the construction
- Angle of the sound
- Tightness (any penetrations/holes)

In this respect critical frequencies will occur, where the sound reduction is considerably lower than in the rest of the range.

The critical frequency is the frequency at which the wavelength of bending waves in the wall matches those of the incident sound. Bending waves of different frequencies travel at different speeds, the velocity increasing with frequency. This means that for every frequency above a certain critical frequency, there is an angle of incidence for which the wavelength of the bending wave can become equal to the wavelength of the impacting sound. This condition is known as coincidence.

When coincidence occurs it allows a far more efficient transfer of sound energy from one side of the panel to the other, hence the big coincidence-dip at the critical frequency. In many thin materials (such as glass and sheet-metal), the coincidence frequency begins somewhere between 1000 and 4000 Hz, which includes important speech frequencies.

In practice the problem is often seen in simple thin plate bulkhead divisions, and the theoretical way of improving is to enhance the thickness of the plate. This is of cause generally not an acceptable solution as the weight of the vessel will be unacceptable high.

The solution is to make correct stiffener design and to combine the bulkhead/deck plates with damping material as Rockwool (i.e. SeaRox SL 340) eventually in combination with visco-elastic materials as fire retardant PU.

As several factors have influence, the related calculations becomes a little more complex. Please see next page (without further explanation) to illustrate.

Theoretical calculations

$$f_c = \frac{C^2}{2\pi}\sqrt{\frac{m}{B}} \qquad C_B = \sqrt[4]{\omega^2 \frac{B}{m}} \qquad B = \frac{E \cdot h^3}{12(1-v^2)}$$

$$f_c = \frac{C^2}{2\pi}\sqrt{\frac{m}{B}} = \frac{C^2}{2\pi}\sqrt{\frac{p \cdot h}{\frac{E \cdot h^3}{12 \cdot (1-v^2)}}} = \frac{C^2}{2\pi}\sqrt{\frac{p}{\frac{E \cdot h^2}{12 \cdot (1-v^2)}}} = \frac{K_c}{h}$$

$$f_c = \frac{K_c}{h}$$

	gypsum	concrete	glass	wood	steel
K_c	27	19	12	15...40	13

$$\frac{\eta}{2} \qquad \delta = \pi \cdot \eta \qquad \delta = \ln\left(\frac{A_n}{A_{n+1}}\right)$$

K_c = Material constant

h = Thickness

f_c = Critical frequency

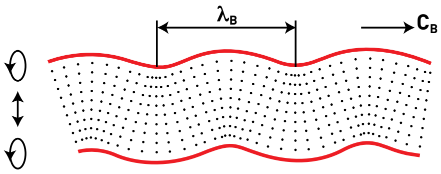
η = (eta) loss factor

ζ = (zeta) damping factor, damping ratio

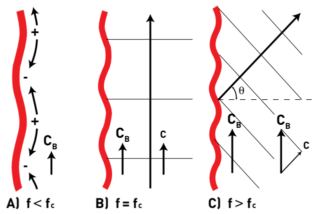
δ = (delta) logarithmic decrement

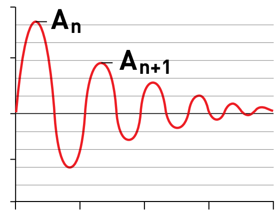
A_n = Response amplitude

Bending Wave

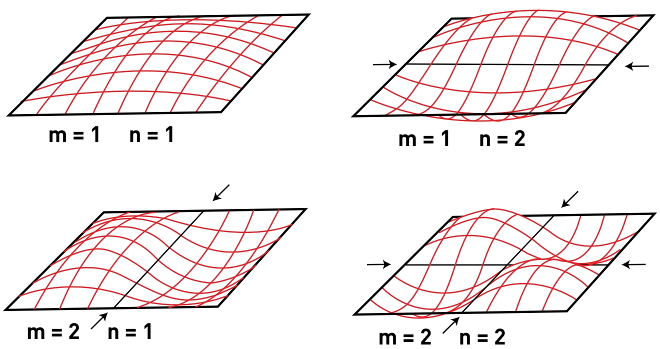


Critical frequency





Free bending movements in a inifite plate can radiate sound to the air when Cb → = c, meaning by frequencies greater or equal to the critical frequency.



4 resonance oscillations in a rectangular thin plate which is simple supported at the edge. The nodal lines, which are the points not dislocating in the plane, are marked by the arrows.
(Morse & Ingard, 1968)

$$f_{mn} = \frac{C^2}{4f_c}\left(\left(\frac{m}{l_x}\right)^2 + \left(\frac{n}{l_y}\right)^2\right)$$

$$f_{11} = \frac{C^2}{4f_c}\left(\left(\frac{1}{l_x}\right)^2 + \left(\frac{1}{l_y}\right)^2\right)$$

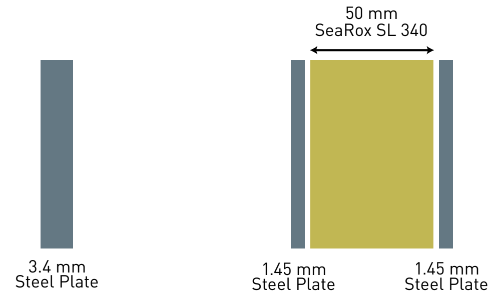
1.12 Double wall construction

The sound insulation for airborne sound can be optimized for a given maximal weight of the construction by using double layer constructions instead of a single homogeneous layer.

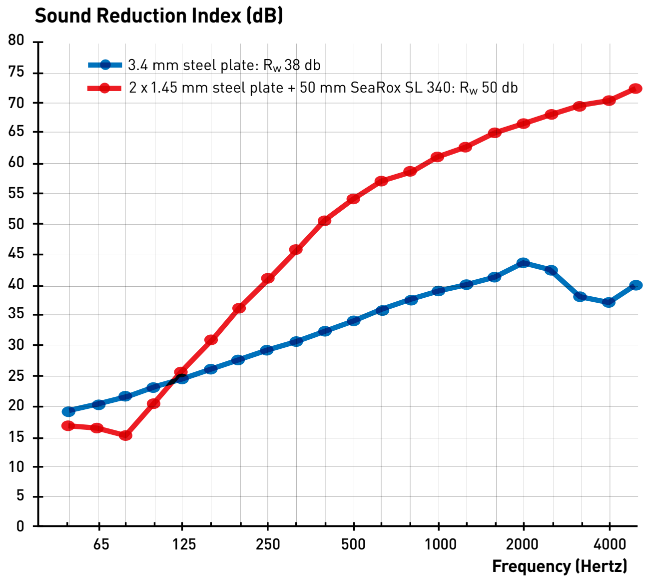
The diagram here, to illustrate the principle, shows a computer simulated calculation of a single steel plate bulkhead of 3.4 mm compared to a system of two thin steel plates with SeaRox SL 340 in between. The Rockwool is not glued to the steel plates.

Both solutions with approx same weight, but with a huge advantage in sound reduction for the double wall construction.

The idea is to create a mass-spring-mass system by using an attenuated cavity between the steel plates mass layers. This air filled cavity with attenuation (i.e. Rockwool insulation) acts as a spring and decouples the mass layers.



26.6 kg/m²	**26.7 kg/m²**
R_w: 38 db	**R_w: 50 db**



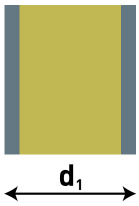
Simulated comparison of sound reduction index

1.13 Double constructions

The mass-spring-mass system becomes efficient with increased sound insu-lation above its resonance frequency f_0. In the schematic diagram the base line (lower limit) represents the sound insulation for the simple mass system (total mass). To obtain the best possible absorption in the cavity, it is recommended to use e.g. mineral wool with an airflow resistivity of at least $r \geq 15$ kPas/m².

Resonance frequency f_0 of the cavity in double constructions (mass - spring - mass system):

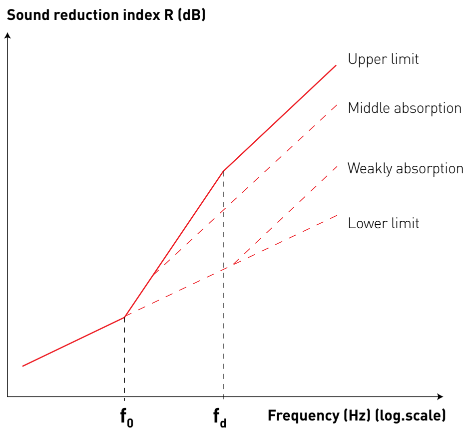
$$f_0 \approx 1600 \cdot \sqrt{\frac{1}{d_1} \cdot \left(\frac{1}{m_1} + \frac{1}{m_2}\right)} \text{ Hz}$$



d = Thickness of cavity in mm

m_1 = Surface density in kg/m²

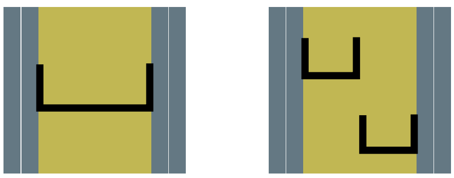
m_2 = Surface density in kg/m²



Reduction: Simple mass system vs cavity with attenuation

If the two mass layers are mechanically connected, these connections create sound bridges and reduce the improvement of the double layer construction with cavity. Following diagram shows in principal this influence.

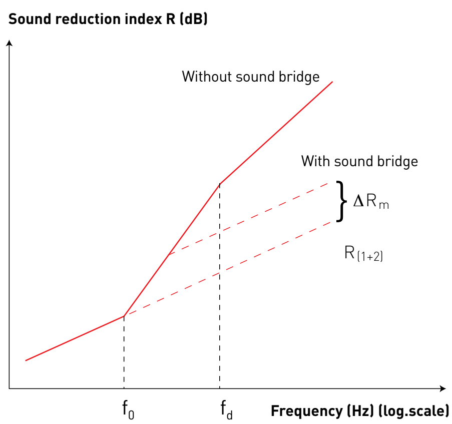
Beside the typical steel connectors which create sound bridges, the insulation material in the cavity can also act as a sound bridge, if the material touches both sides of the double construction. Therefore the use of stiff insulation materials is critical. This is also the reason, that sandwich panels, where the filling material has to transfer the mechanical tensions, are not acting like the here described acoustic double constructions.



R_w = 55 dB **R_w = 60 dB**

A system of two standard marine panels with low density Rockwool infill in the void between the panels can be regarded as a double construction and will perform very well for noise reduction.

Models and software programs exists, able to calculate the total sound insulation for double layer constructions with acceptable accuracy, if all necessary material parameters are known.



Reduction comparison with and without sound bridges

The problem is to have the right values for Young modulus (to calculate fc) and the internal damping factor for the mass layers, to know the number, kind and stiffness of sound bridges and the absorption properties of the used filling material. In practice this means, that calculated sound reduction indices R might differ 5 to 10 dB to measurement results obtained in laboratory measurements for the same constructions.

1.14 Impact noise

Impact noise is noise generated due to impacts in other locations, than in the actual room where disturbance is experienced. A typical example is the noise in a cabin caused by people walking on the deck above.

The impact noise properties are characterised by the measured sound pressure level in a receiving room, when a standardised source (tapping machine) generates a well defined impact on the floor of the source room. The source room and the receiving room must not necessarily have a common wall or floor, but the noise can be transmitted as flanking transmission through the structure of the ship. It is obvious that the kind of connection between the different construction elements has a big influence on the noise transmission. Here, a floating/resilient floor in the sending room and/or an optimised ceiling construction in the receiving room can have a very efficient noise reducing effect.

Typically, sources of impact noise are human activities, such as sports activities, dancing and walking. Another source of impact noise is the use of transport trolleys in the galley or service corridors.

The sports activities, such as ball games, jogging paths and running bands, present a particularly severe problem. The frequency content of the impact arising from a flexible ball or from footsteps has a high content of low frequency energy. As earlier described, it presents a challenge to reduce low frequency noise.

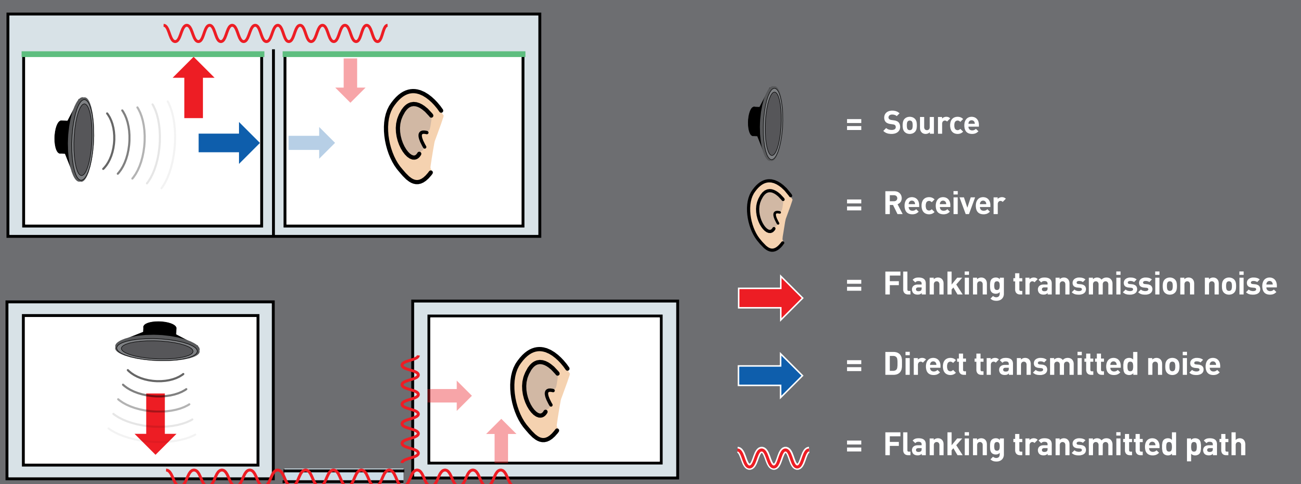
1.15 Flanking noise transmission / Structure borne noise

Flanking noise describes the noise that is transmitted through other paths than the direct path between the source and the receiver, as illustrated below.

The flanking transmission presents a problem, when areas with a high noise level are close to areas where a low noise level is anticipated. The upper figure illustrates a scenario, where the sound transmission through the partition wall is sufficiently reduced by using a construction with a high sound transmission loss. In this case, the noise level in the receiving room will be influenced by the contribution from the flanking transmission i.e. noise going through the ceiling to the common space above the cabins and then down into the adjacent cabin through the ceiling. The situation can be improved by introducing draft stops in high density Rockwool, between the cabins in the common space, or by using ceilings with a high sound transmission loss.

The lower figure illustrates another type of flanking noise transmission. In this case, the sending room could be an engine room with a very high noise level. The airborne noise will excite the wall of the engine room, introducing structure-borne bending waves that will be transmitted through the structure. At the receiver room, these bending waves will excite the surfaces of the room and the structure-borne noise will be re-radiated as airborne noise.

The contribution from this flanking transmission can be reduced by introducing vibration damping of the structure, possibly in combination with an insulation of the wall covered with a steel or aluminium plate.



2.0 Rockwool properties regarding acoustics

The acoustical behaviour of a Rockwool product depends mainly on the following properties and characteristics:

- a Airflow resistance
- b Dynamic stiffness
- c Surface protection of the product
- d Density [kg/m³]
- e Fibre diameter and fibre orientation

2.1 Airflow resistance

(definitions acc. ISO 9053)
The resistance against airflow passing through a porous material with thickness t can be measured with the pressure drop Dp for an airflow with velocity v.

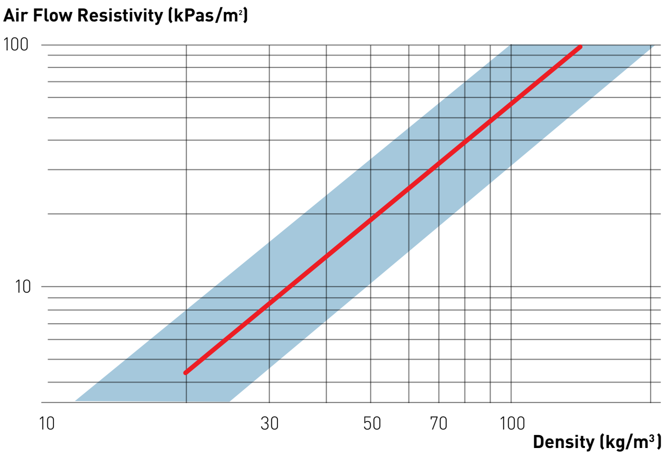
- **Airflow resistance R = Dp/v (Pa/m)**

The measured R/t is called the airflow resistivity r and is a product property independent of the actual thickness:

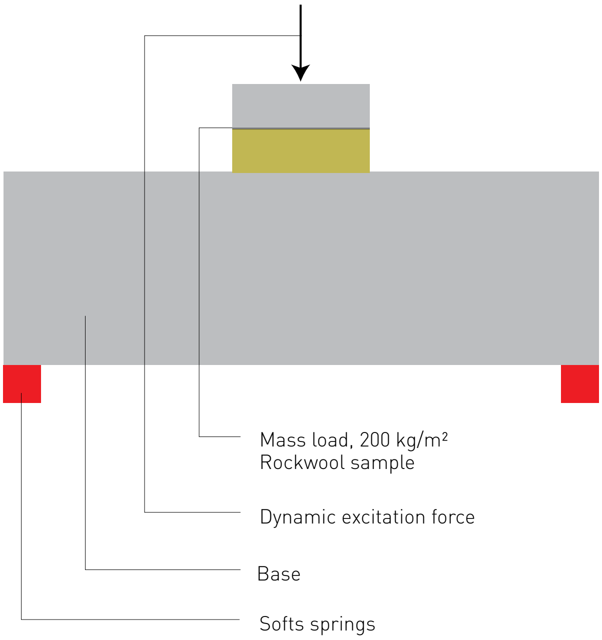
- **Airflow resistivity r = R/t (Pa/m²)**

The airflow resistivity increases with increasing density and decreasing fibre thickness. Beside density and fibre thickness the wool structure (orientation, shot content etc.) influences the airflow resistivity.

The absorption of energy from a sound wave mainly depends on the air flow resistivity of the wool. If the resistivity is too high, the sound wave is reflected and only a minor part is absorbed. If the resistivity is too low, the sound wave can pass through the wool without being absorbed. So depending on the application (thickness of the material, adjacent materials etc.) and the interesting frequency, different optima for the airflow resistivity may occur.



Typical range of airflow resistivity for Rockwool products with different production-settings



S = Is the area of the test specimen

F = Is the dynamic force acting perpendicular on the test specimen

Δd = Is the resulting dynamic change in thickness of the material

2.2 Dynamic stiffness

The dynamic stiffness is the frequency dependant ratio between a dynamic force and the resulting dynamic displacement. Similarly, the well-known static stiffness is the ratio between a static force and the resulting static deflection.

For linear elastic materials the stiffness, below a certain loading, will be independent on the load. For a porous material, like Rockwool, the stiffness will be dependant on the load.

When a material is cyclically compressed, some energy is lost during each cycle. The loss factor describes the fraction of the stored energy that is converted to heat during each cycle.

A high loss factor is beneficial as the propagation of vibration is reduced. This is of interest, for example, when using Rockwool as core material for panels or floating floor.

The dynamic stiffness is given per unit area for a given thickness of the Rockwool.

$$S' = \frac{F/S}{\Delta d} \quad (N/m^3)$$

The dynamic stiffness will normally increase when the static load on the Rockwool is increased. Determination of the dynamic stiffness is normally done following EN 29052-1 (1992) that corresponds to ISO 9052-1 (1989).

The natural frequency of the two degrees of freedom system with the Rockwool acting as the spring is measured. The stiffness of the Rockwool is then determined from the measured natural frequency.

Using ISO 9052-1 provides the dynamic stiffness at one frequency, i.e. at the natural frequency of the system. The set-up can also be used to determine the loss factor by measuring the response at several frequencies.

When the stiffness as function of frequency is needed, the procedure described in ISO 10846-3 (2002) can be used. The same mechanical set-up can also be used for measurements according to ISO 10846-3.

The dynamic stiffness is an important parameter when optimising floating floors. This is true both with respect to air- and structure-borne noise, as well as impact noise.

The dynamic stiffness is influenced by the density of the Rockwool and the manufacturing process. In principle, the dynamic stiffness should be as low as possible, in order to obtain a low natural frequency of the floating floor. On the other hand, the load bearing capacity and the possibly unfavourable experience of walking on a floor that is too soft may set a lower limit for the stiffness.

2.3 Surface protection of the product

Normally an unprotected surface of mineral wool products like Rockwool with more or less loose fibres will not be accepted in working or living rooms. Therefore the surface should be protected in the final application.

In principal this can be done by using materials like glass fleece, aluminium foil, plastic sheets or foils or metal. Doing this, the acoustic properties of the Rockwool application will be changed. The sound reduction will in most cases increase.

The effect on the sound absorption mainly depends on the airflow resistance of the surface protection. Closed surfaces will reflect more or less of the incoming sound waves and the sound absorption will therefore be reduced. Very thin and loose mounted foils (e.g. 20 - 40 μm foil) have a more or less neglecting reduction of the sound absorption coefficient while a 0.5 mm metal sheet will reduce the absorption towards zero.

Metal foils of example 20 - 80 μm aluminium will act almost like metal sheet in sence of acoustic reflection.

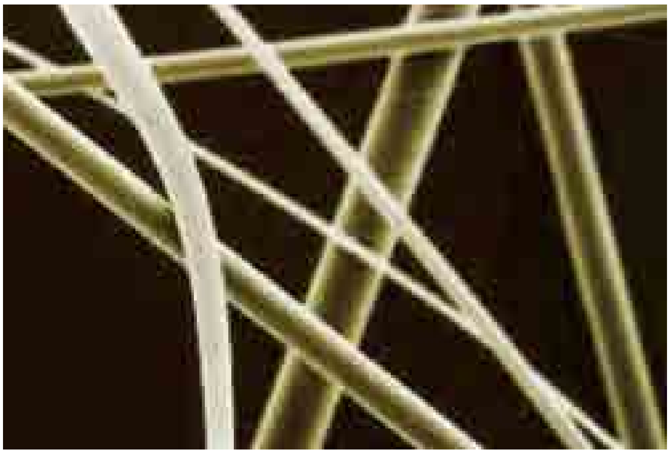
Perforated metal coverings with a effective free area of more than about 25 % (e.g. a perforation with 3 mm holes with a distance of 5 mm, free area > 30%) result only in a minor reduction of the sound absorption coefficients.

It is recommended to make sound absorption measurements to get the actual values for the sound absorption using a specified surface protection, when sound absorption is a crucial issue in the application.

2.4 Density (kg/m³)

For the same kind of product, e.g. the same fibre diameter and fibre orientation, higher density results in a higher airflow resistance.

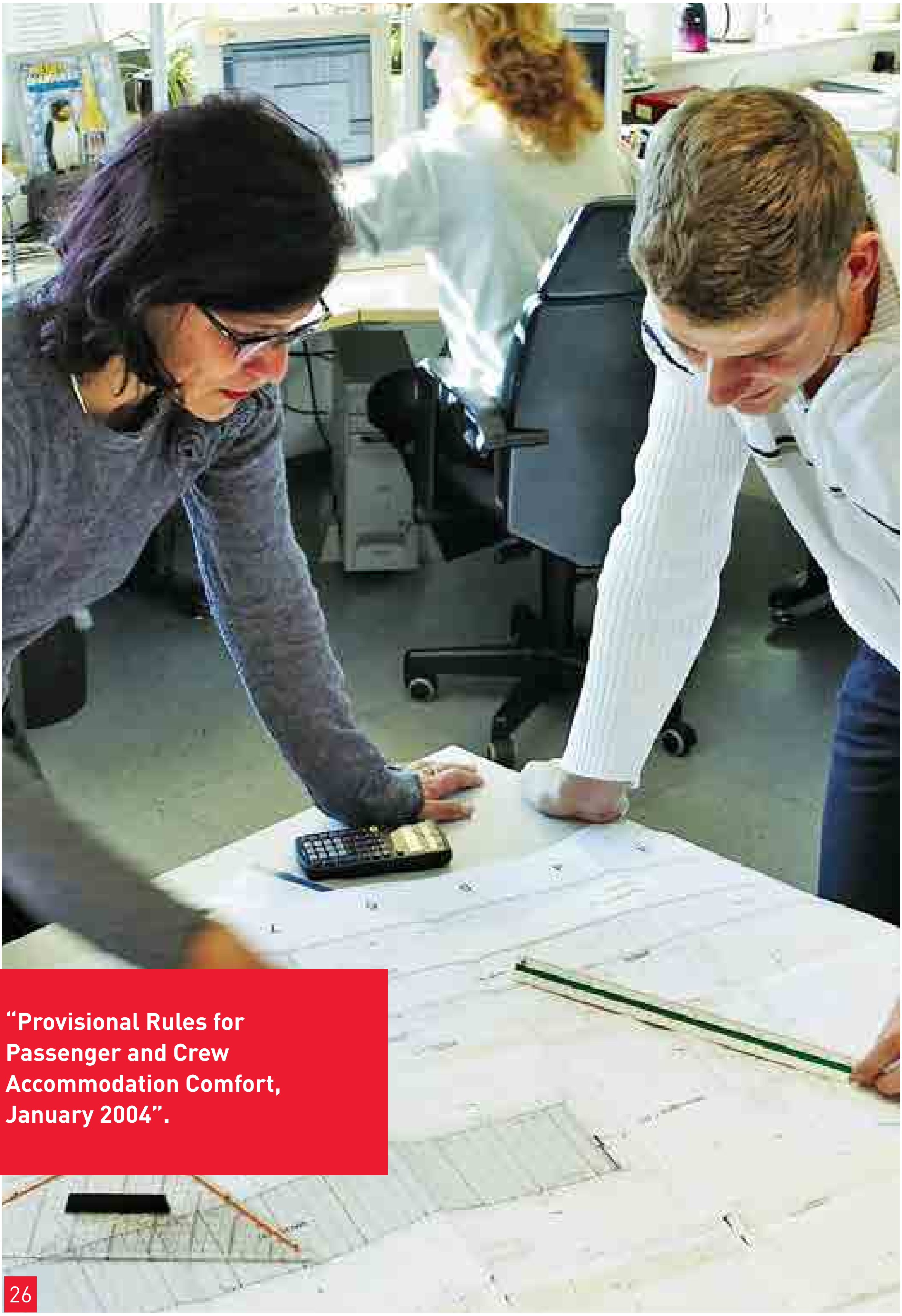
A higher density will normally increase the sound insulation, while the influence on sound absorption can vary.



2.5 Fibre diameter and fibre orientation

Stiffness, airflow resistance and other properties linked to the acoustic performance of a mineral wool product mainly depend on the bulk density, fibre orientation, fibre diameter, binder and possible additives. Rockwool can specify all these parameters in a wide range depending on the desired pro-perties. Even if the density, which is more or less the only "visible" property for the customer, is the same for two products, these products can have totally different properties regarding acoustics, fire and thermal conductivity.

Therefore it is recommended to ensure the right product data for the actual product before making any acoustic calculations.



“Provisional Rules for Passenger and Crew Accommodation Comfort, January 2004”.

Rules

3.0 Rules & regulation

In general for commercial vessels the rules concerning noise levels onboard are quite simple and few. It is basically a set of dB(A) levels given for a range of different positions onboard. These settings are given in the IMO res. A.468(XII).

Limits for noise levels are specified for various spaces as follows:

Work spaces	dB(A)
Machinery spaces (continuously manned)	90
Machinery spaces (not continuously manned)	110
Machinery control rooms	75
Workshops	85
Non-specified work spaces	90

Navigation spaces	dB(A)
Navigating bridge and chart rooms	65
Listening post, including navigating bridge wings and windows	70
Radio rooms (with radio equipment operating but not producing audio signals)	60
Radar rooms	65

Accommodation spaces	dB(A)
Cabins and hospitals	60
Mess rooms	65
Recreation rooms	65
Open recreation areas	75
Offices	65

Service spaces	dB(A)
Galleys, without food processing equipment operating	75
Service and pantries	75

Normally unoccupied spaces	dB(A)
Spaces not specified	90

The basic IMO rules do not specify other relevant issues of sound wellness. But especially within offshore modules, cruise liners and ferries more focus is made towards noise, and therefore we see additional national rules for the offshore industry along with comfort class rules from all major Class Societies. And of course the owner can add his own stricter requirements.

A small cut from Lloyds' Register seen below.

"Provisional Rules for Passenger and Crew Accommodation Comfort, January 2004".

