Knauf
DESIGNING FOR LIFE

CLEANEO®

see how pure sounds

Contents

Mixed Sources
Product group from well-managed forests, controlled sources and recycled wood or fibre
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Project: Slättäng school, Kristianstad, Sweden; architect: Uulas Architects, Kristianstad, Kerstin Wergeni-Wasberg; product: Cleaneo Random Plus R.

Made in Germany with GreenGyps™, Cleaneo® is the world's first acoustic wall and ceiling lining with built-in air purification.

Completely odourless and working day in, day out, Cleaneo incorporates dehydrated zeolite, an aggregate mineral with a nanoporous structure. In Knauf's patented process, zeolite – with pore diameters of less than one millionth of a millimetre – together with gypsum, creates a gigantic inner layer of plaster surfaces within the board itself.

This inner layer works to reduce both smells and airborne pollutants, like the volatile organic compounds (VOCs) formaldehyde, benzene, ammonia and nitrogen. Surprisingly, the airborne pollutants are not bound to the materials, but are fully degraded.

However, Cleaneo doesn't just purify the air. It also has the excellent acoustic performance you need when designing shopping centres, offices, hospitals, schools, galleries and restaurants.

Clean indoor air and acoustic performance aren't the only things a designer values, though. Aesthetics also plays a part.

Not only is Cleaneo manufactured in a variety of shapes with Knauf's signature ultra-sharp perforations, but the range also includes continuously perforated panels for an absolutely seamless finish.

Cleaneo. See how pure sounds.

DESIGNED FOR SOUND

DESIGNED TO CLEAN

GREENGYPS™

GreenGyps™ is recycled gypsum derived from flue gas desulphurisation systems at coal-fired power plants.

Cleaning the air

There's no question that the quality of the air we breathe has a profound effect on our health and wellbeing.

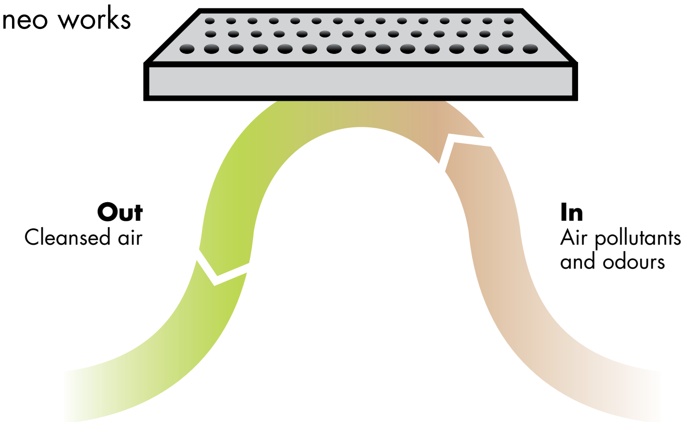
Increasingly, the quality of our indoor air – at home, work, school and leisure – is being assessed and improved. However, it's also being potentially compromised as buildings are made more airtight in the pursuit of energy efficiency.

When it comes to improving indoor air quality, the most efficient method is to restrict the source of fumes and VOCs emitted by furniture, paints, floor coverings, glues, cleaning agents and other products. Ventilation is another key approach.

However, Cleaneo lining provides yet another.

In most commercial buildings, ceilings provide the greatest surface area in constant interaction with indoor air. And when the ceiling is lined with Cleaneo, a lining with the hydroscopic properties of plasterboard as well as its own air purification mechanism, you suddenly have the potential for a major impact on wellbeing.

How Cleaneo works



How it works – fights fungi

In a paper on design strategies for indoor air quality, authors Straube and Acahrya[1] assert that "moderating variations in indoor relative humidity through the liberal use of hygroscopic and 'breathable' materials can virtually eliminate the potential for fungal growth."

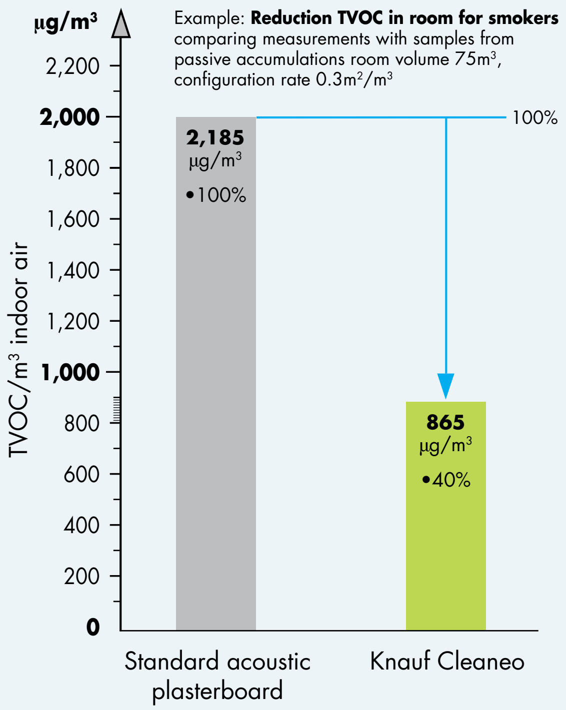
"The speed with which a surface can absorb moisture is important for avoiding surface condensation and surface relative humidities required to support fungal growth. Materials with a combination of the properties of vapour permeability and high hygroscopicity allow that material to quickly moderate humidity variations by storing or releasing significant quantities of water vapour."[2]

Cleaneo is highly hygroscopic due to the high proportion of gypsum it contains.

1 J F Straube, Research Engineer, Building Engineering Group, Civil Engineering Department, University of Waterloo, Waterloo, Ontario, Canada, and V Acahrya, Vice-President, Durisol Building Systems, 'Indoor Air Quality, Healthy Buildings, and Breathing Walls', http://oikos.com/library/breathingwalls/index.html.

2 Straube and Acahrya.

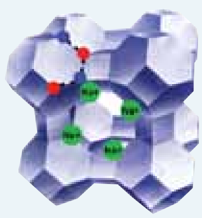
How it works – absorbs pollutants



But Cleaneo is far more than a fungi-fighter. It's what's known as a static sink. It contains zeolite, an aggregate mineral with a nanoporous structure; it absorbs and eliminates a host of environmental air pollutants including VOCs such as formaldehyde and nitrogen.

With pore diameters of less than one millionth of a millimetre, the zeolites helps create a gigantic inner layer of plaster surfaces. In an average room size, if all surfaces were lined in Cleaneo, this void volume of zeolites adds up to a total internal active surface of almost 18 million hectares – equivalent to more than 2,000 football fields.

Tests have shown that Cleaneo reduces the airborne levels of a number of pollutants including tobacco smoke, triethylamine, ammonia, formaldehyde, benzene, aromatic hydrocarbons and chlorinated hydrocarbons.* The causes of these include cleaning agents, combustion, organic decomposition, paints and other common chemicals.



