

Code of practice for

Sound insulation and noise reduction for buildings —

(Formerly CP 3: Chapter III)

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Foreword

This British Standard has been prepared under the direction of the Basic Data and Performance Criteria for Civil Engineering and Building Structures Standards Committee. It supersedes CP 3:Chapter III:1972 which is withdrawn. The code is intended for use by designers and constructors of buildings and those concerned with central and local government building control, planning and environmental health.

This revision incorporates the results of research and experience gained over the last two decades and provides up-to-date information on the rating of noise and the rating of the sound insulation of building elements. Changes in the subjective significances of different kinds of noise are reflected in the revisions to the code.

The present availability of good textbooks and numerous government publications makes much of the explanatory material in CP 3:Chapter III unnecessary for the present code.

The information in this code follows, as far as is reasonable, the usual sequence of activities in building design. For planning and design of new buildings clauses 4 to 7 give a general background and clauses 15 to 17 give more specific information. For a particular type of building, the appropriate clause of clauses 8 to 13 will apply. Clause 14 gives information for the particular combination of building elements being designed.

Where change of use of, or improvements to, an existing building are being considered, the above sequence applies except for clause 6 (outside noise) if it is clear that no new noise will be emitted from or transmitted to the building.

It has been assumed in the drafting of this code of practice that the execution of its provisions is entrusted to appropriately qualified and experienced people.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations. In particular, attention is drawn to the Town and Country Planning Act 1971, the Building Regulations 1985, the Building Regulations (Northern Ireland) 1977 and the Building Standards (Scotland) Regulations 1981.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 62, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

0 Introduction

Noise control in and around buildings is treated in this code of practice on an objective and quantifiable basis as far as is presently possible. It should be borne in mind, however, that people vary very widely in their sensitivity to, and tolerance of, noise. Moreover, there is no such thing as a meter to measure the pleasantness of sounds, so it is difficult to ascribe numerically the difference between “pleasant” sounds like gentle wind in the trees and “unpleasant” sounds like a child crying. Important though these factors may be, it is not practicable to take them into account in this code.

Attention is drawn to the need to comply with fire, health and safety requirements which should be taken into account in all sound insulation considerations.

1 Scope

This British Standard gives recommendations for the control of noise in and around buildings.

Except where it produces sound, vibration in buildings is outside the scope of this code.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover. See also the Bibliography in Appendix F, references to which are identified in the text by numbers in square brackets.

2 Definitions

For the purposes of this British Standard, the definitions given in BS 4727-3:Group 08, BS 5775-7 and BS 5821 apply together with the following.

NOTE 1 Where applicable, the definitions are consistent with those given in ISO 1996/1-1982.

NOTE 2 The term “noise level” is sometimes used in place of “sound level”.

2.1

a-weighted sound pressure

the root mean square sound pressure (measured in pascals) determined by use of frequency-weighting network “A”

NOTE 1 See also BS 5969.

NOTE 2 The A-weighting network modifies the electrical response of a sound level meter so that the sensitivity of the meter varies with frequency approximately in the same way that the sensitivity of the human hearing system varies with frequency.

2.2

a-weighted sound pressure level

ten times the common logarithm of the ratio of the square of the A-weighted sound pressure to the square of the reference sound pressure

the A-weighted sound pressure level L_{pA} (in dB) is given by the equation:

$$L_{pA} = 10 \log (p_A/p_0)^2$$

where

p_A is the A-weighted sound pressure (in Pa);

p_0 is the reference sound pressure (i.e. 20 μ Pa).

NOTE Measurements of A-weighted sound pressure level are usually made to assist in judging the effects of noise on people.

2.3

sound pressure level

ten times the common logarithm of the ratio of the square of the sound pressure to the square of the reference sound pressure

The sound pressure level L_p (in dB) is given by the equation:

$$L_p = 10 \log (p/p_0)^2$$

where

p is the root mean square sound pressure (in Pa);

p_0 is the reference sound pressure (i.e. 20 μ Pa).

NOTE The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient, range of numbers. For example, sound pressure levels ranging from 40 dB to 90 dB correspond to sound pressures ranging from 0.002 Pa to 0.63 Pa.

2.4

percentile level

the A-weighted sound pressure level obtained by using time-weighting “F” that is exceeded by N % of the time interval considered

NOTE 1 Example: $L_{A95, 1h}$ is the A-weighted level exceeded for 95 % of 1h.

NOTE 2 See also BS 5969.

NOTE 3 Percentile levels as determined over a certain time interval cannot generally be extrapolated to other time intervals.

2.5

equivalent continuous A-weighted sound pressure level

value of the A-weighted sound pressure level of a continuous, steady sound that, within a specified time interval T starting at t_1 and ending at t_2 and measured in decibels, has the same mean square sound pressure as the sound under consideration whose level varies with time. The equivalent continuous A-weighted sound pressure level $L_{Aeq, T}$ (in dB) is given by the equation:

$$L_{Aeq, T} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{[p_A(t)]^2}{p_0^2} dt \right]$$

where

p_0 is the reference sound pressure
(i.e. 20 μPa);

$p_A(t)$ is the instantaneous A-weighted sound
pressure of the sound signal (in Pa).

NOTE 1 Equivalent continuous A-weighted sound pressure during time interval T is also called time interval average sound level, $L_{A,T}$, (in dB), with the averaging time interval usually indicated in the format, for example, one hour average sound level, $L_{A,1h}$.

