SILENCERS

Basic Principle of Sound

Noise is an unavoidable part of everyday life and technological development has resulted in an increase in noise level from machines, factories, traffic etc. It is therefore important that steps towards a reduction in noise are taken, so that noise is not something we have to accept. In connection with this fight against noise, you must have some basic knowledge about how and where is noise generated, transmitted and attenuated in system in order to be able to select the proper principle and products.

This description does not claim to teach you how to calculate and attenuate noise in a ventilation system - there are books available on this.

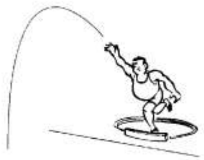
This description only aims at providing information about a few simple rules and hints, which together with common sense can be enough for simple installations.

To take a simple analogy: noise transmission consists of waves in a medium, i.e. air, which we can not see. This is very similar to the way waves spread on water.

Let us examine the analogy, to make the comparison clearer:

Source

Waves on Water
We throw a stone onto completely calm water.



Waves in Air
We fire a starter's gun.

Distribution

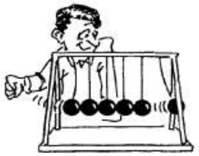
Waves on Water
Waves on water spread out in increasing concentric circles from the centre, where the stone hit the water.

Waves in Air
Sound waves spread out in the air, in all directions, in an increasing ball from the centre, i.e. the gun.

Energy Transport

Waves on Water
Kinetic energy is transmitted from molecule to molecule in the water. They bounce against each other. Molecules move back and forwards. Energy spreads from the source.

Waves in Air
Kinetic energy is transmitted from molecule to molecule in the air. They bounce against each other, and move back and forwards. Energy spreads from the source.



Distance

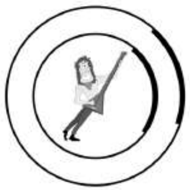
Waves on Water
When waves depart from the centre, where the stone hit, the wave height becomes lower and lower, until they are invisible. The water is calm again.

Waves in Air
When sound waves depart from the source, the starter's gun, wave movement drops off and the sound becomes weaker and weaker until it can no longer be heard.

Intensity

Waves on Water
The energy which started the wave propagation, or the power needed to keep it going, is distributed across and increasing area as the distance, the radius, increases

Waves in Air
The energy which started the wave propagation, or the power needed to keep it going, is distributed across an increasing volume as the distance, the radius, increases.



Obstruction in the Way

Waves on Water
If waves in water encounter the side of a boat or jetty, they will be reflected at the same angle as they met the obstruction.

Waves in Air
If waves in air encounter a wall, they will be reflected at the same angle as they met the obstruction.

In the same way as when you bounce a ball on the wall.

Obstruction in the Way

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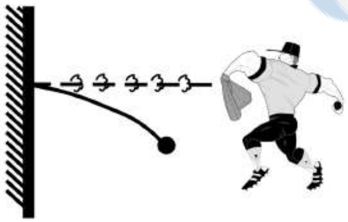


In the same way as when you bounce a ball on the wall.

Absorption

Sound can be absorbed

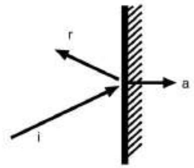
When sound waves meet a soft, porous wall (mineral wool etc.), the vibrating molecules penetrate the surface layer, and are then braked by friction against the material fibres.

The part of the energy which is thus absorbed is converted to heat in the material, and the rest is reflected back into the room. This type of damping, where the sound is braked by the soft surface layer, is referred to as porous absorption.

The sound absorption ability of different materials varies. This property is expressed as the sound absorption factor of the material.

$i = a + r$

$\alpha = \frac{a}{i}$



If nothing is absorbed, everything is reflected, then a = 0 which makes = 0:

$i = a + 0 \qquad \alpha = \frac{a}{a} =$

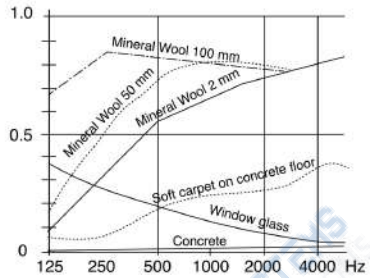
If nothing is absorbed, everything is reflected, then a = 0 which makes = 0:

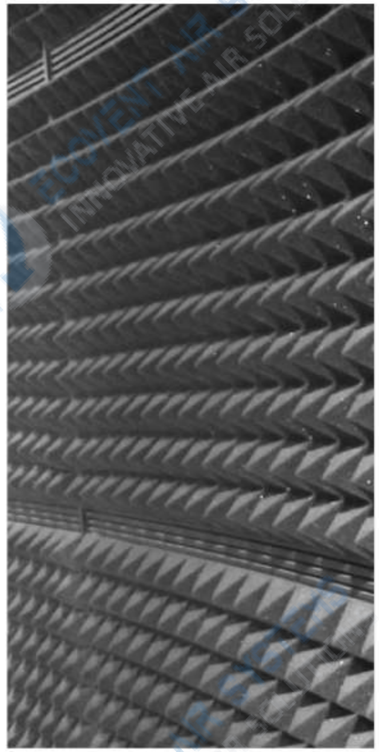
$i = 0 + r \qquad \alpha = \frac{0}{i} =$

An open window can be said to have a = 1, all sound from the room which arrives at the window disappears out!

In hard materials, such as concrete or marble surfaces, virtually no sound energy is absorbed, everything is reflected and the a value is near to zero. In rooms with hard surfaces, the sound bounces for a long time before it dies out. The room has a long reverberation time and we get a strong, unpleasant echo. The sound level caused by normal sound sources becomes high.

In soft materials, such as thick mineral wool boards, the opposite happens. The a value is close to 1. Sometimes, excessively damped, soft rooms are unsuitable "You can't hear what you say". Avoid extremes - the reverberation time in a room should be chosen to suit the activities there.





