



Glass and Noise Control

Technical Bulletin



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Introduction

Noise is unwanted sound, whether it originates from road traffic, railways, aircraft, factories, discos or merely from neighbours. It is a nuisance and may cause annoyance, impair work performance and, in the extreme, contribute to illnesses, both physical (tinnitus) and psychological, a fact recognised and campaigned against by the World Health Organisation.

Glazing and windows have an important role in attenuating outside noise so that building occupants are not unduly disturbed. Achieving this may involve employing thick glass, double or multiple glazing, laminated glass, and their combinations.



The appropriate technique selected depends on a number of factors, including the nature of the noise, when and for how long it occurs, and the task or activity of people inside the building.

This booklet is designed to provide relevant acoustic information on glazing, according to the immediate needs of its readers. For those who are broadly conversant with the subject, the sound insulation data in Tables 1–3 may provide all that is required.

However, the circumstances in which these are applied may demand further study and explanation, and supplementary guidance is given e.g. conversion into attenuation values, according to noise spectrum.

The essential acoustic characteristics of a wide range of glasses and windows may be found in the supporting text, as are the main features of the corresponding spectra of typical major transportation noises.

Where technical terms are used, their meanings are defined, together with a glossary of acoustic indices.



Mondial Centre, Heathrow



Sound Insulation of Glazing

Single Glazing Monolithic Glass

Theoretical Mass Law considerations indicate that a 6 dB increase in sound insulation should result from doubling the glass thickness. However, resonances interfere with this trend, and in practice the incremental increase is reduced to about 4 dB.

Measured values are included in Table 1. These data show a significant resonance - where there is a 'dip' in the sound insulation called Coincidence Resonance – whose frequency – in Hertz (Hz) – is inversely proportional to the glass thickness.

This **Critical Frequency (f_c)** is determined from the formula:

$$f_c = \frac{12,000 \text{ Hz}}{d}$$

where d is the glass thickness, in millimetres (See Figure 1).

Pilkington Toughened Safety Glass, Pilkington **Pyroshield** and coated glasses of the same thickness all behave acoustically the same as the standard product.

Pilkington Texture Glass behaves acoustically the same as standard flat glass of the same average thickness.

Pilkington Laminated Safety Glass

Instead of using ordinary solid (or monolithic) window glass, the thickness may be split up into thinner components, each separated, but bonded together, by a softer interlayer material. This is common in safety and security applications, but such lamination can also have acoustic benefits, particularly in the suppression of the Coincidence Resonance.

Two main types of interlayer material are used; polyvinylbutyral (PVB) in sheet form, and cast-in-place (CIP) resins, each with their own particular merits.

The resins used for CIP laminates can be specially formulated to provide enhanced acoustic performance, and differentiate them from 'standard' PVB laminates. Because CIP resins are 'softer' than PVB sheet, the resonances occur at frequencies which correspond closely with the individual glass components of the laminate. With PVB this resonance occurs at the frequency which corresponds to the total thickness of the laminate (i.e. lower in frequency). Thus, a CIP laminate shifts these resonances to higher frequencies where, generally, they play a less important role in overall acoustic performance.

Examples of the acoustic performances of some laminated glasses are also given in Tables 1, 2 and 4.



Wide Airspace

Double Windows (Secondary Sashes)

Where high sound insulation of windows is required, airspace widths of greater than 100mm may be required. The same principles apply here as for insulating units, the use of dissimilar glass thicknesses, one of them being thick (at least 6mm, and preferably 10mm thick).

Lining the reveals with acoustic absorbent material (fibreboard) is beneficial because it can reduce reverberation in the cavity, giving an overall improvement of 2-6 dB, according to its area and absorption characteristics.

Increasing the width of cavity produces an increase of sound insulation, but not pro rata. Beyond a spacing of about 200mm it is normally uneconomical to install such windows because the incremental acoustic improvement is small. This trend is illustrated in Figure 3.

It is important to point out that these windows will achieve their high performance potential only if all airgaps are sealed. Effectively, this means that the frames carrying the glasses must either be fixed or be of casements, incorporating pressure seals all round and also featuring multipoint locking to avoid twisting (a one millimetre gap will allow six decibels of unwanted noise in).

Sliding sashes are not, therefore, able to secure the required airtightness (see page 10) and their corresponding acoustic performance is, most often, no better than a good insulating unit.

(Ref. BRE Information Paper IP12/89).

Data on some typical arrangements are included in Table 3.

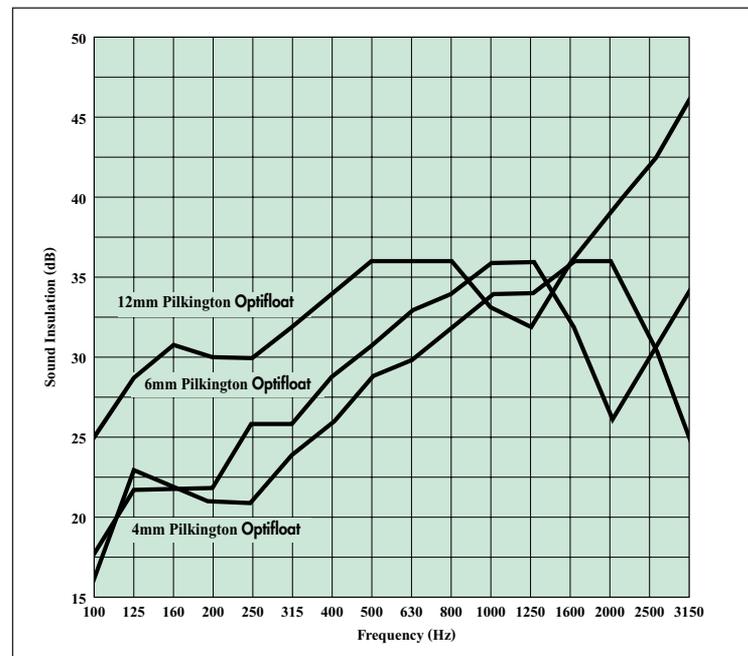


Figure 1. Frequency Spectra for 4mm, 6mm and 12mm Pilkington **Optifloat** showing Coincidence Resonance



Pilkington **Insulight**

Insulating glass units were originally introduced to reduce heat loss through windows. However, by judicious design, it is possible also to achieve moderately high acoustic insulation. The main principles to employ are the use of thick glass, and ensuring that the component glasses differ in thickness by at least 30 percent (e.g. 10 + 6mm or 6 + 4mm) in order to offset individual resonances (suppress sympathetic resonances).