NOTE 2 Equivalent continuous A-weighted sound pressure level is also used for assessment of occupational noise exposure (see ISO 1999).

2.6

sound exposure level

the sound exposure level L_{AE} (in dB) of a discrete noise event is given by the equation:

$$L_{AE} = 10 \log \left[\frac{1}{t_0} \int_{t_1}^{t_2} \frac{[p_A(t)]^2}{p_0} dt \right]$$

where

$p_A(t)$ is the instantaneous A-weighted sound
pressure (in Pa);

$t_2 - t_1$ is a stated time interval long enough to
encompass all significant sound of a
stated event (in h);

P_0 is the reference sound pressure level
(i.e. 20 μPa);

t_0 is the reference time interval (i.e. 1 s).

NOTE L_{AE} is given in BS 5727 as L_{AX} (single-event noise exposure level).

2.7

measurement time interval

that time interval over which the squared
A-weighted sound pressure is integrated and
averaged

2.8

reference time interval

the time interval to which an equivalent continuous
A-weighted sound pressure level can be referred

NOTE It may be specified in national or international standards or by local authorities to cover typical human activities and variations in the operation of sound sources.

2.9

long term time interval

a specified time interval for which the results of the
noise measurement are representative

NOTE The long term time interval consists of a series of reference time intervals and is determined for the purpose of describing the environmental noise and is generally designated by competent authorities.

2.10

long term average sound level

the average over the long term time interval of the
equivalent continuous A-weighted sound pressure
levels for a series of reference time intervals
comprised within the long term time interval

NOTE Averaging should be carried out as described in ISO 1996/2¹⁾.

2.11

rating level

the equivalent continuous A-weighted sound
pressure level during a specified time interval, plus
specified adjustments for tonal character and
impulsiveness of the sound

2.12

long term average rating level

the average over the long term time interval of the
rating levels for a series of reference time intervals

NOTE Averaging should be carried out as described in ISO 1996/2¹⁾.

2.13

noise rating (NR) curves

graphical representation of noise rating as defined
in ISO 1996-1

2.14

sound reduction index

a measure of the sound-insulating properties of a
material or building element

NOTE Sound reduction index is further defined in BS 2750-3.

2.15

weighted sound reduction index

single-number quantity of airborne
sound-insulating properties of a material or interior
building element

NOTE Weighted sound reduction index is further defined in BS 5821-1.

2.16

standardized level difference

sound level difference between rooms adjusted as
defined in BS 2750-4

2.17

weighted standardized level difference

single-number quantity for airborne sound
insulation between rooms

NOTE Weighted standardized level difference is further defined in BS 5821-1.

¹⁾ In preparation.

2.18**impact sound pressure level**

the average sound pressure level in a specific frequency band in a room below a floor excited by a standardized impact sound source

NOTE Impact sound pressure level is further defined in BS 2750-7

2.19**standardized impact sound pressure level**

the impact sound pressure level corrected for the reverberation time of the receiving room

NOTE Standardized impact sound pressure level is further defined in BS 2750-7.

2.20**weighted standardized impact sound pressure level**

a single number characterizing impact sound insulation derived from frequency dependent values of standardized impact sound pressure level

NOTE The method of weighting is given in BS 5821-2.

2.21**cross-talk**

unwanted sound transmission between one room and another room or area via a duct

2.22**break-out**

unwanted sound transmission from inside a duct to the outside

2.23**break-in**

unwanted sound transmission into a duct from outside

2.24**acoustic lagging**

materials applied to the surface of a duct to reduce break-out or break-in

2.25**octave band**

band of frequencies in which the upper limit of the band is twice the frequency of the lower limit

3 Symbols

The main symbols used in this code, together with relevant symbols used in standards referred to in this code, are given in Table 1.

Table 1 — Symbols

Quantity	Symbol	Unit	Remarks
Sound pressure level	L_p	dB	
A-weighted sound pressure level	L_{pA}	dB	
Root mean square sound pressure	p	Pa	
A-weighted sound pressure	p_A	Pa	
Instantaneous A-weighted sound pressure	$p_A(t)$	Pa	
Reference sound pressure	p_o	Pa	
Percentile level	$L_{AN, T}$	dB	Level exceeded for N % of time interval T
Sound exposure level	L_{AE}	dB	For noise events
Noise level	L_{Aeq}	dB	
Equivalent continuous A-weighted sound pressure level	$L_{Aeq, T}$	dB	Time interval to be stated
Time interval	T		
Reference time interval	t_o		
Long term time interval	$t_2 - t_1$	h	
Long term average sound level	$L_{Aeq, LT}$	dB	Time interval to be stated
Rating level	$L_{Ar, T}$	dB	Time interval to be stated
Long term average rating level	$L_{Ar, LT}$	dB	Time interval to be stated
Impact sound pressure level	L_i		
Normalized impact sound pressure level	L_n		
Standardized impact sound pressure level ^a	L'_{nT}		
Weighted standardized impact sound pressure level ^a	$L'_{nT, w}$		
Sound level difference	D	dB	
Weighted sound level difference	D_w	dB	
Standardized level difference	D_{nT}	dB	
Weighted standardized level difference	$D_{nT, w}$	dB	
Sound reduction index	R		
Weighted sound reduction index	R_w		

^a The primed symbol indicates a value obtained in the presence of flanking transmission.