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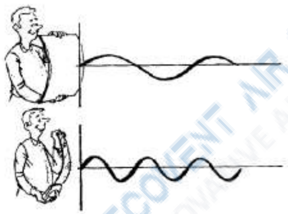
Frequency and Wavelengths

As we see in the tables above, the damping ability varies with the frequency of sound. It could be a good idea to describe the concept of frequency in greater detail.

A sound source influences the surrounding air, and makes it vibrate. The character of the sound depends on the variations in pressure which occur in the air.

Let us assume that the sound source is a vibrating plate - the changes in pressure, or the sound will then have the same frequency as the vibrations in the plate. The strength of the sound will depend on the amount that the plate vibrates, i.e. the amplitude of the movement. Let us start off with that:

If there is only one note, of a single frequency, the pressure will vary sinusoidally, so a pure note is referred to as a sine wave.



The characteristics of sound propagation are:

- frequency (f), which is measured in Hertz, **Hz**, (s-1), (and specifies the number of times a second that a new sound wave arrives).
- wave length (λ, "lambda"), which is measured in metres, **m**, (and specifies the distance between two similar points on the curve).
- speed of sound (c) which is measured in m/s, (and specifies the speed of movement of the sound wave).

These three variables have the following relationship:

c = f • λ

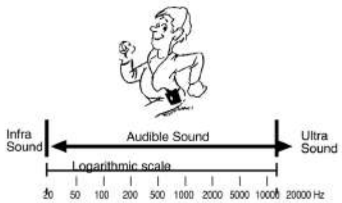
The speed of sound in air is also a function of pressure and temperature.

At normal air pressure and + 20°C:

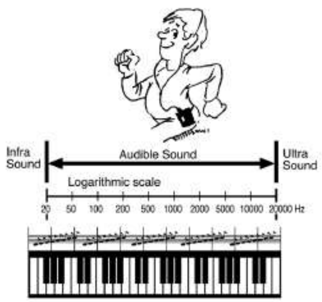
c ≈ 340m/s.

A young person with normal hearing can hear sounds at frequencies from 20-20 000 Hz, i.e. (in air) at wavelengths ranging from 17 m (at 20 Hz) to app. 17mm (at 20 kHz).

We perceive changes in sound frequency on a logarithmic scale, i.e. it is the relative frequency and not the difference in Hz which determines how a change in note is perceived. A doubling of frequency is perceived as being the same, irrespective of whether it is a change from 100 to 200 Hz, 1000 to 2000 Hz or 10 to 20 kHz.



The logarithmic scale is usually sub-divided into octaves. i.e. in scales where the top note is twice the frequency of the bottom note. This has been customary in music for a long time.



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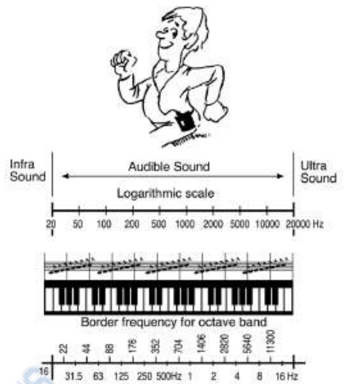
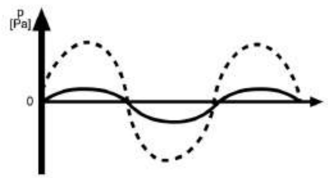
Frequency and Wavelengths



The Concept of Decibel

The stronger the sound is, the harder the particles of air will bump into each other



Sound pressure changes in the audible area can vary within very wide limits. Some sounds are so weak that we can not hear them. The so-called audible limit varies with frequency and is 20 mPa at about 1000 Hz.

Other sounds are so loud that we risk hearing damage. The pain limit, the sound pressure which causes pain in your ears also varies with frequency, but is about 20 Pa at 1000 Hz. This means that it is a million times louder than the weakest sound we can perceive.

We also perceive changes in sound pressure on a logarithmic scale. A sound level concept using the decibel (dB) as the unit, has been created to express comparable values.

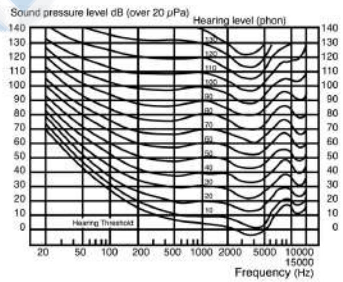
The **dB** unit, which is used in many different applications, is generally defined as: 10 · log (X/X_0), where X is the unit measured, i.e. the sound pressure, and X0 is a reference level expressed in the same units. The reletionship of X/X0 is thus dimensionless. The reference level from which the dB unit is specified, is given instead. This means that you generally express the level in dB (above X_0).

Our Perception of Sound

We react differently to two sounds which have the same sound pressure level and different frequencies.

Curves which describe how people normally perceive sounds of varying strength and frequency have been constructed through experiments on large numbers of volunteers. These so-called hearing level curves are designated by the sound pressure level for each curve at a frequency of 1 kHz. The unit used for the curves is the phon.

Hearing Level Curves



Example:

The sound pressure level 70 dB at 50 Hz is normally perceived as being as loud as 50 dB at 1000 Hz.

