TECHNICAL GUIDE

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VES

Better air for the built environment

Introduction

There is a greater awareness of ventilation noise issues across many situations, in particular for education applications via the Building Bulletin 93 - Acoustics for Schools. This is a key challenge for an HVAC manufacturer hoping to analyse and provide detailed information about something that is relative and subjective in nature. The complication of decibels, the usual confusion about volume, power and logarithmic scales all make it tricky for customers to know how a noise number translates into the user experience.

Along with the challenges of designing low noise products, comes accurately displaying the information in a meaningful way. Acoustic testing is important as it provides useful data about the noise emitted by our product, helping specifiers to make informed decisions when selecting our products for installation in real life applications.

Often a comparison is made between manufacturers, to determine who has the better unit and meets stated regulations, therefore making the information concise, understandable and transparent is our number one aim.

In addition, we know that it is highly unlikely for most applications, where low noise is extremely important, that there will be one single solution. There is generally no direct relationship between room noise level and the sound level generated by the mechanical ventilation system. Alongside this, specifiers and designers have to find a balance between costs, energy, legislation and maintenance; sometimes generating conflicting issues.

It is always recommended to seek the expert advice of an acoustic specialist for noise sensitive applications.

Definition of Sound (Noise)

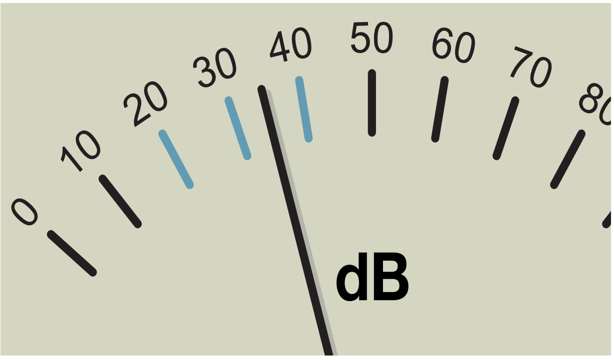
- Sound is any pressure in the air that the human ear can detect
- Noise is any sound that is undesirable by the recipient
- The terminology of noise and sound are used interchangeably

Acoustic Guidance

Sound Definition

When a fan is in operation, it emits acoustic energy that is expressed in Watts (W). This energy is known as sound power and is constant regardless of distance or environment. As the energy radiates away from the source it causes small fluctuations in air pressure, called sound pressure. While sound power cannot be measured directly, sound pressure can be and is expressed in Pascals (Pa).

The Decibel (dB)



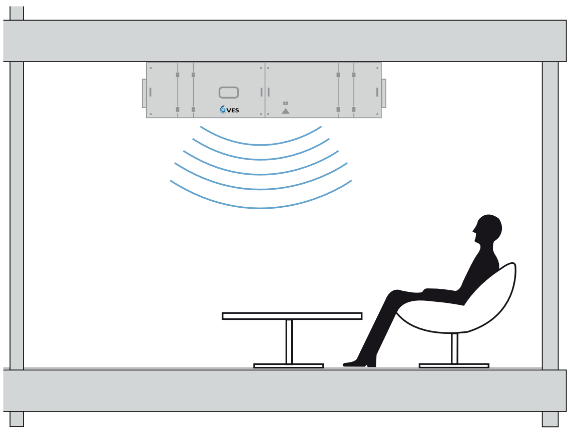
Sound power and pressure levels are both stated in Decibels (dB). The decibel is a logarithmic unit that expresses the ratio of two values: a measured value (P) and a reference value (P_{ref}). In acoustics, this reference value is set at the lowest detectable value by the human ear. Since the human ear can hear a large range of sound levels, the logarithmic scale is used in order to conveniently display this information.

Decibel equation:

$$dB = 10 \log \left(\frac{P}{P_{ref}} \right)$$

"Sound power level and sound pressure level are stated using the decibel (dB) unit, but they are NOT the same decibel"

Sound Pressure Level



Using the decibel equation as a base, we can calculate sound pressure levels using the equation below. Where p is the measured sound pressure level in Pascals and 20 μPa is the reference level the lowest pressure detectable by a human ear). Apart from the abbreviation SPL, for Sound Pressure Level, L_p is normally used in equations.