The lamination of one pane produces a further small improvement, and this is achieved regardless of which glass is laminated.

Reversible Installation

(Glazing of Asymmetric Units)

It is also worth noting that identical sound insulation is obtained irrespective of which way round insulating units are installed. A 10/12/6 unit gives the same performance as a 6/12/10 unit.

Effect of the Cavity Width

Over the usual cavity width range of 6 to 20mm for insulating units, there is little variation in acoustic performance although there is a more significant change in thermal insulation. This acoustic performance plateau is due to the relatively strong coupling of the component glasses.

The associated data presented in Table 2 relates specifically to insulating units with standard 12mm air-filled cavities, but negligible error is introduced if these values are adopted for all cavities within the above range.

Effect of Gas Filling

Insulating glass units are frequently specified which include low emissivity coatings to improve their thermal performance to the standard of triple glazing. In conjunction with this, a further smaller improvement is possible by filling the cavity with argon gas. Such units exhibit exactly the same acoustic performances as standard air-filled units of the same glass combination.

For applications where middle frequency acoustic performance is the most critical (e.g. speech), units may be filled with sulphur hexafluoride (SF_6) gas mixtures. This elevates the corresponding R_w index. Simultaneously, SF_6 introduces a significant resonance at 200-250 Hz and, for noises dominated by low frequency components (road traffic, railways, aircraft on take-off, etc.), this is detrimental. Such units generally offer lower effective sound insulation in these situations than standard air-filled units.

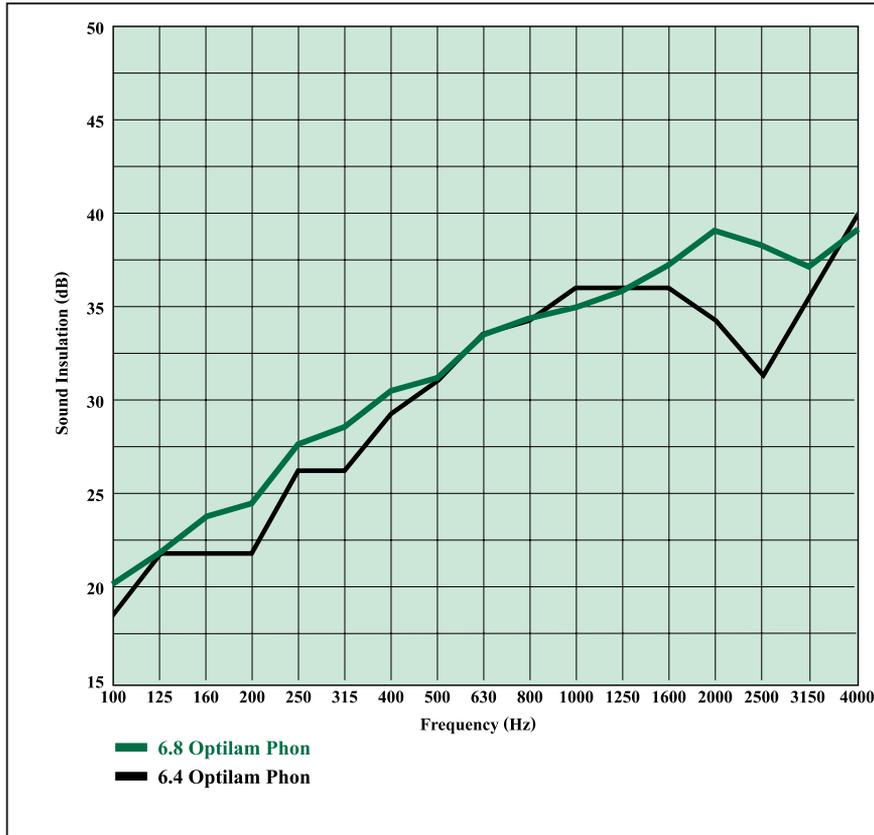


Figure 2. Frequency Spectra for 7mm Pilkington Acoustic Laminate and 6.4mm Pilkington Laminated Safety Glass (PVB)

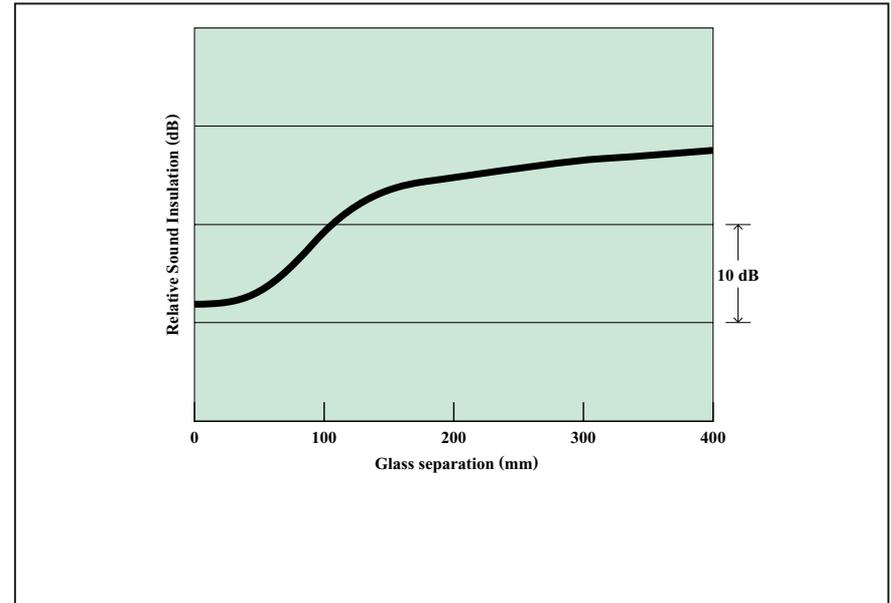


Figure 3. Diagram showing Relative Sound Insulation with increased airspace width



Pilkington **Planar**[™] Assemblies

Pilkington has developed structural glass modular systems which can accommodate both single and double glazing. According to the anchoring system selected, the stiffness/ vibrational characteristics of the plates may vary slightly. Their acoustic performances, however, are little different from ordinary glazing, of similar make-up. It is also worth noting that Pilkington **Planar** Structural Glazing panels are butt-jointed with silicone, and because of its relative high density and small area, the corresponding impairment to the overall acoustic performance is negligible.



Hilton Hotel, London



Effect of Building Height

Noise level does not decay simply with increasing height up buildings. Although the upper floor windows are indeed further from the noise source, they are exposed to more noise sources. Particularly in built-up areas, interreflections of sound between adjacent buildings also tend to maintain the noise exposure at the higher levels.

