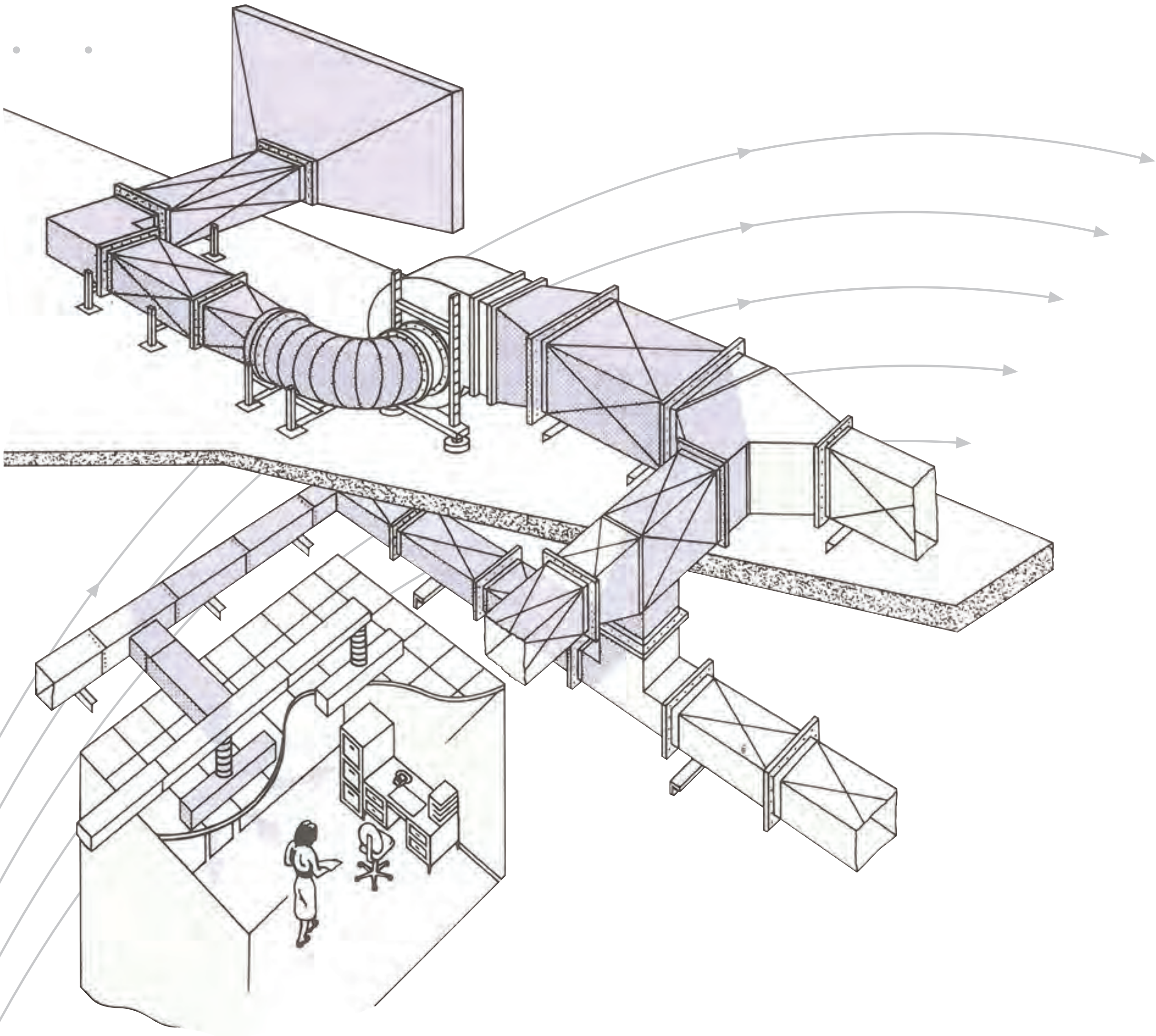
Sound & Sense

Noise Analysis



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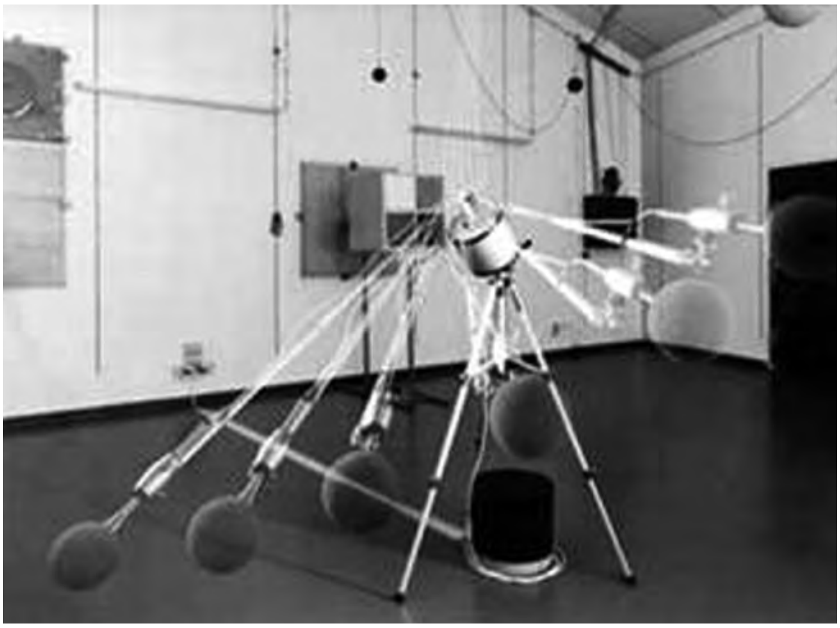


Sound & Sense

TROX has been a leading manufacturer of noise control products since the early 1960s and TROX Acoustics are able to offer a full service in the field of noise and vibration control for the HVAC Industry.
The aim of this publication is to provide an understanding of and a practical approach to the choice of criteria, mathematics and methods involved in noise control. Since its content is drawn from widely recognised authoritative sources within the acoustics field, detailed references and acknowledgements are omitted.

Introduction

In imparting movement to the air, all fans produce noise related to the amount of work they do to move a given air volume against the system resistance.
Much of the noise is generated by the impeller blades cutting through the air setting up complex patterns of vortices and turbulence which cause radiated pressure fluctuations slightly above and below the ambient barometric pressure.
These pressure waves are radiated approximately equally in all directions. However, due to the constrictions of the fan casing there is a noticeable tendency for the noise to be “beamed” from the inlet and the outlet with residual noise passing through the fan casing.
Noise from the fan inlet and outlet which is transmitted along the duct system is referred to as “ductborne noise” whilst that passing through the fan casing or duct walls is called “break-out” or “flanking” noise.

