Horizontal Guidance Note
IPPC H3 (part 2)

Integrated Pollution Prevention and Control (IPPC)

Horizontal Guidance for Noise
Part 2 – Noise Assessment and Control

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First published 2002

ISBN 011 310187 2

Record of changes

Version	Date	Change
Consultation and working draft	October 2001	
1	May 2002	Amended following consultation
2	September 2002	Published
3	June 2004	Amended to include the arrangements for implementing IPPC in Northern Ireland

Note:

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Executive summary

This guidance has been produced by the Environment Agency for England and Wales in collaboration with the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service (EHS). Together these are referred to as “the Agency” or “the Regulator” throughout this document.

Integrated Pollution Prevention and Control (IPPC) is a regulatory system that employs an integrated approach to control the environmental impacts of certain industrial activities. It involves determining the appropriate controls for industry to protect the environment through a single Permitting process. To gain a Permit, Operators will have to show that they have systematically developed proposals to apply the Best Available Techniques (BATs) and meet certain other requirements, taking account of relevant local factors.

The Regulators intend to implement IPPC to:

- protect the environment as a whole
- promote the use of “clean technology” to minimise waste at source
- encourage innovation, by leaving significant responsibility for developing satisfactory solutions to environmental issues with industrial Operators
- provide a “one-stop shop” for administering applications for Permits to operate.

Once a Permit has been issued, other parts of IPPC come into play. These include compliance monitoring, periodic Permit reviews, variation of Permit conditions and transfers of Permits between Operators. IPPC also provides for the restoration of industrial sites when the Permitted activities cease to operate.

The aim of this Guidance

The purpose of this *IPPC Horizontal Guidance Note for Noise Assessment and Control* is to provide supplementary information, relevant to all sectors, to assist Applicants in preventing and minimising emissions of noise and vibration as described in the *IPPC Sector Guidance Notes* (or the *General Sector Guidance Note*).

Throughout this document the term noise also includes vibration, except where clearly differentiated by the context.

This guidance is in two parts:

Part 1 ***Regulation and Permitting*** outlines the main considerations relating to the setting of Permit conditions and subsequent regulation of noise. It is aimed primarily at the information needs of Regulators (see Reference 1).

Part 2 ***Noise Assessment and Control***, this document, describes the principles of noise measurement and prediction and the control of noise by design, by operational and management techniques and abatement technologies. It forms a background to Part 1 and will assist in determining BAT for a given installation. It is aimed equally at the Regulator and at Operators. In addition, and to further support Part 1, this document also covers the basic physics associated with noise and vibration. However, this is not intended to be a substitute for a more detailed study of the subject as taught, for example, in courses accredited by the Institute of Acoustics.

Regulation of noise under IPPC will bring together several legislative regimes with different scope but similar purpose and, in the case of A1 installations, will require a co-ordinated approach between the Regulator and both the Planning functions and the Environmental Health or Environmental Protection Teams of local authorities. At an early stage, lead planning and environmental health/protection officers should be identified to ensure an effective liaison and consultation process.

In England and Wales the Environment Agency is responsible for those IPPC installations designated as "A1". SEPA in Scotland is responsible for the regulatory control of all PPC installations. EHS in Northern Ireland is responsible for the regulatory control of all Part A installations.

This document will be amended when the specific requirements relating to activities moving from the waste management licensing regime to integrated control under the Pollution Prevention and Control Regulations become clearer.

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1 Introduction to noise physics, units and measurement parameters

1.1 Basic noise physics

A glossary of acoustic terms can be found in Appendix 1. A summary of the key points of relevant documents is given in Appendix 2. As well as the References listed at the end of the main text, a list of Standards and Books for further reading or reference is included.

1.1.1 The difference between sound and noise

Noise and sound definitions

Sound is a sensation detected by the ear as a result of pressure variations set up in the air by a vibrating source. Such vibrations set up a series of alternate regions of increased and decreased pressure (compressions and rarefactions) in the surrounding air. The longitudinal motion of these pressure fronts takes the form of sound waves "travelling" from source to receiver. As with waves in a pond, the medium (air or water) does not travel, but the pressure variations travel through the medium.

Noise has been defined in various ways, but essentially is unwanted sound or sound that is not desired by the recipient. Although the various physical attributes of sound can be quantified, the subjective aspects of noise are much more difficult to assess. The degree of annoyance and stress that can result from exposure to noise is almost impossible to quantify, since responses may vary widely between individuals. This can influence the apparent effectiveness of noise–control measures.