The net result of these trends is that the vertical noise field is virtually uniform (no correction for building height is usually appropriate).

Window Sound Insulation Data

For proper comparison of window acoustic performances, their corresponding data should be measured under identical experimental conditions. This is the principle which was strictly followed in establishing the tabulated values presented in this publication.



Towergate, London



Insulation of Spandrel Panels

Many modern buildings are designed to have a fully glazed external appearance, though some areas are opaque. This is achieved by using coated or opacified glazing, backed with insulating material in a metal tray in order to satisfy Part L of the 1991 Building Regulations, relating to the transmission of heat.

As a generality, the addition of the insulation and tray may, because of resonances, impair the performance of the basic glass at very low frequency but enhance it at frequencies above 125 Hz.

Influence of Frame Material

Nowadays there is a wide range of window frame types available on the market, the principle ones being of timber, aluminium and PVC-u. In spite of hollow box sections being an integral feature of aluminium and PVC-u framing, laboratory and field measurements have shown that, up to a glazing R_m of about 35 dB, the window frame is not often a serious leak path (the sound insulation of the glazing can be adopted as being representative of the window, as a whole). Beyond $R_m = 35$ dB, it is prudent to evaluate the acoustic performance of the proposed framing; more substantial sections may be necessary to be compatible with very high performance glazing.

Airtightness of Opening Frames

If a window incorporates opening lights of any kind, it is essential that efficient seals are also fitted. Very small airgaps can have a profound detrimental effect on the aggregate window acoustic performance. Airgaps of only 1 percent of the total window area can reduce the overall potential sound insulation by as much as 10 dB, which means that transmitted noises are heard twice as loud as they would be if fully sealed.

Effect of Area

If the sound insulation of the solid or opaque wall of a facade is at least 10 dB higher than that of the glazing, noise transfer through the wall can be ignored. This is most common, typical single brick walls having an R_m of 45 dB and cavity brick walls of better than 50 dB.

In most cases, the effective performance of a facade is determined by the glazing. Clearly, the bigger the window, the more noise energy can be admitted (or escape) but, owing to the way in which sound levels are additive, this is a relatively small effect. It can be assumed, without serious error, that doubling or halving the window area produces an aggregate corresponding noise level change of 3 dB or – 3 dB respectively, which can only just be noticed.



Tables 1–3 Sound Insulation Data for a Variety of Glazings

(No contribution from wall)

In addition to the full thirdoctaveband sound insulation spectra, corresponding octaveband equivalent values are given in adjacent columns.

Table 1 – Single Glazing

Thirddoctaveband Centre Frequency (Hz)	Sound Insulation (dB) for Glass Thickness (mm)									
	4		6		10		19		6.4 PVB	
100	17		18		24		25		18	
125	23	20	22	20	26	26	29	28	22	20
160	22		22		28		31		22	
200	21		22		26		31		22	
250	21	22	26	24	28	27	32	32	26	24
315	24		26		29		35		26	
400	26		29		32		36		29	
500	29	28	31	31	34	34	38	37	31	31
630	30		33		36		36		33	
800	32		34		37		35		34	
1000	34	33	36	35	36	35	38	37	36	35
1250	34		36		33		40		36	
1600	36		32		33		44		36	
2000	36	34	26	29	38	36	47	46	34	33
2500	31		30		41		50		31	
3150	25		34		43		52		35	
4000	31	28	37	36	44	44	55	54	39	38
R_m (dB)	27		29		33		37		30	
R_w (dB)	30		32		36		40		33	
R_{TRA} (dBA)	27		28		32		35		29	

Table 2 – Pilkington **Insulight**™

Thirdoctaveband Centre Frequency (Hz)	Sound Insulation (dB) for Glass Thickness (mm)											
	4/12/4		6/12/6		6/12/6.4 PVB		10/12/4		10/12/6		10/12/6.4 PVB	
100	25		17		19		23		27		27	
125	24	24	26	20	24	21	28	25	27	26	28	27
160	23		22		21		26		24		26	
200	21		18		19		19		24		26	
250	21	20	18	19	19	20	23	22	29	27	30	29
315	19		24		24		26		31		32	
400	22		27		28		31		33		34	
500	25	25	29	29	32	31	33	33	34	34	36	36
630	30		33		34		36		37		40	
800	33		37		38		39		39		41	
1000	36	35	39	38	40	39	41	40	41	40	42	41
1250	38		39		40		41		41		41	
1600	40		39		39		41		39		41	
2000	41	38	34	36	35	37	45	43	37	38	42	42
2500	35		37		39		45		40		44	
3150	31		42		44		42		43		49	
4000	40	35	47	45	49	47	44	44	47	46	53	52
R _m (dB)	29		30		31		34		34		36	
R _w (dB)	31		33		34		36		38		40	
R _{TRA} (dBA)	25		26		27		29		32		34	



Table 3 – Double Windows (Secondary Sashes)

Thirdoctaveband Centre Frequency (Hz)	Sound Insulation (dB) for Glass Thickness (mm)					
	6/100/4		6/150/4		10/200/6	
100	25		27		32	
125	27	26	30	29	37	35
160	27		30		39	
200	33		34		45	
250	33	34	34	35	46	46
315	37		39		46	
400	41		42		47	
500	46	44	46	45	45	46
630	50		50		45	
800	54		54		44	
1000	57	56	57	56	45	46
1250	59		58		50	
1600	58		58		53	
2000	52	53	52	52	58	56
2500	51		49		58	
3150	48		47		64	
4000	57	52	52	50	64	65
R_m (dB)	44		44		47	
R_w (dB)	46		47		49	
R_{TRA} (dBA)	37		39		45	



Table 4 – Optilam Phon

Technical details

Jumbo Sizes	3210x6000mm
Lehr End Sizes (L.E.S)	3210x2550mm
Thicknesses Available (all sizes):	6.8, 8.8, 10.8 and 12.8mm
Cut Sizes Available:	6.8, 8.8, 10.8, 12.8mm and 16.8mm