Noise after leaving the fan is transmitted along the duct run or through false ceilings and plantroom walls into occupied areas, where as a result of the acoustic qualities if the room surfaces and furniture, it carries both directly and by reflection to the ears of the listener.
The mechanisms of the ear them amplify the slight pressure fluctuations and convert them into electrical impulses for transmission to the brain where the noise is filtered and assembled into a recognisable signal.

Noise Control - Principles

There are three distinct stages to the noise control process:

i. Source
ii. Transmission
iii. Reception

It is correct, though impracticable, to propose that noise can be controlled at any of these stages. In the case of the fan, for example, the manufacturer has already produced a quiet design within the constraints of commercial prudence and the office worker is unlikely to take too kindly to the suggestion that the wearing of ear protectors is a satisfactory means of combating the air-conditioning noise! This leaves us with having to control the noise during the transmission.

Noise control engineers have two weapons with which to combat noise - mass and absorption - usually applied in a combination. The term mass, for example, meaning the plantroom built of heavyweight materials and absorption being the splitter attenuators strategically located to acoustically seal the ducts where they penetrate the mass barrier.

Good Acoustic Design

It is commonly believed that the ventilation engineer having selected the quietest fan for the required duty need play no further role in noise control except perhaps to call in the noise control specialists at a later date.

Frequently when this happens the acoustic engineer demands vast amount of plantroom space for the attenuators or suggests dramatic changes in design. Both clearly can cost considerable time and money.

The obvious approach, even at the very early stages is to take the acoustic requirements into consideration. Certainly the ventilation engineer should seek advice regarding the following:

1. What noise criteria need to be achieved in the ventilated areas?

2. Is the criteria thus established likely to be achievable without the applications of noise control techniques?

3. If noise control is required, ductwork design must leave sufficient space, preferably in straight duct runs. Plantrooms and plant should be located away from noise sensitive areas. Are plantroom walls substantial enough? Is sufficient pressure development available on the fans for attenuators?

4. Are neighbours likely to be affected by noise? What, if any, atmospheric noise control is required?

5. If plant has to be located close to noise sensitive areas or in false ceiling spaces what additional care should be taken in the initial selection of noisy items?

6. Is the client aware that space restrictions imposed by him could result in noise problems; has the client, in applying for planning permission had any requirements related to noise imposed upon him?

During the design stage, the common pitfalls should be avoided, these include:

1. Right angle bends and take-offs.

2. Ineffective expansions and contractions.

3. Incorrectly located dampers, heater batteries and cooling coils.

4. Fans located above lightweight ceilings or immediately above or below the most sensitive rooms.

In addition some acoustic assessment should be carried out in order to ensure that realistic space is allowed for attenuators and that they are positioned effectively. The method of acoustic analysis shown in this booklet in association with the TROX attenuator catalogue can be used by the ventilation engineer for this purpose. A worked example is shown on pages 16 to 18.

Definitions

Definitions
The following terms are commonly used in the field of acoustics and an understanding of their practical (rather than academic) meaning and import might be of use to the ventilation engineer.

Sound Power Level (SWL)
A theoretical assessment of sound produced at source calculated from the measured sound pressure levels at know distances from the source under know 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
A measured sound level which is an indication only of the noise produced from a source since environmental factors such as reverberation and distance from the source have affected the measurement. 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.

Decibel (dB)
Commonly, the unit used to measure sound, It is a logarithmic ratio of two sound pressures or sound powers where one is a reference level. Care must be exercised when mathmatically manipulating decibels.

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) (weighting).

Ductborne Noise
Noise which is transmitted along ductwork, both upstream and downstream of a 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 transmission along the more obvious paths.

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

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

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

Reverberation Time
A measurement of the acoustic “reflectiveness” of a room.

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.

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. Not normally a problem on low velocity systems and is not dealt with in this booklet.

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, 2k, 4k and 8k Hz. and sometimes 31.5 Hz.

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

Roomside Calculation

A system analysis should be carried out on all fan systems having ducted connections to the area under consideration. We recommend that requirements for NC30 or below be checked by TROX Acoustics before final design.

Part 1

A - How to find the In-duct SWL of the fan

Using the fan manufacturer's catalogue information obtain the In-duct Sound Power Level at the mid-frequency Octave Bands of interest, or calculate the approximate In-duct Sound Power Level from Table 1.
In both cases 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.

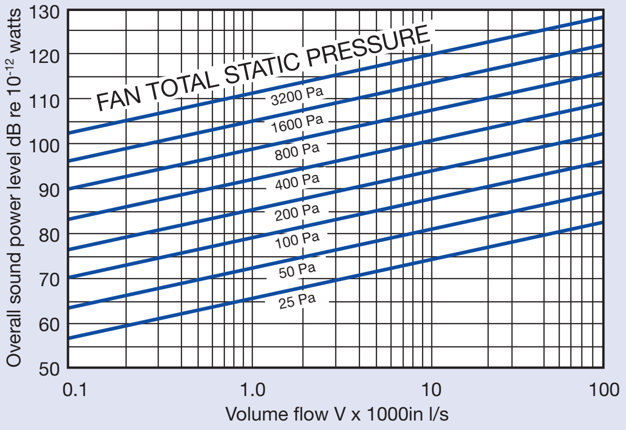
Part 2

Investigate the duct system between the fan and the critical noise outlet

The "critical" noise outlet in the duct system is usually the noise outlet closest to the fan.
Using the following information assess the total duct attenuation:

B - Straight unlined ducts provide a degree of attenuation. This is frequency dependent and varies with the minimum duct dimension and duct length.
Approximate attenuation per metre run is shown in Table 2. To avoid noise breakout problems the duct attenuation taken should be limited to approximately 15dB. Bends provide attenuation as shown in Tables 3a and 3b. Duct and bend attenuation figures should be entered against lines b.
Note: For most pracitcal purposes the attenuation produced by circular ducts can be ignored.