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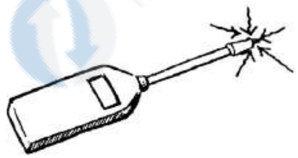
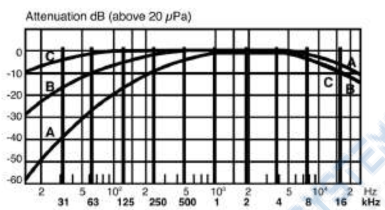
Sound Levels

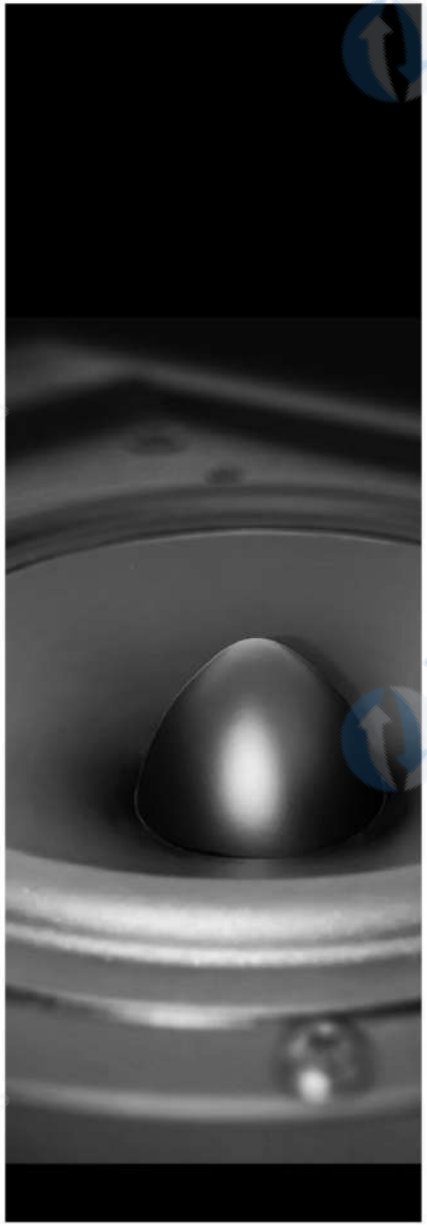


Several methods are used to compare the disturbance caused by two different sounds, and where the perception of the ear to noise has been modelled.

The simplest way is to compare their "weighted" sound levels. The incoming sound is filtered in an electronic filter to reduce the components, mostly the low-frequency components, where the ear is not so sensitive, and amplify the components between 1 and 4 kHz, where we are most sensitive.

Sound meters usually have three electronic filters, A-, B- and C-filter. The A-filter is mostly used these days, where the result, the "weighted" sound level, is expressed in dB (A).





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Sound

Sound is such a common part of everyday life that we rarely appreciated all of its functions. It provides enjoyable experiences such as listening to music or to the singing of birds. It enables spoken communication and it can alter of warn us - for example, with the ringing of a telephone, or a wailing siren. Sound also permits us to make quality evaluations and diagnoses - the chattering valves of a car, a squeaking wheel, or a heart murmur.

Sound and Noise

Yet, too often in our modern society, sound annoys us. Many sounds are unpleasant or unwanted - these are called noise. However, the level of annoyance depends not only on the quality of the sound, but also our attitude towards it.

For example the type of music enjoyed by some people could be regarded as noise by others, especially if it is loud. But sound doesn't need to be loud to annoy. A creaking floor, a scratch on a record, or the intermittent sound of a dripping tap can be just as annoying as loud thunder. The judgement of loudness will also depend on the time of the day. For example, a higher level of noise will be tolerated during the day than at night.

Good Acoustic Design

Adequate noise control in a duct system is not difficult to achieve during the design of the system, providing the basic noise control principles are understood. Despite the addition of noise control items in more and more building designs, complaints about HVAC system noise are still common. Investigations into noise complaints by acoustical professionals have found that, in many cases, the correct equipment and materials were used, but they were not properly integrated into a quiet system.

Virtually every survey on building comfort finds that excessive HVAC system noise levels are responsible for more complaints than any other aspect of the building environment. To minimize the possibility that design decisions could cause noise problems, the design team must consider the acoustical impacts of all design decisions, whether they are part of the schematics, design development, working drawings, or construction administration phases of the project.

Therefore, noise control design should begin during the schematic and design development phases and continue throughout the entire design process.

Noise Control Principles

There are three distinct stages to the noise control process:

1. Source.
2. Transmission.
3. Reception

Noise control problem involves examining the noise sources,(fan noise, duct noise, diffuser noise, and building noise) the sound transmission paths, and the receivers. For most HVAC systems, the sound sources are associated with the building mechanical and electrical equipment.

Noise travels from the source to the receiver through many possible sound transmission paths,(structure-borne path through floor, airborne path through supply air system, duct breakout from supply air duct, airborne path through return air system, and airborne path through mechanical equipment room wall). Sound sources are the components that either generate noise, like electric motors, or produced noise when air passes by them, like dampers or diffusers. Sound receivers are generally the occupant of the building.

The noise control engineers are most often constrained to modifying the sound transmission paths as a mean of achieving the desired sound levels in occupied areas of a building.

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Definitions

Attenuation
The reduction of sound level per unit distance by divergence, diffusion, absorption, or scattering.

A-weighted Sound Level
The sound level measured using the A-weighting network of a sound level meter. For broadband sounds, the A-weighted sound level indicates approximate relative loudness.

Background Noise
It is the irreducible noise level measured in the absence of any building occupants when all of known sound sources have been turned off.

Breakout Noise
The transmission of fan or air system noise through duct walls.

Criteria
Noise levels which are subjectively or objectively acceptable in a given environment. The most commonly used criteria are Noise Criteria Curves (NC Levels), Noise Rating Curves(NR Levels) and dB(A).

Decibel (dB)
Commonly, the unit used to measure sound. It is used to quantify both sound pressure level and sound power level.

Direct SPL
Noise which is transmitted directly from a source (i.e. a grille or diffuser) without reflection.

Ductborne Noise
Noise which is transmitted along ductwork, both upstream and downstream of fan.

Flanking Noise (Breakout)
Noise transmitted through a barrier, often a fan casing or ductwork. Any indirect noise path which tends to devalue noise control measures used to reduce tansmission along the more obvious paths.