1.1.2 Basic principles

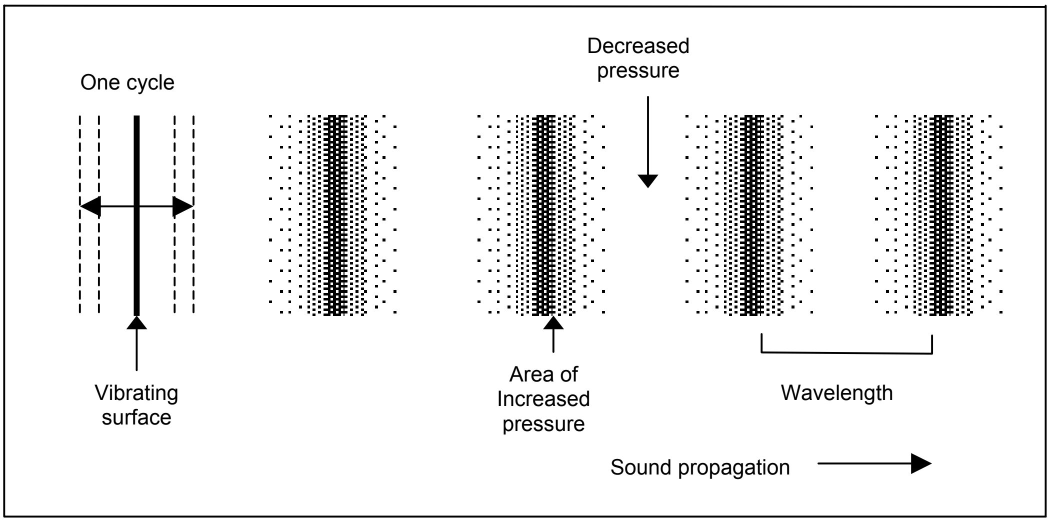
Acoustics — basic principles

A sound wave has wavelength, frequency and amplitude:

1.1.2.1 Wavelength:

Each vibration of the source produces one pressure wave in an elastic transporting medium, usually air in the case of noise. The wavelength is the distance between successive pressure waves — that is, during one cycle from low - high - low pressure (see Figure 1.1).

Figure 1.1 - Propagation of a sound wave



1.1.2.2 Frequency:

Frequency is the rate at which the source vibrates, and subsequently the pressure wave. It is measured in cycles per second (Hertz — Hz). Frequency determines the pitch of the sound. Doubling of frequency produces an approximate increase of one octave.

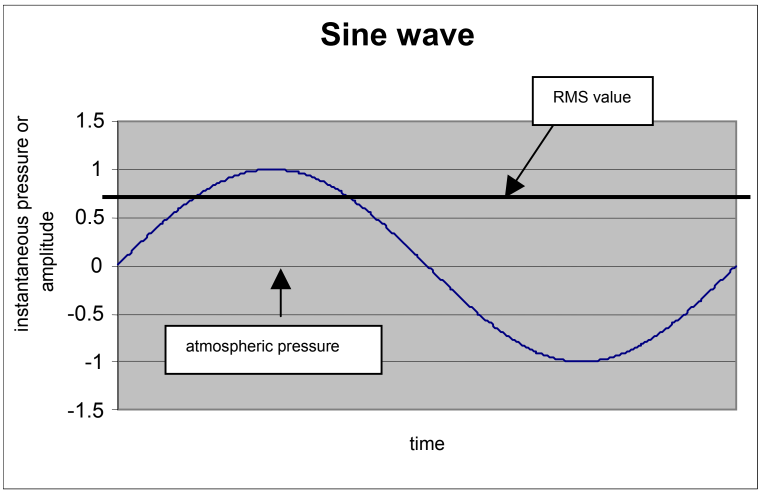
The frequencies that the normal human ear can detect (up to age 21) range from about 20Hz to 20kHz, although individuals vary greatly in terms of their sensitivity. Below 20Hz lies the range of infrasound and above 20kHz lies the ultrasound range.

Most sounds encountered in an industrial or environmental context consist of many different frequencies, although equipment such as fans, turbines, transformers and the like can produce noise with discrete frequencies that may lead to audible tonal characteristics.

1.1.2.3 Amplitude:

The amplitude is the maximum excursion of the pressure difference of a sound wave as shown in Figure 1.2.