Table 1: In-duct SWL of the fan



Specrtum Correction								
Frequency Hz	63	125	250	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	-11	-14	-17

Table 2: The attenuation of straight unlined rectangular ducts - dB per metre

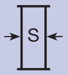
	Minimum duct dim S mm	Octave centre frequency, fm in Hz							
		63	125	250	500	1k	2k	4k	8k
	-200	0.6	0.6	0.45	0.3	0.3	0.3	0.3	0.3
	201-400	0.6	0.6	0.45	0.3	0.2	02	0.2	0.2
	401-800	0.6	0.6	0.3	0.15	0.15	0.15	0.15	0.15
	801-1600	0.3	0.15	0.15	0.1	0.06	0.06	0.06	0.06

Table 3a: The attenuation of mitred bends with short chord turning vanes or no turning vanes

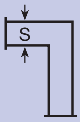
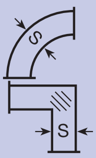
	Dimension S mm	Octave centre frequency, fm in Hz							
		63	125	250	500	1k	2k	4k	8k
	-200	0	0	0	0	6	8	4	3
	201-400	0	0	0	6	8	4	3	3
	401-800	0	0	6	8	4	3	3	3
	801-2000	0	6	8	4	3	3	3	3

Table 3b: The attenuation of mitred bends with long chord turning vanes or radiussed bends (circular or rectangular

	Dimension S mm	Octave centre frequency, fm in Hz							
		63	125	250	500	1k	2k	4k	8k
	-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

Roomside Calculation

C - 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 phenomenom is dependent on frequency and the total area of the outlet. The attenuation from Table 4 is inserted in line c.

D - The total duct attenuation is obtained from lines b and c and is inserted in line d.

E - The Sound Power Level leaving the critical outlet is obtained from: e=a-d

Part 3
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 an the reverberation time, known as the ***Reverberant Sound Pressure Level.***

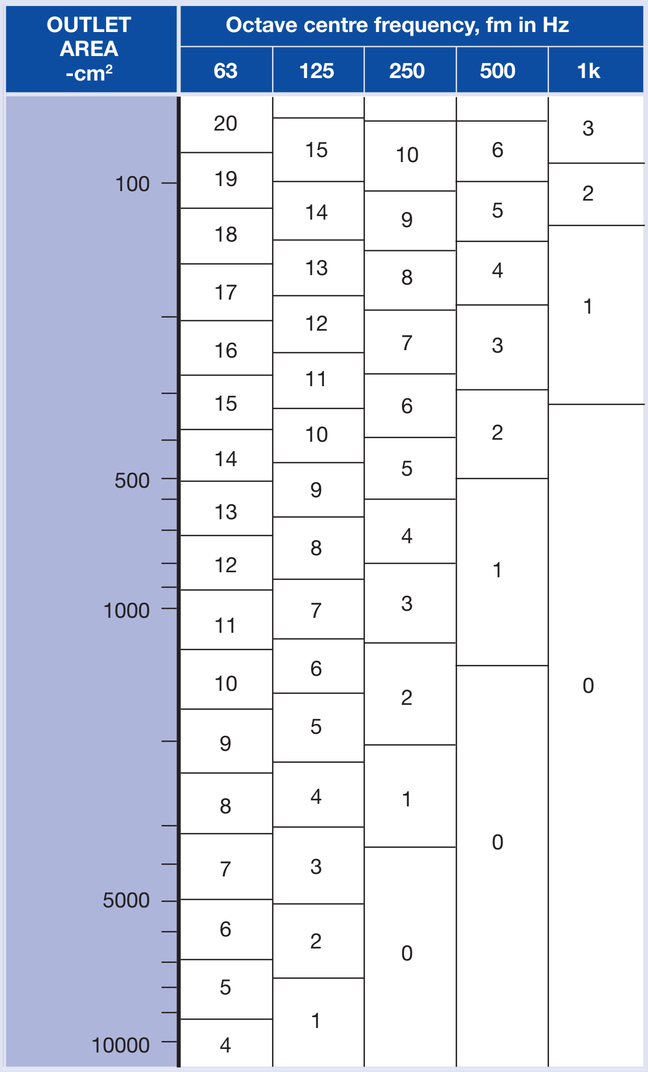
To estimate the ***Direct Sound Pressure Level.***

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

Table 5 gives the factors to be inserted in line f.

G - Estimate the distance between the nearest listening position and the crictical outlet and, using Table 6, insert the distance factors in line g. Unless the specification states otherwise, the commonly applied distance is 1.5 metres.

Table 4: Outlet reflection, dB



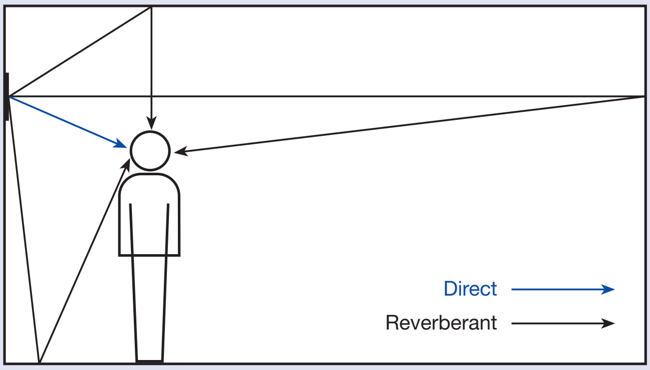


Table 5: Percentage of total sound factors, dB

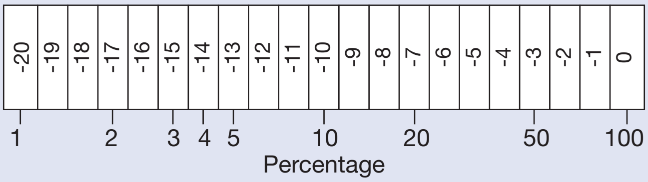
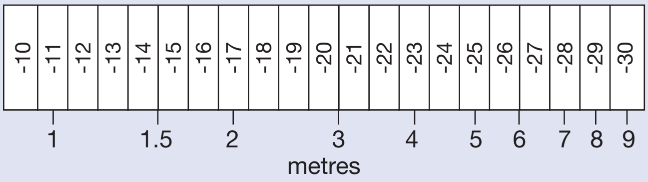


Table 6: Distance Factors, dB



H - By examining Table 7, select the location type (A or B or C) 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.
Note: these figures are positive and to avoid possible confusion the positive sign should also be inserted in line h.

I - The factors tabulated at each Octave Band in lines f, g and h are now added together in line i, to give the total Direct Factors, remembering that the factors in line h are positive.

J - The Direct Sound Pressure Level in the room is equal to the sum of the Sound Power Level leaving the Critical Outlet in line e and the Total Direct Factors shown in line i.

To estimate the ***Reverberant Sound Pressure Level***.

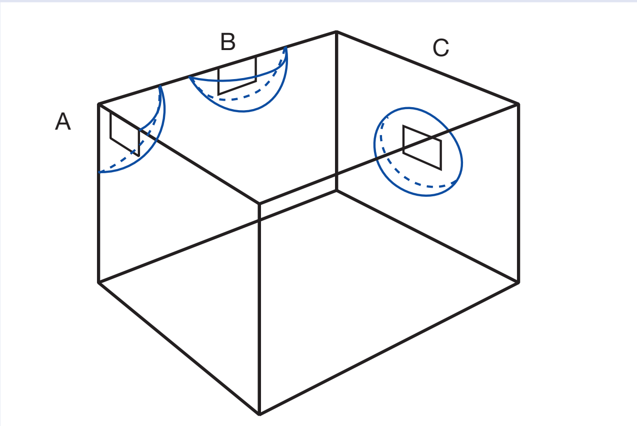
K - For the fan system in question, calculate the percentage of the sound emerging from all th noise outlets in the room served by the fan.