Section 2. Planning and design

4 Principles of assessment

4.1 General

The purpose of noise control is to ensure that people are neither annoyed nor harmed by noise.

When designing a new building or a conversion to an existing building, likely sources of noise should be considered and an assessment made of the possible effects on the occupiers. An assessment should also be made of the effects on neighbours of noises generated within the building. Where there is a risk of disturbance from noise it will usually be possible to control the noise, as perceived by the listener, by careful attention to various factors of the design. These include, for noise sources outside the building under consideration:

- a) choice of site;
- b) reduction of noise at source;
- c) positioning of buildings on site;
- d) orientation of buildings on site;
- e) provision of barriers;
- f) an increase in the sound insulation of the building envelope;
- g) replanning the interior layout of the building.

These design factors may also be applicable for neighbours likely to be disturbed by noise sources from within the building. For noise disturbance originating and heard within the building, the relevant design factors are the internal construction and layout.

Effective design for noise control requires a general understanding of the behaviour of sound.

Information on the principles underlying the transmission of sound from one place to another, the attenuation, absorption and reflection of sound and the way sound affects people can be found in "Acoustics, noise and buildings" [1] and "Noise, buildings and people" [2]. Certain problems require expert advice (see Appendix A).

4.2 Design methods

4.2.1 General. Design for noise control can be done in two ways:

- a) by drawing on experience; or
- b) by calculation, using test data (see Appendix B).

In practice, a judicious mixture of both methods is often employed. This makes it impractical to lay down a detailed formal procedure to be followed in designing for noise control.

4.2.2 By experience. The degree of noise reduction required, and often the means by which it is achieved, are assessed from past experience. This is based on a knowledge of the kind of noisy activity and the kind of people exposed to it. The approach has the advantage of simplicity but is difficult to use for new and unfamiliar situations. This is particularly so when a designer wishes to employ novel and untried features.

4.2.3 By calculation. When designing by calculation an assessment should be made of:

- a) the severity of the noise source; and
- b) the desirable noise level at the receiver.

From a) and b) the desirable noise reduction is calculated. The proposed design is examined and calculations carried out to see if the desirable noise reduction is likely to be achieved. The results indicate whether a higher standard of noise control should be considered or whether a lower standard will do. If a change in the acoustic design is indicated, further calculations should be carried out and the process repeated until a satisfactory result is predicted.

Initial calculations may be carried out on the basis of single-figure data for the following²⁾:

- 1) the noise source or sources (e.g. A-weighted sound pressure level, $L_{Aeq, T}$) at a known position;
- 2) the sound reduction (e.g. average sound insulation); and
- 3) the desirable sound level at the receiver (e.g. $L_{Aeq, T}$).

However, it has to be stressed that in general there is no simple relationship connecting such single-figure data. For proper final calculations, a knowledge of the following are required:

- i) the frequency characteristics of the source noise; and
- ii) the frequency characteristics of the sound reducing element or process.

Generally, frequency data should be for contiguous bands one-third of an octave wide. If this is not available, octave-band data may be acceptable where it is known that frequency characteristics do not vary much within the wider bandwidth.

Calculation will grow in importance as further numerical data on the characteristics of noise sources and sound insulation is acquired. Numerical data is essential if the use of performance standards in building becomes more common (see ISO 6241).

²⁾ Examples of calculations are given in "Acoustics, noise and buildings" [1].

5 Legislative background

5.1 General information

There now exists a considerable amount of legislation and official recommendations concerning noise problems. It is, therefore, essential to consult with local authority and other officials for the district in which building works are proposed at the earliest planning stage.

Officials to be consulted include:

- a) Planning Officer;
- b) Environmental Health Officer;
- c) Building Control Officer;
- d) Factories Inspector (Health and Safety Executive).

Any new noise source is a potential nuisance. Also, an existing noise source may become a nuisance if people are introduced into its vicinity. Appendix C lists the legislative framework relevant to noise as an annoyance, a nuisance or a health risk in England and Wales. For further information see "The law relating to noise" [3].

5.2 Common law

Except for the special case of aircraft noise (see C.5), legal action to stop a noise can be taken under common law. The main principles established are as follows.

- a) It is no defence for a defendant to show that all possible care to prevent noise has been taken.
- b) The noise complained of need not be injurious to health; the question can be one of interfering with ordinary comfort.
- c) There is no fixed standard of comfort. It depends on whether a reasonably minded resident in the locality, accustomed to local noises would take the same view as the plaintiff.
- d) It is no defence in private nuisance cases for the defendant to show that the plaintiff came to the nuisance, nor that the nuisance complained of is beneficial to the public.

5.3 Contracts

It is possible to provide against noise by express provisions in contracts. This may be useful for certain types of buildings. For example, it may be possible in a tenancy agreement to restrict the use of musical instruments, providing the restriction is sufficiently specific to be enforceable.

6 Outside noise

6.1 General

When planning permission is sought for a new building or for change of use of an existing building, the local planning authority may:

- a) refuse permission if the site is too noisy for the proposed use; or
- b) refuse permission if the proposed use is likely to be a noise nuisance; or
- c) impose conditions regarding noise levels.

The local planning authority will be guided by Department of the Environment (DoE) Circular 10/73 "Planning and noise" [4] (or, in Scotland, Scottish Development Department (SDD) Circular 23/73 with memoranda 24/73 [5]) and DoE Circular 1/85 "The use of conditions in planning permissions" [6].