Figure 1.2 — Sine wave showing pressure against time



Basic principles cont.

When sound is measured, an average value over time is required to provide a measurable indication of the amplitude. The signal is therefore passed to a root mean square detector and hence the root mean square (RMS) sound pressure is measured. This is obtained by taking the square root of the arithmetic mean of the square of each value over the given sample period.

1.1.2.4 The speed of sound:

The speed with which the sound travels depends on the medium through which it travels, particularly its elasticity and density. The speed of sound in air at 20°C is 344ms^{-1}.

The speed is related to frequency and wavelength by:

$$c = f\lambda$$

where: c = the speed of sound in metres per second
and f = frequency in Hz
λ = wavelength in metres.

As the velocity of sound is constant for any given medium in a fixed state, if frequency increases then wavelength decreases.

1.1.2.5 Impulsive noise

Sounds of very short duration, typically less than a second, can also cause annoyance. Sources of impulsive noise include hammering, tapping and clattering. Examples of industrial activities include drop forging, impact pile driving and press works.

1.1.2.6 Sound pressure

The sound pressure level, L_p , in dB, is the ratio of the sound pressure level and a reference level. The ear is pressure sensitive and therefore measurement of this parameter is useful for assessing the impact on people and is the most commonly used dB scale.

$$L_p = 10\log_{10} \frac{p^2}{p_o^2} \text{ dB} \quad \text{or} \quad L_p = 20\log_{10} \frac{p}{p_o} \text{ dB}$$

where: p is the rms sound pressure fluctuation of the sound of interest
and p_o is the reference sound pressure of audibility and is (2×10^{-5} N/m^2, or 20μPa)

When sound pressure level is reported, the location or distance from the source of the sound must be stated. The distance from the source and a host of other environmental factors influence the sound pressure level at a receiver.

1.1.2.7 Sound power

Basic principles cont.

Sound power level, L_W, is the energy output of a source and is a property of the source itself. The sound power level is a ratio of the power of a source and a reference and is quoted in dB.

The sound power level is defined as:

$$L_W = 10\log_{10} \frac{W}{W_O} \quad dB$$

where: W is the sound power of the source (watts)

and W_O is the reference sound power (10^{-12} watts)

The sound power level is usually calculated from a series of measurements made around the equipment under carefully defined conditions. These measurements may be either sound pressure level, using a sound level meter or sound intensity, using a sound intensity meter; the measurements are made at a known distance from the source, then the sound power level determined.

Where sound power levels are quoted by manufacturers, a direct comparison can be made of the noise produced by machines, appliances, tools and other equipment. The sound power levels can also be used to calculate the sound pressure level at specific locations.

Note: Sound pressure level and sound power level are often confused, so consider an analogy with a light bulb. If the sound po**W**er is the **W**attage of the light bulb, then the light falling or "**P**ressing" on a surface is the sound **P**ressure.

1.1.2.8 Sound intensity level

Sound intensity level is a measure of the amount of sound power per unit area.

$$I = \frac{W}{4\pi r^2}$$

where: W is the sound power in watts

and r is the distance in metres from the source.

It is a vector quantity and it has both direction and magnitude. Measurement requires the use of a specific type of sound level meter, or module, using a pair of matched microphones.

The human ear is sensitive to a wide range of sound intensities:

- the "quietest" sound that can be heard is approximately 10^{-12} wm^{-2}
- the "loudest" (without pain) sound that can be heard is approximately 10 wm^{-2}

The intensity in decibels is a ratio of two quantities — the intensity of the sound being measured (I) and the reference intensity (I_o), which is normally the threshold of hearing (10^{-12} wm^2).

1.1.3 Vibration

Basic principles — vibration

Vibration is the oscillation of a body about a reference point. The number of oscillations per second gives the frequency of vibration (Hz). What differentiates audible sound from vibration is the way they are perceived; sound can be detected by hearing, whilst vibration can be felt as it is transmitted through solid structures directly to the human body.

As with sound, vibration may occasionally occur at a single frequency, but more usually there are a number of different frequency components in simultaneous combination. Often different parts of a machine will vibrate at different frequencies. It should be noted that the perception range for vibration (1 – 80Hz) is much smaller than for noise (20 – 20,000Hz).

Vibration may be continuous or intermittent. Common sources of vibration include heavy steel presses or guillotines, road and rail traffic and blasting for mineral extraction.