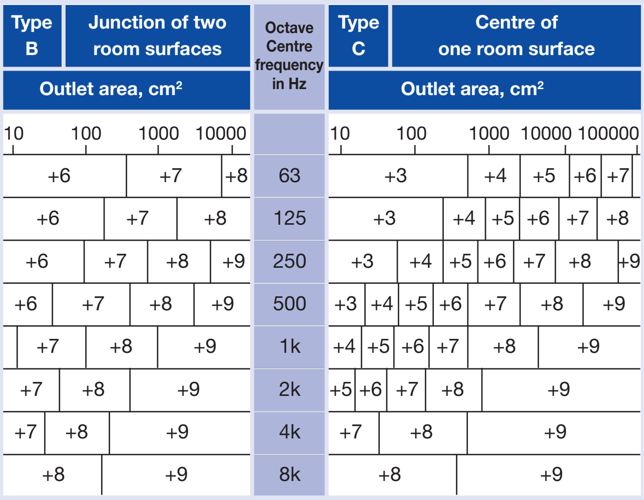
This approximates to the percentage of the fan air volume serving the room under investigation.

Using Table 8 insert the factor in line k.

Table 7: Directivity factor, dB

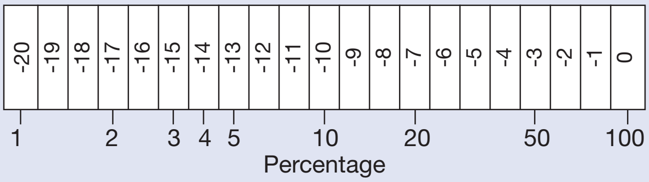
Type A — **Junction of three room surfaces = + 9 throughout**





Type B Junction of two room surfaces Outlet area, cm² (10 – 10000)	Octave Centre frequency in Hz	Type C Centre of one room surface Outlet area, cm² (10 – 100000)
+6 +7 +8	63	+3 +4 +5 +6 +7
+6 +7 +8	125	+3 +4 +5 +6 +7 +8
+6 +7 +8 +9	250	+3 +4 +5 +6 +7 +8 +9
+6 +7 +8 +9	500	+3 +4 +5 +6 +7 +8 +9
+7 +8 +9	1k	+4 +5 +6 +7 +8 +9
+7 +8 +9	2k	+5 +6 +7 +8 +9
+7 +8 +9	4k	+7 +8 +9
+8 +9	8k	+8 +9

Table 8: Percentage of total sound-factors, dB



Roomside Calculation

LM - 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. Tables 9 and 10 give factors related to these which are inserted in lines l and m respectively.

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

O - The Reverberant Sound Pressure Level (line o) in the room is equal to the sum of the Sound Pressure Level leaving the Crtical Outlet (line e) and the Total Reverberant Factors (line n.)

P - 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 11. The combined pressure level can then be entered in line p.

Table 9: Room volume factor, dB

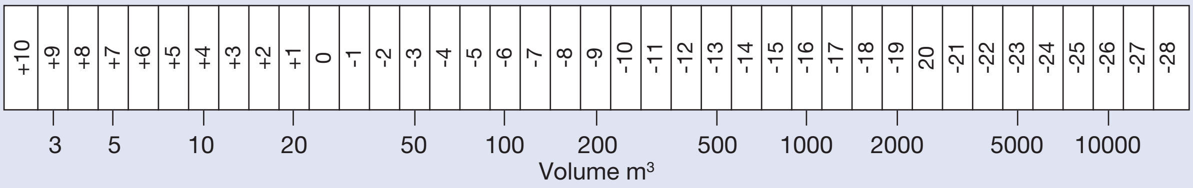
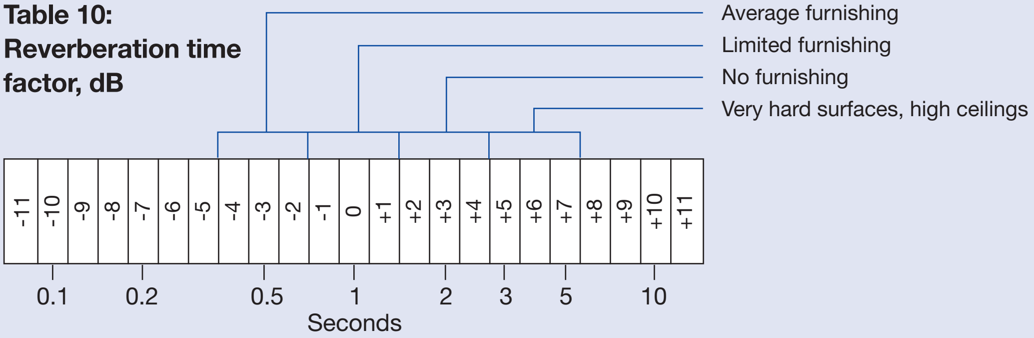


Table 10: Reverberation time factor, dB



Note: reverberation time guide is applicable to typical rooms

Table 11: Addition of Sound Pressure Levels, dB

Differences in SPLs	Add to Larger SPL
0,1	+3
2,3	+2
4,5,6,7,8,9	+1
10+	+0

Part 4
How to find the required insertion loss

Q - The specification will usually give a criterion; where one is not give, Table 12 can be used.

The required or selected criterion is inserted in line q.

R - 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 for the possible addition of noise from other sources a safety margin of typically 3dB may be added.

S - 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 the 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.