Some noise sources may be absent at certain times of day or night. Buildings may be occupied when the outside is noisy. These factors should be taken into account when considering the need for noise reduction.

6.2 Noise assessment

In order to assess the required insulation for a building façade it is necessary to evaluate the offending noise source and the level to which it should be reduced in order to produce acceptable conditions for those subjected to the noise. For assessment of particular outside noise sources, see 6.3. For criteria of acceptable conditions, see clauses 7 to 13.

The local environmental health officer should be asked for data on sound levels on and around the proposed site, for both existing and possible future noise sources. If such data is not available, consideration should be given as to whether published data is an adequate guide or not. If not, a noise survey will be necessary (see Appendix D).

6.3 Noise sources

6.3.1 Road traffic. The noise from road traffic can be calculated for most situations by using the procedure described in "Calculation of road traffic noise" [7].

The basic data required includes an estimate of the number of vehicles passing the building in each hour, their speed and the proportion of heavy vehicles. Such data can usually be obtained from the local highways authority. It is usual to calculate for flow rates expected fifteen years hence.

The calculations provide an estimate of $L_{A10,18h}$, i.e. the traffic noise levels exceeded for 10 % of the time between 0 600 hours and 2 400 hours on a normal working day.

In certain situations, calculation may be inappropriate and measurements may be necessary (see Appendix D). This applies mainly where traffic is severely congested, where the flow rate is small (particularly in rural areas) or on gradients steeper than 1 : 10.

$L_{A10, 18 h}$ is the index used for assessing entitlement to sound insulation under the Noise Insulation Regulations 1975 [8] issued under the Land Compensation Act 1973. Thus, in spite of the current preference for L_{Aeq} as a descriptor of environment noise, $L_{A10, 18 h}$ is likely to be retained for road traffic noise for several years.

For most situations, $L_{Aeq, T} = L_{A10, T} - 3$ with a 95 % confidence limit of ± 2 dB.

Typical values of $L_{A10, 18 h}$ are given in Table 2 together with an estimate of the corresponding values of $L_{Aeq, 18 h}$.

Table 2 — Traffic noise levels

Situation	$L_{A10, 18 h}$	$L_{Aeq, 18 h}$
	dB	dB
At 20 m from the edge of a busy motorway carrying many heavy vehicles, average traffic speed 100 km/h, intervening ground grassed	80	77
At 20 m from the edge of a busy main road through a residential area, average traffic speed 50 km/h, intervening ground paved	70	67
On a residential road parallel to a busy main road and screened by the houses from the main road traffic	60	57

6.3.2 Aircraft. The most serious problems arise from large commercial airports. For historical reasons annoyance around such airports in the UK has been assessed by the use of the Noise and Number Index (NNI). This index is the basis for guidance on planning buildings near airports (see Table 3). It is expected that, in due course, NNI will be replaced by L_{Aeq} in accordance with ISO 1996/1 and BS 5727. Table 4 gives an approximate relationship between NNI and $L_{Aeq, 12 h}$ (see the Noise Advisory Council Guide [9]).

Noise problems can arise from helicopters and near military airfields and flying clubs.

Problems with aircraft noise are often very complex. An expert should be consulted.

6.3.3 Railways. Noise levels for a typical mixed line containing high speed diesel hauled passenger trains and various freight trains (total approximately 120 per day) is given in Table 5 (see publications [9] and [10]). The data are given for an open grassland site.

Noise from the motors of overhead electric trains can usually be ignored.

The data given in Table 5 and Table 6 give a rough guide only. If it appears that railway noise may be a problem, then detailed calculations (see publication [11]) or measurements (see Appendix D) will be necessary.

An extensive survey [12] has shown that for UK residents:

- a) annoyance increases steadily with noise level;
- b) railway noise is less annoying than aircraft or road traffic noise of equivalent noise level;
- c) $L_{Aeq, 24 h}$ correlates well with annoyance;
- d) annoyance is not reduced by increased ambient noise level;
- e) maintenance noise is rated as a bigger problem than passing train noise.

Guidelines published by the former Greater London Council [13] recommend that habitable rooms in new housing exposed to external levels with $L_{Aeq, 24 h}$ greater than 65 dB from railways should be provided with sound insulation.

Ground-borne noise from underground trains can be a nuisance for noise-sensitive buildings. Resilient mounting of rooms or complete buildings sited above or near underground railways may be necessary. An expert should be consulted.

Table 3 — Recommended criteria for control of development in areas affected by aircraft noise

Level of aircraft noise to which site is, or is expected to be exposed	60 NNI and above	50 NNI to 59 NNI	40 NNI to 49 NNI	35 NNI to 39 NNI
Dwellings	Refuse	No major new developments. Infilling only with appropriate sound insulation: see appendix 3 ^a		Permission not to be refused on noise grounds alone
Schools	Refuse	Most undesirable. When, exceptionally, it is necessary to give permission, e.g. for a replacement school, sound insulation should be required to a standard consistent with DES Guidelines (see footnote to paragraph 7 of this circular) ^a	Undesirable	Permission not to be refused on noise grounds alone
			Sound insulation to be required to a standard consistent with DES Guidelines (see footnote to paragraph 7 of this circular) ^a	
Hospitals	Refuse	Undesirable	Each case to be considered on its merits	Permission not to be refused on noise grounds alone
		Appropriate sound insulation to be required		
Offices	Undesirable	Permit	Permit but advise insulation of conference rooms depending upon position, aspect, etc	
	Full insulation to be required			
Factories, warehouses, etc.	Permit (It will be for the occupier to take necessary precautions in particular parts of the factory depending on the processes and occupancy expected. But see paragraphs 25 to 32 of this circular ^a for control of new factories, etc. in relation to their noise EMISSIONS.)			
NOTE This table is derived from Department of the Environment Planning Circular 10/73 “Planning and noise” and is reproduced by kind permission of the controller of Her Majesty’s Stationery Office [4].				
^a These references are to the DoE planning circular 10/73.				