Pilkington Optilam™ Phon (mm)	Sound Reduction R_W C(C C_{tr}) (dB)	Light			Solar Heat				U value (W/m ² K)	
		Transmittance	Reflectance (ext)	Reflectance (int)	Direct Transmittance	Reflectance	Absorptance	Total Transmittance	air-filled	argon-filled
Pilkington Optilam™ Phon (Single Glazing)										
6.8	35(-1;-3)	89	8	8	73	7	20	79	N/A	N/A
8.8	37(-1;-4)	88	8	8	69	7	24	76	N/A	N/A
10.8	38(-1;-2)	87	8	8	67	7	26	74	N/A	N/A
12.8	39(0;-2)	86	8	8	65	6	29	72	N/A	N/A
16.8	40(0;-2)	85	8	8	60	6	34	69	N/A	N/A
Pilkington Insulight™ Phon incorporating Pilkington K Glass™										
6/16/6.8*	38(-2;-6)	74	17	15	53	14	33	68	1.7	1.5
6.8/16/6.8*	39(-2;-6)	73	17	15	52	13	35	65	1.7	1.5
8.8/16/6*	39(-2;-6)	73	16	15	50	12	38	62	1.7	1.5
10.8/16/6*	41(-2;-6)	72	16	15	48	12	40	60	1.7	1.5
12/16/6*	41(-1;-5)	72	16	15	47	11	42	58	1.7	1.5
10.8/16/6*	48(-2;-6)	67	16	14	37	10	53	53	1.6	1.5

Sound insulation data measured in accordance with BS EN ISO 140-3 and indices derived in accordance with BS EN ISO 717-1

R_W , C and C_{tr} are in accordance with BS EN ISO 717-1.

Light and solar optical properties (in%) determined in accordance with BS EN 410.

U value determined in accordance with BS EN 673. for argon gas-filled cavities based on 90% gas fill / 10% air.

*Where the inner pane incorporates Pilkington **K Glass™**



Acoustic Information

Decibels and Frequency

The threshold of the level of hearing is 0 decibels (dB), and 120 dB represents a level at which physical pain can be felt. Typical examples of intermediate sounds are shown in Figure 4. As with the other human senses, hearing sensitivity cannot be represented by a linear scale but by one which is related to relative changes (logarithmic).

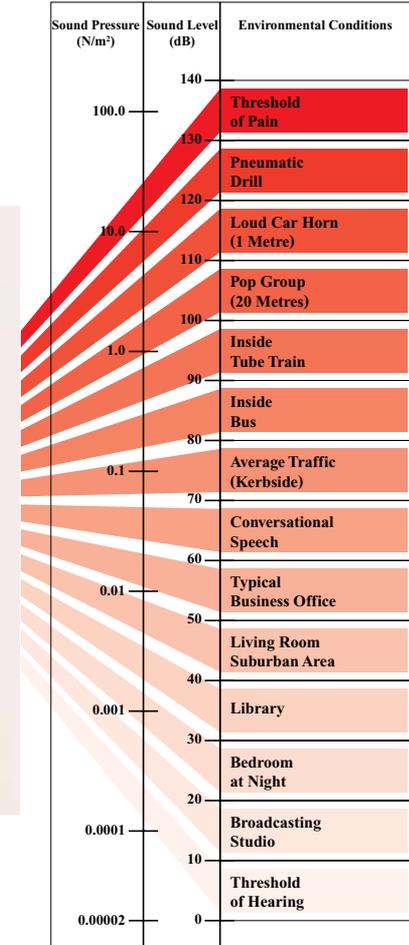


Figure 4. Sound Pressure (N/m²) Sound Level (dB) Environmental Conditions



Figure 5 illustrates how multiple sounds combine. If, say, there are two noises of 81 dB and 85 dB, their difference is 4 dB. Reference to this chart indicates that a corresponding correction of 1.5 dB is appropriate, and should be applied to the higher level, (85 dB), so that the resultant of these two sounds is 86.5 dB.

Multiple sounds can be compounded in the same way, replacing successive pairs of sounds by a single equivalent and, by a repeated process, deriving the final overall equivalent.

Our ears respond to the range of sound frequencies, or pitch, from around 20 Hertz (bass) to 20 Kilohertz (treble) though our response is not linear, being generally more sensitive to the high frequencies than to the low. With advancing age it is the perception of the higher frequency sounds which is most impaired.

Loudness is a subjective composite judgement of the frequency mix of the noise and its basic energy is measured as a Sound Pressure Level (SPL).

In order that measuring equipment can give realistic indications of how people are likely to react to noise, it is usual for it to incorporate electronic circuitry whose response is weighted to simulate that of our ears. Figure 6 is a composite diagram of the ear's typical response at different loudness levels and the internationally agreed standard for the appropriate corrections is called the 'A' Weighting Curve. Note that this is virtually a mirror image of the ear's response so that together, their resultant is almost a horizontal straight line (flat response). Measurements made with this facility are, therefore, termed 'A' Weighted Decibels or, more concisely, dBA, to discriminate from those made in plain dB, which do not depend directly on human reaction (sound insulation).

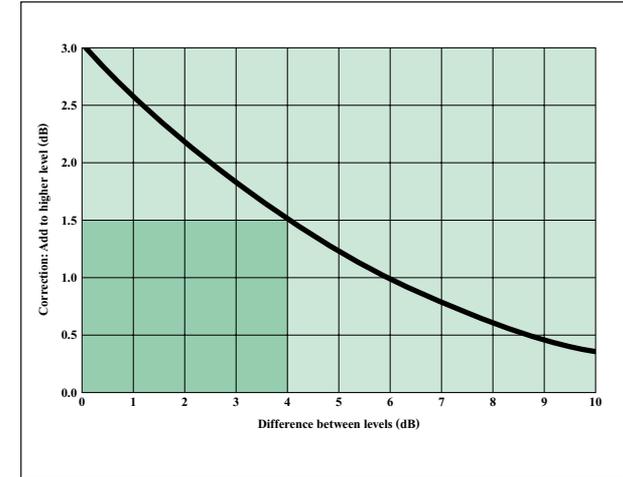


Figure 5. Addition of Multiple Sounds Difference between levels vs. correction add to higher level (dB)

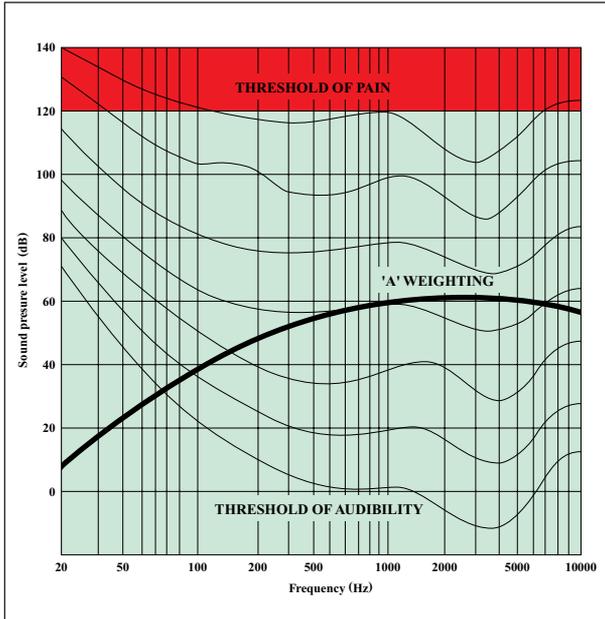


Figure 6. 'A' Weighting Curve Frequency (Hz) vs. Sound pressure level

Important benchmarks for the subjective impression (loudness) that is produced by changes in sound pressure level are:

Change in SPL (dB or dBA)	± 3	± 5	± 10
Apparent Loudness Change	Just perceptible	Clearly noticeable	Twice (or half) as loud



The Receiver (our ears)

Prior reference on page 15 has been made to the basic ear's response in 'Decibels and Frequency'. Other factors in anticipating subjective response include intermittency pattern (warning sirens on level crossings), frequency of occurrence (aircraft noise), age-related annoyance (disco noise) and the influence of other environmental conditions (glare).