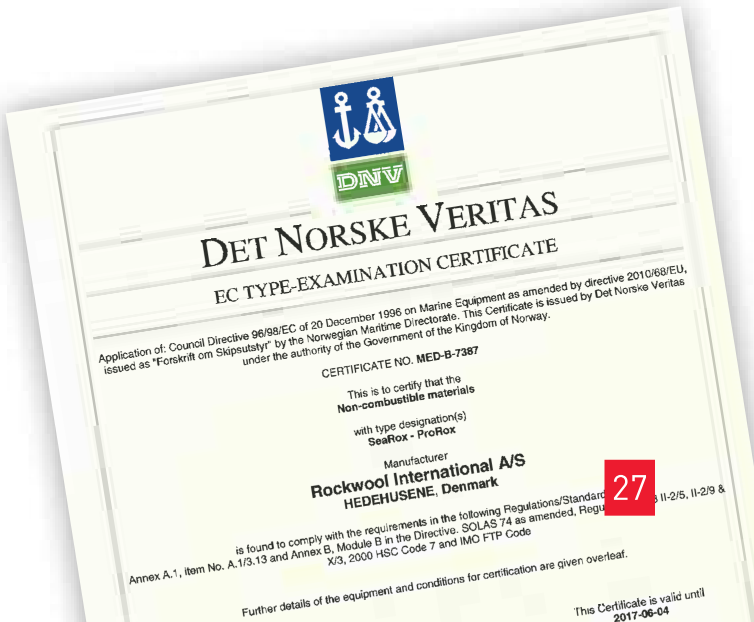
They have a notation system which differs in passenger areas and crew areas, and then in several levels.

Passenger ships - Maximum noise levels in dB(A)

Location		Acceptance Numeral 1	2	3
Passenger cabins:	Standard	48	50	53
	Superior	45	47	50
Public spaces:	Excluding	55	57	60
	Shops	60	62	65
Open deck recreation areas (excluding swimming pools and similar)		67	72	72
Swimming pools and similar		70	75	75

1.5 dB(A) exeedance allowed within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.

2.3 dB(A) exceedance allowed in the accommodation above the propellers, for 3 decks above the mooring deck.


DNV
DET NORSKE VERITAS
EC TYPE-EXAMINATION CERTIFICATE
Application of: Council Directive 96/98/EC of 20 December 1996 on Marine Equipment as amended by directive 2010/68/EU, issued as "Forskrift om Skipsutstyr" by the Norwegian Maritime Directorate. This Certificate is issued by Det Norske Veritas under the authority of the Government of the Kingdom of Norway.
CERTIFICATE NO. MED-B-7387
This is to certify that the
Non-combustible materials
with type designation(s)
SeaRox - ProRox
Manufacturer
Rockwool International A/S
HEDEHUSENE, Denmark
is found to comply with the requirements in the following Regulations/Standard ... II-2/5, II-2/9 & Annex A.1, item No. A.1/3.13 and Annex B, Module B in the Directive. SOLAS 74 as amended, Regu... X/3, 2000 HSC Code 7 and IMO FTP Code
Further details of the equipment and conditions for certification are given overleaf.
This Certificate is valid until
2017-06-04

Thermal, Acoustic and Firesafe Rockwool insulation go hand in hand...

Solution Guidelines

4.0 General sound

Sound theory is one thing but creating a perfect real life environment onboard is another thing.

Noise reduction and sound wellness is the discipline where it is necessary to take a holistic approach to the issue. It is required to investigate, measure and regulate the sound sources. The types of noises have to be determined, noise dampening systems have to be evaluated, rules and regulations have to be fulfilled, cost budgets to be kept etc.

For these issues it will be obvious to investigate if multiple purpose solutions can be utilised. In line of this view Rockwool products will have a major advantage.

Thermal and Acoustic Rockwool insulation go hand in hand.

Fire Protection solutions and Acoustic Rockwool insulation matches each other perfectly.

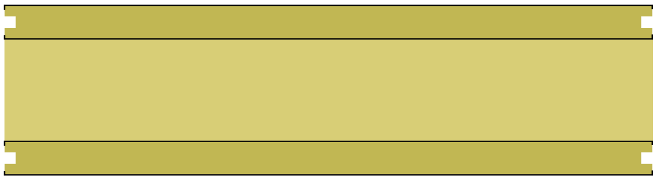
Special Rockwool products for i.e. marine panels deliver exceptional performance in combination of mechanical strength, fire properties and noise reduction. Dedicated noise reduction systems where Rockwool products are combined with other materials to create a sophisticated high-end solution for maximum dampening effect.

Please find on the next pages a schematic overview of some of the noise sources and solutions onboard a vessel.

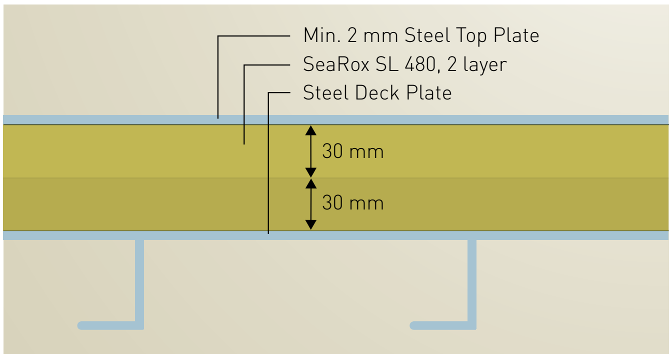
5.0 Noise reduction principles / Acoustic solutions

Room acoustics – sound absorbing surfaces
The reverberation time should be kept short and reflections should be redu-ced as much as possible. Be careful with constructions that focus the noise i.e. concave surfaces. Use screens to separate noise sources from each other.

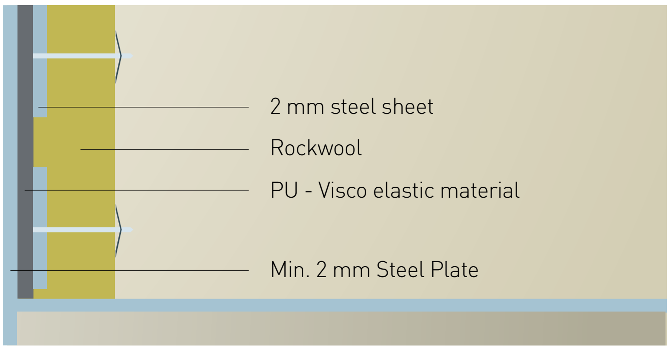
Airborne sound insulation – double layer constructions
If possible use double constructions with absorption in the cavities (best thickness >100...200 mm to achieve low $f_0 < 50...100$ Hz). In practice 50 - 150 mm will provide the desired values. Avoid if possible sound bridges between the solid layers.

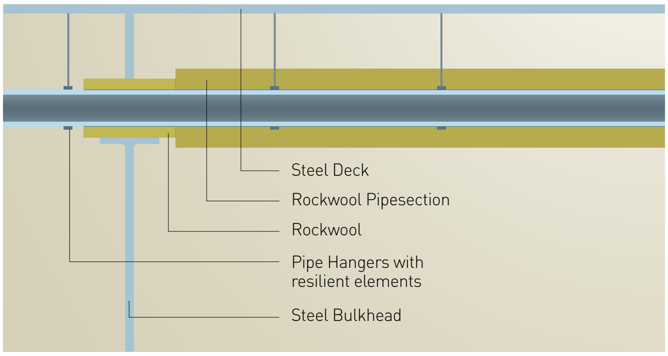


Floating floor construction
Floating floor constructions with a resilient layer of Rockwool improve the airborne sound insulation and impact noise / structure borne noise. Here the optimum for compression strength and dynamic stiffness of the products have to be ad-justed to the required mechanical load maximum on the floor.

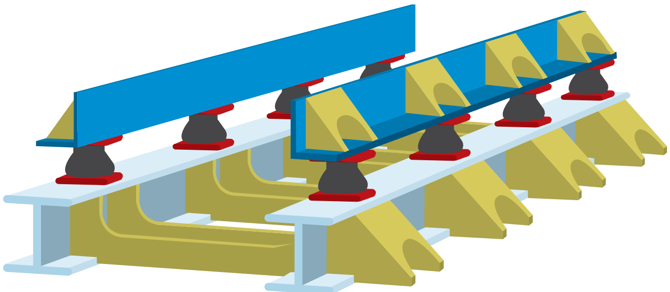


Materials with high internal damping factor
Special sandwich materials with integrated viscoelastic layers are developed for the marine and offshore sector.

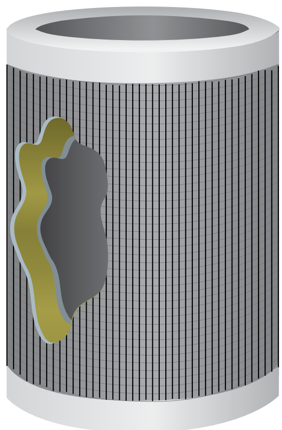




Resilient connections between construction elements
To reduce noise transmission via structural vibrations, resilient connections should be used as much as possible. E.g. pipes and pipe bearings, cable ducts etc. can transmit considerable vibration energy over long distances.



Resilient mounting of machinery
It is strongly recommended to reduce noise problems and noise emission as close to the source as possible. All rotating and vibrating machines should be mounted resiliently.



Silencers in ventilation ducts
Ventilation ducts should be equipped with all necessary silencers. This will not only remove noise from the ventilation plant itself but can also reduce noise transmitting via the duct system from other sound sources on the ship (e.g. from machine room to cabins)

6.0 Rockwool solution examples

Below a list of typically solutions seen, where Rockwool Technical Insulation (RTI) products are used. RTI products are particularly well suited for reduction of noise problems. Some usefull applications are:

- Passive Fire Protection constructions. These Class approved Rockwool solutions provide the additional benefit of noise reduction.
- Marine panels, i.e. sandwich panels with Rockwool core.
- Floating Floor constructions.
- Marine ceiling systems.
- Dedicated "open" Rockwool products installed as absorbers.
- Thermal Rockwool insulation covered by glass cloth facings for a visually nice finish and offering highly improved absorption/reduction.
- Dedicated noise absorbers/reduction cassettes with Rockwool core and perforated outer steel sheeting.
- Encapsulation systems. Noise reduction boxes with inner lining of Rockwool SeaRox Slabs, to cover a noisy engine, compressor or similar completely.
- Rockwool infill for penetrations in bulkhead/deck of cables, pipes, ducts, etc.
- Air intake silencers for ventilation fans.
- Reactive / absorbing silencers. Resonance dampers in funnels.
- Specific frequency noise damping by Rockwool SeaRox Slabs, mounted in calculated distance from bulkhead.
- Rockwool products for absorption covered by SeaRox Acoustic foil allowing the energy to pass into the Rockwool and at the same time acting as vapour barrier for oil and water.
- Combination solution where the Rockwool products are absorbing/reducing the high frequencies and systems with PU-rubber with thin steel sheets, cassettes or similar is dampening the lower frequencies.
- Combination solutions with Rockwool floating floor, vibration mounts, encapsulation and similar.
- Fluid transmission noise from pipes and valves, insulated by Rockwool Pipe Sections / Rockwool SeaRox Wired Mats, and mattresses for valve covering.

SeaRox products are particularly well suited for reduction of noise problems...

7.0 Noise reduction - vessel overview

Open Work Deck

Sources: *mooring winches, cranes, hi-pressure washing, tugger Winches, ventilation inlet and outlet, exhausts, fluid noise in pipes, weather noise.*

Solutions: *vibration mounts, encapsulation, pipe section insulation, equipment design, ventilation bafflers, absorber plates. A difficult area to deal with, but very important for especially offshore rigs. FPSO, special offshore construction vessels as windmill installers, cable ships, etc.*

Bridge

Sources: *structure borne noise, outside noise and from various electronic bridge equipment.*

Solutions: *Floating floor (combined with fire protection), marine panels, absorbing ceiling systems. Fatigue problems to be avoided for crew on duty. Clear communication has to be possible. IMO rules states max 65 dB(A).*

Hi-press room

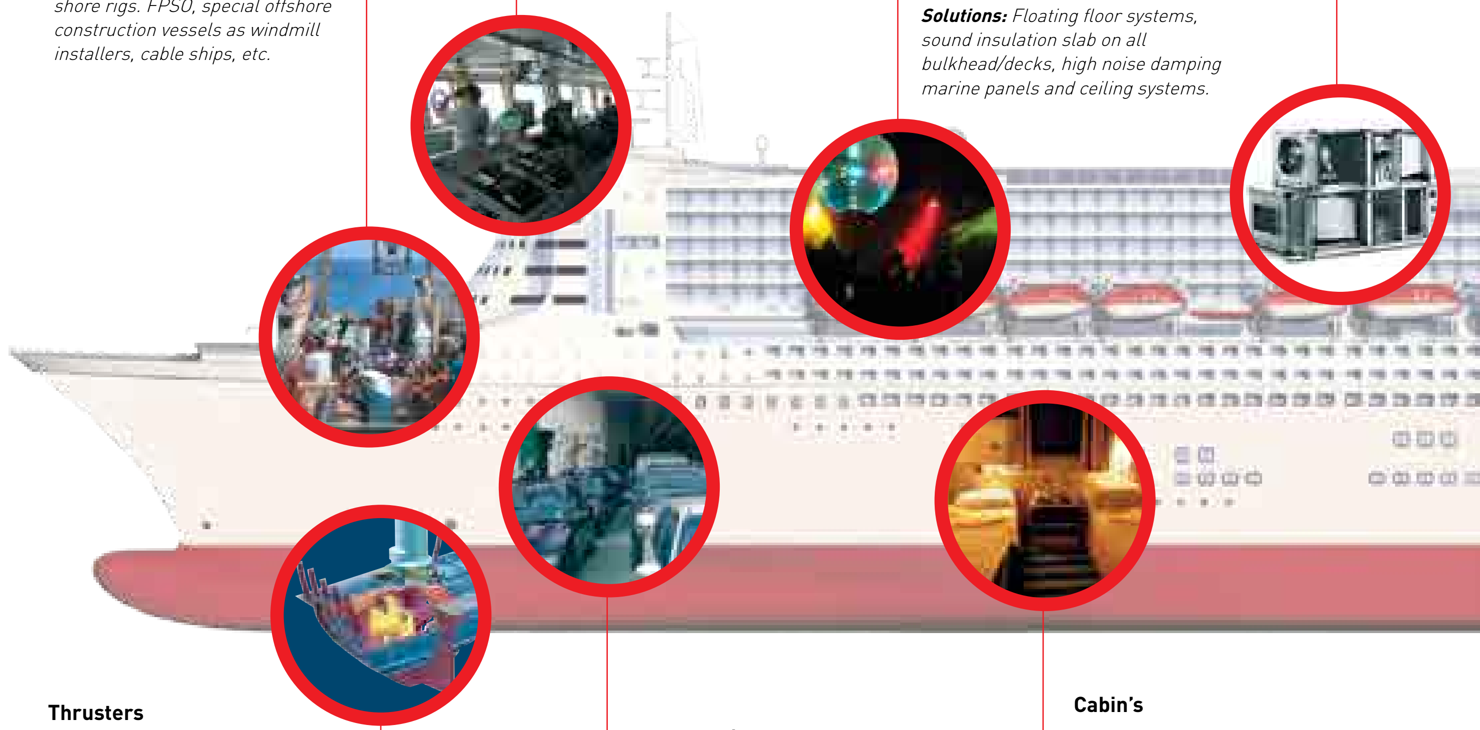
Sources: *Ventilation and air-cond equipment, often with a high frequency noise.*

Solutions: *Vibration mounts, equipment floating floor, encapsulation, utilising the necessary thermal insulation, air baffel systems, regulating airflow speed. The challenge for these types of room is that they are often placed in the accommodation area, and therefore a higher degree of noise damping is necessary in order not to disturb adjacent cabins.*

Disco

Sources: *Area of high noise level with a high content of low frequency sound. It is an area where it is absolutely necessary to sound insulate towards all adjacent areas, not to disturb other customers.*

Solutions: *Floating floor systems, sound insulation slab on all bulkhead/decks, high noise damping marine panels and ceiling systems.*



Thrusters

Sources: *Great structure borne noise. For most vessels only for shorter periods, but for DP vessel like offshore supply boats, cable ships, etc. where thrusters are running most of the time, it is the main source of noise in the vessel.*

Solutions: *Mainly to chose the correct design of thrusters system, but utilising floating floor system on all decks, and a good encapsulation in the thrusters room can greatly reduce the noise level in the accommodation.*

Car-deck / enclosed working deck

Sources: *Ventilation systems, hydraulic power pack equipment, winches, lifts.*

Solutions: *Ventilation baffel systems, absorber systems, encapsulation, vibration mounts, utilise fire protection insulation. Can often be compared to a large industrial production hall. A 'hard" large room were an often high noise level is even made worse with a long reverberation time.*

Cabin's

Sources: *Structure borne noise, human noise - room to room / impact noise, ventilation system.*

Solutions: *Floating floor systems, marine panel system (type of system depending on requirements), ventilation baffel system, absorbing ceiling sy-stems. For commercial vessels the noise level normally dictated by IMO rules for the noise level, but for offshore living quarters and cruise lines much stricter requirements are often seen. And besides the pure dB(A) levels there will be focus on impact noise, speech ability, reverberation and noise containing pure tones noise.*

Air-intake

Sources: *All vessels have large ventilation systems for both engine rooms and accommodation. The intake of such fans often create a lot of noise and often with a specific peak frequency.*

Solutions: *Air-intake dampers with absorbent fill, design of fan blades and fan mounts.*

General outdoor recreational areas

Sources: *Structure borne noise, exhaust funnels, human activity, ventilation fans.*

Solutions: *Steel design, floating floor system, screen division, solutions for ventilation and exhaust funnels. Espacially for cruise liners it is a wish to be outside and only be able to hear the sound of the sea, and this will only be possible if noise control is made properly all over the vessel.*

Exhausts/ air outlet

Sources: *Low frequency resonance noise in harmonics of the engine revolutions.*

Solutions: *Electronic engine control system, reactive/absorption systems, exhaust silencers. Can create a lot of outdoor noise in recreation areas, sun decks, etc if not dealt with. In commercial vessels this is often not done, with great discomfort for the crew. At cruise lines it is a must to noise insulate proper in this area.*

Restaurants

Sources: *Especially in large cruise liner restaurants it is a very important task to make a correct sound design of the area. All customers want to be in a pleasant environment when dinning, which means damping of all external noise, damping of human noise from the room and adjacent seating, but still people must be able to converse in a normal level. Reverberation and speech intelligibility have to be at a correct level.*

Solutions: *Specific designed absorption systems, floating floor systems, screens between seating arrangements, active noise reduction, specific ceiling systems.*

Aux engine rooms

Sources: *Often fast rotating equipment; aux engines, compressors, hydraulic power packs, pumps, fluid noise in pipes.*

Solutions: *Vibration mounts. encapsulation, absorber systems, fire protection insulation utilised as noise damper, pipe section insulation. Areas often characterised by equipment which creates high frequency noise, which can very effectively be reduced by the use of Rockwool insulation.*

Engine Room/ Control Room

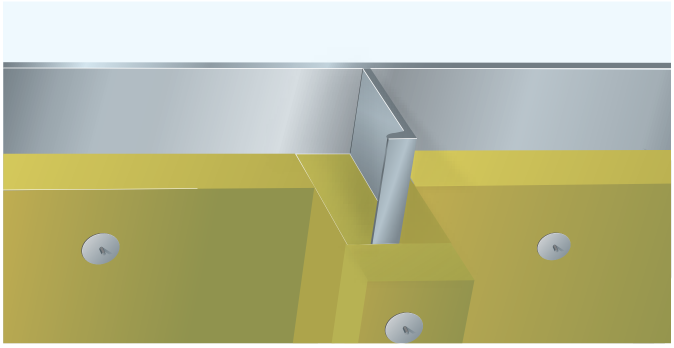
Sources: *Main engine.*

Solutions: *Utilise the fire protection insulation which is mandatory to install to separate the engine room from the rest of the vessel, floating floor system above the engine room, absorber systems to improve the environment in the engine room, SeaRox Acoustic Foil system.*

Propeller System

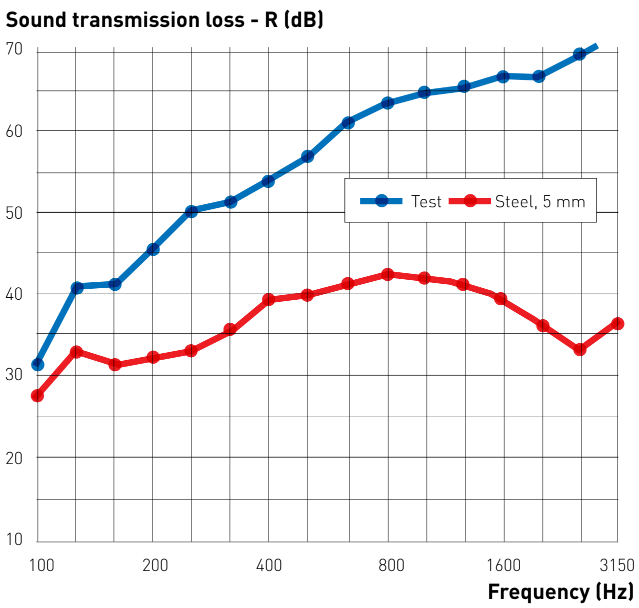
Sources: *Vibration in harmonics of rpm will reflect into hull. Propeller cavitation.*

Solutions: *Vast research is ongoing, mainly driven by the mega yacht designers, to create silent new propulsion systems. Air injection above the propeller can be an efficient way of reducing the transmission into the hull of the noise caused by cavitation. Pod drivers, Voigt-Sneider drives and etc. When moving inside the hull, dampening material could be applied in the void space around the stern tube and rudder area.*



Example with A-60 Deck 40/40 mm SeaRox SL 640 solution and 1 mm steel cladding

	Test	Steel
Hz	dB	dB
100	31.0	27.0
125	40.6	32.7
160	41.1	31.3
200	45.4	32.0
250	50.2	32.8
315	51.0	35.4
400	53.8	39.1
500	56.9	39.5
630	61.1	40.9
800	63.5	42.1
1000	64.8	41.7
1250	65.4	41.3
1600	66.6	39.2
2000	66.8	35.8
2500	69.5	32.7
3150	71.4	36.0
R_w	58	39
C	-2	-2



8.0 Passive fire protection constructions

Passive Fire Constructions utilised as noise reduction.
In case of installations of fire protection constructions the noise reduction is almost a freebee. Please see our examples of constructions which are tested for noise reduction through the construction, page 59 in the appendix I.

All measuring data is available on our web site www.rockwool-rti.com

Here it is clear that these fire protection constructions give a high degree of noise reduction. Thoughts in the design work for, as example an offshore rig, should therefore not be split in separate designs.

It would often be an advantage to work with Rockwool passive fire protection systems, as you gain the combination of the authority required fire protection and at the same time the needed noise reduction, hereby avoiding other (expensive) noise reduction solutions and maybe also a deluge system.
A Rockwool solution would therefore be the far most cost effective solution. Please see our complete set of measurement result at the web site and in the appendix I, starting page 47.

When choosing a fire protective solution, among the many Rockwool possibilities, you should go for following when noise reduction is important.

Bulkhead A-60; 2x30/30 mm SeaRox SL 640 or
Deck A-60; 40/40 mm SeaRox SL 640

The noise reduction through the bulkhead will be improved when a steel cladding is fitted in front of the insulation. It is here important to mount the cladding system as "separate" as possible from the bulkhead/deck, in order to transfer as little sound energy as possible. Flexible hangers/brackets will do the job, and equally important is to seal all edges and joints with flexible sealant.

A range of parameters have been set-up when i.e. fire protective material as SeaRox SL 640 has been designed.
Of cause the fibres have to have the right composition formed into the right structure to withstand the severe conditions found during a fire, but at the same time our research engineers have been investigating the best possible way of also utilising this fire material as noise absorption and noise reduction.

In most cases the general saying is that the higher density mineral wool the better noise reduction and noise absorption characteristics you will find.

But sophisticated and clever design and manufacturing of the Rockwool material and not least the built-up of the solutions can further enhance the qualities, thus the density statement will not always be true.

Studies and design work have given the fire protective solutions made with SeaRox SL 640 as the best solutions, when the improvement of noise is important.

As SOLAS requires the fire insulation in engine rooms to be covered by oil resistant foil or cladding system, this goes nicely together with the noise reduction when using thin steel plate cladding, but for the noise absorption within the engine room itself it is not the best solution.

A perfect solution for A-60 Bulkhead, where the sound absorption is important will be a solution with SeaRox SL 640 covered by loose fitted 19 µ SeaRox Acoustic Foil and then covered by perforated plate (> 25 % hole ratio) for mechanical protection (see page 41).

If cabins are situated just above the engine room, it is important to have all the insulation covered and preferably in a mounting system with anti-vibration studs. It will not be sufficient just to make a good sound insulation at the deck towards the lower cabins, as the airborne noise can be transmitted into the bulkhead and then move as structure-borne noise upwards (flanking transmission path). Therefore the bulkheads should also be proper sound insulated.

Photo of test situation for A-60 bulkhead by 2 x 30/30 mm SeaRox SL 640 + 19 µ SeaRox Acoustic Foil + perforated 1 mm steel plate(SeaRox Acoustic Foil system).

Studies and design work have given the fire protective solutions made with SeaRox SL 640 as one of the best solutions, when the improvement of noise is important.

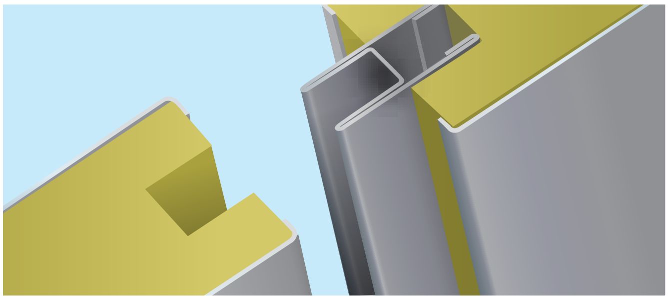
9.0 Marine panels

Rockwool Technical Insulation is a world leading supplier of core material for a large range of marine panel producers.

The marine approved sandwich panel is a well know building method for accommodations, where the requirements are often a combination of the need for B-15 / B-30 fire protection and a request for noise reduction between the individual cabins, salons, public areas, etc. The Rockwool range of SeaRox Slab products offers an excellent choice in material, as it provides both a high fire resistance, mechanical strenght and superb noise reduction ratio to the weight.

The design of marine panel system provides a high range of different solutions. Similar to heat transfer in fire, great care has to be taken concerning joints and edges, as poor design here can lead to passage of sound.

As seen in the test result page 57 in the appendix I Rockwool has performed a reduction measuring on a principle built-up of an A-30 fire protection combined with a standard 25 mm panel. The result is a Rw value of 62 dB.

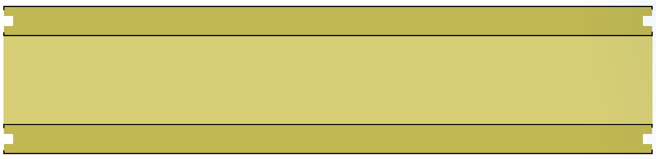


Standard 25 mm single panel. Typically 0.8 mm steel sheets on each side with, as example, 160 kg/m³ Rockwool SeaRox lamellas as core material.

Rw will typically be in the area of 30 - 38 dB. These are in the low range of noise reduction, but still impressively high result for such a thin construction.

Noise Panel by i.e. 50 mm. A noise specified panel, where a simple single panel solution is required. A much higher reduction can be obtained if the panel is made with an air gab in the middle.

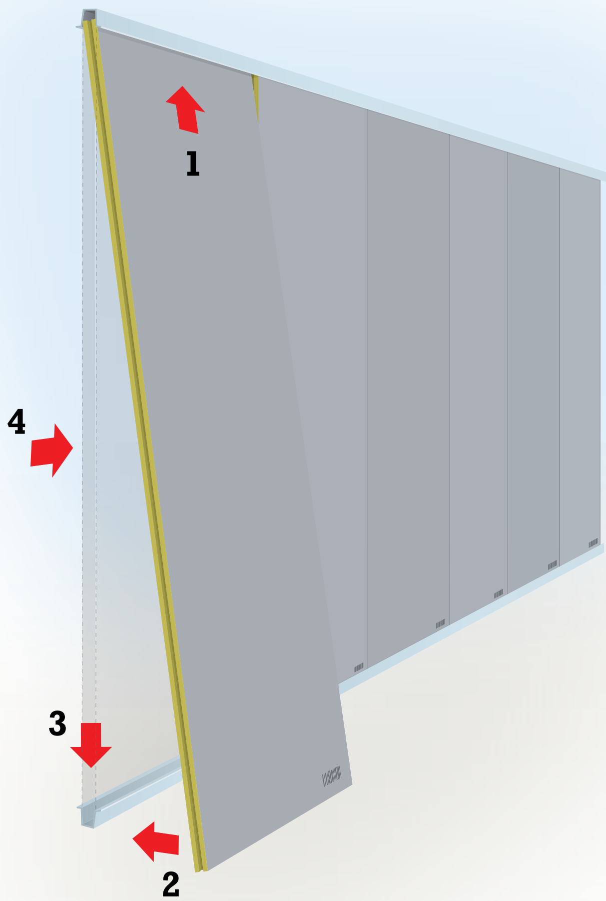
This requires more specialised built-up but with a single 50 mm panel it is achievable to gain a reduction around Rw 42 - 50 dB. Studies have shown that an approx. 3 mm gab is best for a general average damping. If damping in specified frequency ranges is required other size of air gabs is needed.