Sound Pressure Level equation:

Sound Pressure Level (SPL)

$$L_p = 20 \log \frac{p}{(20\ \mu Pa)}$$

Sound Power Level

Sound Power Level equation:

Sound Power Level (PWL)

$$L_W = 10 \log \frac{P}{10^{-12}\ W}$$

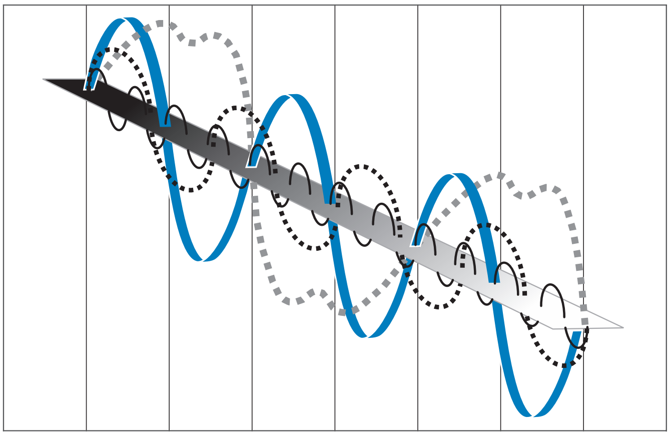
Similarly for the Sound Power level, P is the sound power level and the reference value is 10^{-12} W. Abbreviated as SWL and L_W. Although both L_p and L_W use decibels they do not represent the same decibel, due to the fact that their reference values are different. This means a sound source emitting 30 dB L_p does NOT equal an L_W of 30 dB.

An often-stated analogy for the relationship between L_p and L_W is a room heater: where the heater power represents the L_W and the temperature at a distant point is like the L_p. Similarly with heat, the intensity of sound pressure decreases as it moves away from the source.

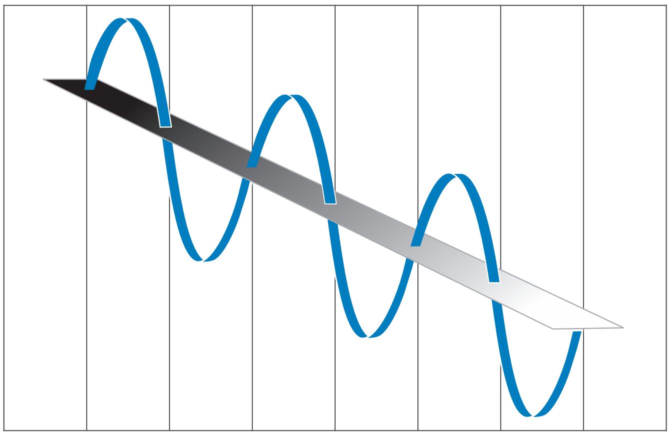
Acoustic Guidance

Frequency (Hz)

Noise consists of sound pressure levels within a range of frequencies. Where frequency is the number of cycles a second, made by a sound wave and is measured in Hertz (Hz). When hearing a noise, its frequency is perceived as its pitch e.g. high frequencies give off a high pitch noise. The normal hearing frequency range for people extends from a low value of 20 Hz (a ‘rumbling’ sound) up to about 20000 Hz (a ‘hissy’ sound). As sound moves from the source to the receiver, it consists of a combination of different frequencies. While a pure sound wave contains a single frequency (below right), realistic sounds are combinations of frequencies (below left).



Multiple frequency wave



Single frequency wave

> “Providing information for each frequency band means that noise migration solutions can be tailored to individual products”

Acoustic Guidance

Octave Bands

When taking sound measurements it is possible to analyse each individual frequency, however this can be very time consuming. This is why a range of frequencies is divided into sets called bands. These bands are an octave in width, where the upper band frequency is double of the lower band frequency. Within building services, the octave band frequency range of 63 Hz - 8 kHz is generally used.

Octave	1	2	3	4	5	6	7	8
Frequency (Hz)	63	125	250	500	1k	2k	4k	8k

For finer resolution of data 1/3 octave bands can be used.

"The amount and frequency distribution of the total noise is determined by measuring it with an octave band analyser"