Table 4 — NNI and $L_{Aeq, 12h}$

NNI	$L_{Aeq, 12h}$ dB
35	57 ± 4
45	66 ± 4
55	75 ± 4
60	80 ± 4

Table 5 — Noise from trains

Distance from track	$L_{Aeq, 24h}$
m	dB
25	67
50	64
100	59
200	54

Table 6 gives the peak noise level from wheel/rail noise for different types of rolling stock.

Table 6 — Peak wheel/rail noise at 25 m from track

Rolling stock	v_o (see note 2)	Peak L_{pA}
	Km/h	dB
Mk II Intercity coaches (tread braked)	160	93
Mk III Intercity coaches (disc braked)	160	85
MGR (disc braked coal freight)	70	79
NOTE 1 For jointed track add 5 dB.		
NOTE 2 For speed, v , add $30 \log (v/v_o)$ where v_o is tabulated speed.		

6.3.4 Industry. Industrial noises arise from such a wide range of different sources that prediction of noise levels from published data is very difficult. BS 5228 gives detailed guidance on the noise from construction and other open sites.

The general approach to noise prediction for industrial noise is given in a guide by the Noise Advisory Council [9]. A noise survey will often be necessary (see Appendix D).

BS 4142 gives a method of rating industrial noise affecting mixed residential and industrial areas. The corrected noise level (CNL) is used as the noise level index. Examples are given in Table 7.

Table 7 — Noise from industrial premises

Situation	CNL
	dB
At 10 m from a building housing an air/steam drop forge hammer	85
At 10 m from an air compressor housed in a building with louvred doors	75
At 15 m from a can-making factory. Continuous noise from stamping machinery and from handling of thin sheet metal	60

As a rough guide, with 95 % confidence limits of ± 6 dB, subtract 3 dB from the value of CNL to get $L_{Aeq, T}$. Also subtract any tonal or impulsive correction if used in calculating CNL.

6.3.5 Other noise sources. Other outside noise sources which may affect the design of buildings include:

- a) discotheques and dance halls;
- b) places of entertainment;
- c) shooting ranges;
- d) hovercraft;
- e) powered boats and ships;
- f) Electricity Board transformers;
- g) rain;
- h) church bells;
- i) externally mounted air-conditioning plant;
- j) air intake and exhaust louvres;
- k) boiler flues;
- l) street parking;
- m) railway station announcements;
- n) motor racing circuits;
- o) slamming of car doors.

6.4 Noise control techniques

6.4.1 General. Design considerations for noise control have been discussed briefly in 4.1.

Noise outside can be reduced in three possible ways:

- a) by quietening the source of noise;
- b) by dissipating the sound on its path to the receiver;
- c) by obstructing the sound path between source and receiver.

For numerical estimates of these factors see the Noise Advisory Council guide [9].

6.4.2 Quietening the source. Reducing the noise at source should always be considered because the number of people benefitting will often be large. This can be the most cost-effective method. Naturally, this method is often resisted by those incurring the cost of noise reduction, especially if they do not also receive comparable benefits.

6.4.3 Dissipating the sound. Sound is dissipated as it travels through the air, because it:

- a) spreads out;
- b) is affected by nearby surfaces such as grass-covered ground; and
- c) is partly absorbed by the air itself.

All these mechanisms which weaken the sound become more effective the greater the distance between the source and the receiver. For buildings, the spreading is the most important effect. For small sources, the reduction is about 6 dB for each doubling of distance between source and receiver. For extended sources, there is a smaller reduction with distance. For example, the noise level from dense road traffic does not diminish very rapidly with height because of the increased view of the noise sources.

The worst situation occurs with traffic in city streets with high buildings on both sides. The noise level diminishes even more slowly as the height increases. This is because of multiple reflections between the façades (canyon effect).

Ground attenuation is negligible for hard ground. For grassland, the attenuation varies with frequency (see publications [1] and [9]).

A screen of trees or belt of trees less than 30 m deep provides little extra sound attenuation. The widespread belief that they are effective should be accepted as a psychological benefit.

6.4.4 Obstructing the sound. Solid barriers weaken sound. Complete enclosure of the noise source or receiver is the most effective form of barrier provided it is impervious and sufficiently heavy. The walls and roof of a building usually perform this function. Their efficiency as a sound insulator is reduced by weaknesses in the envelope (e.g. apertures, thin glazing, doorways).

Barriers which are not complete enclosures (e.g. fences) are most effective when tall, long and close to either the source or the receiver. The maximum attenuation achievable in practice is 25 dB. To calculate the attenuation, see "Acoustics, noise and buildings" [1]. It should be noted that a barrier can reduce the benefit of any ground absorption. Barriers may be solid fences, walls, earth banks or buildings.