Where the need is for highest reduction, it will be required to make a double panel system.

Here it is also possible to create to some extent a specified frequency damping, depending on the distance between the two panels.

It will also be an advantage to fill the void between the two panels by some Rockwool in lighter densities, i.e SeaRox SL 740, to avoid standing waves. Depending on panel type, inter distance and infill it is possible to obtain reduction values of as high as; Rw 48 - 70 dB



10.0 Floating floor constructions

Rockwool offers two dedicated and approved floating floor constructions for fire protection Class A-60 Deck. These solutions are often used in areas where noise reduction is also required. As mentioned earlier the principle of a floating floor is an exceptional good solution to break structure borne noise from either isolating the sound source placed on the floating floor or highly reduce transmitted noise from the compartment below and adjacent.

SeaRox SL 436 is used for normal accomodation load flooring system, but the material is designed for highest absorption of noise and vibrations. SeaRox SL 480 is aimed for general purpose with normal to high load capacity.

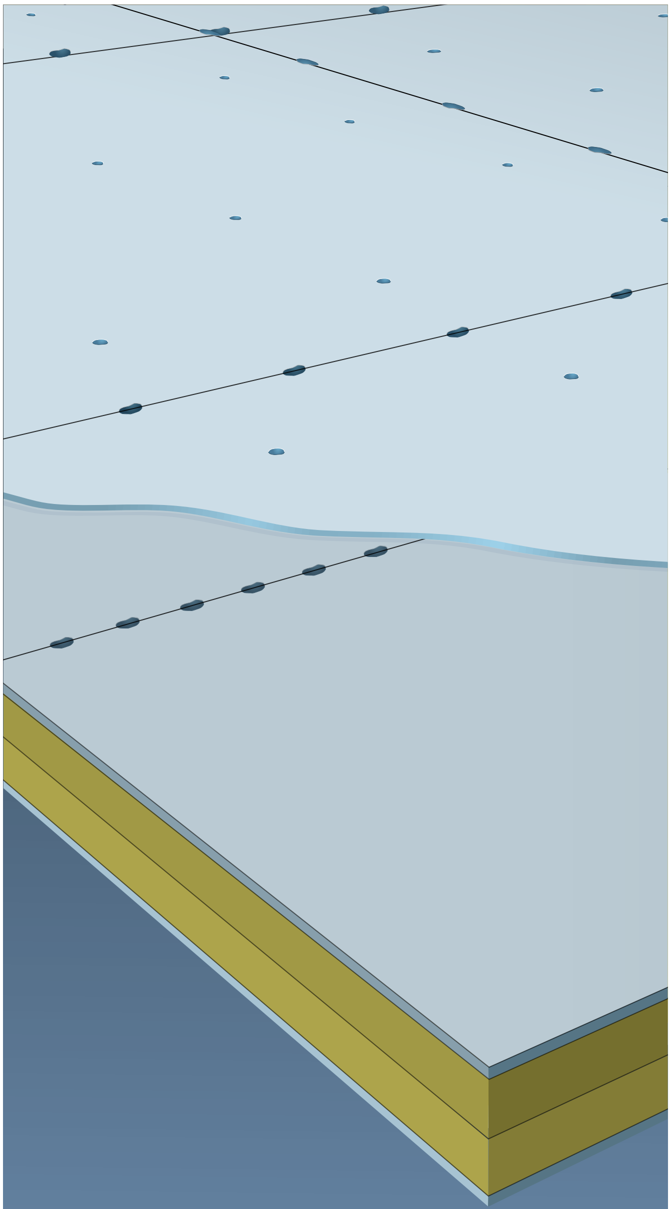
As described in the theory section, the dynamic stiffness of the core material for the flooring system is very important, and should in principle be as low as possible. But as the flooring system has to carry load, it is equally important to have a material which is dimensional stabile and has a compression strength high enough. SeaRox SL 436 will supply the perfect distribution of these requirements, and in addition it is possible to create fire division systems (A-60 Deck).

The research and development of the Rockwool material have made it possible to create floating floor solutions with different approaches as main target. The production methods of the material can make it possible to suit the desired parameters requested.

The SeaRox SL 436 has been designed with focus on the dynamic stiffness, i.e. best possible noise reduction, but still it has been possible to create a flooring system for normal accommodation load and an A-60 fire division solution.

The fibre built-up and production methods of these two materials are actually quite different.

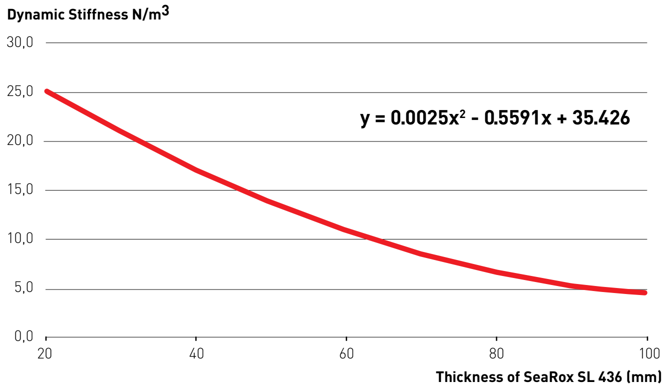
When a floating floor is made it is very important that the top layer has no ridged connection with the steel structure.

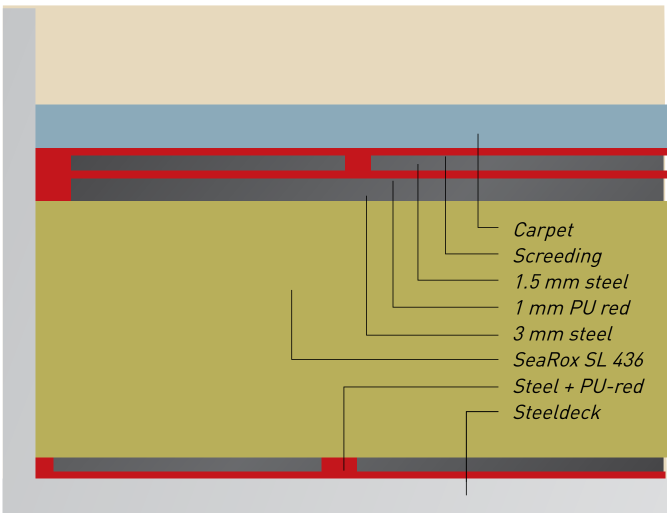


SeaRox SL 480 has been designed to focus on fire and sound properties, but with first priority to ensure the load capabilities of the flooring system.

SeaRox SL 436 is the most common product used for floating floors. This product is produced according to specific levels of dynamic stiffness according to thickness and the static stiffness also called compression strength. The below graph shows the relation to dynamic stiffness and thickness.

SeaRox SL 436:

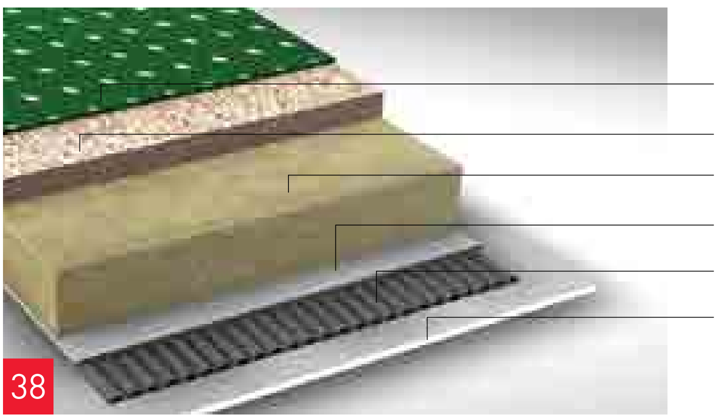




Rockwool Technical Insulation is preferred supplier for many dedicated marine flooring companies.These companies then create more sophisticated solutions for superb noise reduction in both high and low frequencies.

PK/90 Steel - Litosilo Steel By Sika Cufadan

- A60 approved with 30 + 40 mm Rockwool insulation
- Total building height: 78 mm
- Screeding prior to application of carpet or vinyl
- Best solution for noise reduction and dampening of structure borne noise



Tefrolith®M by GTF Freese

Final floor covering

weight distributing layer

SeaRox SL 436, 30 mm

Steel plate

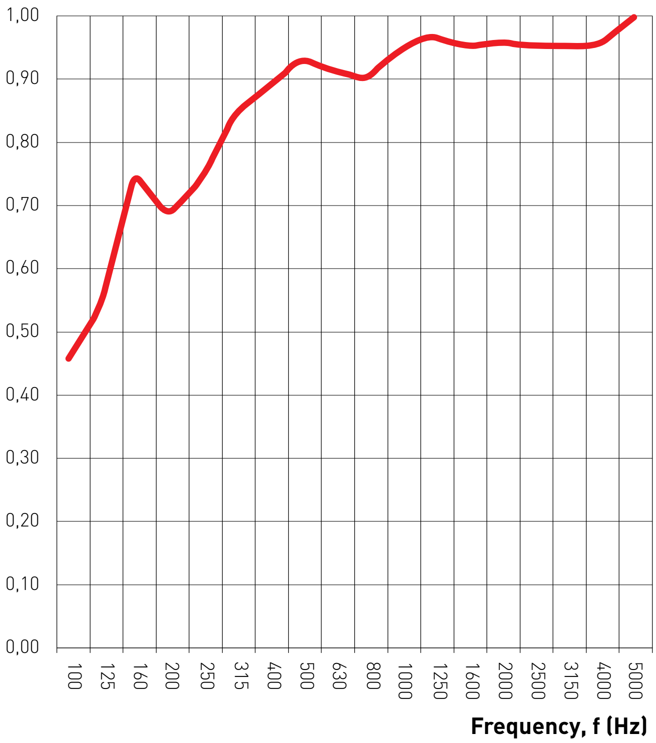
Tefrotex wiscoelastic

Steel deck

Absorption: 2x50 mm SeaRox SL 340

Frequency [Hz]	α_s	α_p
100	0.46	
125	0.54	0.60
160	0.75	
200	0.68	
250	0.74	0.75
315	0.84	
400	0.88	
500	0.93	0.90
630	0.91	
800	0.90	
1000	0.95	0.95
1250	0.96	
1600	0.95	
2000	0.96	0.95
2500	0.95	
3150	0.95	
4000	0.95	0.95
5000	0.99	

Sound absorption coefficient



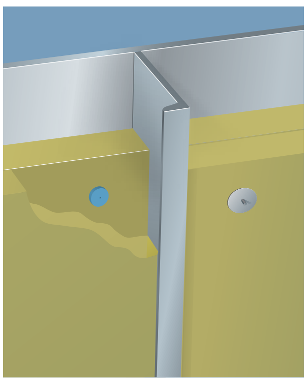
11.0 Absorber systems

In many areas installation of noise absorbers will greatly help to reduce the sound energy level in a room, but not least radically improve the reverberation.

This means that even in a room with a relatively high noise level, experience of being in the room is highly improved to a stage where fatigue and physical discomfort is reduced and it becomes possible to hear normal speech.

The simplest and most effective way to obtain this is installing open SeaRox SL 340, for areas where open insulation is allowed, directly on bulkheads and decks with standard pins and washers. Minimum 50 mm and preferably 2 x 50 mm thickness. In theory you should aim for a thickness of 1/4 of the wavelength for the frequency needed to absorb, but often this is not possible in practice, and by 100 mm insulation very good results will also be achieved.

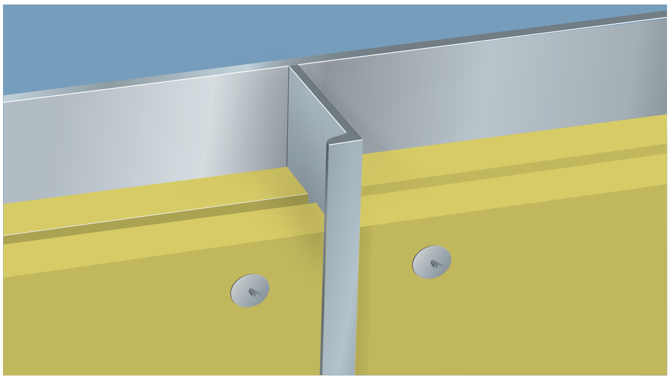
Investigations and measurements have shown that the SeaRox SL 340 will be the best compromise in ratio of weight and noise absorption. And to obtain best possible results it is highly recommended to make two layers with an air gab between the layers of approx 5-15 mm. This enhances both reduction and absorption values.



Absorption:

2 x 50 SeaRox SL 340

2 x 50 mm SeaRox SL 340
during testing of absorption value



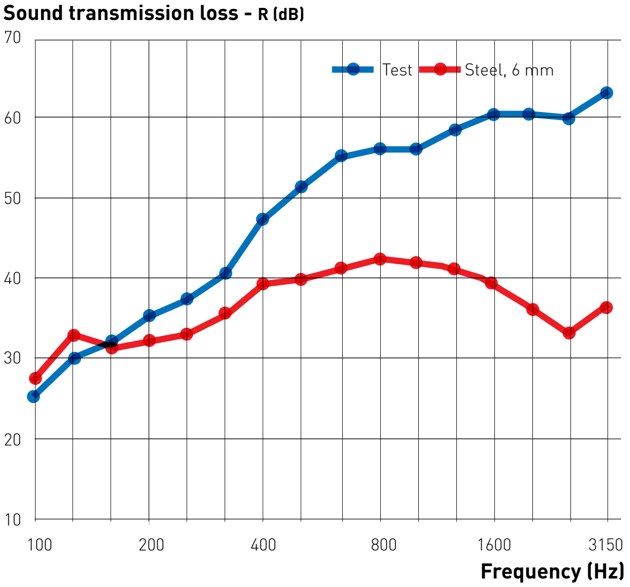
Reduction 2 x 50 SeaRox SL 340, air gap

Built-up of 2 x 50 mm Rockwool SeaRox SL 340 with 10 mm air gap during testing of reduction value

Reduction: 2 x 50 mm SeaRox SL 340, air gap

	Test	Steel
Hz	dB	dB
100	25.4	27.0
125	30.1	32.7
160	32.1	31.3
200	35.1	32.0
250	37.2	32.8
315	40.4	35.4
400	47.1	39.1
500	51.2	39.5
630	54.9	40.9
800	55.8	42.1
1000	56.0	41.7
1250	58.3	41.3
1600	60.1	39.2
2000	60.2	35.8
2500	59.6	32.7
3150	62.9	36.0

R_w	49	39
C	-2	-2



12.0 SeaRox Acoustic Foil system

Providing fire protection and noise reduction in areas where mechanical strength and resistance to oil contamination is required has always been a problem. Now Rockwool has a system which addresses all the these issues.

Traditional solutions of insulation incorporating either an alu-foil or steel plate finish are very good for fire protection and the prevention of oil contamination, but these surface materials unfortunately reduce the otherwise excellent noise absorption properties of the insulation behind.

By using the SeaRox Acoustic Foil system, the noise reduction properties of the SeaRox material will remain.

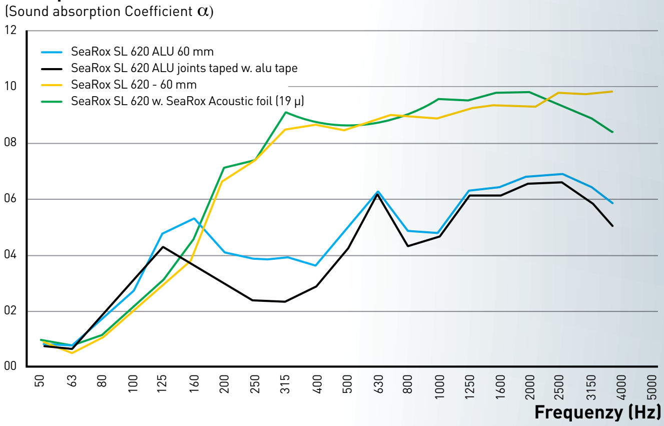
SeaRox Acoustic Foil is very strong, thin and durable film, which is resistant to oil/ oil mist, water and most other substances expected to be found in the environment og the Engine Room.

The film (which covers the mineral wool insulation and is then covered by a perforated steel plate) has been tested for surface flammability, according to IMO Res MSC.61(67), annex 1 part 5 and IMO res 653(16), by the Danish Institute of Fire Technology. The result is in full compliance with SOLAS.

To obtain the optimal sound properties the film must be fitted loosely with a small gap between it and the insulation.

Documented sound properties
The system has also been tested for sound reduction proving its unique acoustic perfomance.

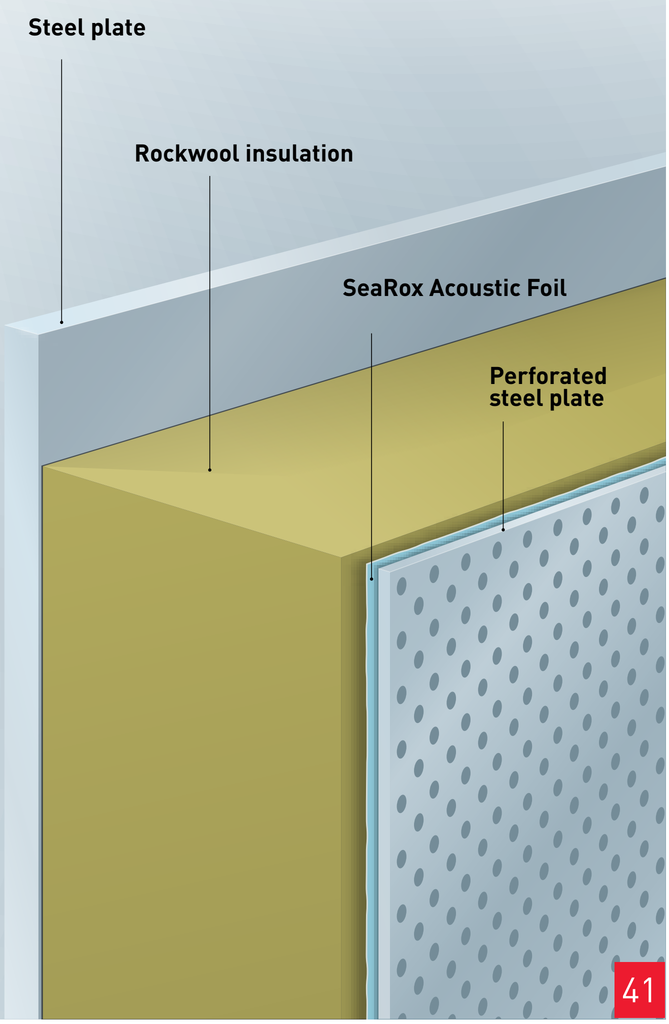
Absorption for SeaRox SL 620
(Sound absorption Coefficient α)



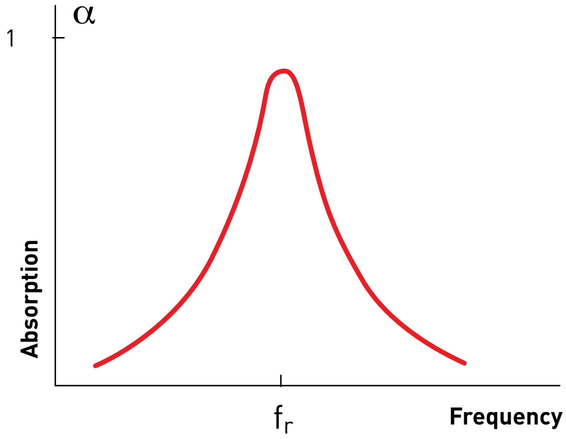
Easy installation
SeaRox Acoustic Foil must not be fixed directly to the insulation. It is essential that the film is fitted loosely, with a small gap between the insulation and the film. This is either done by wrapping it around the slab or by utilising the welding pins required to secure the wool to the substrate.

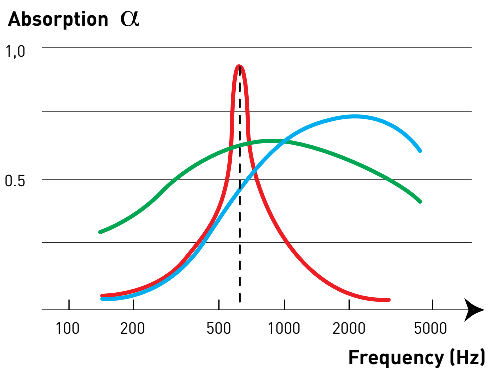
The film should be overlapped by 100 mm minimum. Although the film is very strong, in some cases it may be necessary to reinforce any penetration (from pins etc.) with self adhesive tape. SeaRox Acoustic Foil can be combined in any approved Rockwool fire protection solutions or with any SeaRox thermal/acoustic insulation products.

Although the solution has been tested as a system, which includes a perforated steel plate, Rockwool does not supply this item.



Absorptions curve for a resonance absorbent





Absorptions curve example:
- Resonance absorbent for f_r = 860 Hz
- Resonance absorbent combined with porosity absorbent
- Porosity absorbent alone

p = Perfortion ratio in percentage

h = Distance from bulkhead/deck to perforated plate in meter

s = Plate thickness in meter

d = Perforation hole diameter in meter

In areas where a visual nice surface is required it is recommended to use Rockwool products with glass cloth facings. This is again perfect for the combination solutions. It could be where thermal insulation is required in as example a stores room, and this directly mounted Rockwool will then also act as a good absorbent and provide reduction to adjacent rooms.

The glass cloth will change the absorption coefficient, depending on the type of glass cloth. Thin open woven types will only minimal reduce the absorption. Thick tight woven types will reduce the absorption by 30-50 %, compared to the pure Rockwool. When the aim is to utilise the absorption, the glass cloth must not be painted. It will therefore allways be a decision between the right mix of mechanical strength and absorption.

Please see measuring results at page 47 in the appendix I or at our web site www.rockwool-rti.com

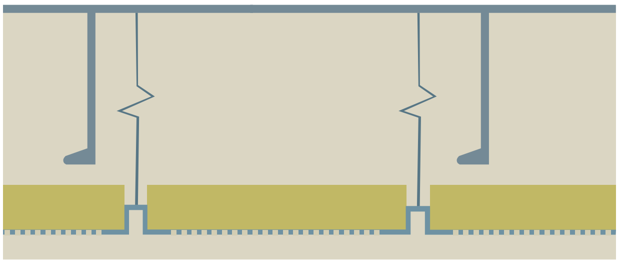
13.0 Dedicated Absorber Systems

For areas with even more focus on the noise absorption, dedicated absorbers should be fitted. It will then be possible to take into account the resonance frequencies. The basic principle is to mount the SeaRox Slab in a calculated distance from the bulkhead / deck. Hereby it is possible to combine the principles of porosity absorbers and resonance absorbers.

Mentioned formula below gives us the possibillity to calculate the resonance frequencies fr:

$$f_r = 5,5 \sqrt{\frac{P}{h\,(s + 0,8 \cdot d)}}\ \text{Hz}$$

It will be possible to enhance the absorption in the very low frequencies, gain a more flat absorption curve, with a designed peak frequency. Such a system for i.e. noise damping in a hi-press room, could be designed towards the machinery's frequency of the worst noise level. A system like this could be built-up by Rockwool SeaRox Slabs and perforated steel sheeting, placed in the calculated distance.
Where necessary a membrane between the perforated steel

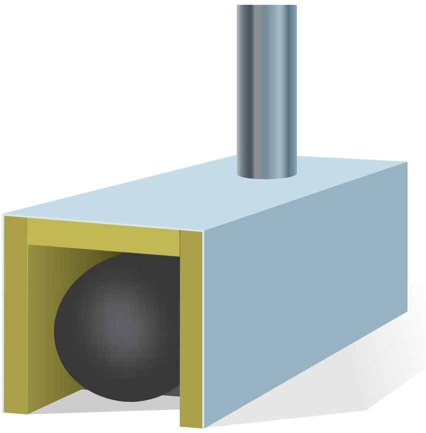


Suspending ceiling system with perforated plates

and the SeaRox product can be fitted, but here great care should be taken not to disturb the ability for the sound energy to pass through the membrane. A foil like aluminium foil glued to the Rockwool will not be the best solution. The membrane has to be an "open" type or a light weight loose foil.

It is also possible to purchase dedicated absorber cassettes complete including bracket system etc from several suppliers. These will of cause also have our non-combustible Rockwool material core.

The same principle is utilised by many ceiling manufactures, again using Rockwool material as the core.

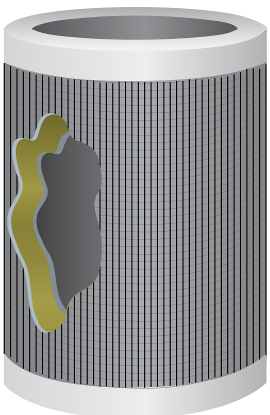


14.0 Encapsulation

In noisy areas / large compartments where the crew is required to perform long term daily work it can be difficult to reduce the sound energy in the room, where the sound sources are placed close within the working area.

Here encapsulation of the source is the most effective solution. A box of steel or alu plates covered by SeaRox product on the inside, which then is placed around the source of sound, i.e. a aux engine, compressor, pump, vent-unit, etc.

Depending on the risk of internal pollution, frequency of maintenance and service, the SeaRox product should be mechanical protected.



15.0 Air silencer for ventilation system

Ventilation fan intakes often create a lot of noise, and it often generates a very annoying resonance noise. Minimum step to reduce the noise here is to install an intake silencer, which generally is an open cylinder of perforated steel with an infill of SeaRox product.

Air outlet can also generate unwanted noise, and here dedicated baffler systems can be installed.

Such systems can be delivered by a variety of dedicated companies.

16.0 Combi solutions

Often the best results will appear when two or more methods are joined in common battle against the noise.

Good examples can be welded on structural damping cassettes for lower frequency reduction in the structure combined with SeaRox insulation to cover the remaining bulkhead for reduction of the higher frequency noise.

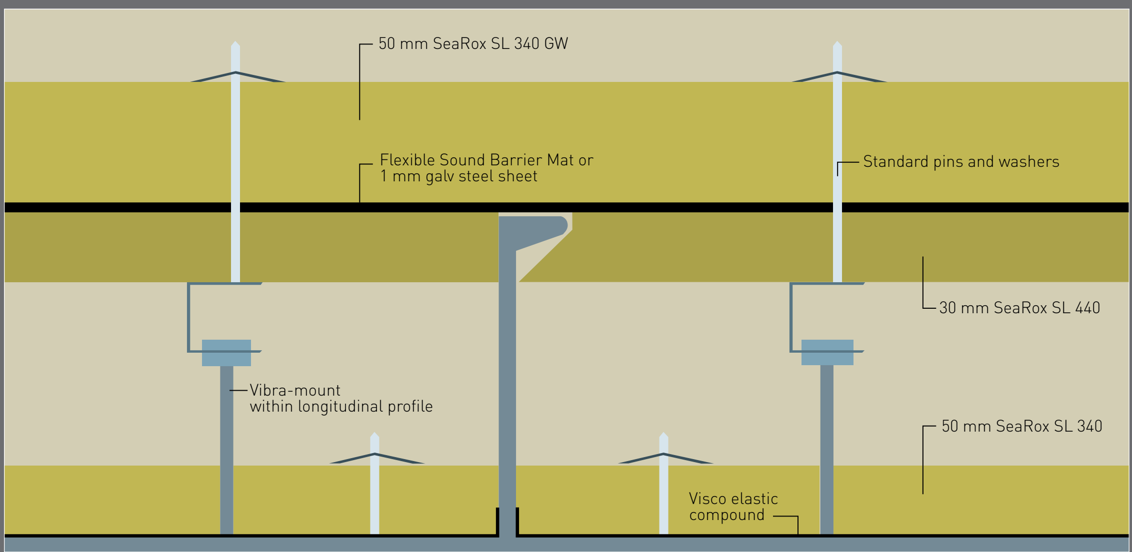
And if this built up is then covered by a thin steel sheet cladding system, non-ridged mounted to the bulkhead, it will create a perfect system for noise reduction through the bulkhead along with dampening of the structure borne noise.

Another very good principle of combination is structural steel damping by applying a special fire resistant PU resin to the bulkhead/deck and gluing into this thin steel sheets, hereafter covering all by SeaRox product to create the excellent combination of structural damping, reduction through the bulkhead/deck and very good absorption.

For areas/ solution where no special strength/compression/bending/etc is required, SeaRox SL 340 is recommended as the best compromise of noise absorption/reduction and

weight/mechanical strength. For floating floor systems it is SeaRox SL 436 or SeaRox SL 480. But for a large range of more specialised solutions Rockwool engineers are available to guide and recommend in order to obtain the best possible solution.