Molecular sieve

How static sinks can help the air

The low air exchange rate in many buildings can lead to major problems with the quality of indoor air. In addition, many workplaces have a far higher concentration of potentially harmful substances than found in homes.

This situation has prompted research into the question of whether the quality of indoor air can be improved by using dynamic and static sinks. Knauf developed Cleaneo as one such static sink as part of a European-funded research project into this area.

Cleaneo uses zeolites – skeletal silicates with a high water content, produced by hydrothermal reactions under special geothermal conditions. They are characterised by a three-dimensional pore system, with pores of a precisely defined diameter that essentially work as a naturally occurring molecular sieve.

The sieve effect occurs because the zeolite pores want to readsorb water or other molecules. (Adsorption is the adhesion of atoms, ions, biomolecules or molecules of gas, liquid, or dissolved solids to a surface. It differs from absorption, in which a fluid permeates or is dissolved by a liquid or solid.)

Aided by strong ionic forces caused by the presence of cations (atoms that have lost an electron to become positively charged) such as sodium, calcium and potassium, the molecular sieve will adsorb a considerable amount of water or other fluids. The strong adsorptive force also allows molecular sieves to remove many gas or liquid impurities.

*Stuttgart College of Technology with supporting measurements and tests undertaken by Stuttgart Central Laboratory, University of Kaiserlautern and others.

Project: Bürgersaal, Germany

DESIGNED FOR SOUND

The sound of clean

While Cleaneo is an always-on air purifier, it is also, first and foremost, an acoustic lining.

When you're designing restaurants, offices, schools and other buildings where people congregate, good acoustics help make a room pleasant to be in, whereas bad acoustics can make a room unusable. Sound waves behave differently depending on the materials they encounter, so the choice of materials determines whether the room is perceived as hard or soft, frenetic or calm.

For example, in a classroom it's important for low frequencies to be well absorbed, so that extraneous sounds don't disturb the lesson. At the same time, the high consonant frequency range should be well reflected, because this is crucial for good speech intelligibility.

In restaurants large glass facades and hard materials on floors and walls amplify the noise from the other diners, so you virtually have to shout at each other. And while not all restaurants are trying to achieve the same atmosphere, it's a good idea, even in lively restaurants, to spread and dampen the sound in selected places.

With a void depth of a mere 60mm, Cleaneo lining has a sound absorption value of w = 0.3 to 0.55 – the absorbent range.* However, many system designs can achieve a performance in the highly absorbent range w = 0.6 to 0.8, when used together with insulation.*

*w = 0.3 to 0.55 is Class D, and w = 0.6 to 0.75 is Class C, according to DIN EN ISO 11654; rated according to VDI 3755.

How good is good?

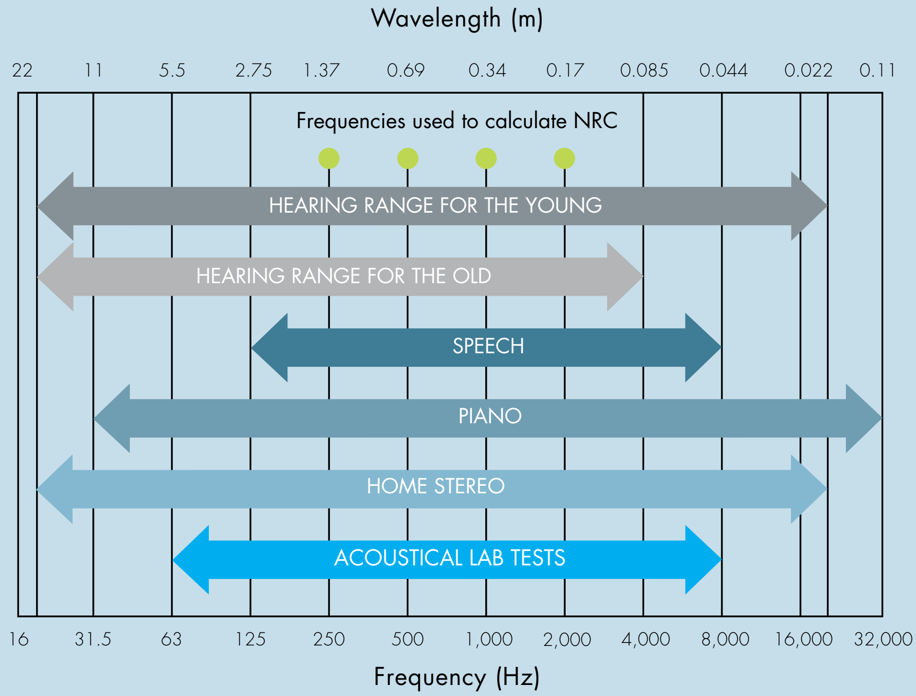
Using the proper type of absorption reduces disturbing echoes and improves audibility. Too much noise reduction can lead to a dead room, where all noise is absorbed by all surfaces, so there is no reflection of sound. Not enough absorption leaves too much disturbing noise.

A product's ability to absorb sound is measured with lab tests in α_w (specified in international standards ISO 20354 and ISO 11654) or NRC, which is more akin to an industry standard than a regulation or code. This industry standard ranges from zero (perfectly reflective) to 1 (perfectly absorptive) and is always expressed as a decimal rounded to the nearest 5%. Due to a slightly different calculation formula α_w and NRC differ very slightly from each other in the end result.

NRC (or αw) can be a valuable tool, as long as you understand what the value actually represents.

- The NRC rating is an average of how absorptive a material is at four frequencies (250, 500, 1,000 and 2,000Hz). This rating is appropriate for assessing how well a material absorbs sound within the adult speech frequencies, but can be inadequate for sound generated by music, mechanical equipment or other low-frequency sounds.
- NRC can be inadequate for sound generated by music, mechanical equipment or other low-frequency sounds and hearing range for the young.
- NRC information is based on a perfect laboratory environment and is void of installed variables, such as people, furniture etc., and therefore won't usually be an accurate representation of field performance.
- Because this rating is an average, two materials with the same rating might not perform the same in identical applications.

Frequency range of audible sound

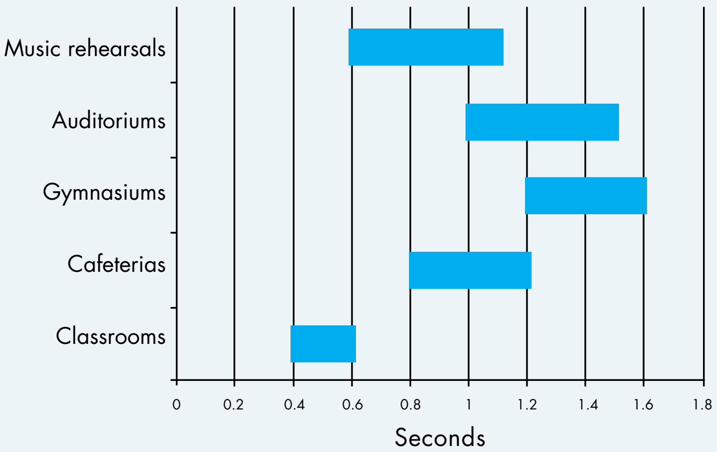


Source: *Concepts in Architectural Acoustics* by M David Egan.