6.4.5 Weather effects. Wind gradients, temperature gradients and turbulence can often affect received sound. The effects range from increasing the sound by 5 dB to reducing it by 25 dB. It is not usually practicable to use this factor in design.

7 Basic design guide

7.1 General

The following methods of noise control are applicable to many types of buildings (see also 4.1 and 6.4):

- a) reducing the noise at source;
- b) increasing the distance between the source and the receiver;

- c) increasing the sound insulation of building elements between the source and the receiver;
- d) increasing the sound absorption between the source and the receiver.

7.2 Checklist for design

7.2.1 General. The checklist given in 7.2.2 to 7.2.6 is an aid for the designer. Situations covered include various combinations of future and existing noise sources, future and existing buildings.

The effects of existing and future noise sources can be predicted if there is reliable published information. Otherwise measurement will be necessary, either of the existing noise or of a noise source similar to that proposed (see Appendix D).

Not all items on the checklist are necessarily applicable (e.g. a noise contour map will be unnecessary for an existing single house). However, the last item on the list (quality control and workmanship) should always be considered very carefully. Experience has shown that many noise control measures fail to perform adequately because the building details are not constructed as the designer intended. Variations in detailing which might appear ordinarily to be unimportant often have serious implications for noise control, e.g. lack of covers for keyholes.

7.2.2 Evaluation of noise sources. The noise source should first be located and the following procedures applied:

- a) select quantities for measurement or predicted evaluation (e.g. $L_{Aeq, T}$ or L_p as a function of frequency);
- b) assess effects of topography and tree planting;
- c) produce noise contour map and cross section for external noise (may not be necessary for a single house);
- d) evaluate noise levels due to user activities in and around buildings, at all building façades.

7.2.3 User requirements. To satisfy user requirements the following procedures should be applied:

- a) select measuring units to match 7.2.2 a);
- b) select acceptable noise level criteria for user areas.

7.2.4 Performance requirements. To satisfy performance requirements the designer should carry out the following:

- a) compare noise levels with design criteria;
- b) calculate required noise reduction between exterior and interior;
- c) calculate noise reduction required between user areas.

7.2.5 Design steps. The following design steps should be carried out:

- a) check feasibility of reducing noise levels and/or relocating noise sources;
- b) check feasibility of replanning building or site;
- c) consider reorientation of proposed building;
- d) select methods for meeting performance requirements;
- e) examine the effects of noise control measures on natural ventilation, fire regulation requirements, health and safety, etc.;
- f) carry out cost exercise to assess viability of alternative solutions.

7.2.6 Quality control and workmanship. To establish good quality control and workmanship the following activities should be carried out:

- a) consider including performance specification in contract documentation;
- b) specify required standards of materials and workmanship in contract documentation;
- c) specify checking and testing procedures.

Section 3. Specific types of building

8 Dwellings

8.1 Selecting design criteria

Recommended maxima for steady intrusive noises (see BRE Digest No. 266 [14]) are as follows.

- a) bedrooms: $L_{Aeq, T} = 30$ dB to 40 dB;
- b) living areas (for conversation and listening to radio and television): $L_{Aeq, T} = 40$ dB to 45 dB.

GLC guidelines [13] for parks and gardens recommend a maximum $L_{A10, T}$ of 55 dB.

8.2 Controlling externally generated noise

8.2.1 General. Housing may be subjected to a variety of external noises. For data on road traffic see **6.3.1** and **8.2.3**. For aircraft, railways, industry and other noises see **6.3.2** to **6.3.5**.

8.2.2 Proposed residential developments: existing noise source(s). When considering proposed residential developments the following recommendations should be taken into account.

- a) For tolerable living conditions, avoid land with a predicted $L_{Aeq, T}$ within 15 years of 65 dB. Otherwise costly sound insulation may be required.
- b) It may cost more to provide sound insulation than to develop an alternative site.
- c) If a noisy site has to be used, it is necessary to ensure that everything reasonable is done to reduce the noise on the site as a whole, particularly as many residents will want to enjoy their gardens and other areas outside their home.

Consideration should be given to the use of:

- 1) mounds;
- 2) screening by fence or walls;
- 3) screening by barrier blocks;
- 4) grassed areas.

Trees can have a useful psychological effect even when their measured noise reduction is insignificant.

NOTE Local authority housing schemes may in certain circumstances qualify for ad hoc additions to the government indicative costs. The increase is proportional to the percentage of the site area exposed to an $L_{A10, 18h}$ greater than 68 dB.

- d) Locate noise-tolerant areas such as staircase, bathrooms, storage rooms and garages nearest to the source of the external noise. Use door lobbies to protect sleeping areas or living rooms. Where possible arrange ventilation intakes away from noise sources.

8.2.3 Proposed residential development: anticipated noise source(s). Where major redevelopment is being considered, the development authority should formulate a policy for noise management and establish guidelines to resolve the conflicts arising between the preservation of the social amenity on the one hand, and provision for industrial, commercial and transportation needs on the other. The authority should note that separation of activities by zoning is not the only approach to solving a planning problem; it may create noise by generating otherwise unnecessary traffic movements.

8.2.4 Existing residential development: proposed new noise source(s). The planning authority should safeguard reasonable standards of amenity wherever possible. Local authorities have powers under the Control of Pollution Act 1974 to set up noise abatement zones. If loss of amenity cannot be avoided and the public case for introducing a new source of noise into an area has been established, compensation may be paid under The Land Compensation Act 1973.