For vessel types where the noise reduction and absorption are required to the extreme, it will be necessary to make complex built-ups. These solutions will often be made vessel specific by dedicated specialist companies, but one bulkhead example of built-up is shown below.



Example of possible high-end built-up
Such solution should be calculated and specific tested, in order to ensure the best possible result.

General pipe insulation

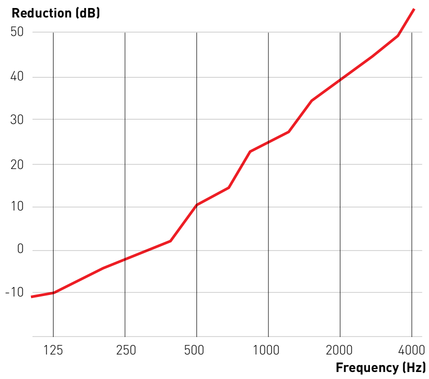
17.0 Pipe insulation

ProRox Pipe sections and Rockwool SeaRox Wired Mats offer excellent noise reduction towards fluid noise in process piping. Especially compared to closed cell insulation, glass foam and similar. Mounting of pipes in flexible fitting is necessary to avoid structure transmitted noise.

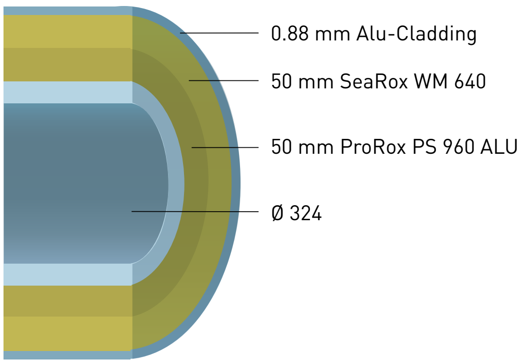
Fluid noise is often of high frequency when insulating pipes for noise, the best results will occur when finished with a cladding system. This is traditionally made with steel cladding, but other systems like RockTight is equally good. It is important that it is ridged but not connected to the pipes, even if distance rings are used.

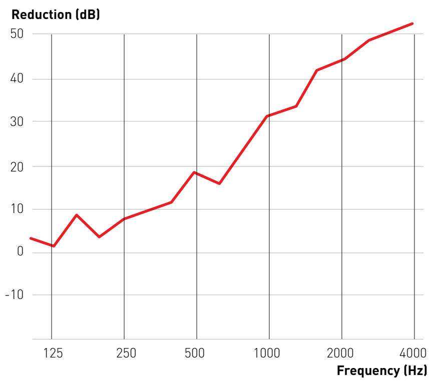
Insulating around valves is also important as much fluid noise is generated here. Encapsulation boxes are the best choice, but more sophisticated prefabricated mats (as often seen offshore) with Rockwool infill and multi layer covering will perform very well for noise reduction.

Test examples:

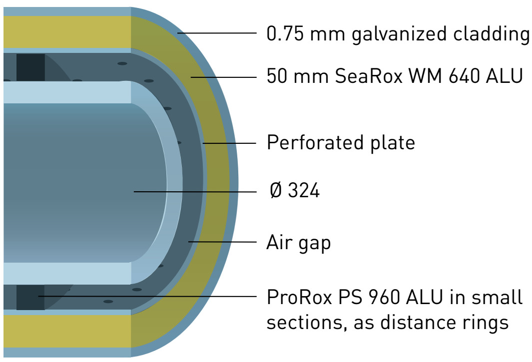


Frequency (Hz)	dB
125	-8
250	-5
500	5
1000	16
2000	34
5000	50





Frequency (Hz)	dB
125	2
250	8
500	18
1000	46
2000	55
5000	50




CMA

Appendix I

In the next section a selection of measurement data has been collected.First a range of material specifications of absorption measurement, a few examples of dynamic stiffness and last some examples of marine built up simulating various fire protection division bulkhead/ deck constructions where the reduction value has been measured.

It is necessary to stress that whenever data is to be compared, this cannot be done, without also knowing according to which standards the measurements have been done, which laboratory and not least under which circumstances (environmental conditions). Apples has to be compared to apples and oranges to oranges, so to speak. It can lead to quite bad misunderstandings, if raw dB or absorption values are uncritically used.

As Rockwool is constantly performing development and measurements, please visit our web site for the full and latest set of data material: www.rockwool-rti.com

Please note the range of standard product may vary from country to country.

NOTE: It is strongly recommended to use this single-number rating in combination with the complete sound absorption coefficient curve that can be found on the following pages.

18.0 Absorption measurements

Sound absorption measurements are performed in a reverberation room according to the main requirements in ISO 354-2003

No	Rockwool products	Weighted absorption
1	SeaRox SL 740, 50 mm	α_w = 0.75
2	SeaRox SL 740 ALU, 50 mm	α_w = 0.65
3	SeaRox SL 320, 50 mm	α_w = 0.85
4	SeaRox SL 340, 50 mm	α_w = 0.90
5	SeaRox SL 340, 50 mm + 1 mm perf. steel suspended 10 mm	α_w = 0.90
6	SeaRox SL 340, 2 x 50 mm	α_w = 0.95
7	SeaRox SL 340, 2 x 50 mm + glass net + 1 mm perf. steel	α_w = 0.95
8	SeaRox SL 340, 2 x 50 mm + glass net + 1 mm perf. steel suspended 10 mm	α_w = 0.95
9	SeaRox SL 436, 50 mm	α_w = 0.85
10	SeaRox SL 440, 50 mm	α_w = 0.75
11	SeaRox SL 480, 30 mm	α_w = 0.75
12	SeaRox SL 480, 50 mm	α_w = 0.75
13	SeaRox SL 480, 2 x 30 mm	α_w = 0.80
14	SeaRox SL 620, 40 mm	α_w = 0.80
15	SeaRox SL 620, 40 mm + alu foil	α_w = 0.50
16	SeaRox SL 620, 60 mm incl. pin's and washer	α_w = 0.90
17	SeaRox SL 620, 60 mm incl. pin's and washer, covered by 19 µ foil	α_w = 0.90
18	SeaRox SL 620 ALU, 40 mm	α_w = 0.77
19	SeaRox SL 640, 30 mm	α_w = 0.70
20	SeaRox SL 640, 50 mm	α_w = 0.80
21	SeaRox SL 640, 2 x 30 mm	α_w = 0.90
22	SeaRox SL 640, 30 mm + 30 mm alu + 1 mm perf. steel suspended 10 mm	α_w = 0.30
23	SeaRox SL 660, 2 x 50 mm	α_w = 0.90
24	SeaRox WM 950, 50 mm	α_w = 0.90
25	SeaRox WM 950 ALU, 50 mm	α_w = 0.75
26	SeaRox WM 950, 100 mm	α_w = 0.95
27	SeaRox WM 950 ALU, 100 mm	α_w = 0.75
28	SeaRox WM 620, 45 mm	α_w = 0.90
29	SeaRox WM 620, 45 mm + SeaRox Acoustic Foil (19 µ)	α_w = 0.90
30	SeaRox WM 620, 45 mm + SeaRox Acoustic Foil (19 µ) + perf. steel plate (suspended)	α_w = 0.90
31	SeaRox WM 620, 2 x 45 mm	α_w = 0.95
32	SeaRox WM 620 GW, 45 mm with 400 gr/m^2	α_w = 0.75
33	SeaRox WM 640, 30 mm	α_w = 0.80
34	SeaRox WM 640, 75 mm	α_w = 0.90
35	SeaRox WM 640, 100 mm	α_w = 0.90

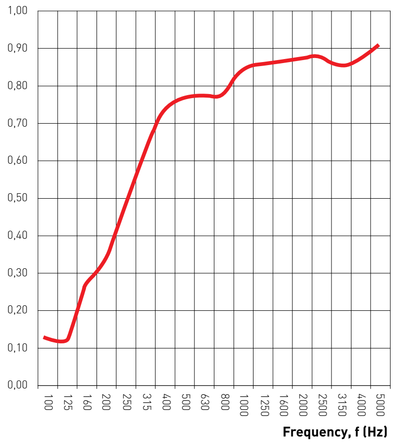
1

Frequency [Hz]	α_s	α_p
100	0.12	
125	0.11	0.15
160	0.27	
200	0.33	
250	0.47	0.45
315	0.63	
400	0.73	
500	0.77	0.75
630	0.77	
800	0.77	
1000	0.85	0.80
1250	0.86	
1600	0.86	
2000	0.87	0.85
2500	0.88	
3150	0.85	
4000	0.87	0.85
5000	0.90	

Sound Absorption Coefficient
SeaRox SL 740, 50 mm
(Direct mounted)

α_w = 0,75
Calculated to EN ISO 11654:1997

Sound absorption coefficient



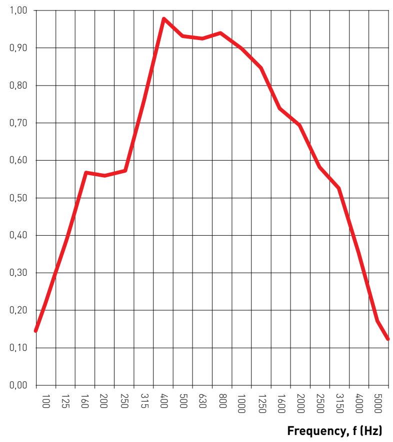
2

Frequency [Hz]	α_s	α_p
100	0.22	
125	0.38	0.39
160	0.56	
200	0.56	
250	0.57	0.63
315	0.76	
400	0.98	
500	0.93	0.94
630	0.92	
800	0.94	
1000	0.90	0.90
1250	0.85	
1600	0.74	
2000	0.69	0.67
2500	0.58	
3150	0.52	
4000	0.35	0.35
5000	0.17	

Sound Absorption Coefficient
SeaRox SL 740, 50 mm
+ alu foil (Direct mounted)

α_w = 0,65
Calculated to EN ISO 11654:1997

Sound absorption coefficient



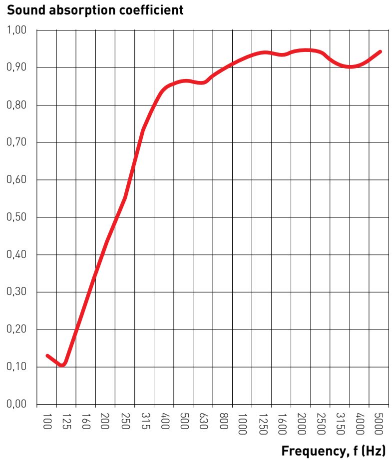
3

Frequency [Hz]	α_s	α_p
100	0.12	
125	0.09	0.15
160	0.25	
200	0.41	
250	0.54	0.55
315	0.73	
400	0.83	
500	0.86	0.85
630	0.85	
800	0.89	
1000	0.91	0.90
1250	0.93	
1600	0.92	
2000	0.94	0.95
2500	0.93	
3150	0.89	
4000	0.89	0.90
5000	0.93	

Sound Absorption Coefficient
SeaRox SL 320, 1 x 50 mm
(Direct mounted)

α_w = 0,85
Calculated to EN ISO 11654:1997

Sound absorption coefficient



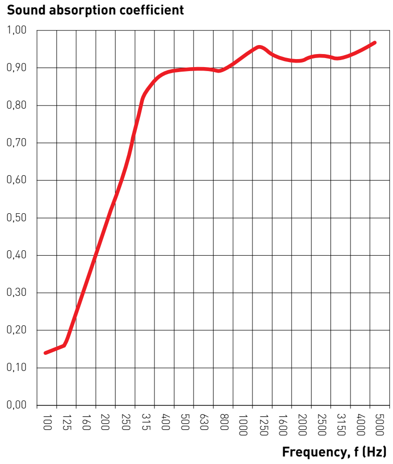
4

Frequency [Hz]	α_s	α_p
100	0.14	
125	0.15	0.20
160	0.31	
200	0.47	
250	0.60	0.65
315	0.82	
400	0.88	
500	0.89	0.90
630	0.90	
800	0.89	
1000	0.92	0.90
1250	0.95	
1600	0.92	
2000	0.91	0.90
2500	0.93	
3150	0.92	
4000	0.93	0.95
5000	0.96	

Sound Absorption Coefficient
SeaRox SL 340, 50 mm
(Direct mounted)

α_w = 0,90
Calculated to EN ISO 11654:1997

Sound absorption coefficient

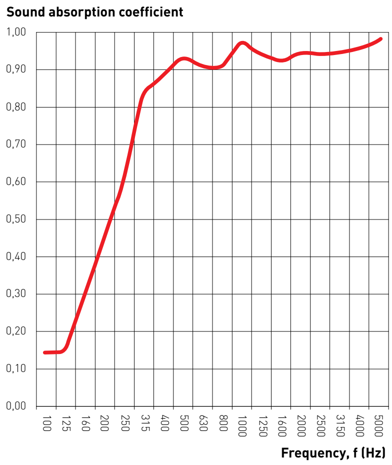


5

Frequency [Hz]	α_s	α_p
100	0.14	
125	0.14	0.20
160	0.28	
200	0.46	
250	0.60	0.65
315	0.84	
400	0.88	
500	0.93	0.90
630	0.90	
800	0.90	
1000	0.97	0.95
1250	0.94	
1600	0.92	
2000	0.94	0.95
2500	0.94	
3150	0.94	
4000	0.95	0.95
5000	0.98	

Sound Absorption Coefficient
SeaRox SL 340, 50 mm + 1 mm perf. steel suspended 10 mm (Direct mounted)

α_w = 0,90
Calculated to EN ISO 11654:1997

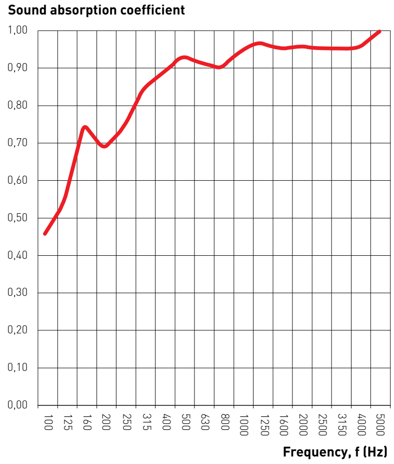


6

Frequency [Hz]	α_s	α_p
100	0.46	
125	0.54	0.60
160	0.75	
200	0.68	
250	0.74	0.75
315	0.84	
400	0.88	
500	0.93	0.90
630	0.91	
800	0.90	
1000	0.95	0.95
1250	0.96	
1600	0.95	
2000	0.96	0.95
2500	0.95	
3150	0.95	
4000	0.95	0.95
5000	0.99	

Sound Absorption Coefficient
SeaRox SL 340, 2 x 50 mm (Direct mounted)

α_w = 0.95
Calculated to EN ISO 11654:1997

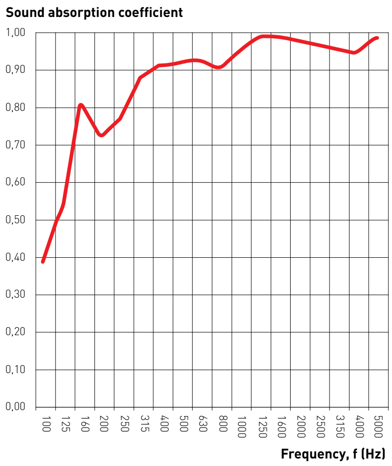


7

Frequency [Hz]	α_s	α_p
100	0.38	
125	0.53	0.55
160	0.81	
200	0.72	
250	0.77	0.80
315	0.87	
400	0.91	
500	0.91	0.90
630	0.92	
800	0.90	
1000	0.94	0.95
1250	0.99	
1600	0.99	
2000	0.97	0.95
2500	0.96	
3150	0.95	
4000	0.94	0.95
5000	0.98	

Sound Absorption Coefficient
SeaRox SL 340, 2 x 50 mm + glass net + 1 mm perf. steel (Direct mounted)

α_w = 0.95
Calculated to EN ISO 11654:1997

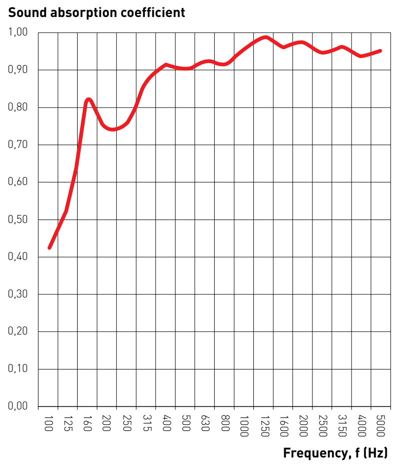


8

Frequency [Hz]	α_s	α_p
100	0.42	
125	0.55	0.60
160	0.83	
200	0.74	
250	0.75	0.80
315	0.87	
400	0.92	
500	0.90	0.90
630	0.92	
800	0.91	
1000	0.95	0.95
1250	0.99	
1600	0.96	
2000	0.97	0.95
2500	0.94	
3150	0.96	
4000	0.93	0.95
5000	0.95	

Sound Absorption Coefficient
SeaRox SL 340, 2 x 50 mm + glass net + 1 mm perf. steel susp. 10 mm (Direct mounted)

α_w = 0.95
Calculated to EN ISO 11654:1997

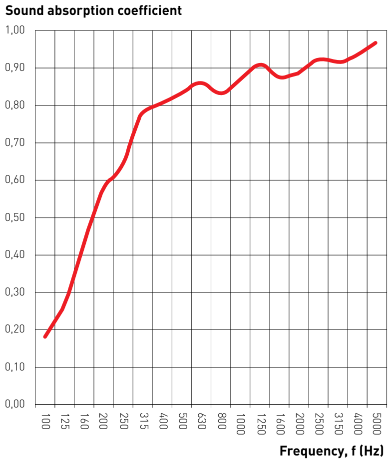


9

Frequency [Hz]	α_s	α_p
100	0.17	
125	0.26	0.30
160	0.42	
200	0.58	
250	0.63	0.65
315	0.78	
400	0.80	
500	0.82	0.85
630	0.86	
800	0.82	
1000	0.86	0.85
1250	0.91	
1600	0.87	
2000	0.88	0.90
2500	0.92	
3150	0.91	
4000	0.93	0.95
5000	0.96	

Sound Absorption Coefficient
SeaRox SL 436, 50 mm

α_w = 0.85
Calculated to EN ISO 11654:1997

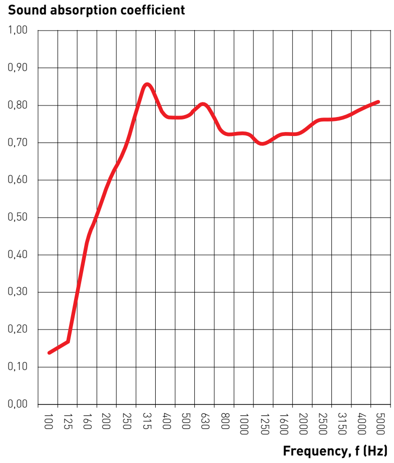


10

Frequency [Hz]	α_s	α_p
100	0.14	
125	0.17	0.25
160	0.44	
200	0.59	
250	0.69	0.70
315	0.87	
400	0.77	
500	0.77	0.80
630	0.81	
800	0.72	
1000	0.73	0.70
1250	0.70	
1600	0.72	
2000	0.73	0.75
2500	0.76	
3150	0.76	
4000	0.79	0.80
5000	0.81	

Sound Absorption Coefficient
SeaRox SL 440, 50 mm
(Direct mounted)

α_w = 0.75
Calculated to EN ISO 11654:1997

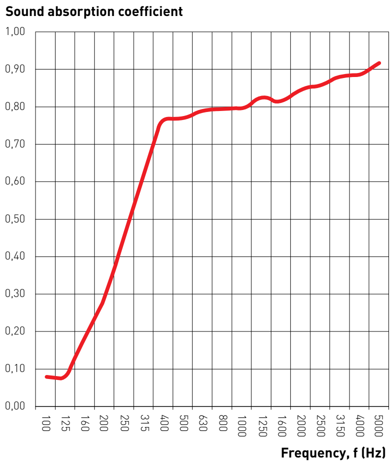


11

Frequency [Hz]	α_s	α_p
100	0.07	
125	0.07	0.10
160	0.18	
200	0.28	
250	0.44	0.45
315	0.61	
400	0.77	
500	0.76	0.75
630	0.79	
800	0.79	
1000	0.79	0.80
1250	0.82	
1600	0.81	
2000	0.85	0.85
2500	0.85	
3150	0.88	
4000	0.88	0.90
5000	0.91	

Sound Absorption Coefficient
SeaRox SL 480, 1x30 mm
(Direct mounted)

α_w = 0.75
Calculated to EN ISO 11654:1997

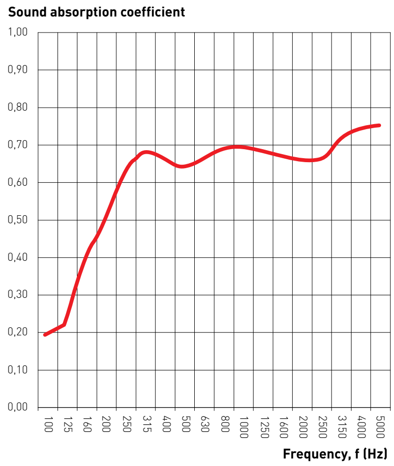


12

Frequency [Hz]	α_s	α_p
100	0.14	
125	0.17	0.25
160	0.44	
200	0.59	
250	0.69	0.70
315	0.87	
400	0.77	
500	0.77	0.80
630	0.81	
800	0.72	
1000	0.73	0.70
1250	0.70	
1600	0.72	
2000	0.73	0.75
2500	0.76	
3150	0.76	
4000	0.79	0.80
5000	0.81	

Sound Absorption Coefficient
SeaRox SL 480, 50 mm
(Direct mounted)

α_w = 0.75
Calculated to EN ISO 11654:1997

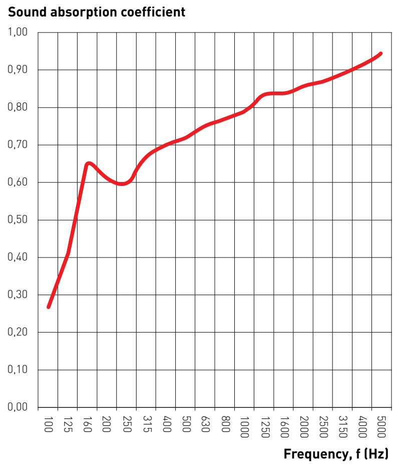


13

Frequency [Hz]	α_s	α_p
100	0.26	
125	0.41	0.45
160	0.65	
200	0.60	
250	0.59	0.60
315	0.66	
400	0.69	
500	0.71	0.70
630	0.74	
800	0.76	
1000	0.78	0.80
1250	0.83	
1600	0.83	
2000	0.85	0.85
2500	0.86	
3150	0.88	
4000	0.90	0.90
5000	0.94	

Sound Absorption Coefficient
SeaRox SL 480, 2x30 mm
(Direct mounted)

α_w = 0.80
Calculated to EN ISO 11654:1997

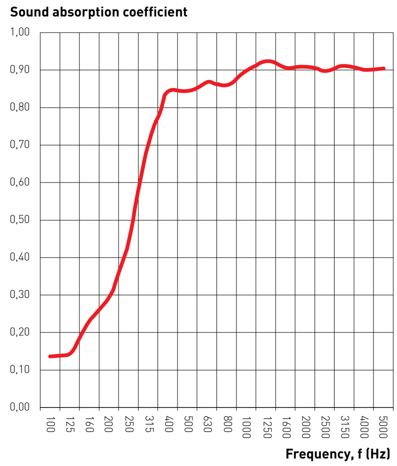


14

Frequency [Hz]	α_s	α_p
100	0.13	
125	0.14	0.15
160	0.23	
200	0.29	
250	0.43	0.50
315	0.71	
400	0.85	
500	0.84	0.85
630	0.87	
800	0.85	
1000	0.90	0.90
1250	0.93	
1600	0.90	
2000	0.91	0.90
2500	0.89	
3150	0.91	
4000	0.90	0.90
5000	0.90	

Sound Absorption Coefficient
SeaRox SL 620, 40 mm
(Direct mounted)

α_w = 0.80
Calculated to EN ISO 11654:1997

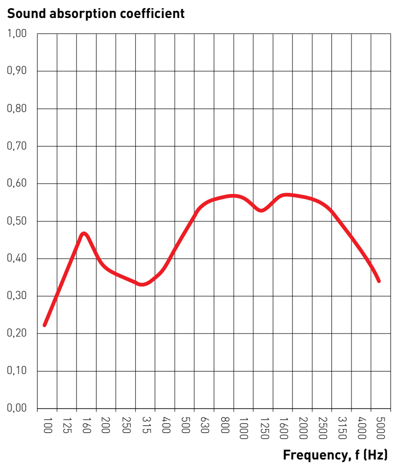


15

Frequency [Hz]	α_s	α_p
100	0.22	
125	0.35	0.35
160	0.47	
200	0.37	
250	0.35	0.35
315	0.32	
400	0.36	
500	0.45	0.45
630	0.54	
800	0.56	
1000	0.56	0.55
1250	0.52	
1600	0.57	
2000	0.56	0.55
2500	0.55	
3150	0.50	
4000	0.42	0.40
5000	0.33	

Sound Absorption Coefficient
SeaRox SL 620, 40 mm
+ alufoil (Direct mounted)

α_w = 0.50
Calculated to EN ISO 11654:1997

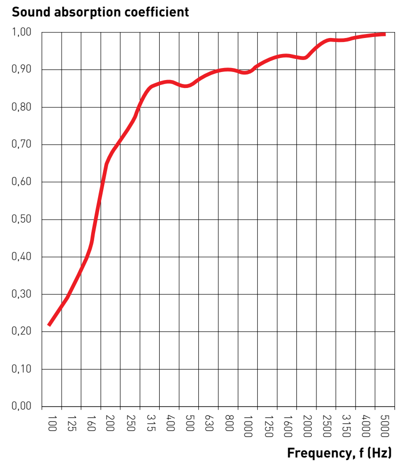


16

Frequency [Hz]	α_s	α_p
100	0.21	
125	0.30	0.30
160	0.41	
200	0.67	
250	0.73	0.30
315	0.85	
400	0.86	
500	0.85	0.85
630	0.88	
800	0.90	
1000	0.88	0.90
1250	0.92	
1600	0.93	
2000	0.92	0.95
2500	0.97	
3150	0.97	
4000	0.99	1.00
5000	0.99	

Sound Absorption Coefficient
SeaRox SL 620, 60 mm
(Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

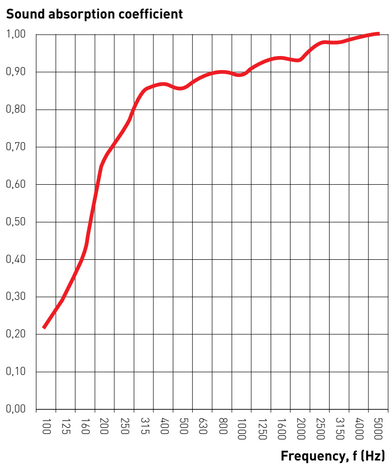


17

Frequency [Hz]	α_s	α_p
100	0.21	
125	0.30	0.30
160	0.41	
200	0.67	
250	0.73	0.75
315	0.85	
400	0.86	
500	0.85	0.85
630	0.88	
800	0.90	
1000	0.88	0.90
1250	0.92	
1600	0.93	
2000	0.92	0.95
2500	0.97	
3150	0.97	
4000	0.99	1.00
5000	0.99	

Sound Absorption Coefficient
SeaRox SL 620, 60 mm
+ 19 µ SeaRox Acoustic Foil
(Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

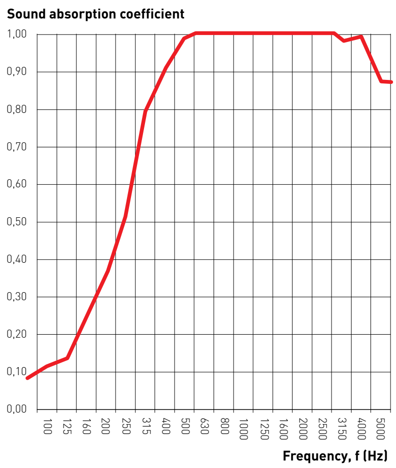


18

Frequency [Hz]	α_s	α_p
100	0.11	
125	0.16	0.17
160	0.25	
200	0.37	
250	0.56	0.56
315	0.74	
400	0.72	
500	0.90	0.96
630	0.97	
800	1.00	
1000	1.00	1.00
1250	1.00	
1600	1.00	
2000	1.00	1.00
2500	1.00	
3150	1.00	
4000	0.95	0.95
5000	0.91	

Sound Absorption Coefficient
SeaRox SL 620, 40 mm
+ alu foil (Direct mounted)