What other tools can you use instead of NRC?

- Depending on the use of a room, its dimensions and function, the echo time (i.e. reverberation) can be defined, and the proper absorption can then be calculated using the Sabine formula.
- This reverberation time is therefore the foremost descriptor of an acoustic environment. Optimal reverberation times depend on the use of whatever space you are trying to optimise.

Suitable reverberation times



Wallace Clement Sabine

Wallace Clement Sabine was a pioneer in architectural acoustics. More than a century ago he began experimenting in a Harvard lecture room to explore the impact of absorption on the reverberation time. For many years his reverberation formula has been used to determine material absorption coefficients by means of reverberation rooms.

The sound of architecture

When you want to modify the sound in a room, there are six basic options available: directing, limiting, emphasising, spreading, dampening and colouring the sound.

In the open air, sound moves around unhindered at a rate of around 340 metres per second. But as soon as the sound encounters a barrier, it changes. The type of barrier encountered by the sound is also important, because the material composition and surface structure of the barrier affect the sound, as do the distance to the barrier and the angle at which the sound hits it.

In rooms like lecture halls and conference rooms, it's important to be able to direct the sound in certain directions. To direct sound, we need to know how it behaves in a room.

Sound moves in a spherical way – when you speak, sound waves are emitted in all directions, forming a ball shape moving away from the sound source, just like a billiard ball. If you send a billiard ball straight into the cushion, it will come straight back again. But if the ball hits the edge of a pocket or strikes the cushion at an oblique angle, the direction of the ball changes and ball has a longer distance to travel after it is deflected – this causes the ball to slow down. The same happens with sound waves.

A fingernail is silent unless it is scraping down a blackboard.

Air gets in the way

Sound is also influenced by the impedance of the air itself, because this is what causes the sound to diminish as the distance to the sound source increases. If you stand right next to the sound source, the sound seems more intense than when you move away.

Over longer distances, the air impedance even causes the sound to be noticeably delayed. High frequencies are the first to die away as a result of resistance from the air, whereas low frequencies are carried over long distances.

Noises in the high frequency range affect our ears the most and are usually created in the same room as the listener, because they can only penetrate structures with great difficulty. However, low frequencies can pass through virtually anything and affect our environment the most.

Project: private residence, Arendal, Norway; photography: Karl Ture Sagen, Reklamefotograferne.

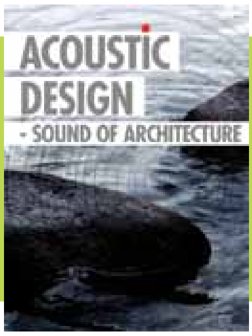
Designing a solution

To reduce or eliminate high-frequency noise, the room design must include structured surfaces and porous materials. The porous materials absorb the high frequencies as a result of friction within the material, while the structured surfaces send the sound waves on a longer journey, where the air impedance finally wears out the sound waves.

However, the sound environment is influenced by more than just the choice of materials. The arrangement of structures is an important element in the acoustic environment, and the smallest changes can have a dramatic effect on the acoustics.

For example, in the case of sound-transparent elements like perforated panels or porous panels, a cavity of 50mm means that sound absorption will cover the high frequencies. If the depth of the cavity is increased to, say, 200mm, the same product will have a wider range of absorption, covering more of the low frequencies and mid frequencies.

Increasing the depth of the cavity will further increase absorption in the low frequencies. A change in the structure therefore brings about a change in the character or 'tone colour' of an absorber.



If you'd like to find out more go to www.soundofarchitecture.com.au to download your copy of the e-book *The Sound of Architecture*, by Erik Ipsen, architect and Head of Research & Design at Knauf Danoline® and Marie Leth Rasmussen, journalist.

Project: Slättäng school, Kristianstad, Sweden; architect: Uulas Architects, Kristianstad, Kerstin Wergeni-Wasberg; product: Cleaneo Random Plus R.

A clean look

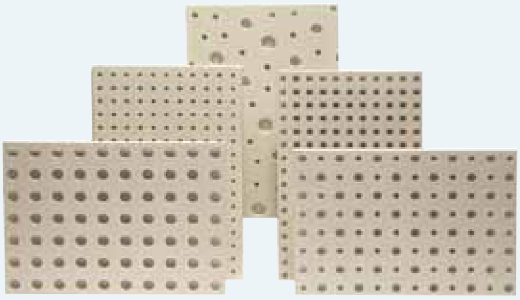
While others may offer only circular and square perforations, the Cleaneo range has a palette of 17 different styles – including block perforations in squares or slotline.

It also offers the choice of white or black pre-laminated 45g/m² fibre fleece, depending on the desired visual effect.

However, it's the unique option of continuous perforations in square, circular, straight line and random patterns that tends to have designers really impressed.

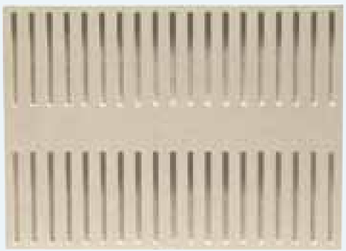
This seamless flow of pattern throughout the room is achieved through the combination of Cleaneo's four precision-cut edges (FF edge for truly seamless, or linear edge for compound-free V joints) and the strong Knauf Uniflott tapeless jointing system.

And, of course, Cleaneo is made with GreenGyps, which has a recycled content of at least 85%, making it light, strong, easy to cut and environmentally friendly.



Continuous perforations

Circular straight line perforation (five designs).
Alternating circular perforation (two designs).
Random plus perforations (two designs).
Square straight line perforation (two designs).



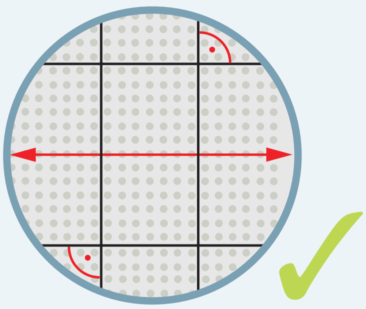
Block perforations

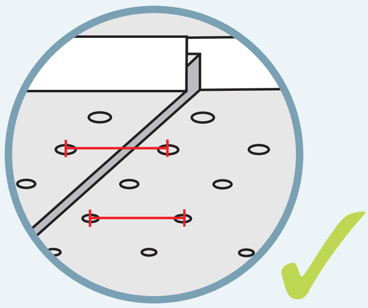
Square pattern (three designs)
Circular pattern (six designs)
Slotline pattern (three designs)

The devil's in the detail

While an expanse of seamless perforations may look simply elegant, a series of importantdetails lie behind its achievement.