Table 12: Recommended design criteria for various area functions (according to CIBSE)

Situation	NC
Concert halls, opera halls, studios for sound reproduction, live theatres (>500 seats)	20
Bedrooms in private homes, live theatres (<500 seats), cathedrals and large churches, television studios, large conference and lecture rooms (>50 people)	25
Living rooms in private homes, board rooms, top management offices, conference and lecture rooms (20-50 people), multi-purpose halls, churches (medium and small), libraries, bedrooms in hotels, etc., banqueting rooms, operating theatres, cinemas, hospital private rooms, large courtrooms	30
Public rooms in hotels, etc., ballrooms, hospital open wards, middle management and small offices, small conference and lecture rooms (<20 people), school classrooms, small courtrooms, museums, libraries, banking halls, small restaurants, cocktail bars, quality shops	35
Toilets and washrooms, large open offices, drawing offices, reception areas (offices), halls, corridors, lobbies in hotels, hospitals, etc., laboratories, recreation rooms, post offices, large restaurants, bars and night clubs, department stores, shops, gymnasia	40
Kitchens in hotels, hospitals, etc., laundry rooms, computer rooms, accounting machine rooms, cafeteria, supermarkets, swimming pools, covered garages in hotels, offices, etc., bowlng alleys	45

Roomside Calculation Sheet

Customer				**Octave centre frequency, fm in Hz**								
Project				63	125	250	500	1k	2k	4k	8k	
Fan duty												
Type												
System	In-duct sound power											a
Duct/Bend	Width x Height	Length/Angle	Type									
												b
Outlet reflection	x	cm²										c
Total duct attenuation (b + c)												d
SWL leaving system												e
Percentage leaving outlet												f
Distance from outlet												g
Directivity												h
Total direct factors (f + g + h)												i
Direct SPL												j
Percentage reaching room												k
Room volume												l
Reverberation time												m
Total reverberant factors (k + l + m)												n
Reverberant SPL												o
Combined SPL												p
Criterion												q
Required insertion loss												r
Selected insertion loss												s
Selection Code:												
			NC55	74	67	62	58	56	54	53	52	
			NR55	79	70	63	58	55	52	50	49	
			NC50	71	64	58	54	51	49	48	47	
			NR50	75	65	59	53	50	47	45	43	
			NC45	67	60	54	49	46	44	43	42	
			NR45	71	61	54	48	45	42	40	38	
			NC40	64	57	50	45	41	39	38	37	
			NR40	67	57	49	44	40	37	35	33	
			NC35	60	52	45	40	36	34	33	32	
			NR35	63	52	45	39	35	32	30	28	
			NC30	57	48	41	35	31	29	28	27	
			NR30	59	48	40	34	30	27	25	23	
			NC25	54	44	37	31	27	24	22	21	
			NR25	55	44	35	29	25	22	20	18	
			NC20	51	40	33	26	22	19	17	16	
			NR20	51	39	31	24	20	17	14	13	

Atmospheric Side Calculation

When the ventilation system inlet or outlet is exposed in a wall or roof, the noise emitted may be heard in the neighbourhood to the annoyance of persons in adjacent properties. The noise level, particularly at night, may be subject to Local Authority regulation and extreme care must therefore be exercised in the calculation and selection of suitable attenuation equipment. The first five stages (lines a-e) required are identical to those given in the Roomside Calculation, except that where there are several noise outlets close together in a wall, the Combined Sound Power of all these outlets should be inserted in line e. We recommend that requirements for NC30 (35dBA) or below be checked by TROX Acoustics before final design.

F - Using Tables 13 & 14, obtain the value of the Directivity Index at the frequencies of interest. Using the appropriate directivity index and angle obtain a Directivity Factor and insert in line f.

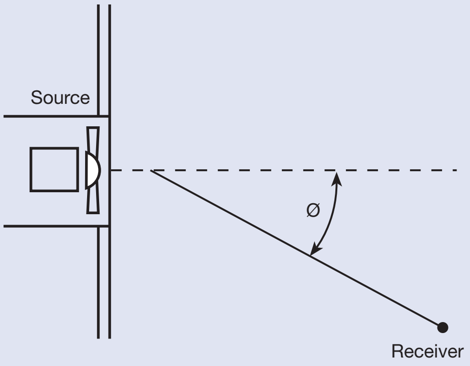
Note: values here may be positive or negative.

Table 13: Directivity Index

Frequency, Hz	Inlet/Outlet Area (m^2)													
	0.25	1	2.5	5	8	14	20	30	40	60	90	120	160	250
63	4	5	6	6	7	7	8	8	8	8	8.5	8.5	9	9
125	5	6	7	7	8	8	8	8.5	8.5	9	9	9	9	9
250	6	7	8	8	8.5	9	9	9	9	9	9	9	9	9
500	7	8	8.5	9	9	9	9	9	9	9	9	9	9	9
1K	8	8.5	9	9	9	9	9	9	9	9	9	9	9	9
2K	8.5	9	9	9	9	9	9	9	9	9	9	9	9	9
4K	8.5	9	9	9	9	9	9	9	9	9	9	9	9	9
8K	9	9	9	9	9	9	9	9	9	9	9	9	9	9

Table 14: Directivity Factor, dB

Index From Table 13	Directivity Angle (Ø)									
	0°	20°	40°	60°	70°	80°	90°	100°	120°	140°
4	+4	+4	+3	+3	+2	+2	+2	+2	+1	0
5	+5	+5	+4	+3	+2	+1	+1	+1	0	-2
6	+6	+6	+4	+3	0	-1	-1	-1	-3	-6
7	+7	+6	+5	+2	0	-1	-2	-4	-9	-15
8	+8	+7	+5	+2	-1	-4	-7	-13	-30	-45
8.5	+8.5	+7	+5	+1	-8	-16	-20	-28	-40	-50
9	+9	+8	+6	0	-15	-25	-35	-45	-50	-60



This table may also be used with stacks, up to a 120° angle from the axis

Atmospheric Side Calculation

G - Estimate the effect on the Sound Pressure level due to the distance between the outlet and the receiving position using Table 15. The specification should state this distance. Where it does not, an inspection of the adjoining properties for the "critical" property should enable the distance to be established.

- Point Source - typically up to 1m2
- Line Source - typically up to 0.5m high by 3m or more wide
- Plane Source - any larger area

Table 15: Reduction, dB of SPL at a distance from noise source. (e.g. a fan behind a louvre)

Distance to receiver, metres	Point Source	Line Source, m		Rectangular Plane Source, m x m			
		3	10	1 x 3	1 x 10	3x3	3 x 10
50	-45	-45	-45	-45	-45	-45	-45
	-44	-44	-44	-44	-44	-44	-44
	-43	-43	-43	-43	-43	-43	-43
	-42	-42	-42	-42	-42	-42	-42
30	-41	-41	-41	-41	-41	-41	-41
	-40	-40	-40	-40	-40	-40	-40
	-39	-39	-39	-39	-39	-39	-39
	-38	-38	-38	-38	-38	-38	-38
20	-37	-37	-37	-37	-37	-37	-37
	-36	-36	-36	-36	-36	-36	-36
	-35	-35	-35	-35	-35	-35	-35
	-34	-34	-34	-34	-34	-34	-34
	-33	-33	-33	-33	-33	-33	-33
	-32	-32	-32	-32	-32	-32	-32
10	-31	-31	-31	-31	-31	-31	-31
	-30	-30	-30	-30	-30	-30	-30
	-29	-29	-29	-29	-29	-29	-29
	-28	-28	-28	-28	-28	-28	-28
	-27	-27	-27	-27	-27	-27	-27
	-26	-26	-26	-26	-26	-26	-26
5	-25	-25	-25	-25	-25	-25	-25
	-24	-24	-24	-24	-24	-24	-24
	-23	-23	-23	-23	-23	-23	-23
	-22	-22	-22	-22	-22	-22	-22
	-21	-21	-21	-21	-21	-21	-21
3	-20	-20	-20	-20	-20	-20	-20
	-19	-19		-19		-19	
	-18	-18	-19	-18	-19	-18	-19
2	-17	-17		-17		-17	
	-16	-16	-18	-16	-18	-16	-18
	-15	-15		-15		-15	
1.5	-14	-14	-17	-14	-17	-14	-17
	-13	-13		-13		-13	
	-12	-12	-16	-12	-16	-12	-16
1	-11	-11		-11		-11	
	-10	-10	-15	-10	-15	-10	-15