Frequency (Hz.)
The pitch of sound. The number of sound pressure waves arriving at a fixed point per second.

Insertion Loss
A measure of the noise reduction capability of an attenuator (sometimes of a partition) so named. After the method of testing where a section of ductwork is replaced by an attenuator between two test rooms. One room contains the noise source and the other the sound level measuring equipment. The difference in recorded noise level is said to be the insertion loss due to the insertion of the attenuator in the system.

Noise Outlet
Usually a grille or a diffuser. Any opening acting as a terminal element on either an extract or supply system.

Octave Bands
Subdivisions of the frequency range each identified by its mid (or centre) frequency. By international agreements these comprise 63, 125, 250, 500, 1k, 4k, and 8k Hz. and sometimes 31.5 Hz.

Regenerated Noise
Noise in addition to that produced by the fan, caused by air passing over fixed duct elements such as blades on grilles, dampers, air turns, splitters in attenuators, etc.

Reverberant SPL
Noise which is transmitted by reflection off room surfaces.

Reverberant Time
A measurement of the acoustic "reflectiveness" of a room.

Sound Power Level (SWL)
A theoretical assessment of sound produced at source calculated from the measured sound pressure levels at known distances from the source under known acoustic conditions.A level which depends only on the source and is independent of the environment or location.The sound power level of a fan is therefore very useful information since any level quoted can be compared directly with data from any other manufacturer.

Sound Pressure Level (SPL)
A measured sound level which is an indication only of the noise produced at source since environmental factors such as reverberation and distance from the source have affected the meassurement. The sound pressure level of a fan is not very useful since environmental factors apparent when the unit was measured may or may not be present in the actual location of the plant.

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Acoustic Design Procedures

Good acoustical design requires broad cooperation in the areas of architecture, structural, mechanical, electrical engineering, and acoustics. Delaying the acoustical design until after the structural system design is essentially complete sometimes leaves the design team with little flexibility in selecting and locating cost-effective noise control equipment and materials.

In order to effectively deal with each of the different sound sources and related sound paths associated with an HVAC system, the following design procedures are suggested :

1. Determine the design goal for HVAC system noise for each critical area according to its use and construction. Use Table 14 to specify the desirable NC levels.

2. Relative to equipment that radiates sound directly into a room, select equipment that will be quiet enough to meet the desired design goal.

3. If central or roof-mounted mechanical equipment is used, complete an initial design and layout of the HVAC system, using acoustical treatment where it appears appropriate.

4. Starting at the fan, appropriately add the sound attenuations and sound power levels associated with the central fan, and duct elements between the central fan and the critical room to determine the corresponding sound pressure levels in the room. Be sure to investigate the supply and return air paths. Investigate possible duct sound breakout when central fans are adjacent to the critical room or roof-mounted fans are above the critical room.

5. If the mechanical equipment room is adjacent to the critical room, determine the sound pressure levels in the room associated with sound transmitted through the mechanical equipment room wall.

6. Add the sound pressure levels in the critical room that are associated with all of the sound paths between the mechanical equipment room or roof-mounted unit and the critical room.

7. Determine the corresponding NC level associated with the calculated total sound pressure levels in the critical room.

8. If the NC level exceeds the design goal, determine the octave frequency bands in which the corresponding sound pressure levels are exceeded and the sound paths that are associated with these octave frequency bands.

9. Redesign the system, adding additional sound attenuation to the paths which contribute to the excessive sound pressure levels in the critical room.
10. Repeat steps 4 through 9 until the desired design goal is achieved.

11. Steps 3 through 10 must be repeated for every room that is to be analyzed.

12. Make sure that noise radiated by outdoor equipment will not disturb adjacent properties.

13. With respect to outdoor equipment, use barriers when noise associated with the equipment will disturb adjacent properties.

14. If mechanical equipment is located on upper floors or is roof-mounted, vibration isolate all reciprocating and rotating equipment. It may be necessary to vibration isolate mechanical equipment that is located in the basement of the building.

A sound analysis should be carried out starting from the fan or noise source having ducted connections to the room of interest.

It is strongly recommend that sound level requirements for NC 30 or below be calculated out by ECOVENT so as to ensure a complete check against noise criteria levels.

Fan In-Duct Sound Power Level

Obtain from the fan manufacturer's catalogue information, or calculate the approximate In-duct Sound Power Level from Table 1.

In both case the approximate duty of the fan needs to be known.

These figures are inserted in line a.
Some manufacturers present noise data as a Sound Pressure Level which needs to be converted by applying the relevant correction factor.

Duct System Between the Fan and the Critical Noise Outlet

Select the most critical noise outlet in the duct system, normally the noise outlet nearest to the fan, and estimate the sound power reduction which occurs along the duct path to this outlet and the outlet itself. Using the following information assess the total duct attenuation.

Straight unlined sheet metal ducts provide a degree of attenuation. This is frequency dependent and varies with the minimum duct dimension and duct length. Approximate attenuation of straigth unlined rectangular sheet metal ducts per meter run is shown in Table 2.

To avoid noise breakout problems in the duct attenuation taken should be limited to approximately 15dB.

Circular sheet metal duct attenuation shown in Table 3. Bends provide attenuation as shown in Tables 4 and 5. Duct and bend attenuation figures should be entered against lines b.

At low frequencies some of the sound power on reaching the critical noise outlet is reflected back along the duct. The degree of attenuation due to this phenomenon is dependent on frequency and the total area of the outlet. The attenuation from Table 6 is inserted in line c.

The Sound Power Level leaving the critical outlet is obtained from e=a-(b+c)

Calculate the Room Effect

In a room the sound pressure waves will reach the listener along two paths:

1. Directly, reducing as the (distance)2 from the noise source, known as the Direct Sound Pressure Level.

2. By multiple reflections off the room surfaces and room contents, which will depend upon the size of the room and the reverberation time, known as the Reverberant Sound Pressure Level.