Furthermore, according to the task being undertaken (clerical work, lecturing, sleeping, etc.), there are corresponding thresholds of background noise levels which should not be exceeded if this is to be accomplished in comfort.

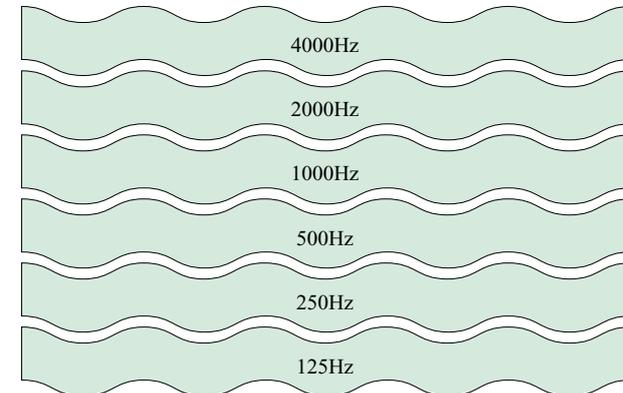
Effective total window design must, in addition, incorporate the requirements of solar control, thermal insulation, daylight admission, aesthetics, safety and security, etc.

Measurement and Specification of Acoustic Performance

Reference has been made on page 15 to the interaction between actual noise level (dB or dBA) and to the frequencies or pitches (Hertz) of its constituent components, in relation to its subjective impact. When describing or specifying sounds, the usual procedure is therefore to evaluate the prevailing sound pressure levels (SPL) over the most sensitive range of audio frequencies.

Often it is sufficient to choose just six such frequencies which have a constant relationship between them, each frequency being double that of the preceding one. This ratio is called an OCTAVE, a term which may be familiar in musical contexts, when notes of the same name ('C') sound similar, yet at different, but related, pitches.

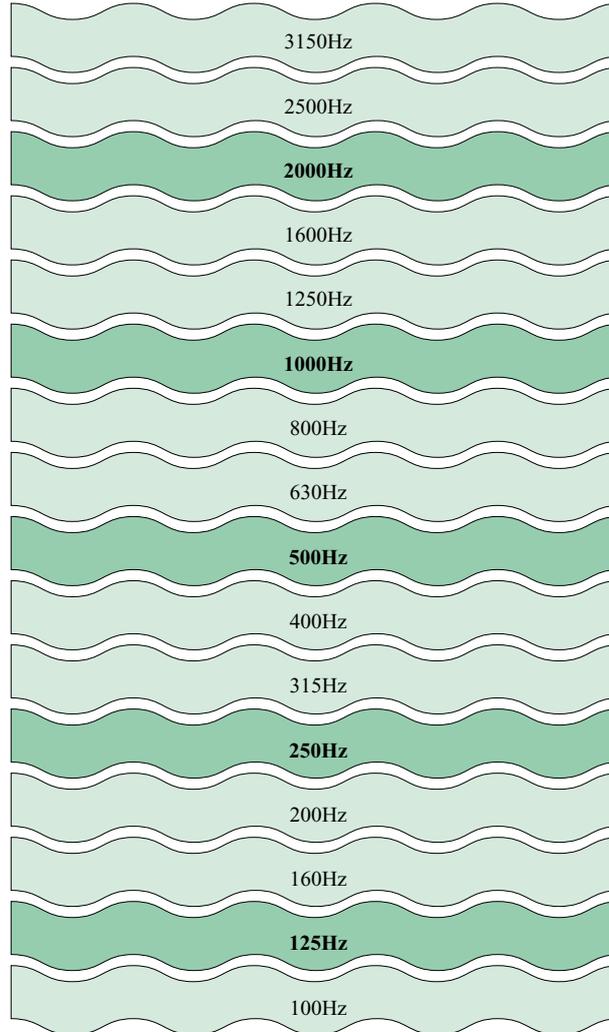
For general building acoustics, the most important frequencies at which to measure are:





These are specified in National, European and International Standards.

When more detailed analysis is appropriate, these octavebands may be subdivided into three, (except for the 4000 Hz band), to give 16 thirdoctavebands. These are:



British and European Standards adopt these frequencies for the more precise analyses of sounds, whereas American and some other countries prefer the 16 thirdoctavebands between 125-4000 Hz (i.e. shifted upwards by a thirdoctaveband).



Hertz Turnaround, Heathrow

If octaveband sound insulation values are required from thirddoctaveband data, it is not sufficient merely to extract corresponding spot values at the octaveband frequencies; due account must be taken of the values on either side of these in order to encompass a full octave ($3 \times 1/3$ octave = 1 octave). A proper energy transmission summation of these three values is then required to derive the correct octaveband value, and it is not correct merely to use their arithmetic average. That significant errors could be introduced from this is evidenced by the fact that thirddoctaveband insulation values of 10 dB, 20 dB and 30 dB result in an octaveband equivalent of only 14 dB (i.e. biased towards the worst individual value).

The tables of glazing sound insulation, 1-3, give both corresponding sets of data, side by side.

Frequently, full analyses of noise problems are not required, and use is made of shorthand methods in describing the offending noise, the glazing's acoustic performance and target values for interior noise quality. The most common of these are defined in the next section.



Acoustic Indices

R_m – Mean Reduction

The complete way of specifying the acoustic performance of glazing, (or any other building element), is to establish its sound insulation over a wide range of frequencies. The British and European preferred frequency range is 100 – 3150 Hz, in which case the corresponding sound insulation value, (or Sound Reduction Index, SRI), should be determined at all the 16 thirdoctavebands between 100 – 3150 Hz, as defined on page 10.

The arithmetic mean, or average, of these insulation values is a simple indicator of performance, designated R_m , or Mean Sound Reduction Index, and is measured in dB.