A-Weighting

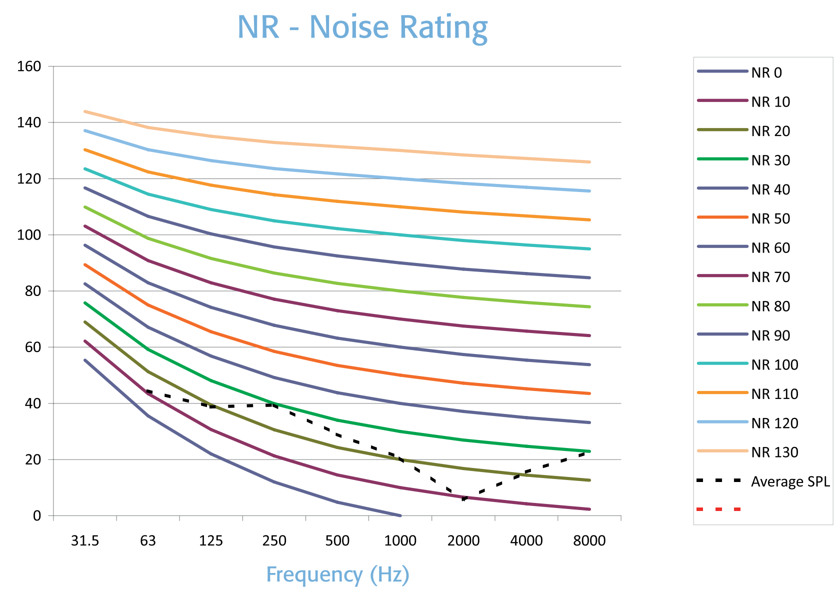
The human ear responds differently to different frequencies of sound. This is why a weighting system is sometimes used to relate how loud various frequencies are perceived by the human ear e.g. humans are less sensitive to low frequencies. A-Weighting is applied by adding/subtracting values to the different octave band levels.
A-Weighting value can be abbreviated to dB(A) or dBA.

Frequency Band (Hz)	63	125	250	500	1k	2k	4k	8k
A-Weighting Correction	-26	-16	-9	-3	0	1	1	-1

Acoustic Guidance

Noise Rating (NR)

Noise rating curves have been used to help describe a sound source's frequency range and distil the information into a single number. It is widely used in the UK and Europe to help determine acceptable noise levels in different indoor environments. The noise rating of a sound is calculated by plotting the octave band frequencies on top of a grid with NR curves. The resultant NR level is where the spectrum touches the highest NR curve. This means that products with the same NR level can have audibly very different sounds. Similar to A-Weighting, NR represents and corrects for how the human ear perceives sound.



Example sound pressure curve over a grid of NR curves, resulting in an NR of 30

> "A number of products could have an identical Noise Rating (NR), but be audibly very different"

Weighted Sound Reduction Index (R_w)

There are several different ways to describe the acoustic performance, or airborne sound insulation power, of building elements and materials. One of which is the sound reduction index (R).

The sound reduction index (R) expresses the difference in sound levels, in dB, hitting one side of a building element and the resultant sound levels measured on the other side. Sound reduction index can only be measured in laboratory conditions, in accordance to BS EN ISO 10140-2: 2010.

While sound reduction index (R) is expressed in octave or 1/3 octaves, covering a range of 100 – 3150 Hz, the weighted sound reduction index (R_w) describes the airborne sound insulation power with a single value. This makes interpretations and comparisons of different products easier. When comparing R_w values, increasing it by one would result in an approximate sound reduction of 1dB in the resultant noise passing through the product. Thus, the higher the R_w, the better a sound insulator it will be.

Part E of the Building Regulations includes details of acceptable sound performance in various types of buildings. This is particularly relevant when HVAC units become part of the building fabric.

Due to the fact that these values (R and R_w) are all based on laboratory conditions, they do not take into account real world factors. Since each product will be used in different situations, it is best to get an expert to help understand how each product would perform in a given environment.

Acoustic Guidance

Noise Categories

Any moving or vibrating parts in a product can produce noise; this varies with the operation of the product. The noise is generated by the mechanical system (i.e. the fan noise) and can be classified into 5 categories:

1 Airborne

Radiated from the air handling unit/fan, the noise is transmitted through the air and directly through walls, windows, doors or ceilings into adjoining spaces.

2 Case Breakout

The first type of break out noise is generated by high speed or turbulent air in ducts that cause the duct walls to vibrate and radiate a low frequency noise. The second is low frequency noise from a remote source, such as a fan in the AHU and can traverse down the duct into spaces or breaks out through the case or ductwork itself.

3 Duct-borne

Originated at a noise-generating source (i.e. the fan) the noise is carried down the ducted air path to receivers in rooms located remote from the source.

4 Self-generated

Produced as air moves through a confined duct system, noise is generated at points of turbulence such as dampers, elbows, T-junctions and air terminal devices. Self-generated noise increases with air velocity and the number of turbulent air points within a system.

5 Structure-borne

Generated from rotating or vibrating equipment such as framework or doors, which vibrates part of a building.