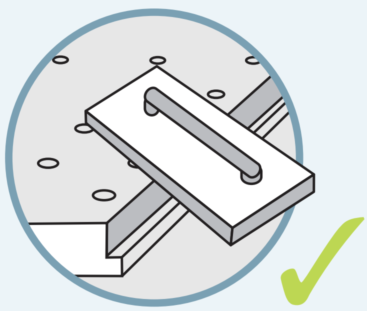
For example, Cleaneo's precise dimensions automatically ensure the proper perforation distance at the board's edges when the boards are joined. This makes it easy to lay boards and perforations in perfect alignment.

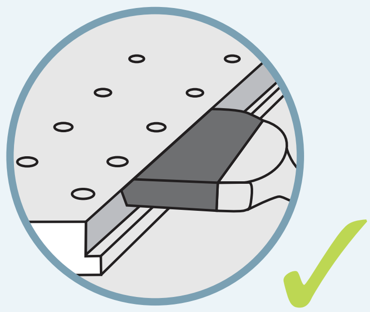




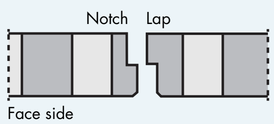
Precise perforation distance

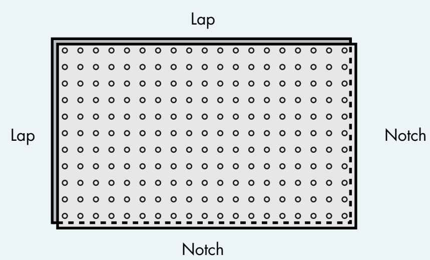
Cleaneo with an FF edge means it has machined lip edges on one long and one short side so that the boards are always perfectly straight, ensuring that the perforation pattern always matches perfectly. What's more, it has pre-bevelled edges on the face side of the board's liners so the paper lining won't bulge – even when it's humid, and the board's cut edges are primed so that the Uniflott filler and the cut edges join perfectly.



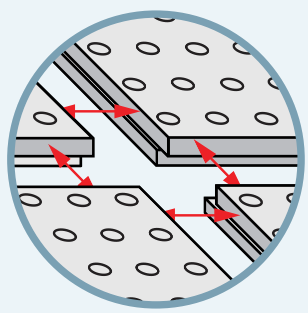


Cleaneo with a linear edge has one cut edge and one long edge each as a linear notch and one cut edge and one long edge each as a linear lap. This allows for an easy and precise alignment of the boards with continuous perforation.





Board view from face side



Project: Audi Forum, London; product: Cleaneo.

Audible success

Cleaneo became the ceiling of choice as part of the specification for Audi's global corporate identity and is now featured in 40 Audi showrooms around the UK, including its flagship, the Audi Forum in Piccadilly, London.

Chosen for its aesthetics as well as its acoustic performance, Cleaneo provides a unique seamless ceiling that is visually appealing – and significantly reduces reverberated sound, making for a pleasant business environment.

The Audi Forum was created as part of a total refurbishment of an existing building and also contains an exhibition centre, a conference venue and an internet cafe.

Project: Wales Millennium Centre, Cardiff, Wales; architect: Capita Percy Thomas; product: Cleaneo.

Cleaneo performs

Cleaneo was given a key role at the Wales Millennium Centre after architects Capita Percy Thomas selected it as the ceiling finish in the principal public areas of the building.

The 31,500m^2 centre is an acclaimed performing arts complex on Cardiff Bay's waterfront. Cleaneo was installed in the centre's north and south concourses, which have restaurants, shops and theatre entrances and provide meeting places where visitors can watch impromptu free music and drama performances in a relaxed, informal setting.

The edge gives an edge

Continuous perforation

Continuous perforation patterns are available in FF and Linear edges. FF is used when a totally jointless option is sought. Joints are invisible when jointed with the Uniflott jointing system.

When the linear edge is used there will be a 1mm bevelled V joint all around each sheet. This tiny joint will become almost invisible when painted, and as there are no jointing compounds, not only is the joint never going to crack, but the sheets are removable and reusable, which may enable you to earn additional green star™ credits.

Continuous perforation (illustrations of these can be found on pages 18–21)

DESIGN	PERFORATION	PERFORATION RATIO (board) %	WEIGHT (kg/m²)	BOARD DIMENSIONS (standard size)		FURRING CHANNEL Max. axial spacings (mm)	EDGE TYPE	
				Width (mm)	Length (mm)		FF	Linear
Standard Circular R	6/18 R	8.7	10.7	1,188	1,998	300	●	*
	8/18 R	15.5	9.9	1,188	1,998	300	●	●
	10/23 R	14.8	9.9	1,196	2,001	300	●	●
	12/25 R	18.1	9.6	1,200	2,000	300	●	●
	15/30 R	19.6	9.3	1,200	1,980	300	*	*
	20/42 R	17.8	9.7	1,176	1,974	300	*	*
Alternating Circular R	8/12/50 R	13.1	10.2	1,200	2,000	300	*	*
	12/20/66 R	19.6	9.4	1,188	1,980	300	●	●
Standard Square Q	8/18 Q	19.8	9.4	1,188	1,998	300	●	*
	12/25 Q	23.0	9.2	1,200	2,000	300	●	●
Random PLUS R	8/15/20 R	9.9	10.5	1,200	1,875	300	●	*
	12/20/35 R	9.8	10.5	1,200		300	●	*

Block perforation

Block perforations in both square and slotline are available with four recessed edges as standard. With a premium ceiling lining, eliminating unsightly butt joints gives you the look you set out to design.

Block perforation (illustrations of these can be found on page 22)

DESIGN	PERFORATION	PERFORATIONS PER BLOCK		PERIMETER Non-perforated		PERFORATION RATIO	BOARD DIMENSIONS (standard size)		FURRING CHANNEL Max. axial spacings (mm)	EDGE TYPE
		lateral	long.	lateral (mm)	long. (mm)	(board) %	width (mm)	length (mm)		4RE
B4	12/25 R	19	19	69	69	11.3	1,200	2,400	300	●
	12/25 Q	19	19	69	69	14.4	1,200	2,400	300	●
B5	12/25 R	7	7	69	69	6.2	1,200	2,400	300	●
	12/25 Q	7	7	69	69	7.8	1,200	2,400	300	●
B6	12/25 R	43	19	69	69	12.8	1,200	2,400	300	●
	12/25 Q	43	19	69	69	16.3	1,200	2,400	300	●

Block perforation 'slotline' (illustrations of these can be found on page 23)