R_w – Weighted Reduction

R_m is now less used since the publication of BS 5821: 1984, in which the index, R_w (Weighted Reduction) is defined, which incorporates a correction for the ear's response. It is derived from comparing the window sound insulation/frequency curve with a family of reference curves (see figure 7) and selecting one to obtain the 'best fit' so that its average adverse deviation over the 16 thirdoctavebands between 100 – 3150 Hz is only 2 dB. The corresponding sound insulation of this reference at 500 Hz then defines the R_w Index of the window.

Numerically, it may be up to 5 dB higher than the corresponding R_m value for the same window data. Hence, it is most important to differentiate between these indices.

R_{TRA} – Traffic Noise Reduction

Neither R_m or R_w can be used directly to estimate interior noise levels because of their independence of the spectrum of the actual noise climate. By adopting an idealised, but typical, spectrum of road traffic noise in town and city centres, the index R_{TRA} (Reduction of road traffic noise) can be derived, by processing this with the basic sound insulation of the window, frequency-by-frequency. This represents the attenuation, in dBA, which the window can achieve in mitigating road traffic noise and gives a very useful guide to in-service performance.

STC – Sound Transmission Class

Occasionally, requirements may be stated, in terms of Sound Transmission Class (STC) values, which is the American Standard ASTM E413. Its derivation is similar to the R_w index, except that the relevant frequency range is 125-4000 Hz (i.e. shifted upwards by 1/3 octave from the British Standard). For this reason STC is, typically, around 1 dB higher than its R_w equivalent, owing to panel materials (including glass) being generally better performers at high frequencies.



NR/NC Values – Noise Reduction / Noise Criterion Values

As an alternative to dBA levels inside buildings, other values based on more detailed spectral data are sometimes preferred. These are better able to identify narrow band peaks – characteristic of annoying tones – and for this reason are most frequently used to rate the noise output from air-conditioning equipment.

The concept is sometimes applied to the specification of total interior noise environments, even though the incident noise is broad band, (no sharp peaks), such as that from road traffic.

Approximately, the NR/NC rating is 5 units lower than the corresponding dBA level so that, for example, 50 dBA is roughly equivalent to NR45 or NC45.

L₁₀ Values – Noise Level exceeded for 10% of the time

Research has shown that disturbance or annoyance does not correlate well with the prevailing average noise level, but is better ranked by the corresponding average peak level which, to some extent, takes account of the ‘startle’ effect. This is most often represented by the noise level which is exceeded for only 10 percent of the measuring period, and is designated L₁₀. If measured in dBA, it is often referred to as L_{A10}.

L₁₀ values are those normally used to describe the ambient road traffic noise exposures for design purposes.

The L₁₀ (18-hour) value is the value derived from measurements over the period from 6 a.m. to midnight on a normal working day. It is this which currently is used to determine eligibility under the Noise Insulation Regulations 1975, by which a sound insulation package may be offered to certain householders, satisfying specified conditions, when their homes are subjected to traffic noise levels of 68 dBA or more.

L_{eq} Values – Equivalent Noise Levels

Particularly with intermittent sounds or noises, (train noise, discos), it is helpful to determine the notional steady noise level which contains the same total energy as the real, varying noise. This is called the Equivalent Noise Level (L_{eq}) and is increasing in use, especially where different or multiple exposures are involved (e.g. a building situated close to both a railway and an airport).

BS 8233: 1987 ‘Sound Insulation and Noise Reduction for Buildings’ is the most recent authoritative document to give recommendations of noise climates for a variety of building types. Throughout, it adopts L_{eq} (dBA) values, which are referred to as L_{Aeq}.

To a close approximation

$$L_{Aeq} = L_{A10} - 3$$



Major Noise Sources

Most noises are not of a single pitch or frequency, but consist of a wide range of frequencies, or spectrum.

The identification of these frequencies and their relative strengths, (tonal mix), is important, as well as the corresponding overall noise level.

The most common noise problems involve Road Traffic Noise, which is dominantly of low frequencies, being influenced by vehicle speed, engine type, road surface, local topography, etc.

Railway Noise has a broadly similar spectrum to road traffic, except that more middle frequency tones are present and, generally, there is a more rapid fall off in high frequency content. Dominant influences here include speed, type of rail, type of sleeper, mix of rolling stock, embankments or cuttings, etc.

Though noise levels adjacent to railways can be very high indeed, people's tolerance is also greater, because the rise and decay of each pass by is predictable and the peaks are of short duration. It is widely accepted that railway noise can exceed road traffic noise by more than 10 dBA, whilst generating only the same degree of annoyance or disturbance.

Aircraft Noise changes significantly with altitude, climatic conditions, type and load utilisation of aircraft, and on whether it occurs at landing or take-off. Take-off noise is dominated by low frequencies whereas landing noise contains strong high frequency components, characteristic of the engines being in reverse thrust.

The most important frequencies of speech lie between 500-2000Hz (middle frequency dominated). Female speech is approximately an octave (or twice the frequency) above male speech. It is the suppression of the higher frequencies which is most important in providing privacy of conversation because these contain the essential aural clues of intelligibility, called the sibilants (s,sh).

The main characteristics of these sources are presented in Figure 8.