α_w = 0.77
Calculated to EN ISO 11654:1997

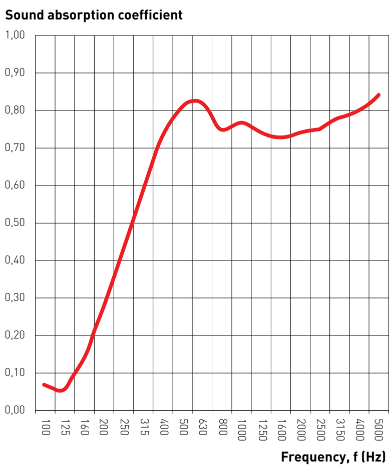


19

Frequency [Hz]	α_s	α_p
100	0.06	
125	0.04	0.07
160	0.12	
200	0.26	
250	0.41	0.40
315	0.58	
400	0.72	
500	0.80	0.80
630	0.82	
800	0.73	
1000	0.76	0.75
1250	0.73	
1600	0.71	
2000	0.73	0.75
2500	0.74	
3150	0.77	
4000	0.79	0.80
5000	0.83	

Sound Absorption Coefficient
SeaRox SL 640, 30 mm
(Direct mounted)

α_w = 0.70
Calculated to EN ISO 11654:1997

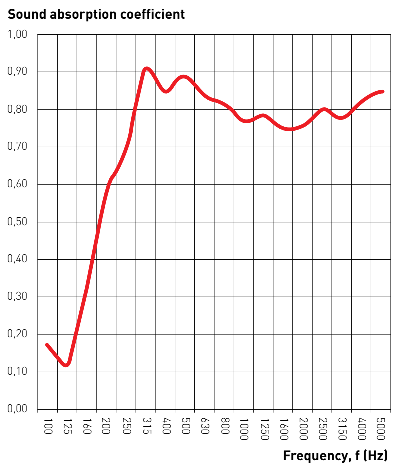


20

Frequency [Hz]	α_s	α_p
100	0.17	
125	0.11	0.20
160	0.33	
200	0.58	
250	0.69	0.75
315	0.92	
400	0.84	
500	0.89	0.85
630	0.83	
800	0.81	
1000	0.76	0.80
1250	0.78	
1600	0.74	
2000	0.75	0.75
2500	0.80	
3150	0.76	
4000	0.83	0.80
5000	0.84	

Sound Absorption Coefficient
SeaRox SL 640, 50 mm
(Direct mounted)

α_w = 0.80
Calculated to EN ISO 11654:1997

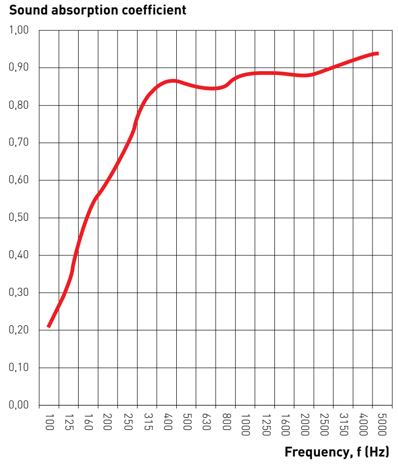


21

Frequency [Hz]	α_s	α_p
100	0.20	
125	0.31	0.35
160	0.51	
200	0.59	
250	0.69	0.70
315	0.81	
400	0.86	
500	0.85	0.85
630	0.84	
800	0.84	
1000	0.88	0.85
1250	0.88	
1600	0.88	
2000	0.87	0.90
2500	0.88	
3150	0.90	
4000	0.92	0.90
5000	0.93	

Sound Absorption Coefficient
SeaRox SL 640, 2 x 30 mm (Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

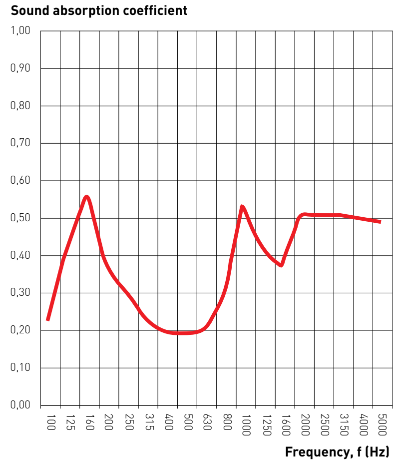


22

Frequency [Hz]	α_s	α_p
100	0.23	
125	0.42	0.40
160	0.55	
200	0.36	
250	0.29	0.30
315	0.22	
400	0.19	
500	0.18	0.20
630	0.19	
800	0.28	
1000	0.52	0.40
1250	0.42	
1600	0.36	
2000	0.50	0.45
2500	0.50	
3150	0.50	
4000	0.49	0.50
5000	0.48	

Sound Absorption Coefficient
SeaRox SL 640, 30 mm + 30 mm alu + 1 mm perf. steel sheet (Direct mounted)

α_w = 0.30
Calculated to EN ISO 11654:1997

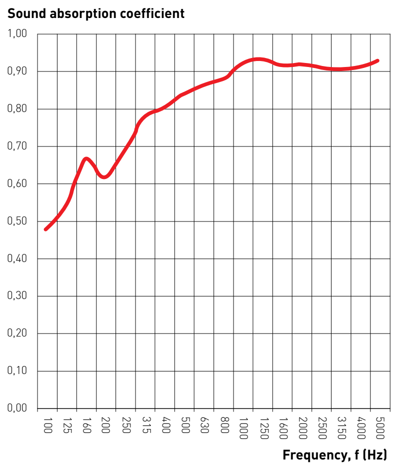


23

Frequency [Hz]	α_s	α_p
100	0.47	
125	0.53	0.55
160	0.67	
200	0.61	
250	0.68	0.70
315	0.78	
400	0.80	
500	0.84	0.85
630	0.85	
800	0.87	
1000	0.92	0.90
1250	0.93	
1600	0.91	
2000	0.92	0.90
2500	0.91	
3150	0.90	
4000	0.91	0.90
5000	0.93	

Sound Absorption Coefficient
SeaRox SL 660, 2x50 mm (Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

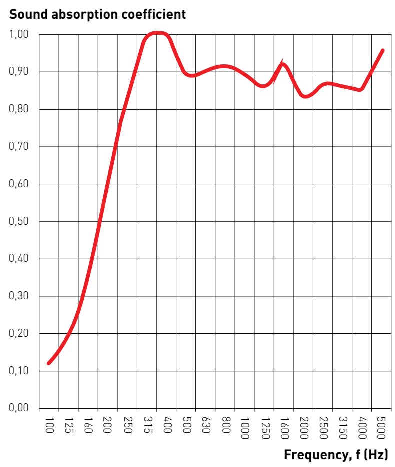


24

Frequency [Hz]	α_s	α_p
100	0.12	
125	0.18	0.22
160	0.35	
200	0.60	
250	0.81	0.80
315	1.01	
400	1.01	
500	0.88	0.95
630	0.90	
800	0.92	
1000	0.90	0.90
1250	0.85	
1600	0.93	
2000	0.82	0.85
2500	0.87	
3150	0.86	
4000	0.85	0.90
5000	0.95	

Sound Absorption Coefficient
SeaRox WM 950, 50 mm (Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

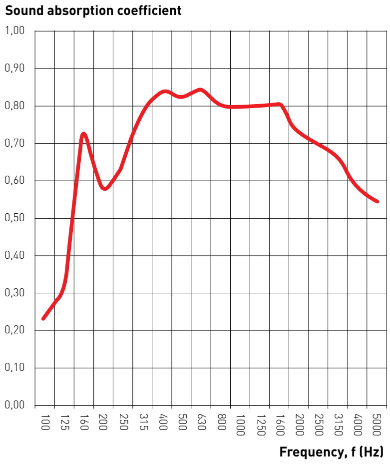


25

Frequency [Hz]	α_s	α_p
100	0.23	
125	0.30	0.42
160	0.74	
200	0.56	
250	0.64	0.65
315	0.78	
400	0.84	
500	0.82	0.85
630	0.84	
800	0.80	
1000	0.79	0.80
1250	0.80	
1600	0.80	
2000	0.72	0.75
2500	0.70	
3150	0.66	
4000	0.57	0.60
5000	0.54	

Sound Absorption Coefficient
SeaRox WM 950, 50 mm
incl. alu foil (Direct mounted)

α_w = **0.75**
Calculated to EN ISO 11654:1997

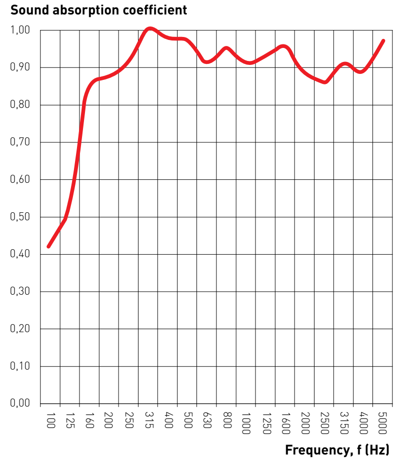


26

Frequency [Hz]	α_s	α_p
100	0.42	
125	0.51	0.45
160	0.86	
200	0.87	
250	0.90	0.95
315	1.01	
400	0.97	
500	0.97	0.95
630	0.90	
800	0.95	
1000	0.90	0.95
1250	0.92	
1600	0.96	
2000	0.88	0.90
2500	0.85	
3150	0.91	
4000	0.88	0.90
5000	0.96	

Sound Absorption Coefficient
SeaRox WM 950, 100 mm
(Direct mounted)

α_w = **0.95**
Calculated to EN ISO 11654:1997

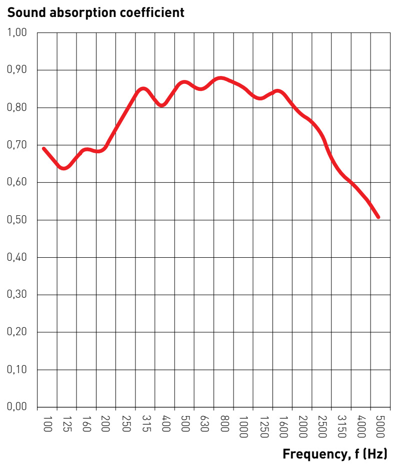


27

Frequency [Hz]	α_s	α_p
100	0.69	
125	0.63	0.67
160	0.69	
200	0.68	
250	0.78	0.75
315	0.86	
400	0.80	
500	0.87	0.85
630	0.85	
800	0.88	
1000	0.86	0.85
1250	0.82	
1600	0.85	
2000	0.79	0.80
2500	0.74	
3150	0.63	
4000	0.58	0.55
5000	0.51	

Sound Absorption Coefficient
SeaRox WM 950, 100 mm
incl. alu foil (Direct mounted)

α_w = **0.75**
Calculated to EN ISO 11654:1997

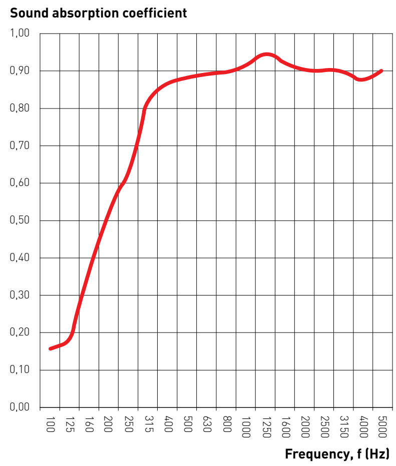


28

Frequency [Hz]	α_s	α_p
100	0.15	
125	0.17	0.25
160	0.37	
200	0.52	
250	0.63	0.65
315	0.82	
400	0.87	
500	0.88	0.90
630	0.89	
800	0.89	
1000	0.91	0.90
1250	0.95	
1600	0.92	
2000	0.90	0.90
2500	0.90	
3150	0.89	
4000	0.87	0.90
5000	0.90	

Sound Absorption Coefficient
SeaRox WM 620, 45 mm
(Direct mounted)

α_w = **0.90**
Calculated to EN ISO 11654:1997

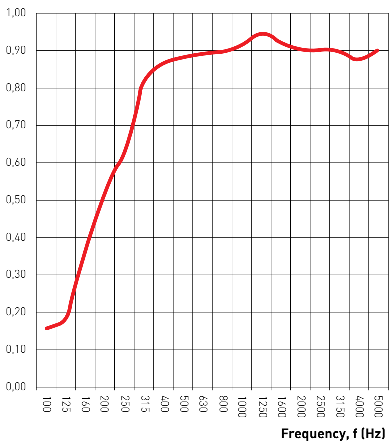


29

Frequency [Hz]	α_s	α_p
100	0.15	
125	0.17	0.25
160	0.37	
200	0.52	
250	0.63	0.65
315	0.82	
400	0.87	
500	0.88	0.90
630	0.89	
800	0.89	
1000	0.91	0.90
1250	0.95	
1600	0.92	
2000	0.90	0.90
2500	0.90	
3150	0.89	
4000	0.87	0.90
5000	0.90	

Sound Absorption Coefficient
SeaRox WM 620, 45 mm + 19 µ SeaRox Acoustic Foil + perf. steel plate (Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

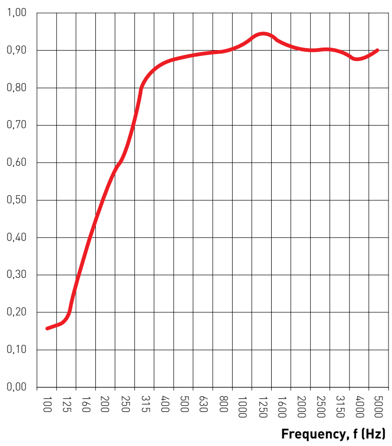


30

Frequency [Hz]	α_s	α_p
100	0.15	
125	0.17	0.25
160	0.37	
200	0.52	
250	0.63	0.65
315	0.82	
400	0.87	
500	0.88	0.90
630	0.89	
800	0.89	
1000	0.91	0.90
1250	0.95	
1600	0.92	
2000	0.90	0.90
2500	0.90	
3150	0.89	
4000	0.87	0.90
5000	0.90	

Sound Absorption Coefficient
SeaRox WM 620, 45 mm + 19 µ SeaRox Acoustic Foil + perf. steel plate (Suspended)

α_w = 0.90
Calculated to EN ISO 11654:1997

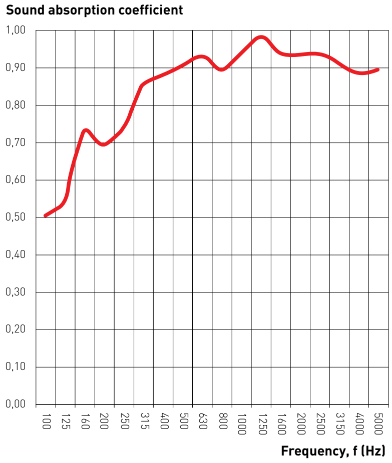


31

Frequency [Hz]	α_s	α_p
100	0.50	
125	0.53	0.60
160	0.74	
200	0.68	
250	0.73	0.75
315	0.86	
400	0.88	
500	0.90	0.90
630	0.93	
800	0.89	
1000	0.93	0.95
1250	0.99	
1600	0.93	
2000	0.93	0.95
2500	0.94	
3150	0.91	
4000	0.88	0.90
5000	0.90	

Sound Absorption Coefficient
SeaRox WM 620, 2 x 45 mm (Direct mounted)

α_w = 0.95
Calculated to EN ISO 11654:1997

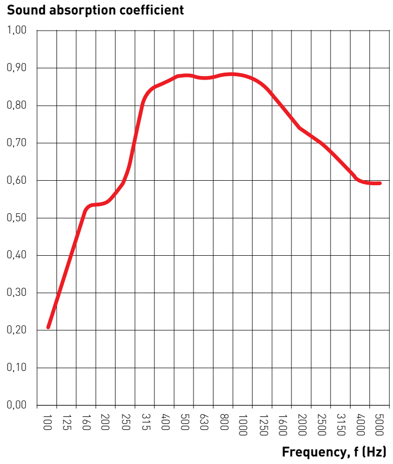


32

Frequency [Hz]	α_s	α_p
100	0.20	
125	0.36	0.35
160	0.53	
200	0.54	
250	0.60	0.65
315	0.83	
400	0.86	
500	0.88	0.85
630	0.87	
800	0.88	
1000	0.88	0.85
1250	0.85	
1600	0.79	
2000	0.74	0.75
2500	0.69	
3150	0.64	
4000	0.59	0.60
5000	0.59	

Sound Absorption Coefficient
SeaRox WM 620, 45 mm with 400 gr/m² glass cloth (Direct mounted)

α_w = 0.75
Calculated to EN ISO 11654:1997

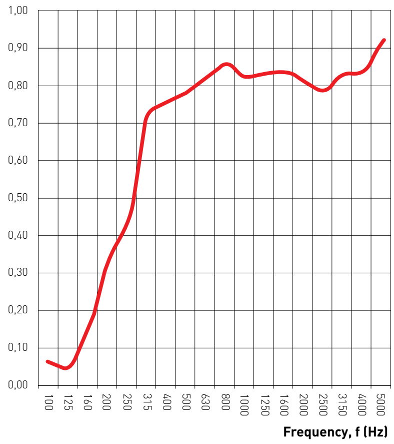


33

Frequency [Hz]	α_s	α_p
100	0.06	
125	0.04	0.08
160	0.14	
200	0.34	
250	0.43	0.50
315	0.73	
400	0.76	
500	0.78	0.80
630	0.82	
800	0.86	
1000	0.82	0.85
1250	0.83	
1600	0.84	
2000	0.81	0.80
2500	0.78	
3150	0.83	
4000	0.83	0.85
5000	0.92	

Sound Absorption Coefficient
SeaRox WM 640, 30 mm
(Direct mounted)

α_w = 0.80
Calculated to EN ISO 11654:1997

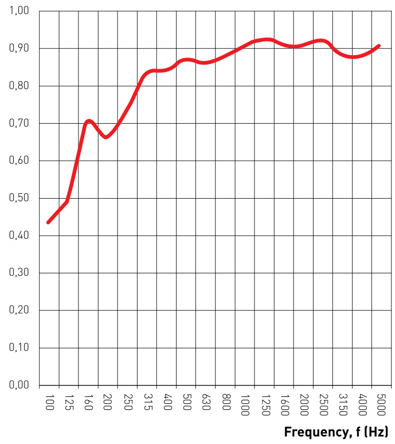


34

Frequency [Hz]	α_s	α_p
100	0.43	
125	0.49	0.55
160	0.71	
200	0.65	
250	0.73	0.75
315	0.84	
400	0.84	
500	0.87	0.85
630	0.86	
800	0.88	
1000	0.90	0.90
1250	0.92	
1600	0.90	
2000	0.90	0.90
2500	0.92	
3150	0.88	
4000	0.87	0.90
5000	0.90	

Sound Absorption Coefficient
SeaRox WM 640, 75 mm
(Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

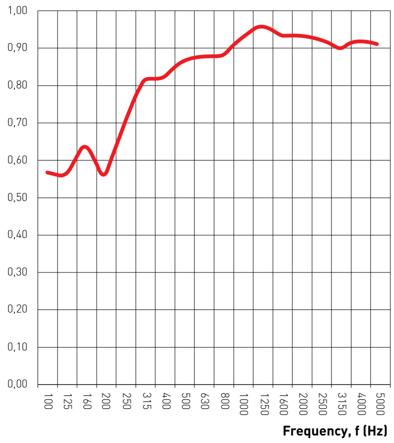


35

Frequency [Hz]	α_s	α_p
100	0.56	
125	0.55	0.60
160	0.54	
200	0.54	
250	0.70	0.70
315	0.81	
400	0.81	
500	0.87	0.85
630	0.87	
800	0.88	
1000	0.93	0.90
1250	0.96	
1600	0.93	
2000	0.93	0.95
2500	0.92	
3150	0.90	
4000	0.92	0.90
5000	0.91	

Sound Absorption Coefficient
SeaRox WM 640, 100 mm (Direct mounted)

α_w = 0.90
Calculated to EN ISO 11654:1997

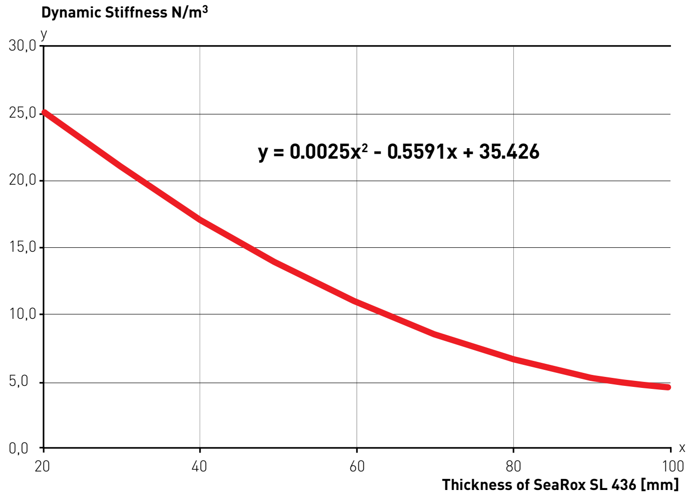


19.0 Dynamic stiffness measurements

The dynamic stiffness is an important parameter when optimising floating floors. This is true both with respect to air- and structure-borne noise, as well as impact noise.

In principle, the dynamic stiffness should be as low as possible in order to obtain a low natural frequency of the floating floor. On the other hand, the load bearing capacity and the possible unfavourable experience of walking on a floor that is too soft may set a lower limit for the stiffness.

SeaRox SL 436 is the most common product used for floating floors. This product is produced according to specific levels of dynamic stiffness according to thickness and the static stiffness also called compression strength.



The graph shows the relation to dynamic stiffness, thickness and compression.

20.0 Reduction measurements

Rockwool Technical Insulation has hosted a series of sound reduction measurements carried out by well-known test institutes, Ødegaard Danneskiold-Samsøe A/S, Copenhagen, Denmark and TÜV Nord Systems GMBH & Co., Essen, Germany.

Please also see the website, www.rockwool-rti.com
Measurement according to ISO 15186-1:2000 and ISO 717-1:1996

Different types of steel bulkhead/deck constructions have been made and insulated with different Rockwool products/ solutions. Please note these test results are to be seen as example guidelines. It is important to ensure all edges and joints are made correctly, otherwise less reduction values could be seen.

When installing, for example, an A-60 Bulkhead solution by SeaRox SL 640, 2 x 30/30 mm, a built-up with a different steel design could possibly result in a change in the real life reduction dB(A) value. This could result in for example an even 5 - 10 dB(A) better result.

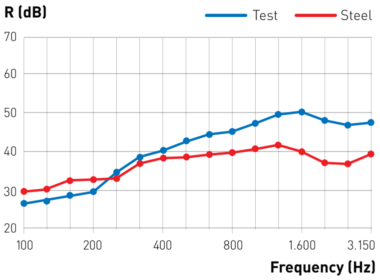
Overview - reduction measurements

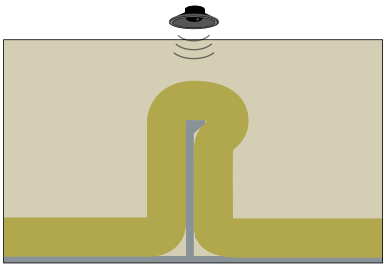
No	Construction	Products	Weighted reduction
1	A-15 steel deck	SeaRox MA 700 GS[d], 40 mm	R_w = 45 dB
2	A-15 steel bulkhead	SeaRox MA 700 ALU[d], 60 mm	R_w = 46 dB
3	A-30 steel bulkhead/deck	SeaRox SL 740, 50 mm/ 30 mm	R_w = 45 dB
4	A-60 steel bulkhead	SeaRox WM 640, 75 mm/ 30 mm	R_w = 47 dB
5	A-60 steel bulkhead	SeaRox WM 620, 2 x 45 mm/45 mm	R_w = 49 dB
6	A-60 steel bulkhead	SeaRox SL 640, 2 x 30 mm/ 30mm	R_w = 48 dB
7	A-60 steel bulkhead	SeaRox SL 620, 60 mm/ 25 mm	R_w = 45 dB
8	A-60 steel bulkhead	SeaRox SL 640, 65 mm / SeaRox WM 640, 30 mm	R_w = 48 dB
9	A-60 steel bulkhead	SeaRox SL 640, 2 x30 mm/ 30 mm with 19 µ SeaRox Acoustic foil	R_w = 47 dB
10	A-60 steel bulkhead	SeaRox WM 620, 2 x 45 mm/ 45 mm with 1 mm steel sheet	R_w = 58 dB
11	A-60 steel bulkhead	SeaRox SL 620, 60 mm/ 25 mm with glass cloth 200 g/m² plus tape	R_w = 45 dB
12	A-60 steel bulkhead	SeaRox SL 620, 60 mm/ 25 mm with reinf. alufoil	R_w = 46 dB
13	A-60 steel bulkhead + thermal	SeaRox SL 640, 65 mm / SeaRox WM 640, 30 mm and SeaRox SL 720, 50 mm	R_w = 49 dB
14	A-60 steel bulkhead + thermal	SeaRox SL 640, 65 mm / SeaRox WM 640, 30 mm and SeaRox MA 720 ALU, 50 mm	R_w = 49 dB
15	A-60 bulkhead restricted	SeaRox SL 620, 40 mm/ 40 mm	R_w = 47 dB
16	A-60 steel deck	SeaRox SL 620, 40 mm/ 25 mm	R_w = 46 dB
17	A-60 steel deck	SeaRox WM 620, 45 mm	R_w = 46 dB
18	A-60 steel deck	SeaRox SL 640, 45 mm / SeaRox WM 640, 30 mm	R_w = 46 dB
19	A-60 steel deck	SeaRox SL 640, 40 mm with 1mm steel sheet	R_w = 56 dB
20	A-60 aluminium bulkhead	SeaRox SL 620, 2 x 30 mm/ 30 mm (on both sides)	R_w = 40 dB
21	A-60 aluminium bulkhead restricted	SeaRox SL 620, 2 x 30 mm/ 30 mm	R_w = 40 dB
22	A-60 aluminium deck	SeaRox SL 620, 2 x 30 mm/ 30 mm	R_w = 40 dB
23	A-60 bulkhead corrugated	SeaRox SL 620, 60 mm	R_w = 40 dB
24	A-60 bulkhead corrugated	SeaRox SL 640, 2 x 30 mm	R_w = 40 dB
25	H-60 bulkhead restricted	SeaRox SL 660, 30 mm and SeaRox WM 660, 40 mm / 40 mm	R_w = 48 dB
26	H-60 bulkhead restricted + thermal	SeaRox SL 660, 30 mm and SeaRox WM 660, 40 mm / 40 mm and 50 mm SeaRox SL 720	R_w = 50 dB
27	H-60 bulkhead restricted + comfort	SeaRox SL 660, 30 mm and SeaRox WM 660, 40 mm / 40 mm and 50 mm SeaRox MA 720 ALU, 50 mm	R_w = 51 dB
28	H-120 bulkhead restricted	SeaRox SL 660, 30 mm and SeaRox WM 660, 40 mm / 2 x 40 mm	R_w = 49 dB
29	H-60 steel deck	SeaRox SL 660, 2 x 50 mm	R_w = 48 dB
30	H-120 bulkhead corrugated	SeaRox SL 660, 50 mm and SeaRox WM 660, 40 mm	R_w = 44 dB
31	A-30 bulkhead with panel	SeaRox SL 740, 50/25 mm and 25 mm panel	R_w = 62 dB
32	Acoustic solution	SeaRox SL 340, 2 x 50 mm with 5-10 mm air gap	R_w = 49 dB

1

SeaRox MA 700 GS[d]
40 mm

	Test	Steel
Hz	dB	dB
100	26.6	29.7
125	27.6	30.2
160	28.6	32.6
200	29.6	32.8
250	34.6	33.1
315	38.6	36.9
400	40.2	38.3
500	42.5	38.5
630	44.4	39.2
800	45.1	39.7
1000	47.2	40.6
1250	49.5	41.7
1600	50.2	40.0
2000	48.0	37.1
2500	46.8	36.8
3150	47.4	39.3
R_w	45	39
C	-1	-2

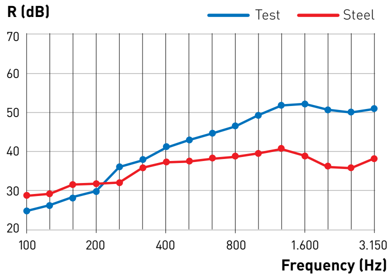


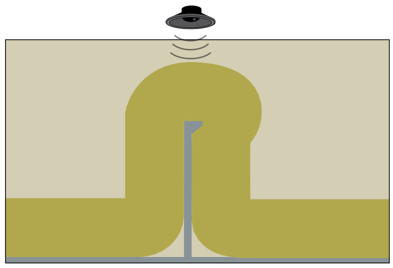


2

SeaRox MA 700 ALU[d]
60 mm

	Test	Steel
Hz	dB	dB
100	25.8	29.7
125	27.3	30.2
160	29.4	32.6
200	30.9	32.8
250	37.1	33.1
315	38.8	36.9
400	42.0	38.3
500	44.0	38.5
630	45.7	39.2
800	47.5	39.7
1000	50.4	40.6
1250	52.9	41.7
1600	53.3	40.0
2000	51.8	37.1
2500	51.1	36.8
3150	52.0	39.3
R_w	46	39
C	-1	-2