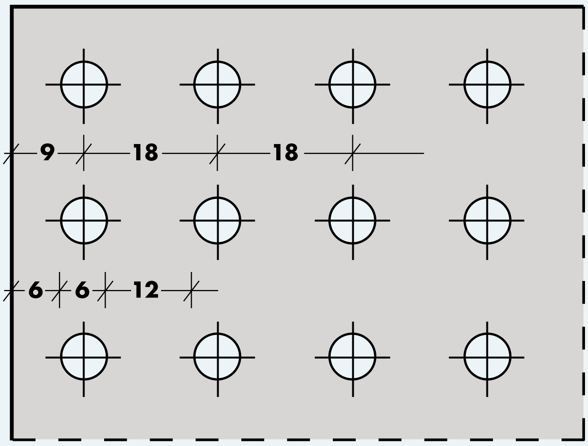
DESIGN	SLOTS PER BLOCK		PERIMETER Non-slotted		SLOT RATIO	BOARD DIMENSIONS (standard size)		FURRING CHANNEL Max. axial spacings (mm)	EDGE TYPE
	lateral	long.	lateral (mm)	long. (mm)	(board) %	width (mm)	length (mm)		4RE
B4 – 'slotline'	30	4	73.9	73.3	13.7	1,200	2,400	300	●
B5 – 'slotline'	4 x 6	4	73.9	73.3	10.9	1,200	2,400	300	●
B6 – 'slotline'	69	4	73.9	73.3	15.7	1,200	2,400	300	●

Please note: Perimeter dimensions are optical specifications.

*These items are available to order; minimum quantities apply.

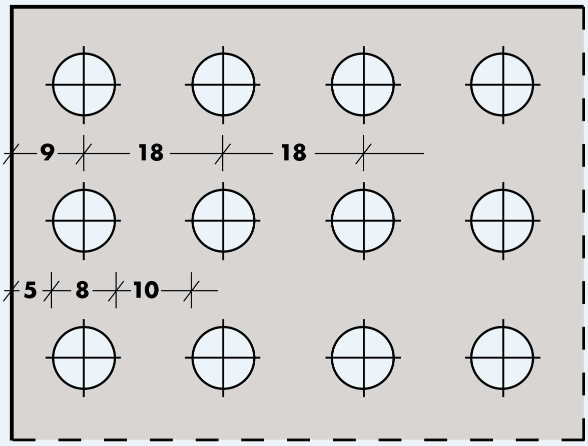
Product range and performance

Perforated: Standard Circular



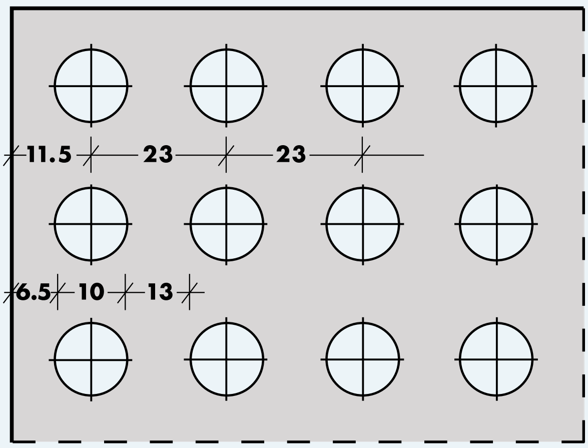
Standard Circular 6/18 R

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.20	0.30	0.45	0.55	0.45	0.45	0.50	D
	200	0.40	0.45	0.50	0.45	0.40	0.50	0.45	D
	400	0.40	0.45	0.45	0.45	0.45	0.50	0.45	D
With Insulation	65	0.35	0.45	0.50	0.50	0.45	0.50	0.50	D
	200	0.40	0.45	0.50	0.45	0.45	0.50	0.50	D
	400	0.40	0.45	0.45	0.50	0.45	0.50	0.50	D



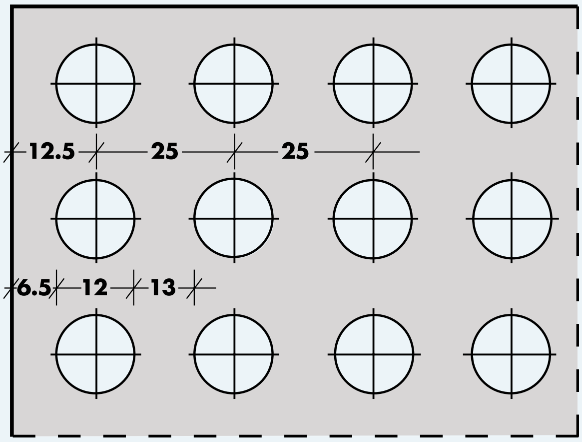
Standard Circular 8/18 R

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.60	0.75	0.65	0.60	0.60	C
	200	0.45	0.60	0.70	0.60	0.55	0.65	0.60	C
	400	0.55	0.65	0.60	0.60	0.55	0.55	0.60	C
With Insulation	65	0.35	0.55	0.70	0.75	0.65	0.65	0.70	C
	200	0.50	0.65	0.70	0.65	0.60	0.70	0.65	C
	400	0.55	0.65	0.60	0.70	0.60	0.65	0.65	C



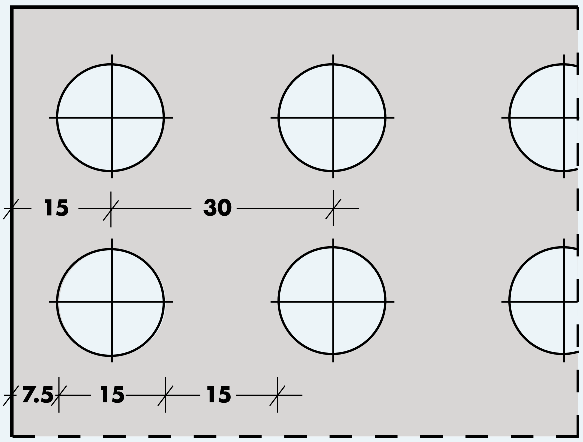
Standard Circular 10/23 R

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.60	0.70	0.65	0.60	0.60	C
	200	0.45	0.60	0.65	0.60	0.55	0.60	0.60	C
	400	0.55	0.65	0.60	0.60	0.55	0.60	0.60	C
With Insulation	65	0.35	0.55	0.70	0.70	0.60	0.65	0.70	C
	200	0.50	0.65	0.70	0.65	0.60	0.65	0.65	C
	400	0.55	0.65	0.60	0.65	0.60	0.65	0.65	C