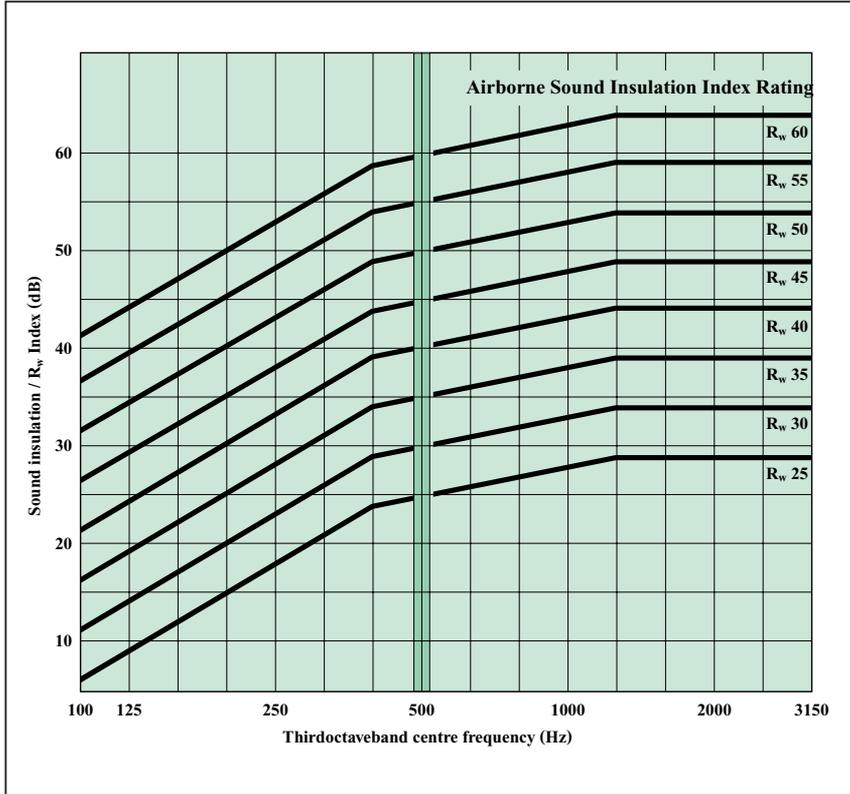


Figure 7. Derivation of the R_w Index

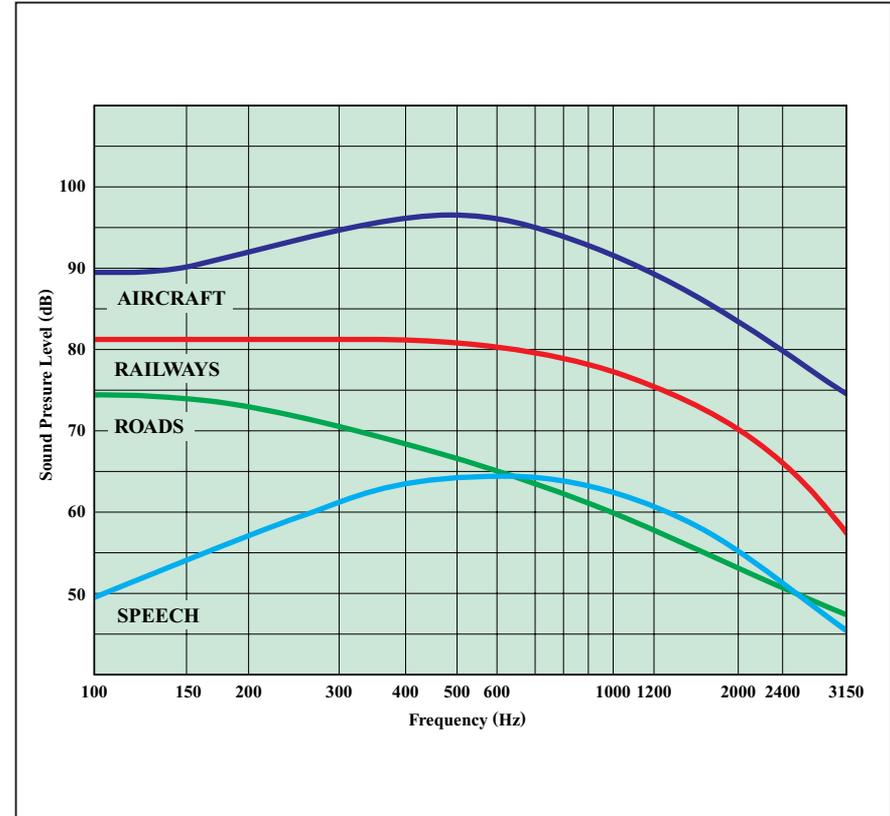


Figure 8. Sound Frequency Spectrum for Aircraft Noise, Railway Noise, Traffic Noise and Speech



Typical Noise Climates

Road Traffic

LOCATION

20m from busy motorway – many HGV's. Average speed 100kph (62mph) – grassed

20m from busy main road through residential area. Average speed 50 kph (31mph) – paved

Residential road parallel to busy main road – screened by houses

UNITS

	L_{A10}	L_{Aeq}
20m from busy motorway – many HGV's. Average speed 100kph (62mph) – grassed	80	77
20m from busy main road through residential area. Average speed 50 kph (31mph) – paved	70	67
Residential road parallel to busy main road – screened by houses	60	57

Decay of noise with Distance

Road traffic noise decreases by approximately 3dBA with doubling of distance at right angles to the road. If, for example, L is the dBA noise level at 5 metres, then the decay follows the pattern:

5 metres	L	dBA
10 metres	(L – 3)	dBA
20 metres	(L – 6)	dBA
40 metres	(L – 9)	dBA
80 metres	(L – 12)	dBA
160 metres	(L – 15)	dBA

Interpolation may be used. For example, to achieve a halving of the 5 metre loudness level (10 dBA change) the distance from the road must be increased to around 50 metres (45 metres back from the original position).



Aircraft

In the UK annoyance around commercial airports has been assessed by the Noise and Number Index (NNI) as a basis for guidance on planning buildings in their vicinity. This is a composite of the number of aircraft movements and of the peak noises which they generate and usually is plotted as contours around the runways.

NNI is gradually being replaced by L_{Aeq} to align with International Standard ISO 1996/1 and BS 5727.

NNI	L_{Aeq} (12 hour)	Probable Community Annoyance
35	57 ± 4	Low
45	66 ± 4	Moderate
55	75 ± 4	High
60	80 ± 4	Very high

Noise from helicopters and military aircraft requires more specialised analysis.

Railways

It is usual to express railway noise exposure, over a 24 hour period, owing to its good correlation with annoyance.

For a line carrying mixed traffic of high speed diesel-hauled passenger trains and various freight trains – around 120 per day – the expected noise levels are as tabulated for open grassland.

Distance From Track (metres)	L_{Aeq} (24 hour)
25	67
50	64
100	59
200	54





Design Guide

Design Guide

By adopting a typical road traffic noise spectrum, such as that in Figure 8, it is possible to calculate its attenuation by any window, whose basic sound insulation performance is known. This is clearly an approximation since the influence of the actual room characteristics is neglected. However, in practice, good correlation is found for typical glazed open plan offices with carpeted floors and suspended acoustic ceilings.

This index of acoustic performance corresponds with R_{TRA} .

It is possible to derive similar indices for railway noise and aircraft noise but, because of their greater variability compared to the noise spectrum of road traffic, their accuracy is somewhat diminished. For this reason these indices are not individually calculated for the tabulated glazing data presented in this publication but, as a rule of thumb, the following approximate relationships may be helpful:

$$R_{\text{RAIL}} = R_{\text{TRA}} + 3$$

$$R_{\text{AIR}} = R_{\text{TRA}} + 2$$

These indices allow a rapid assessment of the glazing system most appropriate to the location of the building and to its activity, by referring to the tabulated data of Table 4, which are based on information given in BS 8233: 1987.