A particle may vibrate in any one of three axes (vertical, longitudinal, and transverse), but often in a combination of all three. In measuring peak vibration levels, sometimes the highest level in any of the axes is used and sometimes the resultant is used. However, the resultant can be complicated by the fact that the three axes may not vibrate in phase. The axes are defined in relation to the human activity that is taking place at the time of the measurement.

Basic principles — vibration cont.

The vibration in each axis of interest can be quantified in terms of three parameters:

- **acceleration** — the rate of change of velocity over time (in m s^{-2} or mm s^{-2})
- **velocity** — the rate at which displacement varies with time (in m s^{-1} or mm s^{-1})
- **displacement, or amplitude** — the distance (in m or mm) moved from the fixed reference position

Vibration can often be induced by airborne sound waves in both the audible and the subsonic ranges. Many complaints of vibration from quarries are not ground–borne vibration, but are of windows rattling or ornaments shaking, induced by the air pressure wave caused by the blast.

The field of vibration measurement and control is a complex area, and situations other than the very basic ones generally require specialist knowledge.

1.2 Units of sound

1.2.1 The decibel scale of sound

Decibel definition

The human ear is a very sensitive system with an extensive dynamic range. To accommodate this very large range, noise levels are measured using the decibel (dB) scale. Table 1.1 below gives examples of common sound levels with an idea of the subjective effect. The sound pressure in microPascals (μPa) is shown to illustrate the need for the use of the decibel. However, it is a logarithmic and not an arithmetic scale. This complicates the mathematics, but makes the numbers more manageable and, with familiarity, more meaningful.

A sound level meter theoretically has a flat response, in other words it responds exactly the same at different frequencies. Unlike a sound level meter, the human ear responds differently at different frequencies, so a weighting, or filter, can be used so that the meter responds more like the human ear. The most commonly used weighting is referred to as the 'A' weighting and readings are usually measured in dBA (see Section 1.3).

It is commonly accepted that for the average person a change of 1 dB is just perceptible under controlled conditions. A change of 3 dB is noticeable, 6 dB obvious and a change of 10 dB is significant and corresponds approximately to halving or doubling the loudness of a sound. For example, if two identical speakers are set up side by side and the observer is a few metres away from both and one speaker is turned off, or turned on, the change in volume is, in practice, the minimum change one can notice and is only 3 dB. Sound levels are normally reported to the nearest whole dB, since to report to even one significant figure implies a greater accuracy of measurement than can be achieved.

Table 1.1 — Typical sound levels in everyday situations

Situation/noise source	Sound pressure level in dBA	Sound pressure in μPa	Average subjective description
30m from a military jet aircraft take off	140	200,000,000	Painful, intolerable
Pop concert	105	3,500,000	
Night club	100	2,000,000	
Pop concert at mixer desk	98	1,600,000	
Passing heavy goods vehicle at 7m	90	630,000	Very noisy
Ringing alarm clock at 1m	80	200,000	
Domestic vacuum cleaner at 3m	70	63,000	Noisy
Business office	60	20,000	
Normal conversation at 1m	55	11,000	
The reading room of the British Museum	35	1,100	
Bedroom in a quiet area with the windows shut	30	630	Very quiet
Remote country location without any identifiable sound	20	200	
Theoretical threshold of hearing	0	20	Uncanny silence

N.B. Since the sound pressure level is in dBA, strictly speaking a comparison with the sound pressure in μPa cannot be made; nevertheless the table illustrates, in general terms, the concept of the log functions of the decibel scale.

1.2.2 Frequency analysis

1.2.2.1 Introduction

Frequency analysis

Just as a given noise is characterised by the way in which it varies over time, it is usually made up of a wide range of different frequencies. The spread of noise energy across the audible frequency "spectrum" (about 20Hz – 20kHz) is one factor that helps to make it identifiable to the human ear.

Often the sound energy will be spread over a wide band of frequencies ("broad-band" noise). Sometimes a noise source will emit noise that is concentrated in a "narrow band" of the spectrum or contains a high proportion of energy at a single frequency (a "pure tone"). This is referred to as "tonal noise". Examples of sources that can cause tonal noise include fans, compressors, motors and transformers. Most have moving parts that rotate or vibrate at a given, audible frequency. Mains

Frequency analysis cont.

electrical power is a common source of tonal noise, for example, in transformers causing them to vibrate at 100Hz. Tonal noise is generally more noticeable and more annoying than non-tonal noise of the same level. To take this into account tonal noise can be penalised in assessments of noise impact, usually by adding 5 dB to the measured level. Whilst tonality can be judged subjectively, it will often be useful to measure it. This can be achieved through ***octave band, 1/3rd octave band or by narrow–band analysis.*** BS 7445:1991 Part 2 - *Description and measurement of environmental noise*, suggests that if the level in one 1/3rd octave band is 5dB or more higher than the level in the two adjacent bands, then an audible tone is likely to be perceived (see Reference 2).