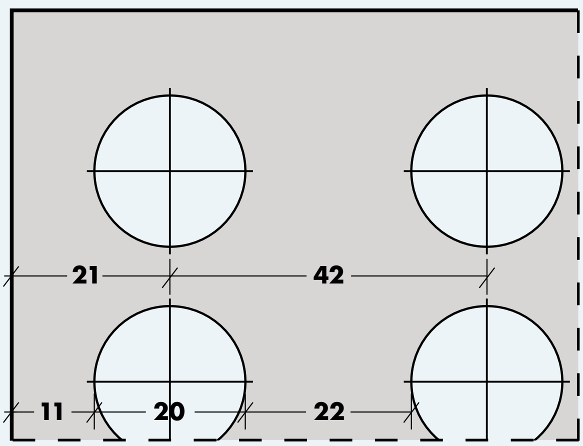
Standard Circular 12/25 R

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.60	0.80	0.70	0.55	0.60	C
	200	0.45	0.65	0.75	0.65	0.60	0.60	0.65	C
	400	0.55	0.70	0.65	0.65	0.60	0.60	0.65	C
With Insulation	65	0.30	0.55	0.75	0.80	0.70	0.60	0.75	C
	200	0.50	0.70	0.75	0.70	0.65	0.65	0.70	C
	400	0.55	0.65	0.70	0.75	0.65	0.65	0.70	C



Standard Circular 15/30 R

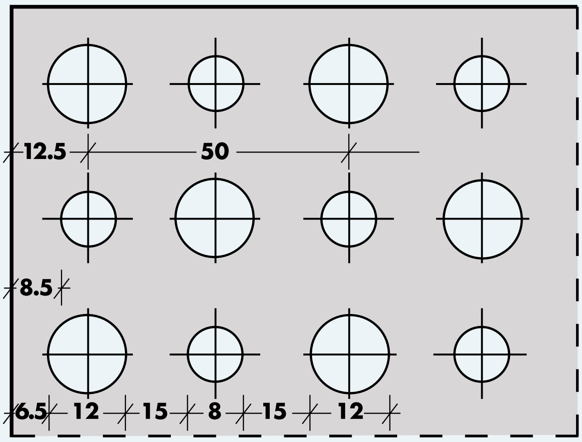
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.60	0.80	0.65	0.60	0.60	C
	200	0.45	0.65	0.75	0.65	0.60	0.60	0.65	C
	400	0.55	0.70	0.65	0.65	0.60	0.60	0.65	C
With Insulation	65	0.30	0.55	0.80	0.80	0.65	0.65	0.75	C
	200	0.50	0.70	0.75	0.70	0.65	0.65	0.70	C
	400	0.55	0.70	0.65	0.75	0.65	0.65	0.70	C



Standard Circular 20/42 R

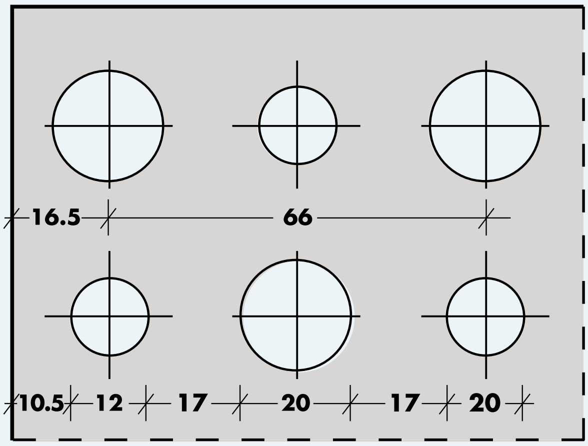
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.60	0.75	0.50	0.50	0.55	D
	200	0.50	0.65	0.75	0.60	0.45	0.55	0.55	D
	400	0.55	0.70	0.70	0.60	0.50	0.55	0.60	C
With Insulation	65	0.30	0.55	0.80	0.80	0.50	0.55	0.60	C
	200	0.55	0.70	0.80	0.70	0.50	0.60	0.60	C
	400	0.55	0.65	0.70	0.75	0.50	0.60	0.60	C

Perforated: Alternating Circular/Random Plus



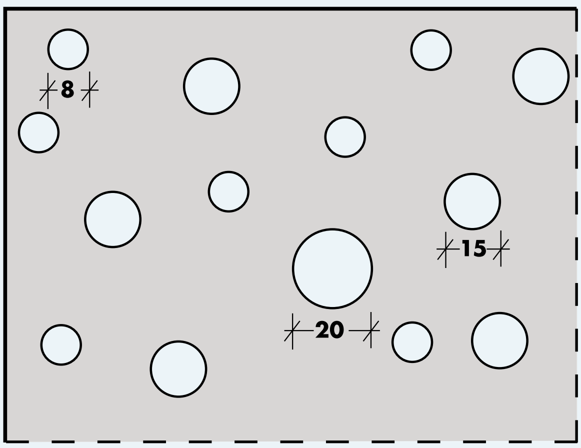
Alternating Circular 8/12/50/R

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.60	0.70	0.60	0.50	0.60	C
	200	0.45	0.60	0.65	0.60	0.50	0.55	0.60	C
	400	0.55	0.65	0.60	0.60	0.55	0.55	0.60	C
With Insulation	65	0.35	0.55	0.70	0.70	0.60	0.50	0.65	C
	200	0.50	0.65	0.65	0.65	0.55	0.55	0.65	C
	400	0.55	0.65	0.60	0.65	0.55	0.55	0.60	C



Alternating Circular 12/20/66 R

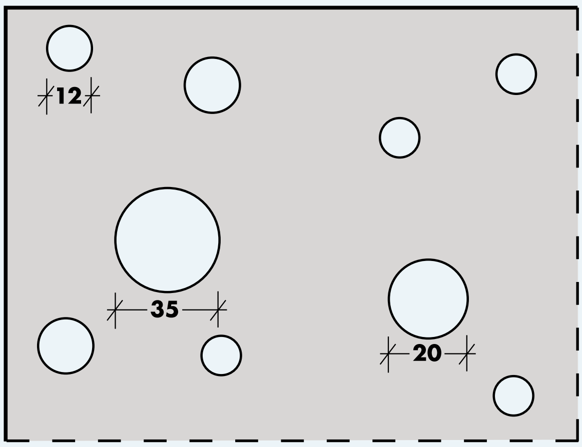
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.10	0.30	0.60	0.80	0.60	0.55	0.60	C
	200	0.45	0.65	0.80	0.65	0.50	0.60	0.60	C
	400	0.60	0.70	0.65	0.65	0.55	0.60	0.65	C
With Insulation	65	0.30	0.55	0.80	0.85	0.60	0.65	0.70	C
	200	0.55	0.70	0.80	0.75	0.60	0.65	0.70	C
	400	0.60	0.70	0.70	0.80	0.60	0.65	0.70	C