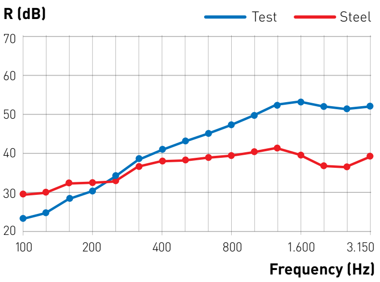


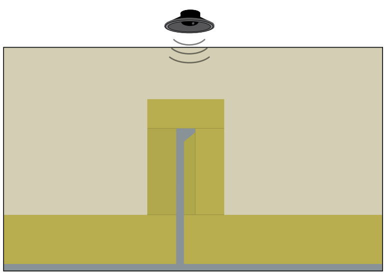


3

SeaRox SL 740
50 mm/ 30 mm

	Test	Steel
Hz	dB	dB
100	23.5	29.7
125	25.0	30.2
160	28.6	32.6
200	30.6	32.8
250	34.3	33.1
315	38.6	36.9
400	41.1	38.3
500	43.3	38.5
630	45.3	39.2
800	47.5	39.7
1000	50.0	40.6
1250	52.8	41.7
1600	53.6	40.0
2000	52.4	37.1
2500	51.7	36.8
3150	52.3	39.3
R_w	45	39
C	-1	-2

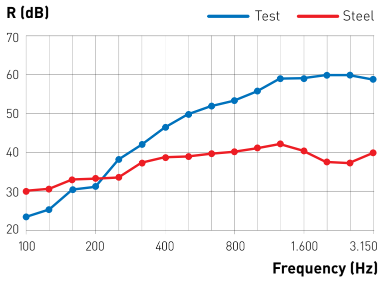


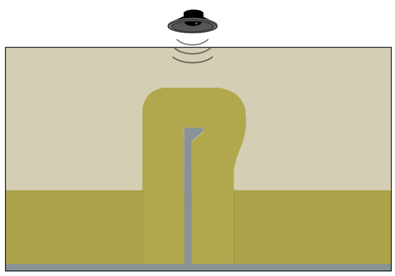


4

SeaRox WM 640
75 mm/ 30 mm

	Test	Steel
Hz	dB	dB
100	23.0	29.7
125	24.9	30.2
160	30.0	32.6
200	30.7	32.8
250	37.7	33.1
315	41.5	36.9
400	45.9	38.3
500	49.3	38.5
630	51.4	39.2
800	52.8	39.7
1000	55.2	40.6
1250	58.5	41.7
1600	58.6	40.0
2000	59.4	37.1
2500	59.4	36.8
3150	58.3	39.3
R_w	47	39
C	-1	-2

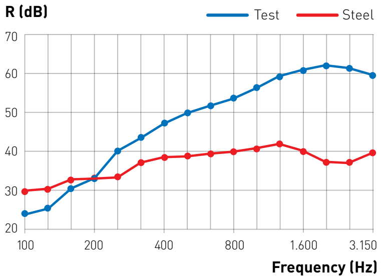


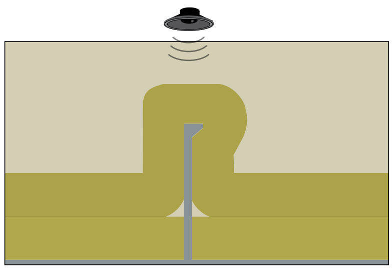


5

SeaRox WM 620
2x45 mm/ 45 mm

	Test	Steel
Hz	dB	dB
100	23.6	29.7
125	25.1	30.2
160	30.3	32.6
200	32.9	32.8
250	39.9	33.1
315	43.2	36.9
400	46.9	38.3
500	49.6	38.5
630	51.5	39.2
800	53.3	39.7
1000	56.0	40.6
1250	59.1	41.7
1600	60.7	40.0
2000	61.9	37.1
2500	61.2	36.8
3150	59.5	39.3
R_w	49	39
C	-1	-3

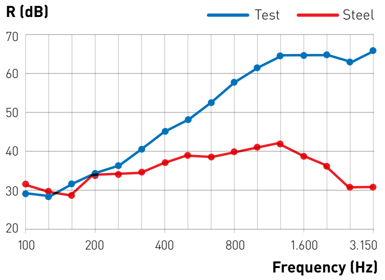


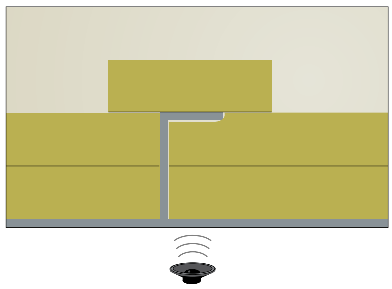


6

SeaRox SL 640
2x30 mm/ 30 mm

	Test	Steel
Hz	dB	dB
100	29.9	31.7
125	28.8	30.2
160	31.7	29.2
200	34.2	33.9
250	35.8	34.1
315	39.2	34.3
400	43.2	36.6
500	46.3	38.0
630	49.5	37.8
800	54.3	38.7
1000	57.4	39.5
1250	60.1	40.9
1600	60.3	38.2
2000	60.4	35.8
2500	58.9	31.1
3150	61.0	31.2
R_w	48	37
C	-1	-2

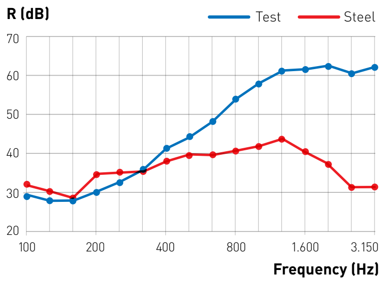


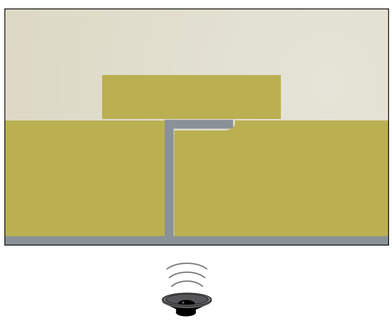


7

SeaRox SL 620 - 60 mm
& 25 mm strips on L-profiles

	Test	Steel
Hz	dB	dB
100	29.6	31.7
125	28.5	30.2
160	28.5	29.2
200	30.2	33.9
250	32.1	34.1
315	34.4	34.3
400	38.8	36.6
500	41.2	38.0
630	44.6	37.8
800	49.3	38.7
1000	52.4	39.5
1250	55.0	40.9
1600	55.3	38.2
2000	56.1	35.8
2500	54.6	31.1
3150	55.6	31.2
R_w	45	37
C	-2	-2

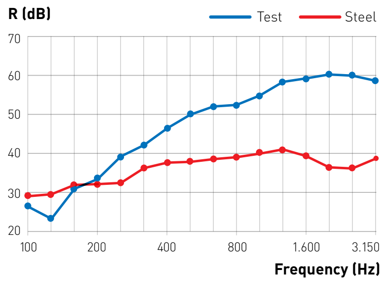


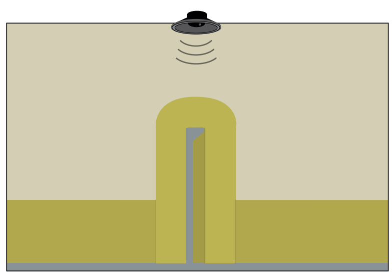


8

SeaRox SL 640, 65 mm/
SeaRox WM 640, 30 mm

	Test	Steel
Hz	dB	dB
100	24.8	29.7
125	24.7	30.2
160	30.7	32.6
200	31.6	32.8
250	37.5	33.1
315	41.5	36.9
400	45.4	38.3
500	47.1	38.5
630	49.0	39.2
800	49.1	39.7
1000	52.1	40.6
1250	55.6	41.7
1600	56.0	40.0
2000	57.1	37.1
2500	57.6	36.8
3150	56.7	39.3
R_w	48	39
C	-1	-3

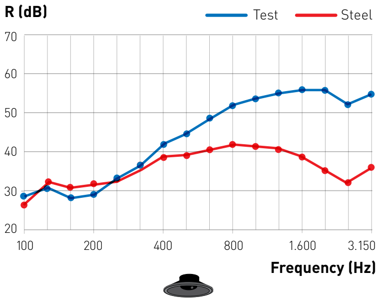


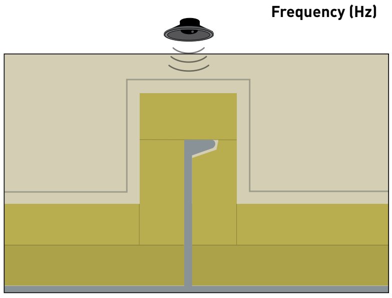


9

	Test	Steel
Hz	dB	dB
100	29.1	27.0
125	31.4	32.7
160	29.0	31.3
200	30.3	32.0
250	33.7	32.8
315	36.8	35.4
400	42.6	39.1
500	45.0	39.5
630	49.0	40.9
800	52.2	42.1
1000	54.0	41.7
1250	55.3	41.3
1600	56.0	39.2
2000	55.8	35.8
2500	52.4	32.7
3150	54.9	36.0
R_w	47	39
C	-2	-2

SeaRox SL 640, 2 x 30 mm/ 30 mm with 19 µ SeaRox Acoustic Foil system + perforated plate

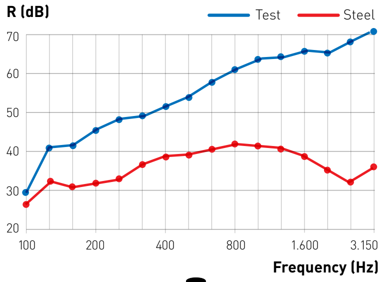


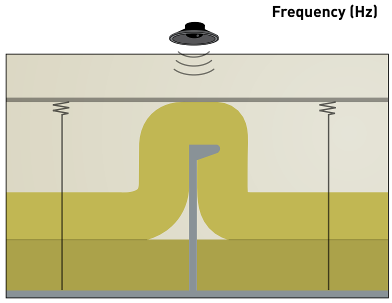


10

	Test	Steel
Hz	dB	dB
100	30.0	27.0
125	41.6	32.7
160	42.3	31.3
200	46.1	32.0
250	48.9	32.8
315	49.8	35.4
400	52.1	39.1
500	54.8	39.5
630	58.5	40.9
800	61.6	42.1
1000	64.2	41.7
1250	64.8	41.3
1600	66.5	39.2
2000	65.9	35.8
2500	69.1	32.7
3150	71.4	36.0
R_w	58	39
C	-3	-2

SeaRox WM 620, 2 x 45 mm with 1 mm steel sheet

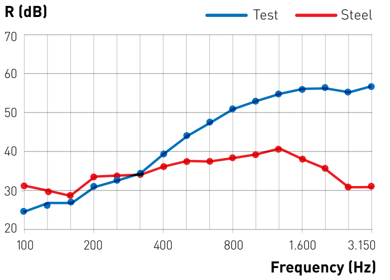


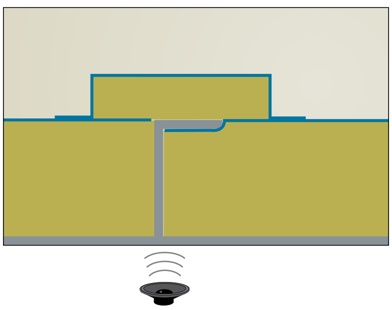


11

	Test	Steel
Hz	dB	dB
100	25.1	31.7
125	26.7	30.2
160	27.3	29.2
200	31.3	33.9
250	32.9	34.1
315	34.7	34.3
400	39.8	36.6
500	44.4	38.0
630	47.7	37.8
800	51.2	38.7
1000	53.3	39.5
1250	55.1	40.9
1600	56.2	38.2
2000	56.3	35.8
2500	55.5	31.1
3150	56.9	31.2
R_w	45	37
C	-2	-2

SeaRox SL 620, 60/25 mm GW 200 plus tape

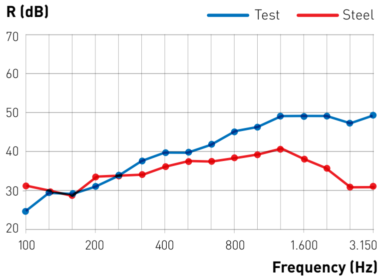


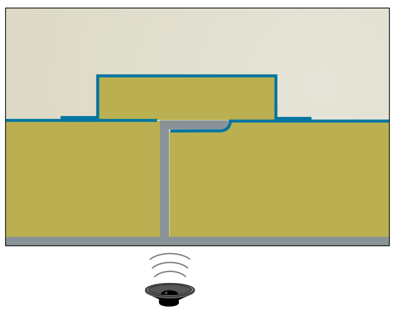


12

	Test	Steel
Hz	dB	dB
100	26.0	31.7
125	30.1	30.2
160	30.1	29.2
200	32.0	33.9
250	34.7	34.1
315	38.5	34.3
400	40.3	36.6
500	40.6	38.0
630	42.4	37.8
800	45.7	38.7
1000	47.0	39.5
1250	49.5	40.9
1600	49.6	38.2
2000	49.6	35.8
2500	47.8	31.1
3150	49.8	31.2
R_w	46	37
C	-3	-2

SeaRox SL 620 ALU, 60/25 mm

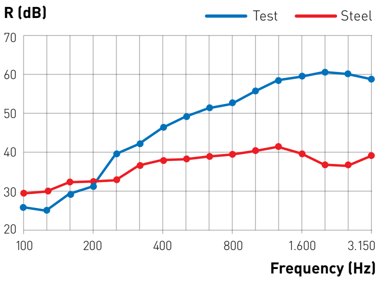


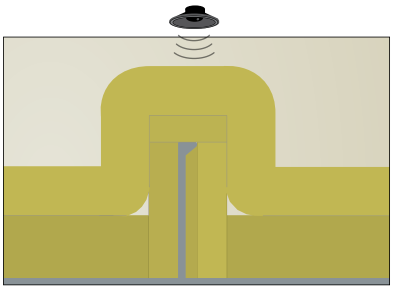


13

	Test	Steel
Hz	dB	dB
100	26.2	29.7
125	25.3	30.2
160	29.6	32.6
200	31.5	32.8
250	39.8	33.1
315	42.4	36.9
400	46.5	38.3
500	49.4	38.5
630	51.6	39.2
800	52.7	39.7
1000	55.9	40.6
1250	58.8	41.7
1600	59.7	40.0
2000	60.9	37.1
2500	60.4	36.8
3150	59.1	39.3
R_w	49	39
C	-1	-3

SeaRox SL 640, 65 mm
SeaRox WM 640, 30 mm
SeaRox SL 720, 50 mm

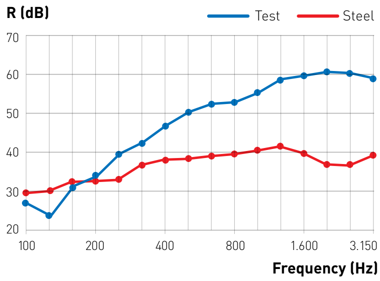


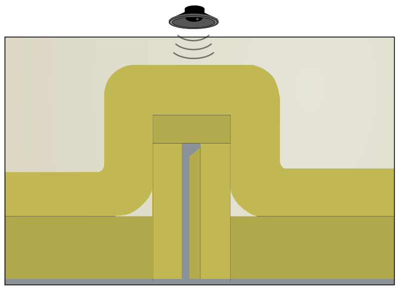


14

	Test	Steel
Hz	dB	dB
100	27.0	29.7
125	23.9	30.2
160	31.6	32.6
200	34.1	32.8
250	39.9	33.1
315	42.8	36.9
400	47.1	38.3
500	50.6	38.5
630	52.7	39.2
800	53.1	39.7
1000	55.5	40.6
1250	59.0	41.7
1600	59.9	40.0
2000	60.9	37.1
2500	60.6	36.8
3150	59.3	39.3
R_w	49	39
C	-1	-3

SeaRox SL 640, 65 mm
SeaRox WM 640, 30 mm
SeaRox MA 720 ALU, 50 mm

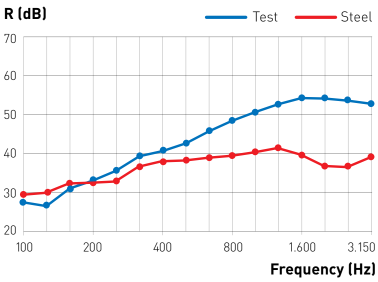


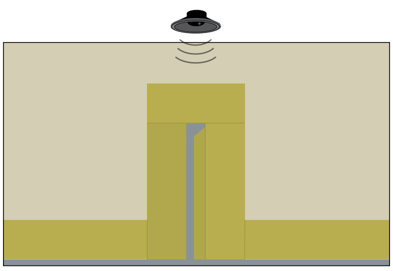


15

	Test	Steel
Hz	dB	dB
100	28.1	29.7
125	27.5	30.2
160	31.8	32.6
200	32.1	32.8
250	35.2	33.1
315	39.8	36.9
400	41.9	38.3
500	43.0	38.5
630	46.4	39.2
800	48.4	39.7
1000	51.2	40.6
1250	53.7	41.7
1600	54.5	40.0
2000	54.4	37.1
2500	54.1	36.8
3150	53.7	39.3
R_w	47	39
C	-1	-2

SeaRox SL 620,
40 mm/ 40 mm

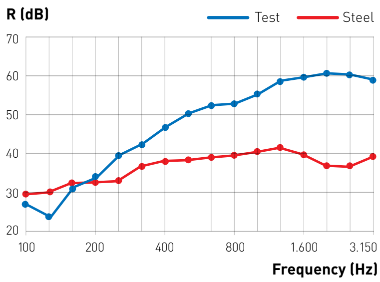


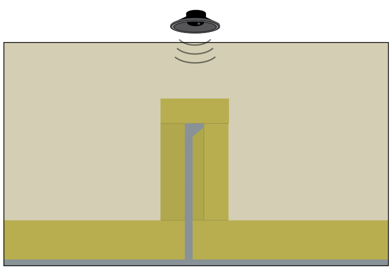


16

	Test	Steel
Hz	dB	dB
100	28.0	29.7
125	27.3	30.2
160	30.7	32.6
200	31.1	32.8
250	34.4	33.1
315	38.9	36.9
400	41.1	38.3
500	42.9	38.5
630	46.1	39.2
800	47.4	39.7
1000	50.4	40.6
1250	53.5	41.7
1600	53.6	40.0
2000	53.6	37.1
2500	53.5	36.8
3150	53.5	39.3
R_w	46	39
C	-1	-2

SeaRox SL 620,
40 mm/ 25 mm

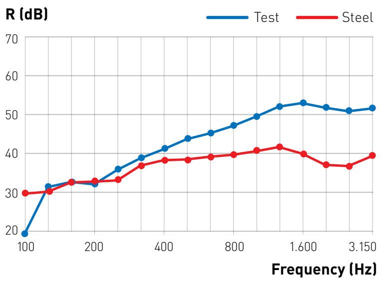


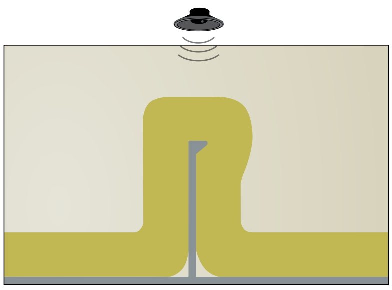


17

	Test	Steel
Hz	dB	dB
100	19.4	29.7
125	31.4	30.2
160	32.7	32.6
200	32.1	32.8
250	35.8	33.1
315	38.8	36.9
400	41.1	38.3
500	43.7	38.5
630	45.2	39.2
800	47.1	39.7
1000	49.5	40.6
1250	52.1	41.7
1600	53.0	40.0
2000	51.8	37.1
2500	50.9	36.8
3150	51.6	39.3
R_w	46	39
C	-1	-2

SeaRox WM 620, 45 mm

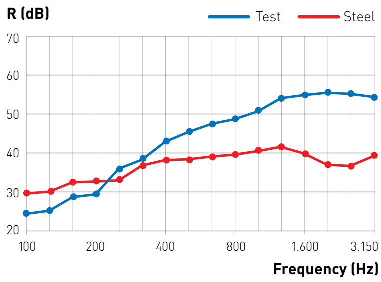


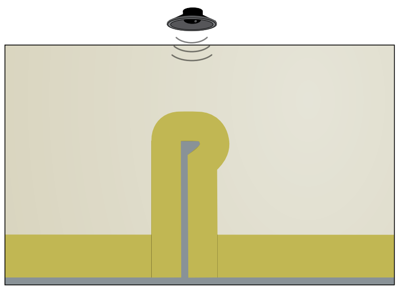


18

	Test	Steel
Hz	dB	dB
100	24.5	29.7
125	25.3	30.2
160	28.8	32.6
200	29.5	32.8
250	36.1	33.1
315	38.4	36.9
400	43.0	38.3
500	45.5	38.5
630	47.6	39.2
800	48.8	39.7
1000	50.8	40.6
1250	54.2	41.7
1600	55.0	40.0
2000	55.6	37.1
2500	55.3	36.8
3150	54.5	39.3
R_w	46	39
C	-1	-2

SeaRox SL 640, 45 mm
SeaRox WM 640, 30 mm

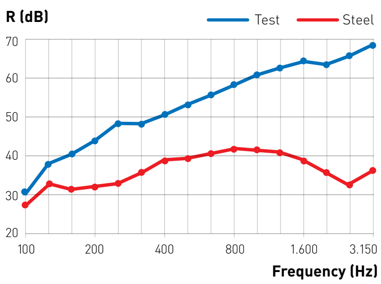


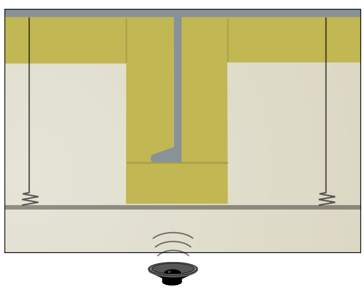


19

	Test	Steel
Hz	dB	dB
100	30.0	27.0
125	38.6	32.7
160	40.8	31.3
200	44.2	32.0
250	48.8	32.8
315	48.6	35.4
400	50.9	39.1
500	53.5	39.5
630	56.1	40.9
800	58.6	42.1
1000	61.3	41.7
1250	63.1	41.3
1600	64.8	39.2
2000	64.1	35.8
2500	65.9	32.7
3150	68.7	36.0
R_w	56	39
C	-2	-2

SeaRox SL 640, 40 mm with 1 mm steel sheet

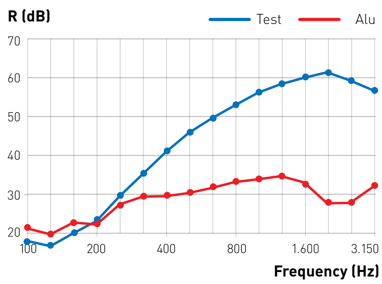


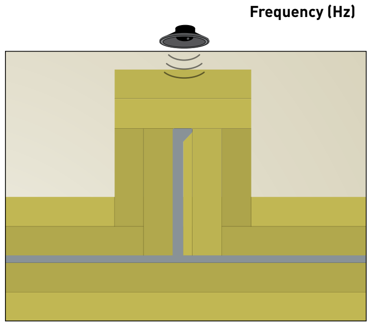


20

	Test	Steel
Hz	dB	dB
100	18.1	21.3
125	16.8	19.8
160	20.1	22.8
200	23.2	22.3
250	29.5	27.4
315	35.1	29.4
400	40.7	29.5
500	45.6	30.3
630	49.3	31.6
800	52.6	33.1
1000	55.8	33.8
1250	58.0	34.6
1600	59.6	33.0
2000	61.0	27.7
2500	58.9	27.8
3150	56.4	31.9
R_w	40	32
C	-2	-3

SeaRox SL 620, 2 x 30 mm on both sides/ 2 x 30 mm

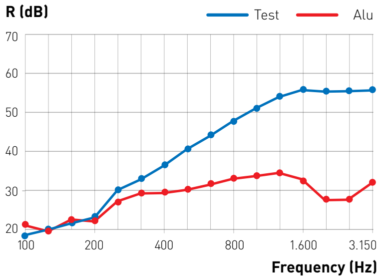


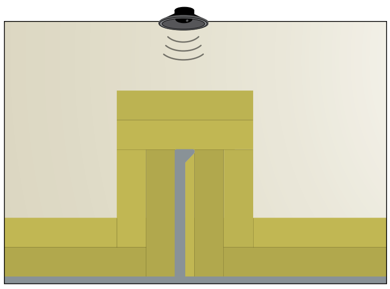


21

	Test	Steel
Hz	dB	dB
100	18.5	21.3
125	19.9	19.8
160	21.5	22.8
200	23.0	22.3
250	30.0	27.4
315	32.7	29.4
400	36.2	29.5
500	40.4	30.3
630	43.8	31.6
800	47.6	33.1
1000	50.9	33.8
1250	53.8	34.6
1600	55.6	33.0
2000	55.2	27.7
2500	55.3	27.8
3150	55.5	31.9
R_w	40	32
C	-2	-2

SeaRox SL 620, 2 x 30 mm/ 2 x 30 mm

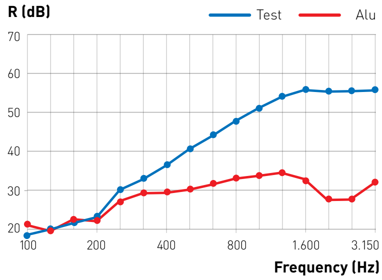


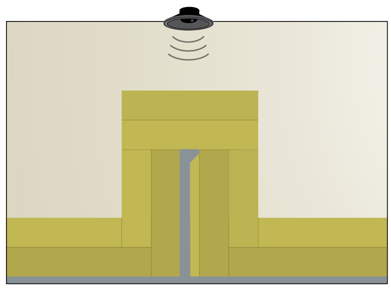


22

	Test	Steel
Hz	dB	dB
100	18.5	21.3
125	19.9	19.8
160	21.5	22.8
200	23.0	22.3
250	30.0	27.4
315	32.7	29.4
400	36.2	29.5
500	40.4	30.3
630	43.8	31.6
800	47.6	33.1
1000	50.9	33.8
1250	53.8	34.6
1600	55.6	33.0
2000	55.2	27.7
2500	55.3	27.8
3150	55.5	31.9
R_w	40	32
C	-2	-2

SeaRox SL 620, 2 x 30 mm/ 2 x 30 mm

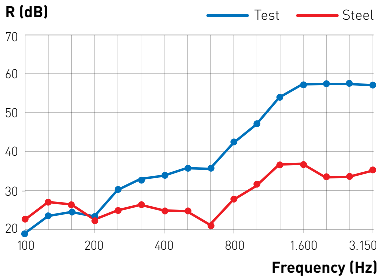


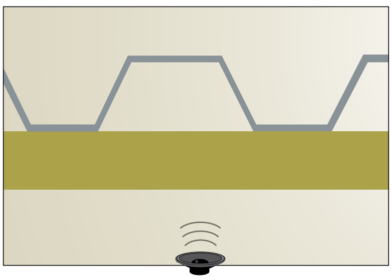


23

	Test	Steel
Hz	dB	dB
100	19.4	22.8
125	23.7	27.2
160	24.7	26.6
200	23.6	22.8
250	30.2	25.1
315	33.0	26.5
400	33.8	25.1
500	35.7	24.9
630	35.5	21.5
800	41.9	27.7
1000	46.6	31.2
1250	53.4	36.6
1600	56.7	36.8
2000	56.8	33.4
2500	56.8	33.5
3150	56.5	35.0
R_w	40	30
S	-1	-2

SeaRox SL 620, 60 mm

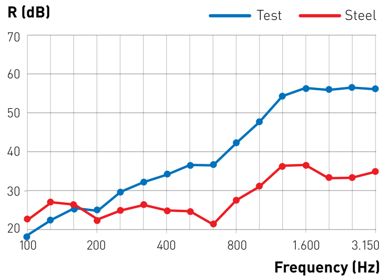


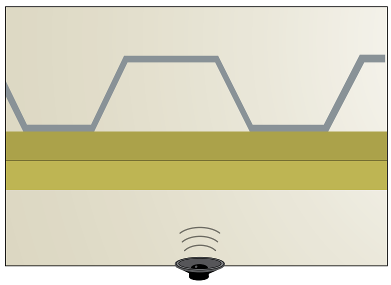


24

	Test	Steel
Hz	dB	dB
100	18.9	22.8
125	22.7	27.2
160	25.7	26.6
200	25.0	22.8
250	29.9	25.1
315	32.4	26.5
400	34.3	25.1
500	36.8	24.9
630	36.7	21.5
800	42.4	27.7
1000	47.8	31.2
1250	54.5	36.6
1600	56.6	36.8
2000	56.1	33.4
2500	56.7	33.5
3150	56.3	35.0
R_w	40	30
S	-1	-1