Noise

- Noise produced might be broadband, containing sound energy in several frequency bands, but no audibly distinct components in one frequency band.
- Noise that whines or hums at particular frequencies can produce an audible tone that can be annoying to the receiver.
- In ventilation the rotational fan speed causes an annoying low frequency hum between 100-250 Hz known as fan ‘Blade Pass Frequency’.
- The fan ‘Blade Pass Frequency’ noise can be very intense - varying with the number of blades and rotation velocity.
- Understanding the noise sources and frequencies allows for a better understanding of how that particular noise will be transmitted in a real application.

Acoustic Testing

Unit Measurement and Testing

At VES, we value the ability to provide transparent data that allows for clear acoustic judgments to be made. VES strives to showcase this by having our units independently tested in an array of environments.

Acoustic testing carried out by VES on its products

- In-house by VES.
- Independently at Southampton University's Institute of Sound and Vibration Research (ISVR) to BS EN ISO 3744:2010 "Determination of sound power levels of noise sources using sound pressure - Engineering method in an essentially free field over a reflecting plane", and BS EN ISO 10140-2:2010 "Acoustics - Laboratory measurement of sound insulation of building elements Part 2. Measurement of airborne sound insulation".
- Independently tested at the Ziehl ABEGG InVent development and technology centre, using DIN EN ISO 3745:2003 "Acoustics - Determination of sound power levels of noise sources using sound pressure - Precision methods for anechoic and hemi-anechoic rooms".
- In-situ by HRS Services Ltd, confirming adherence to the Acoustic Performance Standards for the Priority Schools Building Programme and the ESFA Output Specification.

Unit testing at University of Southampton

"The tests provided conclusive results for a variety of conditions and equipment specifications"

Acoustic Results

Noise Data

VES aims to provide accurate and comprehensive sound data for all products. The acoustic properties are detailed to the customer and the data covers a range of possible performance levels. This allows the customer to get an understanding of how the product would perform at their required duty points.

A step-by-step guide is provided below to give an understanding of the data shown in the example below.

Fan Speed	Sound Power Levels	Frequency (Hz)								Casing Radiated			
		63	125	250	500	1k	2k	4k	8k	NR@1m	NR@3m	dBA@1m	dBA@3m
100%	Casing Radiated	72	67	56	43	41	39	35	32				
	Intake	58	64	62	54	59	57	51	45	35	27	39	32
	Outlet	77	59	54	45	56	52	41	27				
80%	Casing Raditated	66	61	50	38	38	34	31	31				
	Intake	53	58	55	51	56	51	48	42	29	21	34	27
	Outlet	69	51	46	41	52	46	36	23				
60%	Casing Radiated	60	55	44	33	32	29	29	31				
	Intake	44	53	46	50	49	46	44	37	24	17	28	21
	Outlet	58	45	37	40	46	41	32	19				
40%	Casing Radiated	54	49	38	38	24	24	25	30				
	Intake	40	48	37	51	42	39	33	24	23	16	24	17
	Outlet	46	40	29	41	38	33	22	7				

Units are independently tested at ISVR in accordance with BS EN ISO 3741:2010.

	Parameter	Description
1	Sound Power Levels: Casing Radiated	These sound power levels (SWL / L_W), in dB, describe the sound being emitted by the unit, at various fan speeds
2	Sound Power Levels: Intake / Outlet	These sound power levels (SWL / L_W), in dB, describe the sound being emitted by the intakes and outlets of the unit, at various fan speeds
3	Noise Rating (NR)	The unit sound power levels above are independent of distance. Once distance (usually at 1 or 3 meters away) is accounted for, the unit sound pressure levels can be calculated. This spectrum is plotted against NR curves to find the unit's resultant NR level, at the respective distances
4	Unit A-Weighted Values (dBA)	Similarly, once the unit sound pressure levels are calculated and the A-weighting correction is applied, the spectrum is then condensed into a single dB(A) value

The resultant figures displayed are specific to a given duty point. Differing duty points may result in different acoustic performance. When selecting products to meet an acoustic need, it is best to get advice from an acoustician to help meet specific site requirements.

Note: *Data for design guidance only. Detailed information is available upon request.*

Acoustic Design Process

During the life cycle of a building, there are many stages where acoustic performance can be affected: from the initial design through to how it is maintained. At every stage of the building's life the acoustic performance should be considered, to be able to find the most effective noise solution and meet the desired expectations.

Co-ordinate mechanical equipment selection

- Balance must be struck between loudness of the sound source and distance located from the space.
- Required coordination between mechanical engineering (system selection) and the architect (space planning).