Random Plus Circular 8/15/20 R

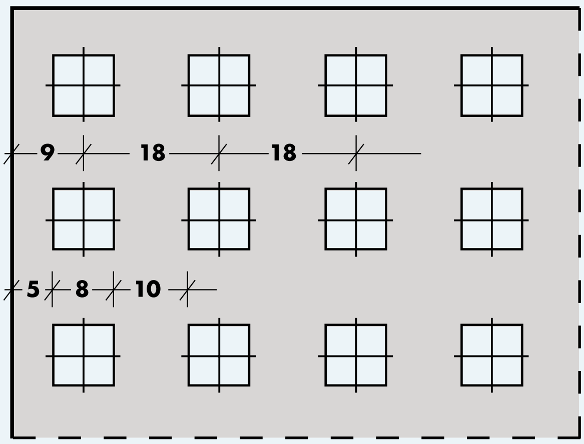
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.50	0.60	0.45	0.45	0.50	D
	200	0.40	0.50	0.55	0.50	0.40	0.45	0.50	D
	400	0.45	0.50	0.50	0.50	0.40	0.45	0.50	D
With Insulation	65	0.35	0.45	0.55	0.55	0.40	0.45	0.50	D
	200	0.45	0.50	0.55	0.50	0.40	0.50	0.50	D
	400	0.45	0.50	0.50	0.55	0.45	0.45	0.50	D

Perforated: Random Plus/Standard Square



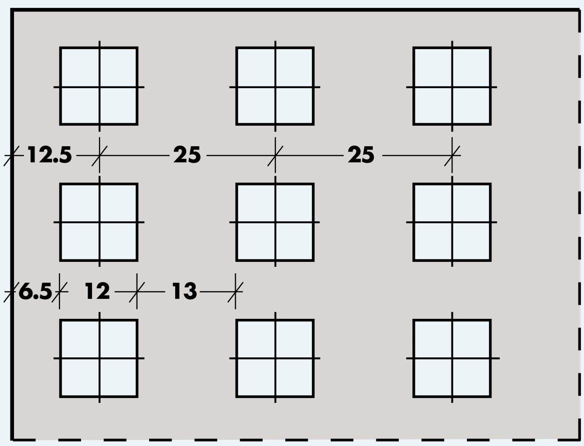
Random Plus Circular 12/20/35 R

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.30	0.55	0.55	0.40	0.35	0.45	D
	200	0.40	0.50	0.60	0.45	0.32	0.35	0.45	D
	400	0.45	0.55	0.55	0.45	0.35	0.35	0.45	D
With Insulation	65	0.35	0.50	0.65	0.55	0.35	0.35	0.45	D
	200	0.45	0.55	0.60	0.50	0.35	0.40	0.45	D
	400	0.45	0.50	0.55	0.50	0.35	0.40	0.45	D



Standard Square 8/18 Q

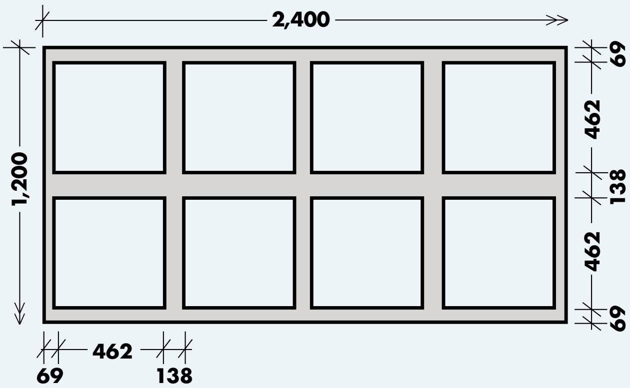
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.10	0.30	0.60	0.80	0.70	0.65	0.60	C
	200	0.45	0.65	0.75	0.65	0.60	0.70	0.65	C
	400	0.55	0.70	0.65	0.65	0.60	0.70	0.65	C
With Insulation	65	0.30	0.55	0.80	0.80	0.70	0.75	0.75	C
	200	0.55	0.70	0.75	0.70	0.70	0.75	0.75	C
	400	0.60	0.70	0.70	0.75	0.70	0.75	0.75	C



Standard Square 12/25 Q

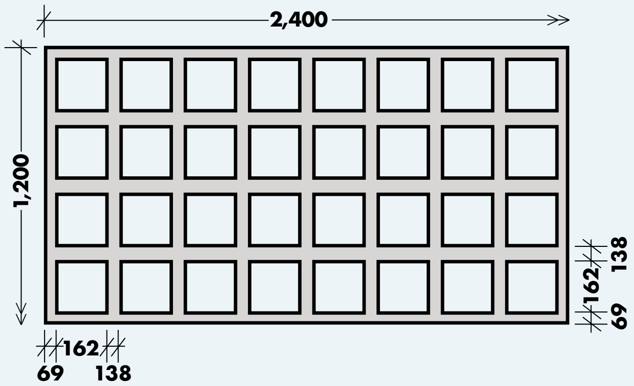
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.10	0.30	0.60	0.80	0.75	0.60	0.60	C
	200	0.50	0.70	0.80	0.70	0.65	0.65	0.70	C
	400	0.60	0.75	0.65	0.70	0.65	0.60	0.70	C
With Insulation	65	0.30	0.60	0.85	0.90	0.75	0.70	0.80	B
	200	0.55	0.75	0.80	0.75	0.75	0.75	0.80	B
	400	0.60	0.75	0.70	0.80	0.75	0.70	0.75	C

Patterned: Block Perforation Circular/Square



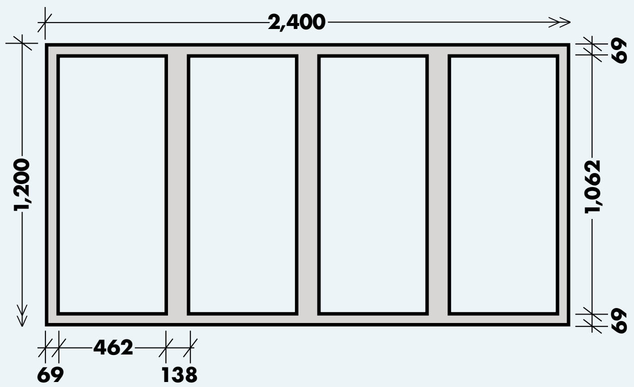
Block Perforation B4-12/25 R & Q

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
CIRCULAR (R)									
Without Insulation	65	0.15	0.35	0.55	0.60	0.60	0.40	0.55	D
	200	0.45	0.55	0.60	0.50	0.45	0.40	0.50	D
	400	0.50	0.60	0.55	0.50	0.45	0.40	0.50	D
With Insulation	65	0.35	0.50	0.65	0.60	0.50	0.40	0.55	D
	200	0.50	0.55	0.60	0.55	0.50	0.45	0.55	D
	400	0.50	0.55	0.55	0.55	0.50	0.45	0.55	D
SQUARE (Q)									
Without Insulation	65	0.15	0.35	0.55	0.65	0.55	0.45	0.55	D
	200	0.45	0.60	0.65	0.55	0.50	0.45	0.55	D
	400	0.50	0.60	0.55	0.55	0.50	0.45	0.55	D
With Insulation	65	0.35	0.55	0.70	0.65	0.55	0.50	0.60	C
	200	0.50	0.60	0.65	0.60	0.55	0.50	0.60	C
	400	0.55	0.60	0.60	0.60	0.55	0.50	0.60	C