The Noise Insulation Regulations 1975 [8] enable certain residents in existing buildings to receive grants for sound insulation. This only relates, however, to situations where new roads are constructed or existing roads physically improved, e.g. widened, and the residents suffer from increased road traffic noise having an $L_{A10, 18h}$ at or above 68 dB.

8.3 Airborne and impact sound transmission between new dwellings

Part E of Schedule 1 of the Building Regulations 1985 [15] requires that certain walls and floors separating dwellings have reasonable resistance to airborne sound. Certain floors above dwellings are required to have reasonable resistance to impact sound. This also applies to the Building Regulations (Northern Ireland) 1977 (as amended) [16].

For Scotland, the Building Standards (Scotland) Regulations 1981 [17] lay down standards which are mandatory for the sound insulation performance for separating walls and floors.

The requirements of the Regulations can be met by the use of wall and floor constructions scheduled in the Building Standards (Scotland) Regulations 1981 [17] or in Part E of Schedule 1 of the Building Regulations 1985 [15]. Constructions not in these schedules may be used if sufficient tests (in accordance with BS 2750) on similar constructions provide satisfactory results. It is important to remember that the design and construction of the flanking walls and floors and the positions of windows may profoundly influence the effectiveness of the separating wall insulation.

8.4 Controlling internally generated noise

8.4.1 Design. In order to control internally generated noise the following should be considered.

- a) *Quiet room.* It is desirable that there is at least one room for reading, studying, etc., which provides reasonable protection against noise from the others in the house. This need not be a single purpose room.
- b) *Internal planning.* Avoid positioning a bedroom of one dwelling next to the living room of an adjacent dwelling. In flats, bedrooms of one flat should be directly below the bedrooms of the flat above. Locate bedrooms away from access balconies. Vertical ducts, refuse chutes and lifts should not adjoin bedrooms or living rooms.
- c) *Conversions.* Large houses are often converted into flats so that existing internal walls and floors become the dividing elements between separately occupied dwellings.

Measures to ensure that these separating walls and floors achieve sound insulation performance similar to those for new construction should be taken. Methods of improving existing sound insulation are given in publications [18], [19], [20] and [21].

8.4.2 Construction

8.4.2.1 Separating walls constructed of plastered or rendered masonry having a mass of at least 375 kg/m^2 have been shown to be adequate in most situations, provided that care is taken to ensure that the mass of the construction is uniform and free from air paths through the wall. Flanking walls also have to be constructed so as to prevent sounds bypassing the separating wall. Other wall constructions, both cavity and solid, formed of materials having lower masses can provide adequate sound insulation.

Alternative methods of construction using the principles of discontinuity can achieve similar or better results with a carefully designed and constructed cavity wall (e.g. precast wall panels or separating walls in timber framed houses). Again, it is essential that the flanking construction is designed to provide adequate sound insulation. These principles can also apply to the design of floors.

8.4.2.2 Sound-absorbent materials should, unless otherwise indicated, be applied to the wall and ceiling surfaces of internal access ways, corridors and stair walls. Floor coverings such as carpet and underlay, rubber and other materials with resilient backings can be used on stair treads, corridors and landing floors. They can improve the acoustic characteristics of the building and hence its acceptability to the user. Conformity with fire safety requirements should be checked.

8.4.2.3 The quietest types of sanitary, heating and plumbing equipment (e.g. WCs, ball valves, refuse chutes etc.) should be used; however their location is more important than their detailed design. Partitions around toilet areas should have an average sound insulation of at least 38 dB (see "Reducing noise from WCs in dwellings" [20]).

8.4.2.4 Care should be taken to isolate heating pipework, without restraint, from the building structure. Where pipes pass through walls and floors in flats any air gaps should be sealed in such a way that structure-borne noise is not transmitted. Central heating pumps, ventilation fans and similar equipment should have resilient mountings and flexible connections wherever possible.

8.4.2.5 Lift motors should, where possible, be mounted on isolating resilient supports; access doors should be most carefully designed and lift doors should operate quietly.

9 Educational buildings

9.1 General

Acoustic problems should be considered at the earliest stage of design. Appropriate planning of space use, including the separating of noise-sensitive from noise-producing spaces, can eliminate many acoustic problems.

A brief outline of the acoustic requirements in schools is given in "Guidelines for environmental design and fuel conservation in educational buildings" [22]. A more detailed treatment is given in "Acoustics in educational buildings" [23].

9.2 Design criteria

Table 8 gives recommended maximum noise levels generated from all sources other than those arising from normal use.

Table 8 — Maximum noise levels in unoccupied spaces

Type of space	$L_{Aeq, T}$
	dB
Circulation spaces/workshops/practical areas	50
Teaching groups of less than 15 people within a communication distance less than 4 m	45
Resource areas/individual study spaces/libraries	
Teaching groups of 15 to 35 people within a communication distance of not more than 8 m	40
Small lecture rooms/presentation rooms	
Medical inspection rooms/offices	
Seminar rooms	
Teaching groups of more than 35 people and a communication distance over 8 m	35
Large lecture rooms	
Language laboratories	
Music and drama spaces	30

9.3 Controlling externally generated noise

External sources of noise include:

- a) transportation noise;
- b) deliveries of fuel and stores;
- c) playing fields;
- d) open-air swimming pools;
- e) playgrounds.