1.2.2.2 Octave band analysis

A sound can be subdivided into frequency bands to look at the distribution of components across the frequency spectrum. By international convention, the frequency spectrum is divided into bands with a width of one octave. The centre frequencies of the octave bands are in Hz. One octave represents a doubling of frequency; hence the bandwidth increases with increasing frequency (see Table 1.2 below).

Table 1.2 — Octave band centre frequencies and widths

Lower limit	22	44	88	176	353	707	1,414	2,825	5,650	11,300
Octave band centre frequency	**31.5**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**16k**
Upper limit	44	88	176	353	707	1,414	2,825	5,650	11,300	22,500

Figure 1.3 — Sample of octave band data

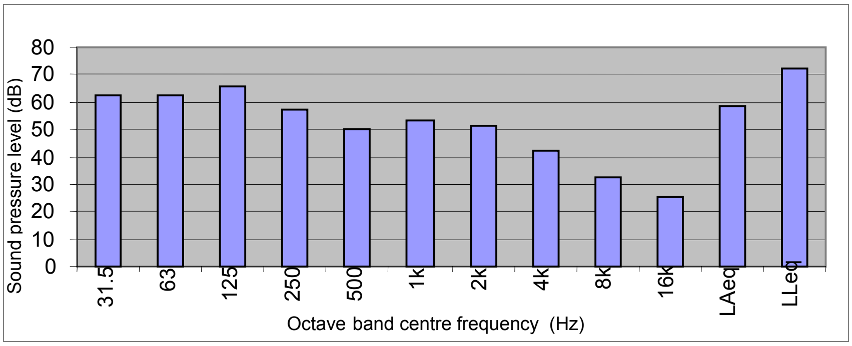


Figure 1.3 above shows an octave band analysis of environmental noise. The dominant source is a nearby motorway, and there is an electricity substation close by. The graph shows the general drop off in level with frequency that would be expected, since the traffic noise produces less energy at the highest audible frequencies and the higher the frequency the more the sound is absorbed by the atmosphere, but the lower frequencies are less affected.

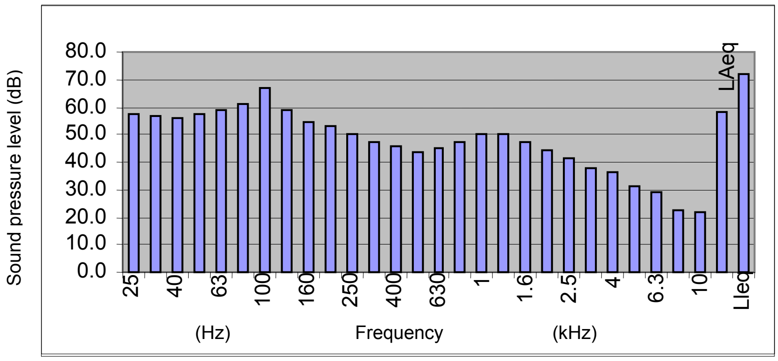
1.2.2.3 1/3rd octave band analysis

Often the information provided by octave band analysis is insufficiently detailed to identify a particular frequency. A more detailed breakdown can be obtained by octave band analysis, whereby the sound level meter divides the sound signal into bandwidths of 1/3rd of an octave. The sound pressure level is determined within each 1/3rd octave band and the total sound pressure energy will be the sum of all the 1/3rd octave band levels. More sophisticated sound level meters can perform this analysis and also give linear and ‘A’ weighted broad–band levels. Table 1.3 shows 1/3rd octaves with the single octaves in bold.