Guidance is given in the probable levels of noise climates dominated by road traffic, aircraft and railways and, by reference to the recommended maximum noise levels for building interiors, the required window attenuation may be derived by simple subtraction, as illustrated in the following example:

Example

A private office is to be located 40 metres from a busy motorway. What R_{TRA} index is required and what are the corresponding insulating units options?

Basic Traffic Noise = 77 L_{Aeq}
(20m) Page 24

Correction for distance = 3 dBA
(40m) Page 24
(difference between levels at 40 metres and 20 metres)

Effective noise climate = 74 dBA

From Table 4, internal background noise level required = 40 to 45 L_{Aeq} .

Therefore, R_{TRA} is 74-40 to 74-45 dBA
(R_{TRA} required is between 29 and 34 dBA).



Options

- 6/12/6 **Insulight** has an $R_{\text{TRA}} = 26 \text{ dBA}$ (Table 2 on page 3) an attenuation which is insufficient to meet the required targets. In any case, as a general rule symmetrical units are not recommended owing to the risk of sympathetic resonances being generated
- 10/12/4 **Insulight** has an $R_{\text{TRA}} = 29 \text{ dBA}$ and would therefore be just acoustically suitable, although the 4mm component may limit the window size, owing to considerations of safety, wind loading, etc.
- 10/12/6 **Insulight** has an $R_{\text{TRA}} = 32 \text{ dBA}$ and do not suffer the limitations of the thinner or symmetrical units, and they would comply with the middle of the target performance range
- 10/12/6.4 (PVB Laminate) **Insulight** has an $R_{\text{TRA}} = 34 \text{ dBA}$, and so would provide sufficient attenuation to satisfy the most stringent of these requirements



Recommended Interior Noise Levels

The table below is compiled from typical values contained in BS 8233: 1987.

The original document should be consulted for guidance on less common noise exposures.

Table 4 – Interior Noise Targets



Location

**Recommended
Maximum L_{Aeq}
Levels (dBA)**

Dwellings:

Bedroom	30 – 40
Living Rooms	40 – 45

Offices:

Private Offices/Small Conference Rooms	40 – 45
Large Offices	45 – 50

Educational:

Classrooms (15 – 35 people)/ Small Lecture Rooms	40
Classrooms (more than 35 people)/ Large Lecture Rooms/ Language Laboratories	35
Music and Drama Spaces	30

Health and Welfare:

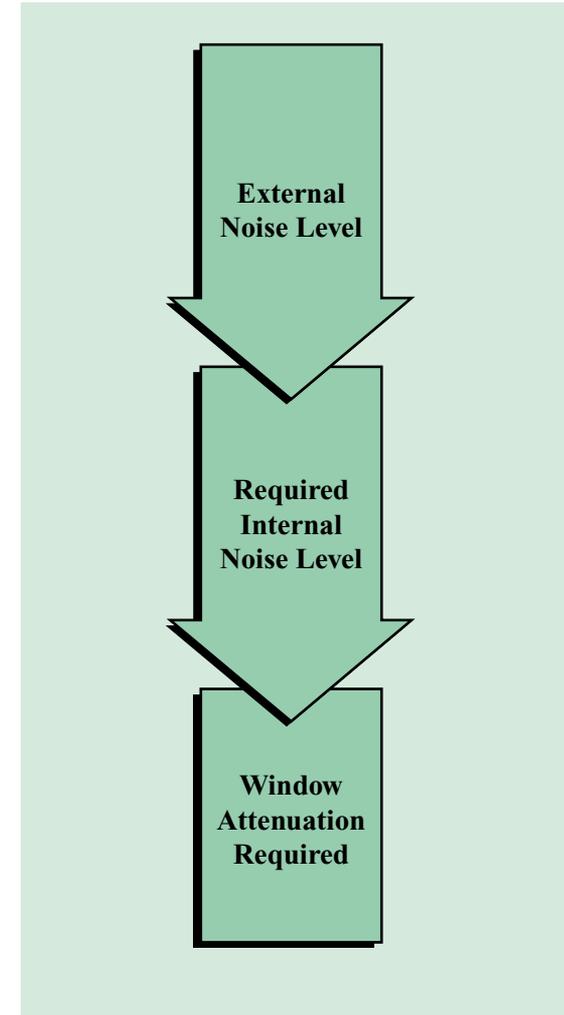
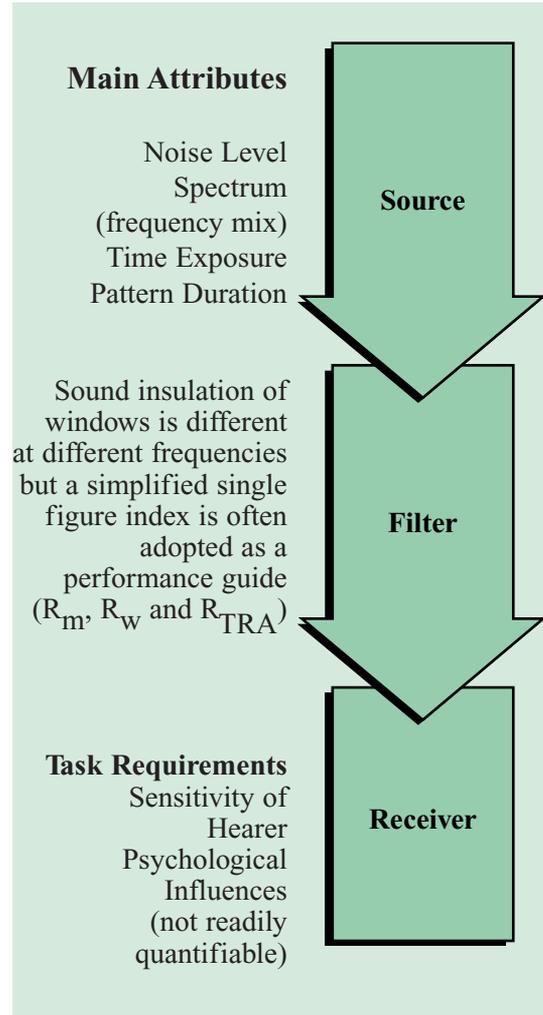
General Wards	55
Small Consulting Rooms	50
Diagnosis Rooms	45



Acoustic Problem Solving

Generally, noise problems can be resolved into three components for analysis and subsequent treatment or remedy:

Clearly, from a knowledge of any two of these elements, the third can be derived. Most often, however, it is the window performance which is required, so that the corresponding flow chart is:





Anchor Village, near Birmingham Airport.



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