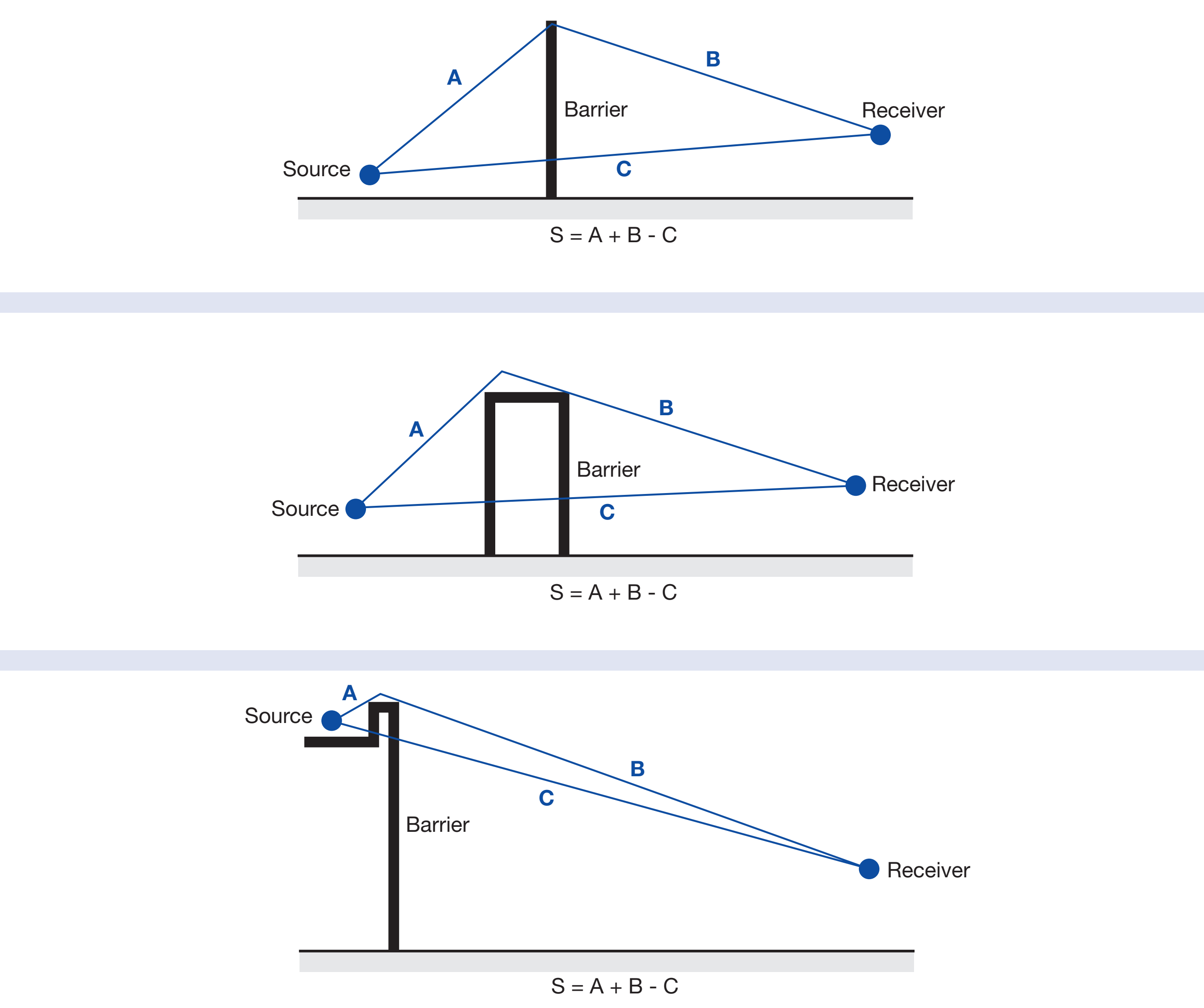
H - Where the criterion is to be achieved inside an adjacent building, the sound insultation performance of the structure will dictate, to a large extent, the amount of noise which enters the building. For most practical purposes, it can be assumed that non-openable windows will offer a reduction which is equivalent to raising the criterion by NC/NR10 and openable windows by the equivalent of NC/NR5 this can be inserted in line h. In critical locations, the criterion will be established at the neighbour's boundary and the above will not therefore apply.

I - When a barrier is located in such a position that it blocks the direct noise path, some attenuation can result particularly at the higher frequencies.

Table 16 shows three such positions and enable the calculcation of the "S" value, which can then be entered on Table 17 to find the attenuation which is in turn inserted in line i.

This chart assumes that the barrier has infinite length and for most practical purposes, a barrier such as a boundary wall or parapet can be assumed to be infinite. However, where a barrier does not meet with this definition, that is, where noise clearly not only diffracts over the top but also around the sides of a barrier, the resultant Sound Pressure Level must be calculated for each noise path and then logarithmically combined using Table 11 found in Roomside Calculation Method.

Table 16



J - The figures in lines f, g, h and i at each Octave Band are summated in line j.

K - The Sound Pressure Level at the specified location in line k is equal to the sum of the Sound Pressure Level leaving the critical outlet (line e) and the total reduction (line j) obtained from directivity, distance, construction and barriers.

L - The specification should give the criterion and at what specific location. This criterion is inserted in line l.

M - If the Sound Pressure Level at the specified location exceeds the criterion in any Octave Band then the difference is the Insertion Loss required (line m).