Table 1.3 — 1/3rd octave band centre frequencies and bandwidths

Octave band	31.5			63			125			250			500		
Lower limit	22	28	35	44	57	71	88	113	141	176	225	283	353	440	565
1/3rd octave band centre frequency	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630
Upper limit	28	35	44	57	71	88	113	141	176	225	283	353	440	565	707
Octave band	1k			2k			4k			8k			16k		
Lower limit	707	880	1,130	1,414	1,760	2,250	2,825	3,530	4,400	5,650	7,070	8,800	11,300	14,140	17,600
1/3rd octave band centre frequency	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8K	10k	12.5k	16k	20k
Upper limit	880	1,130	1,414	1,760	2,250	2,825	3,530	4,400	5,650	7,070	8,800	11,300	14,140	17,600	22,500

Figure 1.4 — Sample of 1/3rd octave band data



In the example shown in Figure 1.4, a distinct peak of 67dB can be seen in the 100Hz band. This would be judged as tonal, since the levels either side are 61dB at 80Hz and 59 dB at 125Hz. BS 7445:1991 gives guidance on tonality, and suggests that where a single 1/3rd-octave band level is at least 5 dB higher than the level in both of the two adjacent bands, then tonal character may be present. The broader peak around 1kHz and 1.25kHz would not be judged as tonal.

Very often a 1/3rd-octave band analysis is sufficient to identify significant tonal components. A more detailed analysis can be undertaken by tape recording the noise and analysing the recording in a laboratory. The noise spectrum can then be examined thoroughly (narrow–band analysis).

1.2.2.4 Narrow–band analysis

Frequency analysis cont.

The graph in Figure 1.5 below shows the frequency components of different industrial noise. It shows high levels of noise below the 250Hz band and then a gradual drop off up to 1.4kHz. The spikes at 100, 416, 470 and 1118Hz could pinpoint the frequency of a tone that has been subjectively identified. The data are in constant bandwidths of 2Hz.

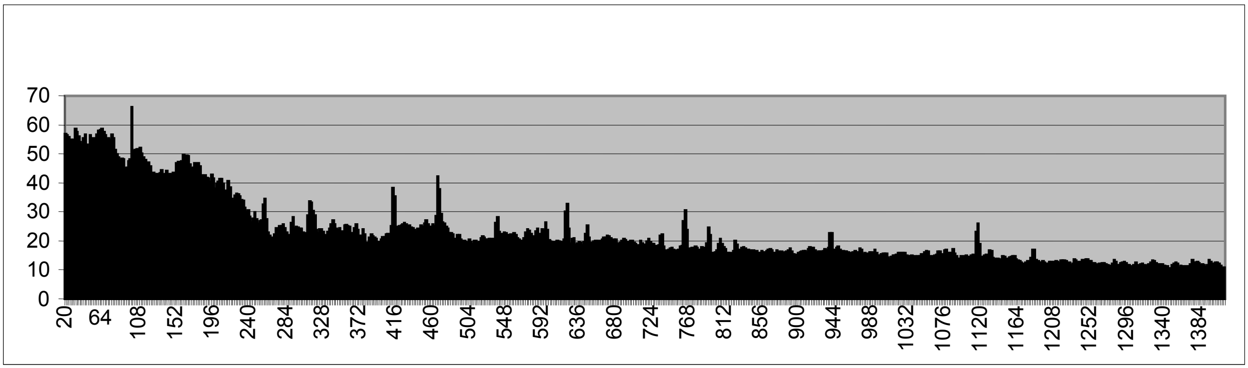


Figure 1.5 — Sample of narrow–band data in a 2Hz bandwidth 20 – 1414Hz

The above graph (Figure 1.5) shows how much more detail can be obtained about the noise source by using narrow–band analysis. However, it does have some limitations and experience is needed in its use. To positively identify audible tonal components, a technique known as constant bandwidth analysis has to be employed.

Finally Figure 1.6 below is a combination of all three analyses, for the industrial noise above, illustrating how more detail emerges as the bandwidths reduce. It also shows how the octave and 1/3rd octave bandwidths increase as the frequency increases.