SeaRox SL 640, 2 x 30 mm

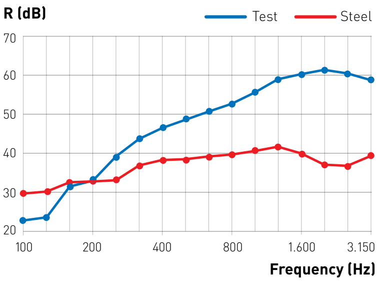


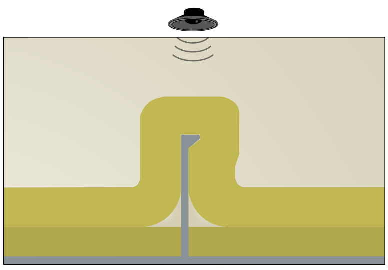


25

	Test	Steel
Hz	dB	dB
100	22.8	29.7
125	23.6	30.2
160	31.5	32.6
200	33.0	32.8
250	39.2	33.1
315	43.7	36.9
400	46.5	38.3
500	48.6	38.5
630	50.7	39.2
800	52.7	39.7
1000	55.6	40.6
1250	59.0	41.7
1600	60.3	40.0
2000	61.4	37.1
2500	60.5	36.8
3150	58.8	39.3
R_w	48	39
C	-1	-3

SeaRox SL 660, 30 mm & SeaRox WM 660, 40 mm

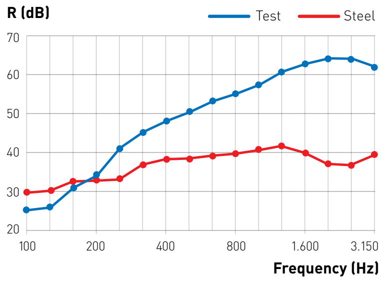


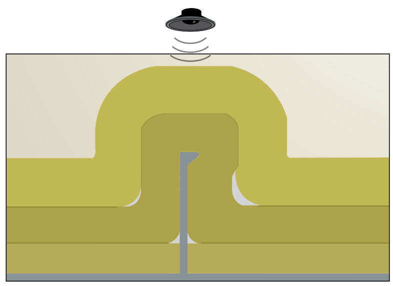


26

	Test	Steel
Hz	dB	dB
100	25.0	29.7
125	25.7	30.2
160	30.8	32.6
200	33.9	32.8
250	41.0	33.1
315	45.1	36.9
400	47.9	38.3
500	50.2	38.5
630	53.0	39.2
800	54.9	39.7
1000	57.2	40.6
1250	60.6	41.7
1600	62.6	40.0
2000	64.0	37.1
2500	63.9	36.8
3150	61.8	39.3
R_w	50	39
C	-1	-3

SeaRox SL 660, 30 mm SeaRox WM 660, 40 mm SeaRox SL 720, 50 mm

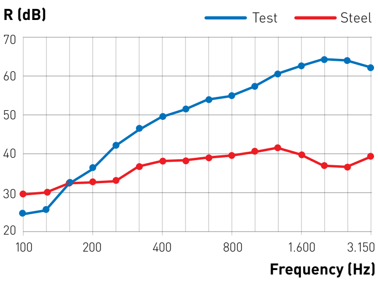


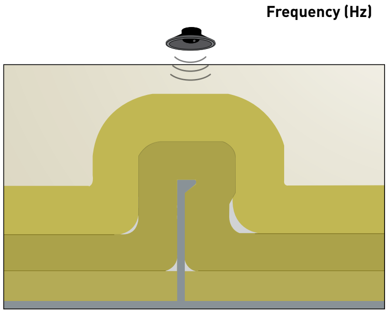


27

	Test	Steel
Hz	dB	dB
100	24.4	29.7
125	25.4	30.2
160	32.2	32.6
200	35.9	32.8
250	41.9	33.1
315	46.0	36.9
400	49.4	38.3
500	51.3	38.5
630	53.9	39.2
800	54.8	39.7
1000	57.2	40.6
1250	60.5	41.7
1600	62.5	40.0
2000	64.3	37.1
2500	64.0	36.8
3150	62.3	39.3
R_w	51	39
C	-1	-4

SeaRox SL 660, 30 mm & SeaRox WM 660, 40 mm & SeaRox MA 720 ALU, 50 mm

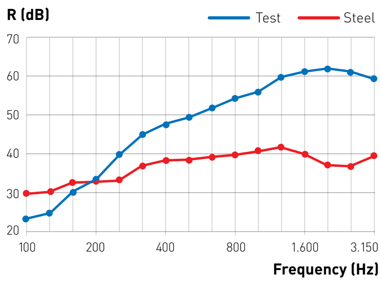


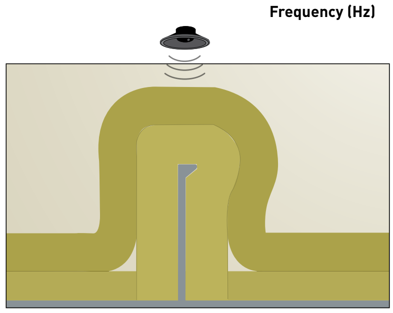


28

	Test	Steel
Hz	dB	dB
100	23.3	29.7
125	24.7	30.2
160	30.3	32.6
200	33.4	32.8
250	39.7	33.1
315	44.9	36.9
400	47.7	38.3
500	49.3	38.5
630	51.7	39.2
800	54.2	39.7
1000	55.9	40.6
1250	59.7	41.7
1600	61.1	40.0
2000	61.9	37.1
2500	61.1	36.8
3150	59.2	39.3
R_w	49	39
C	-1	-3

SeaRox SL 660, 30 mm & SeaRox WM 660, 40 mm/2 x 40 mm

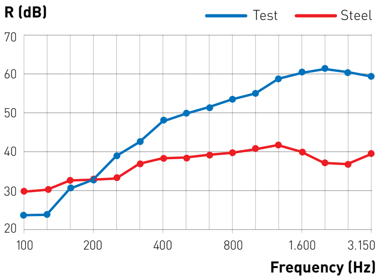


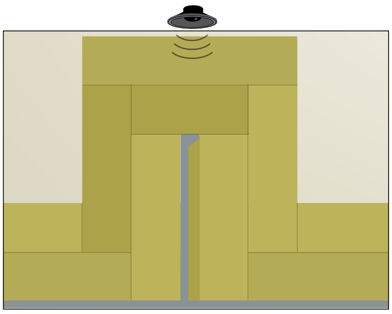


29

	Test	Steel
Hz	dB	dB
100	23.6	29.7
125	23.7	30.2
160	30.4	32.6
200	32.7	32.8
250	38.8	33.1
315	42.4	36.9
400	47.7	38.3
500	49.7	38.5
630	51.4	39.2
800	53.4	39.7
1000	54.9	40.6
1250	58.7	41.7
1600	60.2	40.0
2000	61.2	37.1
2500	60.4	36.8
3150	59.3	39.3
R_w	48	39
C	-1	-3

SeaRox SL 660, 2 x 50 mm

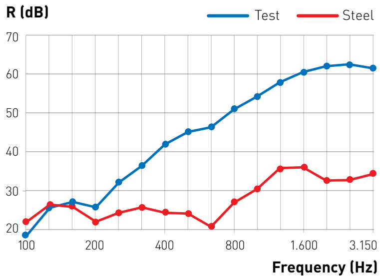


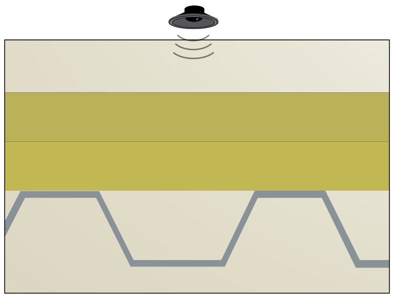


30

	Test	Steel
Hz	dB	dB
100	19.3	22.8
125	26.4	27.2
160	27.9	26.6
200	26.5	22.8
250	32.9	25.1
315	37.2	26.5
400	42.7	25.1
500	45.9	24.9
630	47.1	21.5
800	51.7	27.7
1000	55.0	31.2
1250	58.7	36.6
1600	61.3	36.8
2000	62.8	33.4
2500	63.3	33.5
3150	62.3	35.0
R_w	44	30
C	-1	-2

SeaRox SL 660, 50 mm & SeaRox WM 660, 40 mm

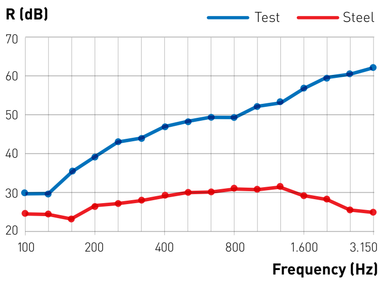


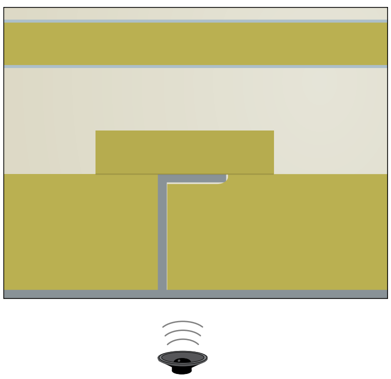


31

	Test	Steel
Hz	dB	dB
100	36.6	29.4
125	36.4	29.2
160	43.9	27.9
200	48.9	32.5
250	53.9	33.0
315	55.3	34.1
400	59.2	35.5
500	61.0	36.7
630	62.6	37.0
800	62.4	38.0
1000	66.1	37.9
1250	67.3	38.8
1600	72.2	35.9
2000	76.2	34.5
2500	77.2	31.0
3150	79.4	30.1
R_w	62	36
S	-4	-2

SeaRox SL 740, 50/25 mm strips on L-profiles and 25 mm panel

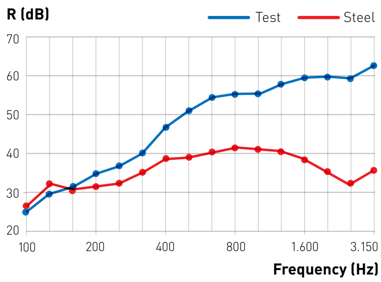


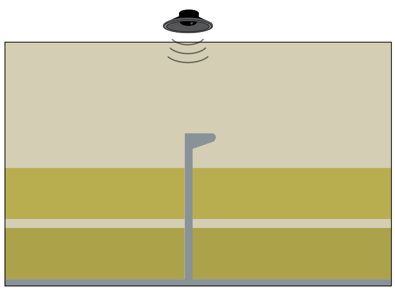


32

	Test	Steel
Hz	dB	dB
100	25.4	27.0
125	30.1	32.7
160	32.1	31.3
200	35.1	32.0
250	37.2	32.8
315	40.4	35.4
400	47.1	39.1
500	51.2	39.5
630	54.9	40.9
800	55.8	42.1
1000	56.0	41.7
1250	58.3	41.3
1600	60.1	39.2
2000	60.2	35.8
2500	59.6	32.7
3150	62.9	36.0
R_w	49	39
S	-2	-2

SeaRox SL 340, 2 x 50 mm with 5-10 mm air gap





Appendix II

21.0 Rules & regulations

Overall seen the marine and offshore world of rules & regulations is quite complex. It can be necessary to investigate a large range of documents to ensure fulfilment of rules, but at the same time many of the requirements are actually basic regulations.

Most rules within noise only look at simple sound energy levels and not further parameters, i.e. reverberation, which could aid the "sound wellness"

The challenge is therefore to combine the rules & regulations with professional sound engineering and design.

Basic rules are given by IMO, but for many countries the national marine authorities add stronger regulations to ensure the health, safety and work environment for the crews.

For the marine vessels all Class Societies additionally have guidelines and comfort class'ing.

For offshore installations rules are mainly given by the national authorities, and these are in most countries the "Energy Departments".

On top of these we look at customer specifications, especially from large cruise line companies, major oil companies and common industry guidelines.

Please find below a listing of examples of rules and guidelines.

- SOLAS II-1 reg 36
- HSC 2000 Code, Chp 10.4
- IMO Res A.468(XII) Code on Noise Levels on Board Ships
- NORSOK S-002 Working environment aug2004
- Danish Energy Authority - Noise Guide bekg54 jan06
- NORSOK C-002 Architectural Components and Equipment 1997-11-02
- Norway Marine Authority - Work Enviroment
- Class Societies (DNV, LR, ABS, BV...) Comfort Class
- Lloyd's Register Provisional Rules on Noise Comfort Class
- DNV Tentative rules for classification of ships, 2005
- GL Harmony Class - Rules on rating noise and vibration for comfort, Cruise ships, 2003
- BV Service notations - comfort onboard, 2000
- ABS Guide for crew habitability on ships, 2001
- RINA Rules for the evaluation of noise and vibration comfort on board passenger ships, 1999
- National Environmental Authorities

Our engineers will be available for further assistance.

22.0 Test standards

A range of international agreed methods of testing is used today. A few is targeted at marine and offshore but the far most of them are general ISO standards used all over.

A selection of some of the standards used:

Marine Measurements	
ISO_2923-1997 + ISO_2923_Cor	Measurements of noise onboard vessels

Sound Insulation	
ISO 140	Acoustics – Measurement of sound insulation in buildings and of building elements
ISO 717-1	Acoustic - Rating of sound insulation in buildings and of building elements , airborne sound insulation
ASTM E90	Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions
ASTM E413	Classification for Rating Sound Insulation
ISO 15186	Acoustics - Measurement of sound insulation in buildings and of building elements using sound intensity
ISO 10848	Acoustics - Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms

Sound Absorption	
ISO 354	Acoustics – Measurements of sound absorption in a reverberation room
ISO 11654	Sound absorbers for use in building - Rating of sound absorption
ASTM C423	Standard test method for sound absorption and sound absorption coefficients by the reverberation room method
ISO 10534	Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes

Product Properties	
ISO 9052	Acoustics - Determination of dynamic stiffness
ISO 9053	Acoustics - Materials for acoustical applications - Determination of airflow resistance

Room Acoustic	
ISO 3382	Acoustics – Measurement of room acoustic parameters

23.0 Symbols & units

Symbol	Unit		Description
α	-	-	sound absorption coefficient
α_w	-	-	weighted sound absorption coefficient (acc. ISO 11654)
c	m/s	meter per sec.	speed of sound
f	Hz	Herz	frequency
f_{11}	Hz	Herz	first natural frequency of panel vibration
f_c	Hz	Herz	critical frequency
f_o	Hz	Herz	resonance frequency (e.g. of mass-spring-mass system)
I	W/m^2	Watt/square m.	sound intensity
λ	m	meter	wave length
L_A	dB	decibels	A-weighted sound pressure level
L_I	dB	decibels	sound intensity level
L_{lin}	dB	decibels	sound pressure level without frequency weighting
L_n	dB	decibel	normalized impact sound pressure level (normally in 1/3 octave bands)
L_p	dB	decibels	sound pressure level
SPL	dB	decibels	sound pressure level
L_w	dB	decibels	sound power level
p	Pa	pascals	sound pressure
P	W	watt	sound power
p_{ref}	Pa	pascals	reference sound pressure (= $20*10^{-6}$ Pa = 20 µPa)
P_{ref}	W	watt	reference sound power (= 10^{-12} W)
r	kg/m^3		density
R	dB	decibel	sound reduction index (normally in 1/3 octave bands)
R_w	dB	decibel	sound reduction index weighted acc. ISO 717
R_s	Pa*s/m		specific airflow resistance (definition acc. ISO 9053)
r_s	$Pa*s/m^2$	airflow resistivity	(definition acc. ISO 9053)
s'	N/m^3	newton per m^3	dynamic stiffness (definition acc. ISO 9052)
η	-	-	loss factor


COSCO

24.0 Web-links

Below a small selection of relevant web sites concerning marine noise.

- http://www.rockwool-rti.com
- http://www.lr-ods.com
- http://www.imo.org
- http://www.iacs.org.uk/explained/members.aspx
- http://www.bksv.com
- http://www.eaa-fenestra.org
- http://www.eaa-fenestra.org/links/mme
- http://www.i-ince.org
- http://www.icacommission.org
- http://www.astm.org

25.0 Textbook references

Acoustic literature

Leo L. Beranek
Acoustical Measurements, Acoustical Society of America, New York (1988)

István L. Vér and Leo L. Beranek
Noise and Vibration Control Engineering, John Wiley & Sons, Inc. (2006)

Heinrich Kuttruff
Room Acoustics, Applied Science Publishers, London (1973)

Z. Maekawa and P. Lord
Environmental and Architectural Acoustics, E & FN Spon, London (1993)

Absorption
Acoustical absorption is the energy transformation from acoustic energy (pressure waves) to thermal energy in a porous material like mineral wool.

Appendix III

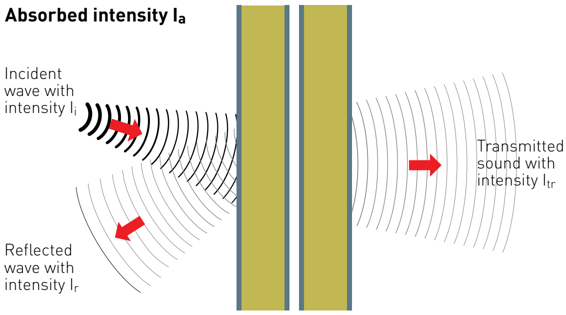
26.0 Dictionary

A

Absorption Coefficient α

The absorption coefficient α is a material property, which describes how well a material absorbs sound waves... α = 1 means 100% absorption, α = 0 means 100% reflection.

When building materials for inner boarding are chosen, the function of the room and the absorption coefficient of the boarding must be harmonized. A high absorption coefficient is not necessarily a good one – it depends on the function of the individual room. The absorption coefficient has an impact on reverberation time.



A measure of the sound-absorbing ability of a surface. It is defined as the fraction of incident sound energy absorbed or otherwise not reflected by a surface. Unless otherwise specified, a diffuse sound field is assumed. The values at the sound-absorption coefficient usually range from about 0.01 for marble slate to almost 1.0 for long absorbing wedges often used in anechoic rooms.

The sound absorption coefficient can be measured in 1/3 octave bands according to ISO 354 and weighted as α_w acc. to ISO 11654.

Acoustic impedance

The acoustic impedance Z (or sound impedance) is the ratio of sound pressure p to particle velocity v in a medium or acoustic component and is usually represented in complex notation as Z = R + iX. The real and imaginary components are called, respectively, acoustic resistance and acoustic reactance. See also characteristic impedance.

Airflow resistance

See specific airflow resistance.

Airflow resistivity

See specific airflow resistance.

Air absorption
Air absorption is usually neglected in calculations of reverberation times for auditoriums, but for large enclosures it may become significant. Air absorption is greater for high frequencies and is dependent upon air temperature and relative humidity.

In calculations of reverberation times the air absorption can be included by adding an equivalent absorption area for the sound attenuation by air as (acc. to EN 12354-6):

$A_{air} = 4*m * V$
V – room volume

	m in 10^{-3} Neper per metre, for octave bands with centre frequency in Hz						
	125	250	500	1k	2k	4k	8k
10 °C, 30% - 50% humidity	1.0	0.2	0.5	1.1	2.7	9.4	29.0
10 °C, 50% - 70% humidity	1.0	0.2	0.5	0.8	1.8	5.9	21.1
10 °C, 70% - 90% humidity	1.0	0.2	0.5	0.7	1.4	4.4	15.8
10 °C, 30% - 50% humidity	1.0	0.3	0.6	1.0	1.9	5.8	20.3
10 °C, 50% - 70% humidity	1.0	0.3	0.6	1.0	1.7	4.1	13.5
10 °C, 70% - 90% humidity	1.0	0.3	0.6	1.0	1.7	3.5	10.6

NOTE: These values are deduced from the tables with the atmosphenc-absorption attenuation coefficient in decibels per kilometre in ISO 9613-1 for 1/3 octave bands, by dividing the values in those Tables by 4.343 (=10 ig e). The values for the octave bands are those for the centre 1/3 octave band below 1 kHz and those for the lower 1/3 octave band above 1 kHz. The values are lineary averaged over the humidity within the indicated range.

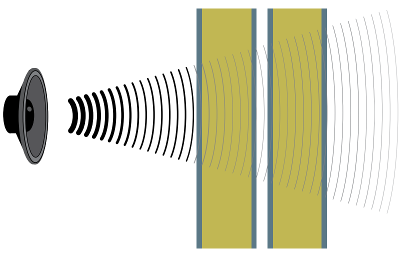
Example 1000 Hz: Room volume 500 m², Air at 20°C, 50% ⇒ m= 1*10-3 = 0.001
$A_{air,1000\ Hz}$ = 4*m*V = 4*0.001*500 = 2 m²

Airborne sound
Airborne sound is the sound propagation in air as pressure waves. The sound propagation in solid materials is called structure borne sound propagation.

Airborne sound insulation
The reduction of the sound intensity for a sound wave passing through a building element. (level difference for the incoming airborne sound wave and transmitted airborne sound wave).

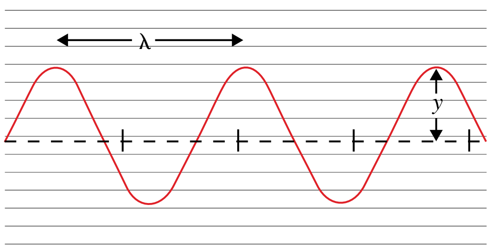
The sound insulation is normally expressed as the sound reduction index R.

R depends on the frequency of the sound passing through the element and is measured in 1/3 octave bands.



Ambient noise
The composite of airborne sound from many sources near and far associated with a given environment. No particular sound is singled out for interest.

Amplitude
The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.



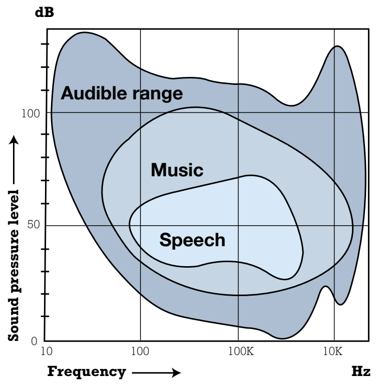
Anechoic Chamber
An anechoic chamber is a room where there is no reverberation and no echo. An acoustic space without echo or reverberation. Often used for the acoustic testing (e.g. microphones and loudspeakers) or sound recordings without any reflections for use in auralization examples.

ASTM E90 - Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions
This test method covers the laboratory measurement of airborne sound transmission loss of building partitions such as walls of all kinds, operable partitions, floor-ceiling assemblies, doors, windows, roofs, panels, and other space-dividing elements.

ASTM E413 - Classification for Rating Sound Insulation
The STC value (Sound Transmission Class) is calculated from 125Hz to 4000 Hz. The Weighted Sound Reduction Index (Rw) is the ISO equivalent of STC. It is determined in accordance with ISO 717, Rating of Sound Insulation in Buildings and of Building Elements. The reference contour extends from 100 to 3150 Hz and there is no 8 dB rule. Usually STC and Rw are approximately equal.

ASTM C423
Standard test method for sound absorption and sound absorption coefficients by the reverberation room method Measurement of sound absorption coefficient a in a diffuse field (room methode) and calculation of the NRC value (Noise Reduction Coefficient)

Attenuation
When sound travels through a medium, its intensity diminishes with distance. This weakening in the energy of the wave results from two basic causes, scattering and absorption. The combined effect of scattering and absorption is called attenuation.



Audible frequency range

Audible frequency range
A human ear can normally perceive frequencies from 20 Hz to 20.000 Hz. This is called the audible frequency range.

Aural
Relating to the ear or to the sense of hearing.
From Latin auris, ear.

Auralization
Auralization is the process of rendering audible, by physical or mathematical modelling, the sound field of a source in a space, in such a way as to simulate the binaural listening experience at a given position in the modelled space. [Kleiner et al 1993].

A-weighting
A frequency-response adjustment of a sound measurement that conditions the output signal to an approximate human response (fits best to the human ear at a sound level of app. 40 ... 50 dB(A)).

The A – filter values [dB] in 1/1 octave bands from 31 HZ to 8 kHz are:

31 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

B

Background Noise
Background noise is a definition of all kinds of sound beyond the particular sound wanted.

Baffle
A flat board or plate, deflector, guide or similar device. In acoustics free installed baffles of absorbing material (e.g. mineral wool) can be used to control the room acoustics or can be mounted in a ventilation duct to attenuate airborne sound.

Bandwidth
The range of frequencies, expressed in Hertz (Hz), for the filters used for the frequency spectrum analysis. Often used bandwidth are 1/1 octave band or 1/3 octave band, but also 1/12 octave band.

Broadband noise
In the frequency domain, a broadband noise has a continuous spectrum - that is, energy is present at all frequencies in a given range. This type of sound is often referred to as noise because it usually lacks a discernible pitch. White noise and pink noise are typical broadband noises used for acoustic measurements.

C

Characteristic impedance
The characteristic impedance of a medium (usually air, but also for instance exhaust gases in a silencer) is the ratio of sound pressure p to particle velocity v in open field (i.e. in a condition of no reflecting waves). This impedance is a material constant and equals the product of the density of air ρ (rho) and the speed of sound c:

ρ (rho) = density of air in kg/m^3
c = speed of sound (acoustic wave velocity) in m/s
Note: Z_0 is expressed in Pa·s/m. Before the Pascal was introduced by the SI, impedance was expressed in N·s/m^3.
The characteristic acoustic impedance of air Z_0 equals:
410 Pa·s/m at a temperature of 25°C (77°F)
413 Pa·s/m at 20°C (68°F).
°C = degree Celsius and °F = degree Fahrenheit.

Clarity C80, C50 (dB)
The measurement of Clarity is the ratio of the energy in the early sound compared to that in the reverberant sound, expressed in dB. Early sound is what is heard in the first 80 msec (C50 - 50 msec) after the arrival of the direct sound. It is a measure of the degree to which the individual sounds stand apart from one another.

If the clarity is too low, the fast parts of the music are not "readable" anymore. C80 is a function of both the architectural and the stage set design. If there is no reverberation in a dead room, the music will be very clear and C80 will have a large positive value. If the reverberation is large, the music will be unclear and C80 will have a relatively high negative value. C80 becomes 0 dB, if the early and the reverberant sound is equal.

Often the values for 500Hz, 1000Hz and 2000Hz are averaged. This will be expressed by the symbol C80(3). For orchestral music a C80 of 0dB to -4dB is often preferred, but for rehearsals often conductors express satisfaction about a C80 of 1dB

to 5dB, because every detail can be heard. For singers, all values of clarity between +1 and +5 seem acceptable. C80 should be generally in the range of -4dB and +4dB. For speech, in comparison to music, the clarity will be measured as the ratio of the first 50 msec (C50) instead of 80 msec (C80) for music.

Critical frequency

In building acoustics (sound transmission) the frequency, where the sound of speed in air equals the propagation speed of bending waves in the partition. The main mechanism of sound transmission through the partition changes at the critical frequency. At this frequency the sound reduction index drops down drastically.

The critical frequency depends on the material type (bending stiffness) and thickness of the partition.

D

dB(A)

See under A-weighting.

dB, Decibel

The dB is a logarithmic unit (logarithm with base 10) used to describe a ratio. The ratio may be power, sound pressure, voltage or intensity or several other things. In acoustics the sound power P [in W] and the sound pressure p [in Pa] are expressed in dB values as ratio to a defined reference value:

Sound power level in dB

$$L_w = 10 \bullet \log \frac{P}{P_0} \qquad \text{reference value: } P_0 = 10^{-12\,W}$$

Sound pressure level in dB

$$L_P = 20 \bullet \log \frac{P}{P_0} \qquad P_0 = 20\mu Pa = 0.000020 Pa$$

Decay rate

At a stated frequency, time rate at which sound pressure level decreases in a room after the excitation has stopped. For a room with total diffuse sound field (reverberant room) the decay rate d is constant and is related to reverberation time T by T = 60 dB.

Directivity index, directivity factor

The directivity factor, Q, is defined as the ratio of the intensity (W/m^2) at some distance and angle from the source to the intensity at the same distance, if the total power from the source were radiated uniformly in all directions.

$$Q = \left(\frac{I_\theta}{I}\right) \qquad DI = 10 \bullet \log_{10} \left(\frac{I_\theta}{I}\right)$$

where Iq = Sound intensity at distance r and angle q from the source. I = Average sound intensity over a spherical surface at the distance r. And the directivity index (DI) is defined as:

Double construction
In building acoustics a partition consisting of two outer membranes and a cavity between, where the interactions between the outer membranes and the cavity determine the acoustic behaviour for the sound transmission. Normally the sound insulation increases by using absorbing material as Rockwool inside the cavity. The positive acoustic behaviour of a double construction with absorption is partly reduced by sound bridges (like steel frame in gypsum walls), which mechanically connects the two membranes. Typically used double constructions are lightweight partitions Marine Panels. Mathematically double constructions can be described as mass-spring-mass systems with the two membranes as mass and the cavity (compression of air) as the spring.