To estimate the Direct Sound Pressure Level.

Calculate the percentage of the total sound leaving the critical noise outlet. This is approximately equal to the percentage of the fan air volume which passes through the critical outlet.

Table 7 gives the factors to be inserted in line f.

Estimate the distance between the nearest listening position and the critical outlet, and using Table 8, insert the distance factors in line g. Unless the specification states otherwise, the commonly applied distance is 1.5 meters.

By examining the position of the nearest outlet in relation to the walls and ceiling of the room will affect the resultant sound pressure level, due to directivity. Select the location type (A, B, or C) using Table 9, which is closest to matching the position of the critical outlet in the room.

Using the charts for the chosen location type and outlet area, insert the factors obtained in line h.

The Direct Sound Pressure Level in the room in line i is equal to the sum of the Sound Power Level leaving the Critical Outlet in line e and lines f g h.

To estimate the Reverberant Sound Pressure Level.

For the fan system in question, Calculate the percentage of the sound emerging from all the noise outlets in the room served by the fan.

This approximates to the percentage of the fan air volume serving the room under investigation.

Using Table 10 insert the factor in line k.

The amount of reflection or absorption of the sound emerging from the noise outlets depends upon the volume and the reverberation time (which is a function of the amount of absorption) of the room. Table 11 and 12 give the factors related to these which are inserted in lines l and m respectively.

The factors tabulated at each Octave Band in lines k,l and m are now added together to give the Total Reverberant Factors.

The Reverberant sound Pressure level (line o) in the room is equal to the sum of the Sound Power Level leaving the Critical Outlet (line e) and the Total Reverberant Factors (lines k + l + m).

To arrive at the Combined Sound Pressure Level, it is necessary to logarithmically sum the Reverberant Sound Pressure Level and the Direct Sound Pressure Level. This can be simplified by using Table 13. The combined pressure level can then be entered in line p.

Required Insertion Loss

The specification will usually give a design criteria for various area function; where one is not given, Table 14 can be used.

The required or selected criterion is inserted in line q.

If the Combined Sound Pressure Level exceeds the Criterion in any Octave Band, then the difference is the Insertion Loss required from the attenuator (line r).

To allow the possible addition of noise from other sources a safety margin of typically 3dB may be added.

The attenuator can now be selected to meet the parameters of insertion loss, physical size and the pressure loss. The Insertion Loss figures are placed in line s as a final check.

The above analysis method takes no account of regenerated noise from attenuators or ductwork elements.

Similarly, it is not possible to deal with the method of selecting attenuators for high pressure systems which commonly have terminal devices that generate noise and often have some attenuation capability

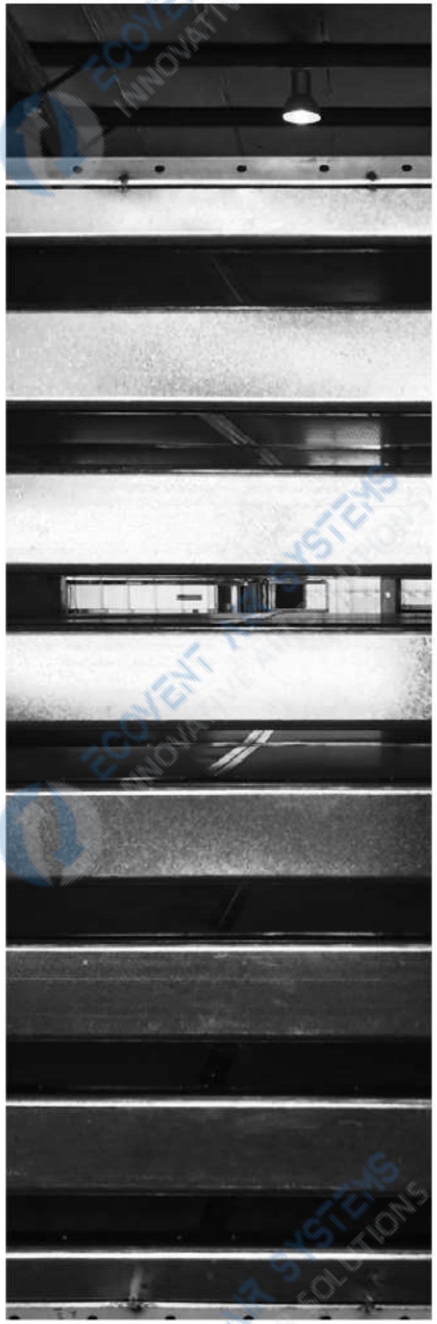

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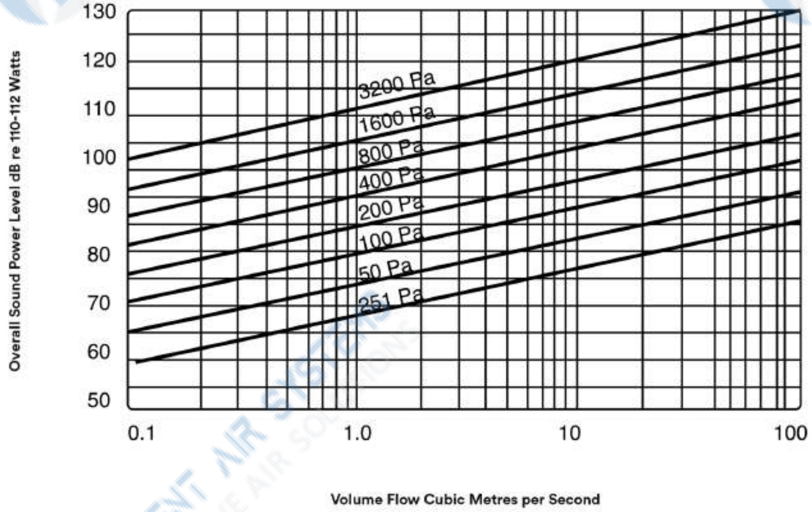
Table 1: In-Duct SWL of the Fan