If noise-sensitive rooms are required to be located facing a noise source, the amount of glazing should be reduced to a minimum, located if possible in areas of acoustic shadow and have no opening lights.

9.4 Controlling internally generated noise

9.4.1 Airborne noise. For purposes of sound insulation, rooms in educational buildings may be classified as follows.

(Class A)
Noise-producing: workshops;
kitchens;
dining rooms;
gymnasiums;
indoor swimming pools;
boiler rooms.

(Class B)
Noise-producing but needing quiet at times: assembly halls;
lecture halls;
music rooms;
commerce and typing.

(Class C) Average: general classrooms;
practical rooms;
laboratories;
offices.

(Class D) Rooms needing quiet: libraries;
division rooms;
studies;
medical rooms;
staff rooms.

The recommended minimum average sound insulation (based on sixteen one-third octave band measurements between 100 Hz and 3150 Hz in accordance with BS 2750) between rooms of the same class is given in Table 9.

Table 9 — Minimum sound insulation

Class of room	D	D_w
	dB	dB
Class A	25	28
Class C or D	35	38
Class B	45	48

Where a room is likely to have a dual use, e.g. a dining room to be used as a classroom, the higher sound reduction value should be used.

The recommended minimum sound reduction between rooms in different classes is 45 dB ($D_w = 48$ dB), subject to the following.

- a) Workshops should be regarded as a special category requiring more than 45 dB insulation from rooms of any other class.
- b) Assembly halls and music rooms may need more than 45 dB insulation from rooms in class A, if the latter are very noisy.
- c) Circulation spaces can vary from a long and frequented corridor to a small private lobby and it is therefore difficult to give precise recommendations. For partitions between rooms in class C and most corridors 35 dB ($D_w = 38$ dB) for the partition itself is appropriate: for partitions between rooms in other classes and corridors more may be necessary or less be permissible.

Consideration may need to be given to the increasingly common practice for the facilities in schools to be used after school hours. Potentially noisy activities, e.g. discotheques, can be annoying to those in neighbouring houses during evenings and weekends.

9.4.2 Impact sound. It is recommended in multi-storey construction that the minimum standard of impact sound insulation for floors above teaching spaces should be equal to a weighted standardized impact sound pressure level $L'_{nT,w}$ of 70 dB.

9.5 Special schools

Special attention should be given to noise reduction in schools for the deaf, the blind and other handicapped children. Deaf children are taught by means of hearing aids, which cannot be used satisfactorily in high noise levels or in reverberant conditions. Blind children depend on good hearing for understanding speech and for detecting changes in environment. Design Note 25 [24] gives further information.

9.6 Universities and colleges

The accommodation found in university and college buildings is very diverse and sometimes highly specialized. Much of what has been said in this section is applicable; for laboratories, lecture rooms, and auditoriums see 9.2 and 9.4. The problems of administrative, tutorial and seminar rooms are similar to those encountered in offices (see clause 11).

9.7 Construction notes

Some of the forms of light and dry construction developed for school and community buildings lack the qualities necessary for high values of sound insulation. Lightweight construction requires careful joint design and assembly detailing to prevent flanking sound paths which affect the nominal sound reduction value.

Where good sound insulation is required the use of movable partitions should be avoided.

Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another on internal angles. Rooflights and ventilators over noisy rooms should be avoided if they are likely to be a source of nuisance to adjacent upper floors.

10 Industrial buildings

10.1 Selecting design criteria

Where noise-tolerant sites are not available, extensive noise precautions may be required, especially if the noise is impulsive or is of a strong tonal character. Where a proposed development is situated in the vicinity of noise-sensitive buildings the local planning authority will usually specify the maximum permissible noise level at the site boundary.

They may require that no detectable increase in background level takes place, i.e. the plant is at least 10 dB below background level ($L_{A90, T}$), or they may allow a small increase in background level, generally no more than 1 dB.

Documents used in consideration of planning applications are as follows.

- a) BS 4142;

- b) DoE Circular 10/73 [4];
- c) DoE Circular 2/76 [25];
- d) SDD Circular 23/73 with memoranda 24/73 [5];
- e) DoE Circular 1/85 [6].

A local authority may publish its own guidelines.

10.2 Controlling externally generated noise

Wherever possible the noisier factories should be sited in the centre of an industrial estate and a neutral area placed around the whole by interposing roads, garages, playing fields and other open spaces. Offices, warehouses and quiet production departments should be used as screens or buffer zones between factory and dwellings.

Possible nuisance may be caused by:

- a) calling systems;
- b) piped music;
- c) bells rung at the ends of shifts.

Noise from night-time working may be a nuisance.

10.3 Controlling noise produced in production areas

Unless suitable ear protection is provided, no employee should work in situations where the equivalent continuous noise level $L_{Aeq,8h}$ is greater than 90 dB over the working day. For further information refer to the DoE "Code of Practice for reducing the exposure of employed persons to noise" [26].

The methods available for noise reduction include:

- a) use of quieter machinery;
- b) screening;
- c) enclosing noisy equipment;
- d) separating noisy areas from noise-sensitive areas;
- e) modifying working processes;
- f) use of rubber-tyred trolleys;
- g) use of rubber or plastic doors;
- h) providing resilient buffers at points of impact;
- i) applying damping material to large radiating surfaces;
- j) fitting efficient exhaust silencers;
- k) use of fibre or plastic bins rather than metal;
- l) fitting efficient anti-vibration mounts.