Dynamic range
The range between the maximum and minimum sound levels that a sound system can handle. It is usually expressed in decibels.

E

Early Decay Time EDT(s)
The Early Decay Time is measured in the same way as the reverberation time, except that it relates to the early part of the reverberation curve (0 to -10 dB). EDT is also called "Early reverberation time". The EDT can vary locally in a room much more than the reverberation time T20 or T30 and is therefore more used as a local parameter for a part of the room (e.g. the stage in a concert hall) and not as a global parameter for the whole room.

Echo
An echo is the delayed reflection of a sound, which is detected from the human ear independent of the direct sound. An echo can be very disturbing for the human ear and can make speech unintelligible.

Equivalent absorption area
The area of a surface multiplied with its absorption coefficient. The equivalent absorption area of an element differs with the frequency and is normally stated per octave band or 1/3 octave band. The total absorption area of a room is used to calculate the reverberation time acc. to Sabine's formula.

F

Filter
An acoustic filter passes or blocks components of sound of different frequencies. The passing components may be amplified or attenuated. Most used filters are:

Octave band filter: Only the desired frequency range inside the octave is transmitted, outside this range all frequencies are blocked.

dB(A)-filter: the different frequency components are attenuated (or amplified) according to the A-filter values (see dB(A)).

High-pass filter: All the low frequencies below the cut off frequencies are blocked.

Low-pass filter: All the high frequencies above the cut off frequencies are blocked.

Band pass filter: A combination of a high-pass and low-pass filter with different cut-off frequencies so that only a defined range of frequencies passes through the filter. Octave band filters and 1/3 octave band filters are typical band pass filters.

Flanking transmission
Flanking transmission occurs when sound is transmitted from one space to another indirectly, through adjoining parts of the structure. For example, impact sound may be transmitted from one room to another through a timber floor, but also through the supporting wall.

Flutter echo
In room acoustics, a series of specific reflective returns caused by large surfaces being parallel to each other.

Free field
A sound field whose boundaries exert a negligible influence on the sound waves. In a free-field environment, sound spreads spherically from a source and decreases in level at a rate of 6 dB per doubling of distance from a point source, and at a rate of 3 dB per doubling of distance from a line source. Free field conditions can be used as a reference situation for defining room acoustics parameters, e.g. Strength G

Frequency
Frequency is measured in Hertz [Hz] and is defined as the number of times an event is repeated per time unit. For example with sound it is the number of repeated waveforms per second.

Human hearing 20-20.000 Hz

G

Geometrical acoustics
Simulations based on geometrical acoustics rely on ray theory, i.e. the approximation that sound propagates between two points along straight, ray-like paths. Thus, an un-occluded linear path between a source and receiver is sufficient to model the direct sound, and specular reflections can be simulated by piecewise linear paths that obey Snell's Law when they encounter flat, reflecting surfaces.

H

Hard room
A hard room is defined as a room with surfaces which absorb a limited amount of sound waves. The surfaces will reflect a large part of the sound waves and the room is the opposite of an anechoic room. The average absorption coefficient may be about 0.1 or less.

Hearing loss
The difference between the level of sound that can just be heard by an individual with impaired hearing and a standard level that has been determined by averaging measurements from a group of young hearing people. It is usually expressed in decibels. The hearing loss is normally different at different frequencies.

People exposed to sound levels can get noise-induced temporary or permanent hearing loss. Sounds of less than 80 decibels, even after long exposure, are unlikely to cause hearing loss.

Helmholtz resonator:
A Helmholtz resonator is a device which is designed like a closed container with a small hole. It can be shaped like a cylinder or a kind of sphere. A normal bottle can be looked at as a Helmholtz resonator. The device is used in acoustics to trap sounds with low frequencies. It can be used as a passive noise control device.

Hertz
Hertz is the unit of frequency and is abbreviated Hz. See also frequency

Impact noise
In building acoustics noise generated by mechanical impact excitation like foot steps or hammer. According to ISO 140 impact noise transmitted in a building through the construction is measured using a standardized tapping machine. The measured sound pressure level Li in a room is called the impact sound pressure level and expressed as normalized impact sound pressure level Ln = Li + 10 log(A/10 m2) (A is the equivalent absorption area of the room). See also structure borne noise.

Impact sound transmission
Sound transmission of impact noise through the building elements. Impact sound transmission happens if something is dropped on the floor or even just when someone is walking on the floor. Impact noise can be transmitted as vibrations in the building elements over a long distance and be radiated to rooms far away and not directly adjacent to the source room.

Impulse response
Measured or calculated sound pressure signal (versus time) in a receiving point, when an impulse is emitted in a source point. Knowing the impulse response, all acoustic local parameters can be calculated. (e.g. reverberation time, speech intelligibility,). The impulse response indicates all reflections between source point and receiving point.

Insertion loss
Sound attenuation of an element which is inserted in a construction. E.g. the attenuation of airborne duct sound inside a ventilation duct using a ducted silencer. The insertion loss is often measured as the difference of noise level in a receiving point with and without the considered element.

Intelligibility
See speech intelligibility

ISO 140
Acoustics -- Measurement of sound insulation in buildings and of building elements
Part - 1 ... 18 - Definition of sound reduction index, impact noise and measurements (R, Dne, L)

Most relevant:
Part 3: Laboratory measurements of airborne sound insulation of building elements

Part 4: Field measurements of airborne sound insulation between rooms

Part 6: Laboratory measurements of impact sound insulation of floors

Part 7: Field measurements of impact sound insulation of floors

ISO 717
Acoustics - Rating of sound insulation in buildings and of building elements

Rw, (C, Ctr)

The Rw value (Weighted Sound Reduction Index) is calculated from 100 Hz to 3150 Hz based on results from e.g. ISO 140-3 measurements, different adaptation terms for extended frequency ranges and noise spectra available.

Ln,w

The Ln,w value (weighted normalized impact sound pressure level) is calculated from 100 Hz to 3150 Hz based on results from e.g. ISO 140-6 measurements

ISO 15186
Acoustics - Measurement of sound insulation in buildings and of building elements using sound intensity.

ISO 15186-3:2002 specifies a sound intensity method to determine the sound reduction index and the element-normalized level difference of building elements at low frequencies. This method has significantly better reproducibility in a typical test facility than those of ISO 140-3, ISO 140-10 and ISO 15186-1.

The results are more independent of the room dimensions of the laboratory and closer to values that would be measured between rooms of volume greater than 300 m3. ISO 15186-3 is applicable in the frequency range 50 Hz to 160 Hz but is mainly intended for the frequency range 50 Hz to 80 Hz.

The results found by the method of ISO 15186-3 can be combined with those of ISO 140-3 and ISO 15186-1 to produce data in the frequency range 50 Hz to 5 000 Hz.

ISO 10848
Acoustics - Laboratory measurement of the flanking transmission of airborne and impact sound between adjoining rooms.

ISO 10848-2:2006 applies to light elements such as suspended ceilings, access floors, light uninterrupted facades or floating floors. The transmission from one room to another can be simultaneous through the test element and via the plenum, if any. With measurements according to ISO 10848-2:2006, the total sound transmission is measured, and it is not possible to separate the two kinds of transmission.

ISO 10848-3:2006 applies to structurally connected light elements forming a T or X junction. The performance of the building components is expressed either as an overall quantity for the combination of elements and junction, or as the vibration reduction index of a junction.

ISO 354
Acoustics – Measurements of sound absorption in a reverberation room. Measurement of sound absorption coefficient in a diffuse field (room methode)

ISO 11654
Acoustics – Sound absorbers for use in buildings – Rating of sound absorption. Calculation of ap (octave band values) and aw (weighted sound absorption) and definition of sound absorption classes A ... E.

ISO 10534
Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes.

Specifies a method for the determination of the sound absorption coefficient, reflection factor, surface impedance or admittance of materials and objects. The values are determined by evaluation of the standing wave pattern of a plane wave in a tube, which is generated by the superposition of an incident sinusiodal plane wave with the plane wave reflected from the test object.

ISO 9052
Acoustics - Determination of dynamic stiffness.
Relates to the unit area of resilient materials with smooth surfaces, including mineral wool. Does not apply to loadings lower than 0,4 kPa or greater than 4 kPa, that is not for materials in wall linings and not for machinery foundations.

ISO 9053
Acoustics - Materials for acoustical applications -- Determination of airflow resistance

ISO 3382
Acoustics – Measurement of room acoustic parameters
ISO_2923-1997 +
ISO_2923_Cor Measurements of noise onboard vessels

K

kHz (kilo Hertz)
Unit for the frequency : 1 kHz = 1000 Hz

L

Lateral Energy Factor
LEF is a parameter that, somewhat simplified, describes how much early sound arrives from the sidewalls to a listener's position in relation to the sound that arrives late. This parameter is correlated to the subjective perception of spaciousness in a concert hall.

Lightweight partition walls
Internal walls usually formed from timber or metal studs with outer panels (gypsum, plywood) and a cavity filled with absorbing material (e.g. mineral wool) forming a acoustic double construction with high sound insulation properties. This can be compared to standard double marine panels.

Ln
Normalized sound pressure level for the impact noise in a room generated from a standardized tapping machine in another room.

M

Mass law
An approximation that describes the sound transmission loss TL (sound reduction index R) of a limp, flexible barrier in terms of mass density and frequency. For each doubling of the weight or frequency of a partition, mass law predicts a 6 dB increase in TL (or R).

For most building elements the mass law is a valid approximation only in a limited frequency range and other effects as the decrease of the sound reduction at the critical frequency has major influence on weighted values as Rw .

N

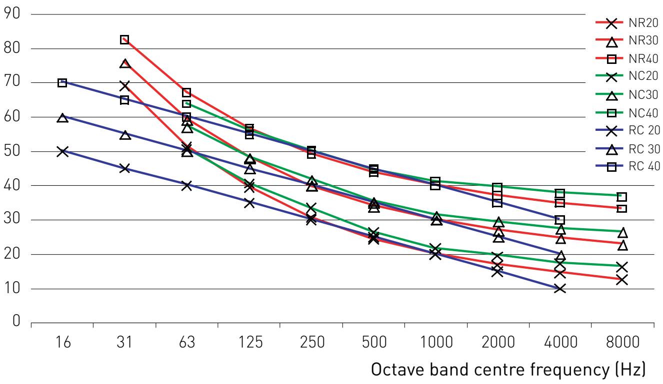
Noise
Noise is sound which is undesirable. It is any kind of sound and depends only on which sounds are wanted and which sounds are not. Noise interferes with the sound you wish to hear. The degree of noise depends on volume and frequency. See also broad band noise.

Noise rating
To define demands for the maximum sound pressure level for background noise like noise from HVAC components, different type of noise rating curves are defined:

NR curves – value of the curve is the SPL value at 1000 Hz
NC curves – value of the curve is the SPL value at 2000 Hz
RC curves (room criteria) – value of the curve is the SPL at 1000 Hz

A given background noise has to fulfil the requirements in all frequencies of the chosen noise rating curve.

Noise rating curves



Noise Reduction Coefficient
The Noise Reduction Coefficient NRC is the average sound absorption coefficient measured at four frequencies: 250, 500, 1,000 and 2,000 Hz expressed to the nearest integral multiple of 0.05.

O

Octave
In music, an octave (sometimes abbreviated 8ve or 8va) is the interval between one musical note and another with half or double the frequency. For example, if one note is pitched at 400 Hz, the note an octave above it is at 800 Hz, and the note an octave below is at 200 Hz. The ratio of frequencies of two notes an octave apart is therefore 2:1. Further octaves of a note occur at 2n times the frequency of that note (where n is an integer), such as 2, 4, 8, 16, etc. and the reciprocal of that series.

For example, 50 Hz and 400 Hz are one and two octaves away from 100 Hz because they are 1 / 2 (1 / 21) and 4 (22) times the frequency, respectively, however 300 Hz is not a whole number octave above 100 Hz, despite being a harmonic of 100 Hz.

Octave band
A frequency range with an upper limit that is twice the frequency of its lower limit. The audible frequency range is often divided into bands of frequencies because sound transmission through solid barriers can vary dramatically with the frequency of the sound. The broadest bandwidth commonly used is an octave. An octave is any band where the highest included frequency is exactly two times the lowest included frequency. For example, the frequency band that covers all frequencies between 707 Hz and 1,414 Hz is an octave band. The band is identified by its centre frequency, which is defined as the square root of the product of the highest and lowest frequency. In the above case the centre frequency is 1000 Hz. The entire frequency range of human hearing can be covered in the following 10 standard octave bands: 31 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, 8000 Hz, and 16000 Hz

One-third octave band
A frequency band that has a width (in Hz) that is only 1/3 of the width of an octave. It takes 31 one-third octave bands to cover the entire frequency range of human hearing. One-third octaves are used when octave band analysis does not provide adequate resolution in the frequency domain.

Overtone
A whole-number multiple of the fundamental frequency of a tone. The overtones (also called harmonics; 1st overtone is 2nd harmonic) define the harmonic spectrum of a sound. E.g. a fan with a rotating frequency of 45 Hz (= 60*45 = 2700 rpm) can generate vibrations at 45 Hz and overtones in 90,135, 180 Hz.

P

Peak level
The maximum instantaneous amplitude of the wave (e.g. sound pressure).

Phon
The phon is a unit of perceived loudness, which is a subjective measure of the strength (not intensity) of a sound. The phon value of a given sound is the sound pressure level in dB of a 1000 Hz sound, which is perceived as loud as the given sound. E.g. if a given sound is perceived to be as loud as a 60 dB sound at 1000 Hz, then it is said to have a loudness of 60 phons.

Pink noise
Pink noise is a noise containing equal power per octave band.

Plenum
In suspended ceiling construction, the space between the suspended ceiling and the main structure above or analogue for a raised floor the space between raised floor and main construction. The acoustic properties of the plenum influence the sound propagation in the building and the room acoustics in the room.

Porous absorption
Sound absorption in a porous material like Rockwool wool caused by friction between air movement and the material (e.g. fibres). Other forms of absorption can be based on wave interference in Helmholz absorbers or membrane absorbers.

Pure tone
A pure tone is a sound which only contains one single frequency, the wave form is a simple sine wave (sine tone).

R

Rapid Speech Transmission Index RASTI
Rapid Speech Transmission Index RASTI is a measure for the speech intelligibility like STI. The measurement method for RASTI uses a limited frequency range compared with the STI method.

RC (Room Criteria) curves
Noise rating curves used mainly in the USA to evaluate background noise from e.g. HVAC components.

Reflection
Reflection occurs when a sound wave hits a surface which has a low absorption coefficient. The sound wave is reflected by the surface and returns into the room.

Resonance
The condition that results when a system is acted upon by a periodic driving force the frequency of which coincides with one of the natural frequencies of the system. The steady-state amplitude of the system, for fixed amplitude of the driving force, is a local maximum at a resonance frequency.

Resonance frequency
The frequency at which any system vibrates naturally when excited by a stimulus. A tuning fork, for example, resonates at a specific frequency when struck. In building acoustics the resonance of the mass-spring-mass system for a double construction reduces the sound insulation of this construction at this frequency. See also Resonance.

Reverberant sound field (diffuse sound field)
A sound field made of reflected sounds in which the time average of the mean square sound pressure is everywhere the same and the flow of energy in all directions is equally probable. This requires a room with hard surfaces with very low absorption coefficients like a reverberation room for acoustic measurements.

Reverberation
Reverberation is an expression of the fact that a sound continues after the sound source has stopped. See reverberation time.

Reverberation time
Reverberation time is a measurement used in acoustic design. It is defined as the length of time taken for a sound to decay 60 dB after the source has stopped. Some times, the reverberation time is called T20 – indicating that the 60 dB decay time is extrapolated from the decay -5 dB to -25 dB or T30, extrapolated from the decay -5 dB to -35 dB.

R_w. R'_w: weighted sound reduction index, dB
A single-number rating of the sound reduction through a wall or other building element. Since the sound reduction may be different at different frequencies, test measurements are subjected to a standard procedure which yields a single number that is about equal to the average sound reduction in the middle of the human hearing range. The weighting procedure is standardized in ISO 717-1 for the sound reduction of airborne noise.

R'_w (dB) is the weighted apparent sound reduction index in a building, including flanking sound transmission.

R_w is the laboratory value for the weighted sound reduction without flanking transmission.

Room acoustics
Room acoustics describes how sound behaves in an enclosed space. Deals with the sound propagation inside a room (sound absorption and reflection on surfaces, absorption in air). Important parameters are reverberation time, echoes and speech intelligibility.

S

Sabine
The originator of the Sabine reverberation equation. Wallace Clement Sabine, a founder of modern architectural acoustics (1868-1919). Developed a relationship between reverberation time and the amount of acoustic absorption in a room. Designed Boston Symphony Hall, considered being one of the best concert halls in the world.

Sine wave
The simplest form of periodic wave motion, expressed by the equation y = sin x, where x is degrees and y is voltage or sound pressure level. All other forms can be created by adding (mixing) a number of sine waves. The wave form of a "Pure tone" is a sine wave.

Sound
A pressure fluctuation, usually in the range of audible frequencies, resulting from a displacement of a gas, liquid, or solid, that can be detected by a mechanical or electromechanical transducer (e.g., a barometer, microphone, or the human ear). Sound propagation as sound waves in gas or liquids or vibrations in solid materials.

Sound absorption
Sound absorption is a material property which describes how well sound waves are absorbed in a material. When a sound wave is absorbed, it simply means that the sound wave is transferred into another kind of energy i.e. heat. See also sound absorption coefficient.

Sound absorption coefficient
See absorption coefficient

Sound attenuation
The reduction in the intensity or the sound pressure level of sound, which is transmitted from one point to another.

Sound bridge
Analogue to thermal bridges in heat insulation constructions sound bridges transmit sound energy as structure borne sound between two part of a construction, which (besides the sound bridges) are not mechanically connected. Typical example in building acoustics is the steel studs in double wall constructions (e.g. gypsum wall). Sound bridges can reduce the sound insulation with many dB's and be the main transmission path for sound transmission.

Sound insulation
The reduction of sound transmission through a building element.

Sound insulation material: Special material increasing the sound insulation of a construction as e.g. Rockwool.

Sound intensity
Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered. Unit, watt per square meter (W/m{sup 2}); symbol, I.

Sound intensity level LI
Sound intensity I expressed as dB value

LI = 10*log(I/Io) dB

The reference value Io = 10-12 W/m2 is defined so that the sound pressure level and the sound intensity level in propagation direction in a free sound field have the same dB values.

Sound power
The acoustic energy in W emitted from a sound source or transmitted through a defined transmission path (e.g. a duct).

Sound power level
The sound power expressed in dB
Sound power level in dB

Sound pressure
Sound pressure p (or acoustic pressure) is the measurement in Pascals of the root mean square (RMS) pressure deviation (from atmospheric pressure) caused by a sound wave passing through a fixed point. The symbol for pressure is the lower case p. The upper case P is the symbol for power. This is often misprinted. The unit is Pa = Pascals.

$$L_w = 10 \bullet \log \frac{P}{P_0} \qquad \text{reference value: } P_0 = 10^{-12\,W}$$

Sound pressure level (SPL)
The sound pressure level is the sound pressure p expressed as dB value:

The reference value po corresponds to the average hearing threshold for the human ear.

$L_P = 20 \bullet \log \frac{P}{P_0} \qquad P_0 = 20\mu Pa = 0.000020Pa$

Sound reflection
See reflection

Sound reduction index R
See also: $R_w \cdot R'_w$:weighted sound reduction index, dB. Acoustic property of a bulkhead / deck (partition) for reduction of air borne noise.

Sound Transmission Class (STC)
A single number rating according to ASTM E413 Classification for Rating sound insulation of the sound transmission loss (sound reduction) similar to the Rw weighting acc. to ISO 717. The STC includes frequencies from 125 Hz to 4000 Hz, the Rw from 100 Hz to 3150 Hz.

Sound transmission coefficient, r
[dimensionless]---of a partition, in a specified frequency band, the fraction of the airborne sound power incident on the partition that is transmitted by the partition and radiated on the other side.

Sound waves
See sound

Specific airflow resistance Rs
According to ISO 9053 the quotient of the air pressure difference across the specimen divided by the linear velocity, measured outside the specimen, of airflow through the specimen.

For a homogeneous material the quotient of the specific airflow resistance divided by its thickness is called the airflow resistivity r.

The airflow resistance is a main product property of porous materials influencing the sound absorption in the material.

Spectrum
In mathematics, physics and signal processing, the frequency spectrum is a representation of a signal or other function in terms of frequency (in the "frequency domain").

In audio, the frequency range is basically 20 Hz to 20,000 Hz. The frequency spectrum sometimes refers to the distribution of these frequencies. For example, bass-heavy sounds have a large frequency content in the low end (20 Hz - 200 Hz) of the spectrum.

E.g. the spectrum of background noise can be described in octave bands.

Speech intelligibility
A measure of the intelligibility of speech that indicates the ease of understanding speech. It is a complex function of psychoacoustics, signal-to-noise ratio of the sound source, and direct-to-reverberant energy within the listening environment. The intelligibility of speech (usually measured in the presence of noise or distortion) can be measured as Speech Transmission Index STI.

Speech Transmission Index - STI (%)
The measurement method for STI includes frequencies from 125-8000 Hz and results in a value between 0 and 1 which can be interpreted according to following subjective scale. The STI is a local parameter measured between a single speaker point and a single receiver point.

Subjective scale	STI value
Bad	0.00 - 0.30
Poor	0.30 - 0.45
Fair	0.45 - 0.60
Good	0.60 - 0.75
Excellent	0.75 - 1.00

Speed of sound
(Also velocity of sound.) Usually taken as the mean value of the phase speed of an acoustic (or sound) wave. In an ideal, stationary gas the speed of sound c is a thermodynamic property depending only on the equilibrium state of the gas and is given by where is the ratio of specific heat capacities, at constant pressure and volume, respectively; R is the gas constant; and T is absolute temperature.

For normal air, for t = 20°C ⇒ c ≈ 340 m/s

In water the speed is about 1500 m/s. In solid materials the sound propagation depends on the wave form. For longitudinal waves the speed in m/s is about:

- Glass 5,500-6,000
- Aluminium, Steel 5,100
- Wood 3,400-4,500
- Concrete 4,000
- Brick 3,600
- Ice 3,100
- Water 1,500
- Mineral Wool 180

W

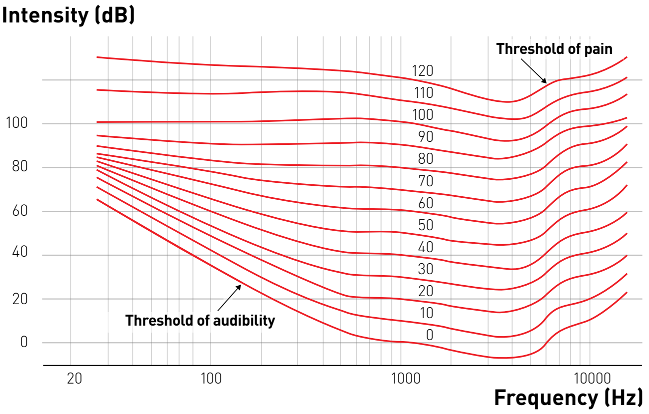
Standing waves
A resonance condition in an enclosed space in which sound waves travelling in one direction interact with the reflections on hard walls travelling in the opposite direction, resulting in a stable condition as a standing wave. Standing waves in a room are characterized by sound pressure maxima in a distance of half a wave length.

Structure borne sound / noise
As a result of airborne or impact excitation the building constructions are vibrating. The machines standing on or attached to the building constructions cause also vibration of the constructions. The components of vibration in the range of audible sound are called the structure borne sound. Generally they are the propagation of different forms of waves (bending, longitudinal, transversal, etc.), that is the vibrations are also propagating. They reach even rooms where there is no sound source operating. The normal component of the vibrations to the surface of the building constructions is responsible for sound radiation.

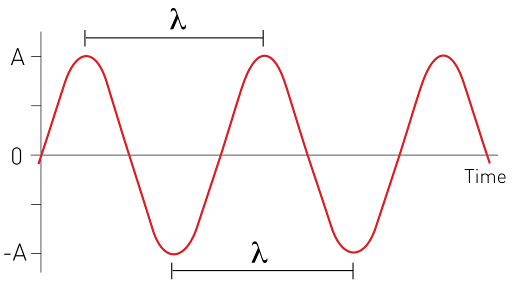
T

Threshold of hearing
The threshold of hearing is the sound pressure level SPL of 20 μPa (microPascals) = 2x10-5 Pascal (Pa). This low threshold of amplitude (strength or sound pressure level) is frequency dependent. See the frequency curve in Fig. 2. The absolute threshold of hearing (ATH) is the minimum amplitude (level or strength) of a pure tone that the average ear with normal hearing can hear in a noiseless environment.

The Threshold of hearing is frequency dependent, and typically shows a minimum (indicating the ear's maximum sensitivity) at frequencies between 1 kHz and 5 kHz. A typical ATH curve is pictured in Fig. 1. The absolute threshold of hearing represents the lowest curve amongst the set of equal-loudness contours, with the highest curve representing the threshold of pain.



Wavelength
A wavelength l is the distance between two peaks or two crests on a wave.



White noise
White noise is a noise signal which contains equal sound energy level at all frequencies.

About Rockwool Technical Insulation (RTI)

Rockwool Technical Insulation (RTI) – an independent entity within the Rockwool group – is active on the industrial insulation market in two dedicated segments: shipbuilding & offshore and the process industry. Through the SeaRox range for marine and offshore and the ProRox range for industry, our experts offer you a full spread of products and systems for the thermal and firesafe insulation of technical installations.

RTI is always on top of the latest advancements. For more than 70 years we have presented high-grade products and given expert advice through research, innovation and intensive employee training. And we remain fully committed to providing the very best service.

Your highest quality is a minimum demand for us
All RTI insulation products – from SeaRox to ProRox – meet the most stringent quality and safety standards. All products and constructions for marine and offshore have been tested according to the latest IMO regulations and approved by all major classification societies. RTI demands excellence. In every segment we are always searching for new systems, methods and formulas. The trick is to develop ever more efficient products and to constantly optimise production processes and processing technologies

Up-to-date information? Wherever, whenever? We can help!
As a highly skilled professional you are always looking for the best possible end result. The quickest way to achieve that is with RTI premium products and the detailed information that comes with them, which always incorporates the latest technical findings. That's why you should always check that the information you have is up-to-date.

If you have any questions about specific application issues, working methods or product properties, contact our Rockwool sales team or visit our website at **www.rockwool-rti.com**

Notes

Rockwool Technical Insulation

Rockwool Technical Insulation (RTI), an independent organisation of the international Rockwool Group, is the world wide market leader in technical insulation. With the ProRox range for the industrial market and the SeaRox range for the marine and offshore industry, our experts provide a full range of products and systems for the thermal and firesafe insulation of industrial applications. In the segments of process industry, marine & offshore, RTI stands for a total approach. From sustainable products to reliable expert advice, from documentation to delivery and after sales service. Throughout the whole chain from specifier, through dealer to contractor and installer we aim to add value. We don't just sell products, we supply solutions. It is this total approach that makes RTI the ideal choice for professionalism, innovation and trust.

All explanations correspond to our current range of knowledge and are therefore up-to-date. The examples of use outlined in this document serve only to provide a better description and do not take special circumstances of specific cases into account. Rockwool Technical Insulation places great value upon continuous development of products, to the extent that we too continuously work to improve our products without prior notice. We therefore recommend that you use the most recent edition of our publications, as our wealth of experience and knowledge is always growing. Should you require related information for your specific application or have any technical queries, please contact our sales department or visit our website www.rockwool-rti.com

The Rockwool Group

The Rockwool Group is the world's leading supplier of innovative products and systems based on stone wool, improving the environment and the quality of life for millions of people. The Group is amongst the global leaders within the insulation industry. Together with other building-related products such as acoustic ceilings, cladding boards and our consultancy business, the Group ensures energy efficient and firesafe buildings with good acoustics and a comfortable indoor climate. We create green solutions for the horticultural industry, inventive special fibres for industrial use, effective insulation for the process industry and marine & offshore as well as noise and vibration systems for modern infrastructure.

Our more than 8,800 employees in more than 30 countries cater for customers all over the world. The Group's head office is located close to Copenhagen. In 2010 the Group generated sales of EUR 1.57 billion. The company is listed on the NASDA Q OMX Nordic Exchange Copenhagen. The Group's operations have a main presence in Europe and we are expanding production, sales and service activities in North and South America and Asia. Together with a broad network of business partners, this ensures that the Group's products and systems reach almost every corner of the globe. For more information, please visit www.rockwool.com

Rockwool Technical Insulation
Hovedgaden 501
2640 Hedehusene
Denmark
Tel: (+45) 46 56 16 16
Fax: (+45) 46 56 16 04
www.rockwool-rti.com
export@rockwool.dk
Rockwool Technical Insulation
is part of Rockwool International A/S

ROCKWOOL®
TECHNICAL INSULATION

3B-Reklame • 0812