Spectrum Correction

	Octave Centre Frequency (f_m in Hz)							
	63	125	200	500	1k	2k	4k	8k
Forward Curved Centrifugal	-2	-7	-12	-17	-22	-27	-32	-37
Backward Curved Centrifugal	-7	-8	-7	-12	-17	-22	-27	-32
Axial	-5	-5	-6	-7	-8	-8	-14	-17

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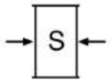
Table 2: Attenuation of Straight Unlined Rectangular Sheet Metal Ducts - (dB/m)

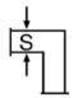


Min. Duct Dimension S (mm)	Octave Centre Frequency (f_m in Hz)							
	63	125	250	500	1k	2k	4k	8k
000 - 200	0.6	0.6	0.45	0.3	0.3	0.3	0.3	0.3
201 - 400	0.6	0.6	0.45	0.3	0.2	0.2	0.2	0.2
401 - 800	0.6	0.6	0.3	0.15	0.15	0.15	0.15	0.15
801 - 1600	0.3	0.15	0.15	0.1	0.06	0.06	0.06	0.06

Table 3: Attenuation of Straight Unlined Circular or Round Sheet Metal Ducts - (dB/m)

Min. Duct Dimension S (mm)	Octave Centre Frequency (f_m in Hz)							
	63	125	250	500	1k	2k	4k	8k
000 - 180	0.03	0.03	0.05	0.05	0.1	0.1	0.1	0.1
181 - 380	0.03	0.03	0.03	0.05	0.07	0.07	0.07	0.07
381 - 760	0.02	0.02	0.02	0.03	0.05	0.05	0.05	0.05
761 - 1520	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02

Table 4: Attenuation of Mitred Bends Without Turning Vanes or with Short Chord Turning Vanes (Rectangular Ducts) - dB



Min. Duct Dimension S (mm)	Octave Centre Frequency (f_m in Hz)							
	63	125	250	500	1k	2k	4k	8k
000 - 200	0	0	0	0	6	8	4	3
201 - 400	0	0	0	6	8	4	3	3
401 - 800	0	0	6	8	4	3	3	3
801 - 2000	0	6	8	4	3	3	3	3

Table 5: Attenuation of Radiussed Bends or Mitred Bends with Long Chord Turning Vanes (Circular or Rectangular Ducts) - dB

Min. Duct Dimension S (mm)	Octave Centre Frequency (f_m in Hz)							
	63	125	250	500	1k	2k	4k	8k
000 - 250	0	0	0	0	1	2	3	3
251 - 500	0	0	0	1	2	3	3	3
501 - 1000	0	0	1	2	3	3	3	3
1001 - 2000	0	1	2	3	3	3	3	3

Table 6: Outlet Reflection (dB)

Outlet Area -cm²	63	125	250	500	1k
	20	15	10	6	3
100	19	14		5	2
	18	13	9	4	
	17		8		
	16	12	7	3	1
	15	11	6		
500	14	10	5	2	
	13	9	4		
	12	8		1	
1000	11	7	3		
	10	6	2		0
	9	5			
	8	4	1		
	7	3		0	
5000	6	2			
	5		0		
10000	4	1			

Octave Centre Frequency (f_m in Hz)

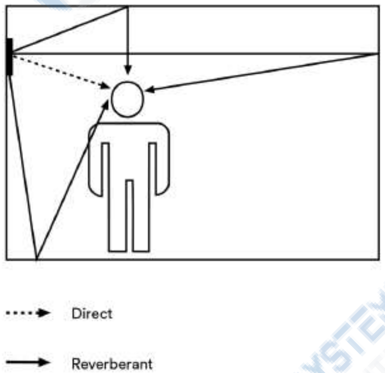


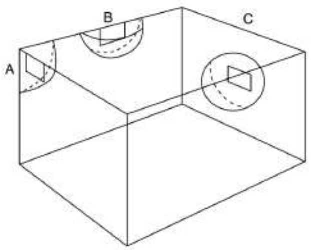
Table 7 : Percentage of Total Sound Factors (dB)

dB	%
-20	1%
-19	
-18	
-17	2
-16	
-15	3
-14	4
-13	5
-12	
-11	
-10	10
-9	
-8	
-7	20
-6	
-5	
-4	
-3	50
-2	
-1	
0	100

Table 8 : Distance Factors (dB)

dB	Distance
-10	
-11	1 meters
-12	
-13	
-14	1.5
-15	
-16	
-17	2
-18	
-19	
-20	3
-21	
-22	4
-23	
-24	
-25	5
-26	6
-27	
-28	7
-29	8
-30	9

Table 9: Directivity Factor (dB)



Type B – Junction of Two Room Surfaces: Outlet Area (cm²) 10 / 100 / 1000 / 10000	Octave Centre Frequency (Hz)
+6, +7, +8	63
+6, +7, +8	125
+6, +7, +8, +9	250
+6, +7, +8, +9	500
+7, +8, +9	1k
+7, +8, +9	2k
+7, +8, +9	4k
+8, +9	8k

Type C – Junction of Two Room Surfaces: Outlet Area (cm²) 10 / 100 / 1000 / 10000 / 100000	Octave Centre Frequency (Hz)
+3, +4, +5, +6, +7	63
+3, +4, +5, +6, +7, +8	125
+3, +4, +5, +6, +7, +8, +9	250
+3, +4, +5, +6, +7, +8, +9	500
+4, +5, +6, +7, +8, +9	1k
+5, +6, +7, +8, +9	2k
+7, +8, +9	4k
+8, +9	8k