Reduce source sound levels to the extent possible

- Try and reduce sound levels particularly close to the receiver.
- Avoid low frequency producing equipment, like forward curve fans, as low frequencies are difficult and costly to attenuate.
- Design constant volume fans to operate at peak efficiency and use viable frequency/ EC fans to control fan speed for variable volume units, replacing the need for inlet guide vanes/throttling dampers.

Install duct-borne noise control devices as required

- It can be difficult to meet noise level requirements using standard inline sheet ducts.
- Some combination of sound attenuation, sound plenums and acoustic flex duct will be required to achieve conformance with the standard specified.

Follow guidelines related to air velocities, air flow and air balancing

- Larger duct that allows slower air velocities and a duct system designed for smooth airflow to help reduce self-generating noise through air turbulence.
- Install flex without kinks and hard bends.
- Avoid opposed blade dampers on terminal devices.
- Select air terminal devices (grilles, diffusers) with NR rating of 18 or less.

Avoid common duct routing pitfalls

- Don't use unducted/plenum returns/exhausts.
- Route noise ducts away from sound sensitive spaces.
- Route common duct away from adjacent sound sensitive spaces - avoid cross talk phenomenon.

Correct HVAC equipment

- Correctly specify, install and commission HVAC equipment.

Monitor the engineering process

- Avoid value engineering noise critical parts.
- Monitor the construction and installation process with regular reviews.
- Ensure site specific reviews are carried out.

Regulations and Guidance

Building Regulations and Standards

Building Regulations Approved Document E: resistance to the passage of sound gives guidance for compliance with Building Regulations for building work carried out in England (and defined building work in Wales). Similarly Technical Handbooks covering Noise are available for compliance guidance in Scotland. These documents cover all aspects of acoustic treatment and consideration, for domestic and non-domestic buildings.

Building Bulletin 93 - Acoustic design of schools

BB93: Acoustic Design of Schools sets out minimum performance standards for the acoustics of school buildings and describes the normal means of demonstrating compliance with the Building Regulations. It is relevant to both noise transferred through the building structure and from ventilation equipment and provides guidance on noise ingress from external sources, noise transfer between spaces, and acoustic absorption within spaces. The table below is an excerpt from the current document (2015) showing as an example general teaching spaces have a noise limit of 35dB(A) $_{LAeq,\ 30mins}$ for new builds and 40dB(A) for existing buildings.

For further reading, copies of the above documents are freely available from the respective government websites.

Type of Room	Upper limit for the indoor ambient noise level ($L_{Aeq,\ 30mins}$ dB)	
	New Build	Refurbishment
General Teaching Area	35	40
Science Laboratory	40	45
Design & Technology	40	45
Sports Hall	40	45
Libraries	40	45
Recording Studio	30	35
Kitchen	50	55
Office	40	45

Solutions For Schools

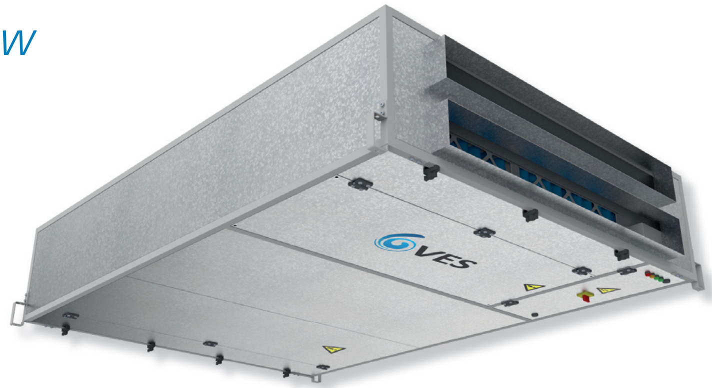
VES offers ventilation and heat recovery solutions to comply with the current BB101, BB102 and BB93 guidelines. The ErP-ready products below are ideal for school classrooms.

Ecovent® EVCB *Counterflow*

With a range of low profile heat recovery units designed to fit into shallow ceiling voids, **Eco**vent® EVCB *Counterflow* from VES is an ideal choice for classroom heat recovery ventilation.

Ecovent® EVCA *Counterflow*

With the same benefits as the EVCB, the **Eco**vent® EVCA *Counterflow* offers a very low profile heat recovery solution. The spigot arrangement has been changed from side-by-side to top and bottom while still achieving airflow and acoustic requirements.



Ecovent® EVH *Hybrid*

A hybrid ventilation approach utilising natural ventilation where possible and integrating mechanical ventilation as required. This makes the **Eco**vent® EVH *Hybrid* range the perfect balance between comfort and energy consumption.

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VES reserves the right to amend product specifications and details without notice.

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