Block Perforation B5-12/25 R & Q

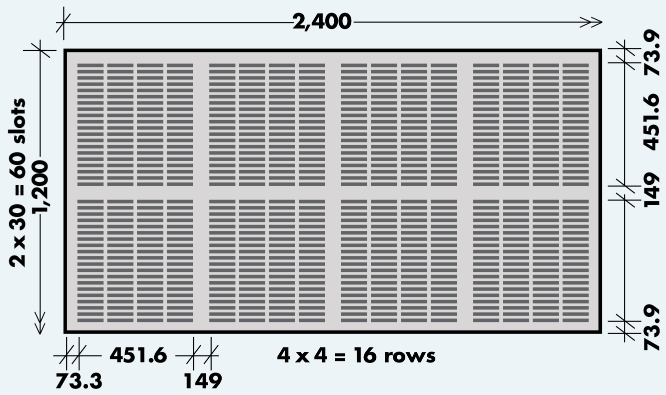
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
CIRCULAR (R)									
Without Insulation	65	0.20	0.35	0.45	0.40	0.35	0.25	0.40	D
	200	0.40	0.45	0.45	0.35	0.30	0.25	0.35	D
	400	0.40	0.45	0.40	0.35	0.30	0.25	0.35	D
With Insulation	65	0.35	0.45	0.45	0.40	0.35	0.25	0.40	D
	200	0.40	0.45	0.45	0.40	0.35	0.30	0.40	D
	400	0.40	0.45	0.45	0.40	0.35	0.30	0.40	D
SQUARE (Q)									
Without Insulation	65	0.20	0.35	0.50	0.45	0.50	0.30	0.45	D
	200	0.40	0.50	0.50	0.40	0.35	0.30	0.40	D
	400	0.40	0.45	0.45	0.40	0.35	0.30	0.40	D
With Insulation	65	0.40	0.45	0.50	0.45	0.40	0.30	0.45	D
	200	0.45	0.50	0.50	0.40	0.35	0.35	0.40	D
	400	0.45	0.45	0.45	0.45	0.40	0.35	0.45	D



Block Perforation B6-12/25 R & Q

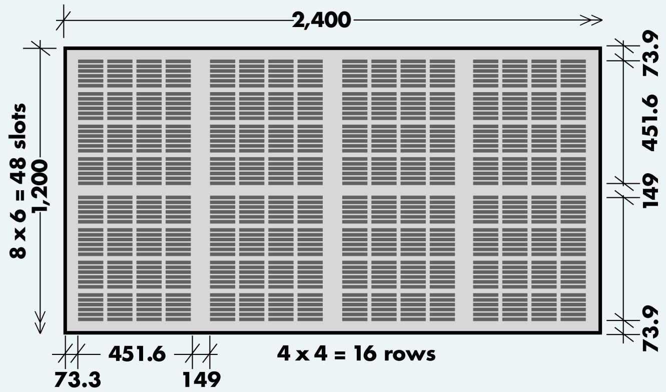
	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
CIRCULAR (R)									
Without Insulation	65	0.15	0.35	0.55	0.65	0.55	0.40	0.55	D
	200	0.45	0.60	0.65	0.55	0.50	0.45	0.55	D
	400	0.55	0.60	0.60	0.55	0.50	0.45	0.55	D
With Insulation	65	0.35	0.55	0.70	0.65	0.55	0.45	0.60	C
	200	0.50	0.65	0.65	0.60	0.55	0.50	0.60	C
	400	0.50	0.60	0.60	0.60	0.55	0.50	0.60	C
SQUARE (Q)									
Without Insulation	65	0.15	0.30	0.60	0.70	0.60	0.45	0.55	D
	200	0.50	0.65	0.70	0.60	0.55	0.50	0.60	D
	400	0.55	0.65	0.60	0.60	0.55	0.50	0.60	C
With Insulation	65	0.35	0.55	0.75	0.75	0.60	0.55	0.65	C
	200	0.55	0.65	0.70	0.65	0.60	0.55	0.65	C
	400	0.55	0.65	0.65	0.65	0.60	0.55	0.65	C

Patterned: Block Perforation – Slotline



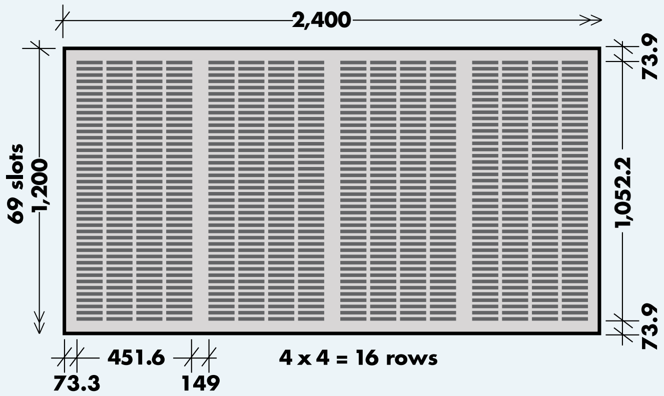
Block Perforation B4 - Slotline

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.35	0.60	0.65	0.50	0.40	0.55	D
	200	0.45	0.60	0.65	0.55	0.45	0.45	0.55	D
	400	0.55	0.65	0.55	0.55	0.45	0.45	0.55	D
With Insulation	65	0.35	0.55	0.70	0.65	0.50	0.45	0.55	D
	200	0.50	0.65	0.65	0.60	0.50	0.50	0.60	C
	400	0.55	0.60	0.60	0.60	0.50	0.50	0.60	C



Block Perforation B5 - Slotline

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.35	0.55	0.60	0.45	0.35	0.50	D
	200	0.45	0.55	0.60	0.50	0.40	0.40	0.50	D
	400	0.50	0.60	0.55	0.50	0.40	0.40	0.50	D
With Insulation	65	0.35	0.55	0.65	0.60	0.45	0.40	0.50	D
	200	0.50	0.60	0.60	0.55	0.45	0.45	0.55	D
	400	0.50	0.55	0.55	0.55	0.45	0.40	0.50	D



Block Perforation B6 - Slotline

	Void Depth Hz	125	250	500	1000	2000	4000	α_w	Class
Without Insulation	65	0.15	0.35	0.60	0.70	0.55	0.45	0.55	D
	200	0.45	0.55	0.60	0.50	0.45	0.50	0.50	D
	400	0.55	0.65	0.60	0.55	0.50	0.45	0.55	D
With Insulation	65	0.35	0.55	0.75	0.70	0.55	0.50	0.60	C
	200	0.55	0.70	0.70	0.65	0.55	0.55	0.65	C
	400	0.55	0.65	0.65	0.65	0.55	0.50	0.60	C

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