ROOMSIDE ANALYSIS

Table 10: Percentage of Total Sound Factors (dB)

dB	%
-20	1%
-19	
-18	
-17	2
-16	
-15	3
-14	4
-13	5
-12	
-11	
-10	10
-9	
-8	
-7	20
-6	
-5	
-4	
-3	50
-2	
-1	
0	100

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Table 11: Room Volume Factor (dB)

dB	Room volume
+10	
+9	3
+8	
+7	5
+6	
+5	
+4	10
+3	
+2	
+1	20
0	
-1	
-2	
-3	50
-4	
-5	
-6	100
-7	
-8	
-9	200
-10	
-11	
-12	
-13	500
-14	
-15	
-16	1000
-17	
-18	
-19	2000
-20	
-21	
-22	
-23	5000
-24	
-25	
-26	10000
-27	
-28	

Table 12: Reverbation Time Factors (dB)

dB	Furnishing
-11	
-10	
-9	
-8	
-7	
-6	
-5	
-4	
-3	Average Furnishing
-2	
-1	
0	Limited Furnishing
+1	
+2	
+3	No Furnishing
+4	
+5	
+6	Very Hard Surface High Ceilings
+7	
+8	
+9	
+10	
+11	

Table 13: Addition of Sound Pressure Levels (dB)

Difference in SPLs	Add to larger SPL
0 to 1	+3
2 to 3	+2
4 to 9	+1
10 and above	+0

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Table 14: Recommended Design Criteria for Various Area Functions

Situation	NC
Section 1 - Studios and Auditoria	
Sound Broadcasting (drama)	15
Sound Broadcasting (general), TV (general), Recording Studio	20
TV (audience studio)	25
Concert Hall, Theatre	20 - 25
Lecture Theatre, Cinema	25 - 30
Section 2 - Hospitals	
Audiometric Room	20 - 25
Operating Theatre, Single Bed Ward	30 - 35
Multi-bed Ward, Waiting room	35
Corridor, Laboratory	35 - 40
Wash Room, Toilet, Kitchen	35 - 45
Staff Room, Recreation Room	30 - 40
Section 3 - Hotels	
Individual Room, Suite	20 - 30
Ballroom, Banquet Room	30 - 35
Corridor, Lobby	35 - 40
Kitchen, Laundry	40 -45
Section 4 - Restaurants, Shops and Stores	
Restaurant, Department Store (upper floor)	35 - 40
Club, Public House, Cafeteria, Canteen, Retail Store (main floor)	40 - 45
Section 5 - Offices	
Boardroom, Large Conference Room	25 - 30
Small Conference Room, Executive Office, Reception Room	30 - 35
Open Plan Office	35
Drawing Office, Computer Suite	35 - 45
Section 6 - Public Buildings	
Court Room	25 - 30
Assembly Hall	25 - 35
Library, Bank, Museum	30 - 35
Wash Room, Toilet	35 - 45
Swimming Pool, Sports Arena	40 - 50
Garage, Car Park	55
Section 7 - Ecclesiastical and Academic Buildings	
Church, Mosque	25 - 30
Classroom, Lecture Theatre	25 - 35
Laboratory, Workshop	35 - 40
Corridor, Gymnasium	35 - 45
Section 8 - Industrial	
Warehouse, Garage	45 - 50
Workshop (light engineering)	45 - 55
Workshop (heavy engineering)	50 - 65
Section 9 - Private Dwelling (Urban)	
Bedroom	25
Living Room	30

Calculation Sheet

Ecovent Acoustics

Project:

Client:

Contractor:

Engineer:

Roomside Analysis Calculations

Date:

Building:

Equipment No:

Offer No:

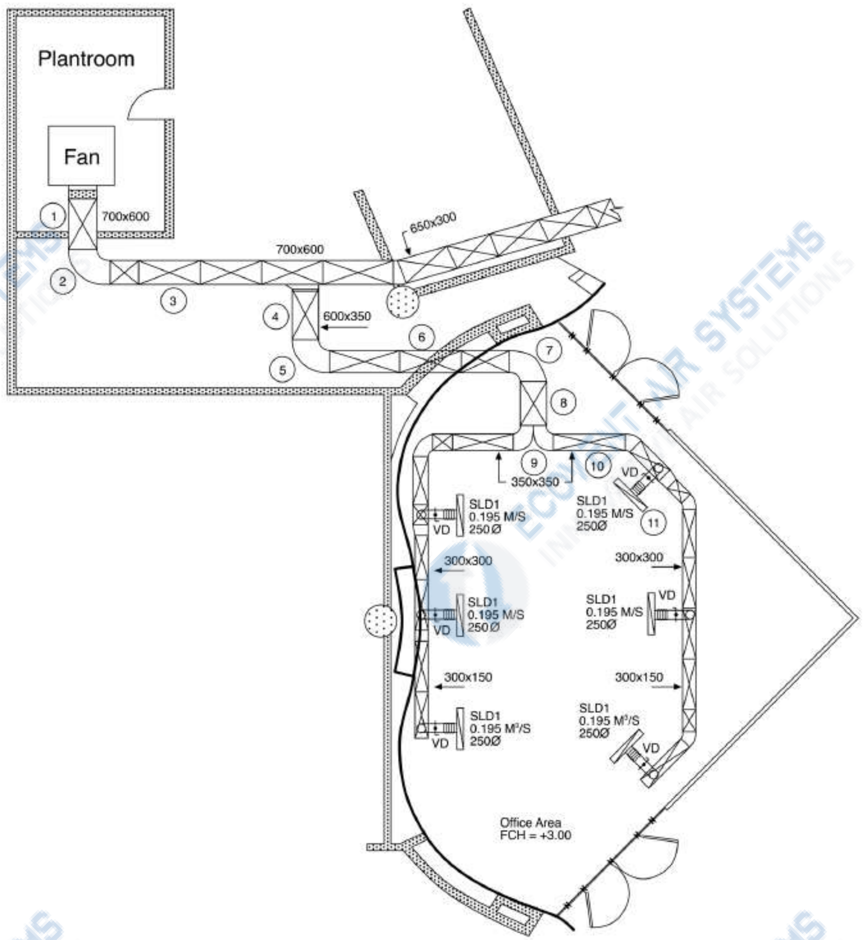
Total Air Flow (M^3/s)