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

Table 17

Additional Attenuation due to Screens:
S = A + B - C (metres)

S(m)	Octave centre frequency, fm in Hz							
	63	125	250	500	1k	2k	4k	8k
-0.3	1	0	0	0	0	0	0	0
-0.2	2	1	0	0	0	0	0	0
-0.1	3	2	1	0	0	0	0	0
-0.05	3	3	2	1	0	0	0	0
-0.01	4	4	4	3	3	2	1	0
0	5	5	5	5	5	5	5	5
0.01	5	6	6	6	7	8	8	9
0.05	7	7	8	9	10	12	13	15
0.1	7	8	9	10	11	14	16	18
0.2	8	9	10	11	14	16	19	20
0.3	8	9	10	13	16	18	20	22
0.4	9	10	12	14	17	20	22	24
0.5	9	10	12	15	18	20	23	25
1.0	11	12	14	18	20	23	25	27
1.5	13	14	16	19	22	25	27	30
2.0	14	15	18	20	24	27	29	31
3.0	15	17	20	22	25	28	30	32
4.0	16	18	20	24	26	30	31	33
5.0	16	18	21	25	27	30	32	34

Atmospheric Side Calculation Sheet

Customer				**Octave centre frequency, fm in Hz**								
Project				63	125	250	500	1k	2k	4k	8k	
Fan duty												
Type												
System	In-duct sound power											a
Duct/Bend	Width x Height	Length/Angle	Type									
												b
Outlet reflection	x		cm^2									c
Total duct attenuation (b + c)												d
SWL leaving system												e
Directivity												f
Distance from outlet												g
Building contruction												h
Barrier												i
Total attenuation (f + g + h + i)												j
SPL at specified location												k
Criterion												l
Required insertion loss												m
Selected insertion loss												n
Selection Code:												
			NC55	74	67	62	58	56	54	53	52	
			NR55	79	70	63	58	55	52	50	49	
			NC50	71	64	58	54	51	49	48	47	
			NR50	75	65	59	53	50	47	45	43	
			NC45	67	60	54	49	46	44	43	42	
			NR45	71	61	54	48	45	42	40	38	
			NC40	64	57	50	45	41	39	38	37	
			NR40	67	57	49	44	40	37	35	33	
			NC35	60	52	45	40	36	34	33	32	
			NR35	63	52	45	39	35	32	30	28	
			NC30	57	48	41	35	31	29	28	27	
			NR30	59	48	40	34	30	27	25	23	
			NC25	54	44	37	31	27	24	22	21	
			NR25	55	44	35	29	25	22	20	18	
			NC20	51	40	33	26	22	19	17	16	
			NR20	51	39	31	24	20	17	14	13	

A Worked Example

Fan details: Centrifugal. Duty: 9.5m^3/s at 870 Pa.
SWL Noise spectrum at mid frequency Octave Bands

63	125	250	500	1k	2k	4k	8k	Hz
105	104	101	98	97	94	90	86	dB

Roomside Calculation

System Element		W	H	Length/Type
1	Duct	1500	1500	5metres
2	Bend	750	1500	Radiused
3	Bend	750	750	Radiused
4	Bend	750	450	Radiused
5	Bend	450	450	Right angled
6	Duct	750	450	10 metres
7	Duct	450	450	10 metres
8	Outlet	2 slot diffuser 2000mm long, each slot 15mm wide. Each diffuser handles 0.58m^3/s.		

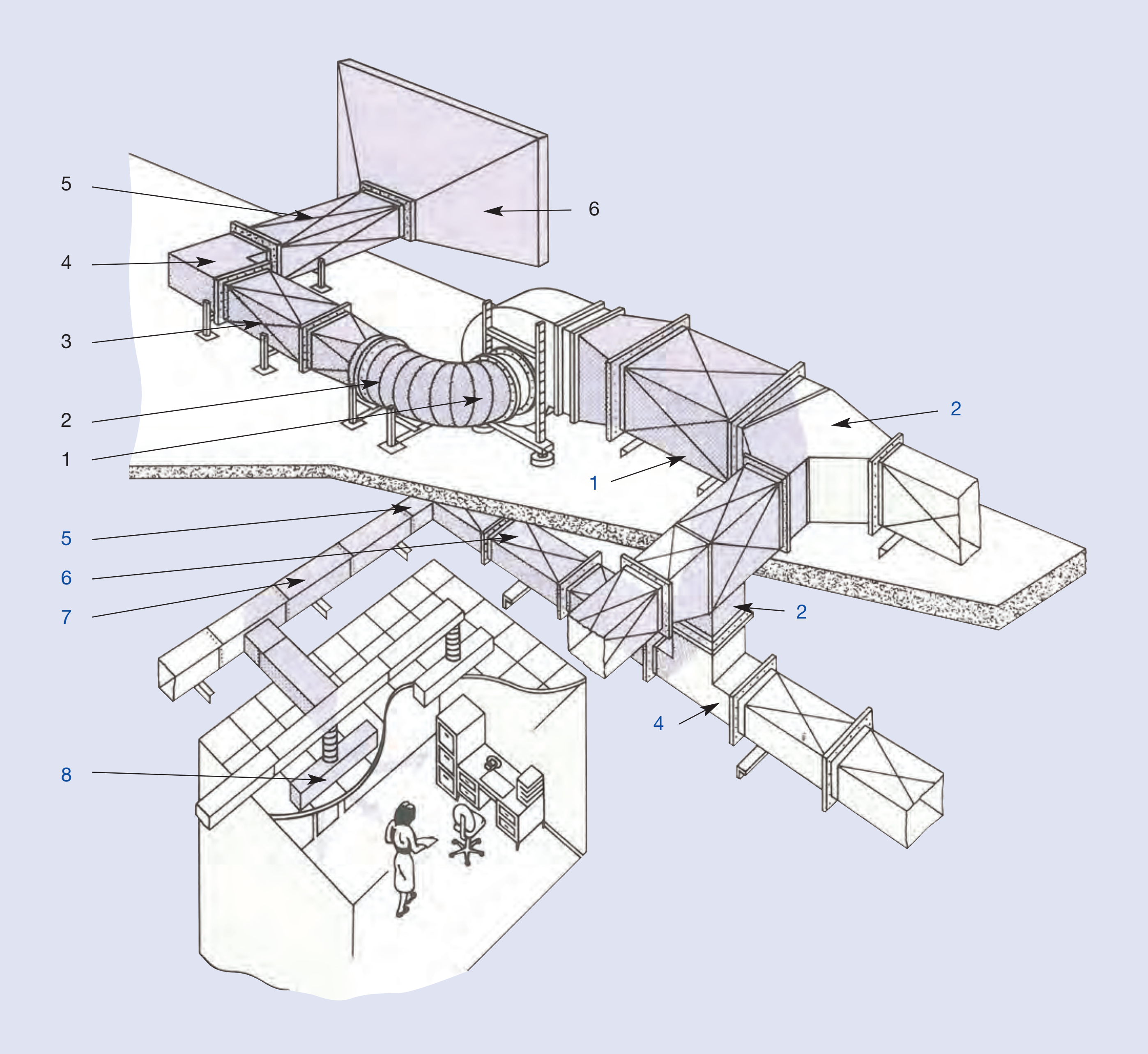
ROOM DETAILS
Size: 10 metres long x 3.5 metres wide x 2.25 metres high.
Two diffusers in room

ROOM CRITERION
NC35 at 1.5 metres from the noise outlet.
Office accommodation.