			Octave Centre Frequency							
			63	125	250	500	1k	2k	4k	8k
Source Sound power Level										
Smallest Ducts Dimension (mm)	Length (mm)	-								
		-								
		-								
		-								
		-								
Radiussed Elbows Width (mm)	Qty .	-								
		-								
		-								
		-								
		-								
Additional Attenuation		-								
		-								
		-								
Outlet Reflection Length (cm)	Width (cm)	-								
SWL Leaving System										
Percentage Leaving Outlet M^3/s		-								
Distance from Outlet to Listener (m)		-								
Directivity	Centre of Wall or Ceiling	+								
Direct SPL										
Percentage Leaving Outlet M^3/s		-								
Room Volume Length x Width (m^2)	Height (m)	-								
Reverbation Time	Seconds	+								
Reverberant SPL										
Combined SPL										
Criterion NC / NR / dBA	NC		57	48	41	35	31	29	28	27
Add dB Safety Factor										

Required Insertion Loss

	Octave Centre Frequency							
	63	125	250	500	1k	2k	4k	8k
Required Insertion Losses dB								
Selected Insertion Losses dB								
Air Generated Sound Power Level								

Figure 1 : Duct System For Fan Noise Calculation Example



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Calculation Example

The simple duct system shown in figure 1 will be entered on the calculation sheet to show the steps to be followed to determine whether sound attenuating materials are required to reduce the fan noise in a duct system.

For the duct system described in Figure 1, the sound power level produced by the fan is known from manufacturer's data. Calculate the sound pressure level in office area, at the nearest occupied position to a supply ceiling slot linear diffuser, which is given to be 1.5 meters from the diffuser and directly in line with its axis, and the diffusers are located in the ceiling.

Fan Details

Type : Centrifugal
Duty : 2.26 m3/s at 600 Pa.
Sound Power Level at mid frequency Octave Bands

Hz	63	125	250	500	1k	2k	4k	8k
dB	86	91	87	92	88	88	82	74

Room Details

Room Value : 300 m³
Room Height : 3m
Outlet : : Slot diffuser with 30mm neck width, 1200mm long. Slot diffuser handles 0.195 m³/s.

Room Criterion

NC 35 at 1.5 metres from the noise outlet.
Office area

Roomside Calculation

System Element

Ref	Type	W	H	Length / Type
1	Duct	700	600	2 meters
2	Bend	700	600	Radiused
3	Duct	700	600	5 meters
4	Duct	600	350	2 meters
5	Bend	600	350	Radiused
6	Duct	600	350	6 meters
7	Bend	600	350	Radiused
8	Duct	600	350	2 meters
9	Bend	350	350	Radiused
10	Duct	350	350	2 meters
11	Outlet	2 slot diffuser, 30 mm neck width 1200 mm long		

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Calculation Example

Ecovent Acoustics

Project:
Client:
Contractor:
Engineer:

Roomside Analysis Calculations
Date:
Building:
Equipment No:
Offer No:

Total Air Flow (M^3/s) 2.26

Source Sound power Level

Smallest Ducts Dimension (mm)	600; 350
Length (mm)	7; 12
Radiussed Elbows Width (mm)	700; 600; 350
Qty.	1; 2; 1
Additional Attenuation	
Outlet Reflection – Length (cm)	120
Width (cm)	3

SWL Leaving System {a-(b+c)}

Percentage Leaving Outlet (M^3/s)	0.195	9%
Distance from Outlet to Listener (m)	1.5	
Directivity		Centre of Wall or Ceiling

Direct SPL {e-(f+g)+h}

Percentage Leaving Outlet (M^3/s)	1.17	52%
Room Volume – Length x Width (m^2)	100	Height (m) 3
Reverbation Time		1 Second

Reverberant SPL {e-(k+l)+m}

Combined SPL (logarithmic addition of i an o)

Criterion NC / NR / dBA		NC 35
Add dB Safety Factor	3	

Required Insertion Loss

	Sign	63	125	250	500	1k	2k	4k	8k
a		86	91	87	92	88	88	82	74
b	-	4.2	4.2	2.1	1.05	1.05	1.05	1.05	1.05
b	-	7.2	7.2	5.4	3.6	2.4	2.4	2.4	2.4
b	-			1	2	3	3	3	3
b	-			2	4	6	6	6	6
b	-				1	2	3	3	3
b	-								
c	-	15	10	6	2				
e		60	70	71	78	74	73	67	59
f	-	10	10	10	10	10	10	10	10
g	-	15	15	15	15	15	15	15	15
h	+	3	4	5	6	7	8	8	8
i		38	49	51	59	56	56	50	42
k	-	3	3	3	3	3	3	3	3
l	-	-11	-11	-11	-11	-11	-11	-11	-11
m	+								
o		46	56	57	64	60	59	53	45
p		47	57	58	65	61	61	55	47
q		60	52	45	40	36	34	33	32
q		3	3	3	3	3	3	3	3
r			8	16	28	28	30	25	18

Sound Attenuator Selection

SA / O / 20 - 150 O / 900L x 700W x 600H
Required Insertion Losses dB
Selected Insertion Losses dB
Attenuator Air Flow 2. 26 M3/s
Attenuator Pressure drop 47 Pa

Octave Centre Frequency	63	125	250	500	1k	2k	4k	8k
s		8	16	28	28	30	25	18
s	8	14	20	37	47	32	26	24