Atmospheric Calculation

System Element Ref	Type	W	H	Length/Type
1	Bend	900dia		Radiused
2	Duct	900dia		5 metres
3	Duct	900	700	5 metres
4	Bend	900	700	Radiused
5	Duct	900	700	10 metres
6	Outlet	2000	2000	

ATMOPSPHERIC CRITERION
NC40 at 10 metres at 45° to the axis of the noise outlet



Roomside Calculation Sheet

Customer				**Octave centre frequency, fm in Hz**								
Project				63	125	250	500	1k	2k	4k	8k	
Fan duty 905m^3/s @ 870 Pa												
Type Centrifugal												
System Supply		In-duct sound power		105	104	101	98	97	94	90	86	a
Duct/Bend	Width x Height	Length/Angle	Type									
Duct	1500 x 1500	5 metres	Rect.	1	1	1	0	0	0	0	0	b
Bend	750 x 1500		Radiused	0	0	1	2	3	3	3	3	
Bend	750 x 750		Radiused	0	0	1	2	3	3	3	3	
Bend	750 x 450		Radiused	0	0	0	1	2	3	3	3	
Duct	750 x 450	10 metres	Rect.	6	6	3	1	1	1	1	1	
Bend	450 x 450		Rt-angled	0	0	6	8	4	3	3	3	
Duct	450 x 450	10 metres	Rect.	6	6	3	1	1	1	1	1	
Outlet reflection	3 x 200		= 600 cm^2	13	9	4	1	0	0	0	0	c
Total duct attenuation (b + c)				26	22	19	16	14	14	14	14	d
SWL leaving system				79	82	82	82	83	80	76	72	e
Percentage leaving outlet			6%	-12	-12	-12	-12	-12	-12	-12	-12	f
Distance from outlet			1.5m	-14	-14	-14	-14	-14	-14	-14	-14	g
Directivity			Type C	+3	+4	+5	+6	+7	+8	+8	+9	h
Total direct factors (f + g + h)				-23	-22	-21	-20	-19	-18	-18	-17	i
Direct SPL				56	60	61	62	64	62	58	55	j
Percentage reaching room			12%	-9	-9	-9	-9	-9	-9	-9	-9	k
Room volume			79 m^3	-5	-5	-5	-5	-5	-5	-5	-5	l
Reverberation time			1 sec	0	0	0	0	0	0	0	0	m
Total reverberant factors (k + l + m)				-14	-14	-14	-14	-14	-14	-14	-14	n
Reverberant SPL				65	68	68	68	69	66	62	58	o
Combined SPL				66	69	69	69	70	67	63	60	p
Criterion			NC35	60	52	45	40	36	34	33	32	q
Required insertion loss				6	17	24	29	34	33	30	28	r
Selected insertion loss				11	17	30	50	50	50	42	33	s
Selection Code:												
			NC55	74	67	62	58	56	54	53	52	
			NR55	79	70	63	58	55	52	50	49	
			NC50	71	64	58	54	51	49	48	47	
	DS 20-100/1500		NR50	75	65	59	53	50	47	45	43	
			NC45	67	60	54	49	46	44	43	42	
			NR45	71	61	54	48	45	42	40	38	
			NC40	64	57	50	45	41	39	38	37	
			NR40	67	57	49	44	40	37	35	33	
			NC35	60	52	45	40	36	34	33	32	
			NR35	63	52	45	39	35	32	30	28	
			NC30	57	48	41	35	31	29	28	27	
			NR30	59	48	40	34	30	27	25	23	
			NC25	54	44	37	31	27	24	22	21	
			NR25	55	44	35	29	25	22	20	18	
			NC20	51	40	33	26	22	19	17	16	
			NR20	51	39	31	24	20	17	14	13	

Atmospheric Side Calculation Sheet

Customer				**Octave centre frequency, fm in Hz**								
Project				63	125	250	500	1k	2k	4k	8k	
Fan duty 905m^3/s @ 870 Pa												
Type Centrifugal												
System Supply	In·duct sound power			105	104	101	98	97	94	90	86	a
Duct/Bend	Width x Height	Length/Angle	Type									
Bend	900 dia.		Radiused	0	0	1	2	3	3	3	3	b
Duct	900 dia.	5 metres	Circular	0	0	0	0	0	0	0	0	
Duct	900 x 700	5 metres	Rect.	3	3	1	1	1	1	1	1	
Bend	900 x 700		Radiused	0	0	1	2	3	3	3	3	
Duct	900 x 700	10 metres	Rect.	6	6	3	1	1	1	1	1	
Outlet reflection		200 x 200	40000 cm^2	0	0	0	0	0	0	0	0	c
Total duct attenuation (b + c)				9	9	6	6	8	8	8	8	d
SWL leaving system				96	95	95	92	89	86	82	78	e
Directivity		4m^2	@ 40°	+4	+5	+5	+6	+6	+6	+6	+6	f
Distance from outlet			10m	-31	-31	-31	-31	-31	-31	-31	-31	g
Building construction												h
Barrier												i
Total attenuation (f + g + h + i)				-27	-26	-26	-25	-25	-25	-25	-25	j
SPL at specified location				69	69	69	67	64	61	57	53	k
Criterion			NC40	64	57	50	45	41	39	38	37	l
Required insertion loss				5	12	19	22	23	22	19	16	m
Selected insertion loss				8	12	22	39	50	40	28	23	n
Selection Code:												
			NC55	74	67	62	58	56	54	53	52	
			NR55	79	70	63	58	55	52	50	49	
			NC50	71	64	58	54	51	49	48	47	
	DS 20-150/1500		NR50	75	65	59	53	50	47	45	43	
			NC45	67	60	54	49	46	44	43	42	
			NR45	71	61	54	48	45	42	40	38	
			NC40	64	57	50	45	41	39	38	37	
			NR40	67	57	49	44	40	37	35	33	
			NC35	60	52	45	40	36	34	33	32	
			NR35	63	52	45	39	35	32	30	28	
			NC30	57	48	41	35	31	29	28	27	
			NR30	59	48	40	34	30	27	25	23	
			NC25	54	44	37	31	27	24	22	21	
			NR25	55	44	35	29	25	22	20	18	
			NC20	51	40	33	26	22	19	17	16	
			NR20	51	39	31	24	20	17	14	13	