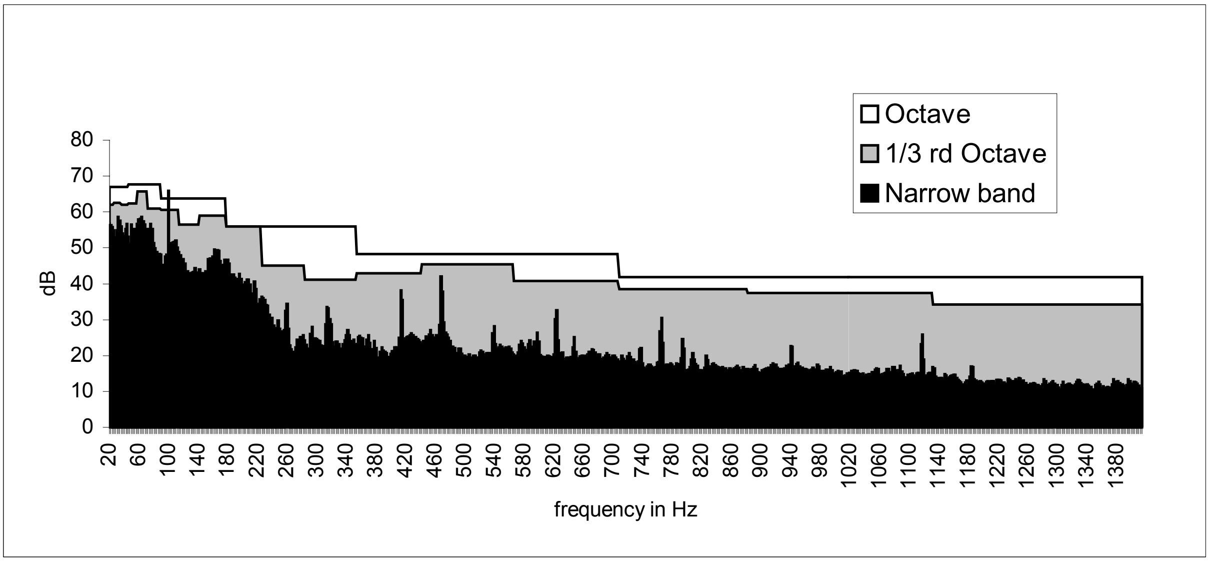
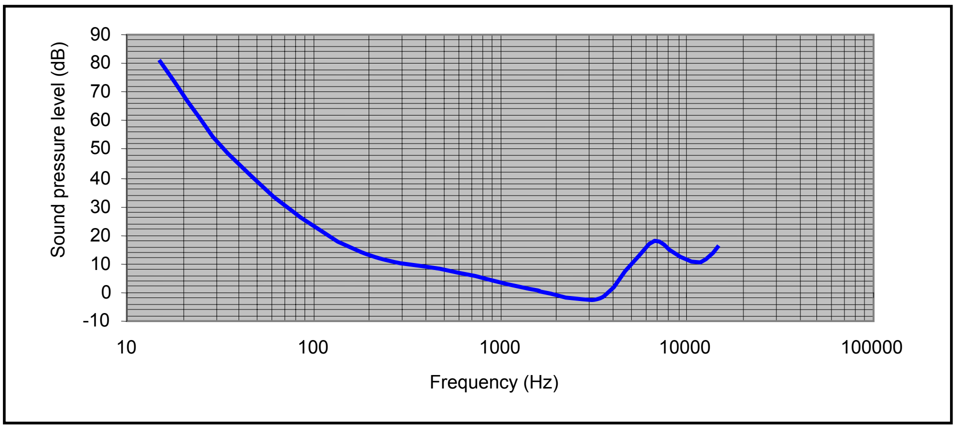


Figure 1.6 — Octave, 1/3rd octave and narrow–band analysis to show increasing bandwidth and level of detail

1.3 The response of the ear

The human ear converts minute pressure fluctuations in the air into signals, which are transmitted by the auditory nerve to the brain where they are perceived as sound. Figure 1.7 shows the threshold of hearing for people aged 18-25 with normal hearing.

Figure 1.7 — Threshold of audibility (18-25 age range)



This shows that the ear has a relatively poor response to low frequencies, whilst it is more responsive in the range 1– 5kHz, with a peak response at 2 – 3kHz. In descriptive terms, looking at the graph, sound at 100Hz has to be around 20 dB louder than a sound at 1kHz before it can be heard. Hearing deteriorates with age, the higher frequencies being most affected, and the curve becomes flatter as the ability to hear higher frequencies is lost.

In assessing the subjective impact of noise on individuals, both the sound pressure level and the frequency need to be taken into account, so weighting networks are used.

1.3.1 Weighting networks

dB weighting networks

To make a sound level meter respond more like the human ear, a frequency weighting is applied to most environmental noise measurements. The most commonly used one is the 'A' weighting. The 'C' weighting is sometimes used to assess sound with low–frequency content, such as fan noise, and for peak noise.

All weightings have a flat response at 1000Hz, that is, no correction is applied, since the ear's response can be regarded as equal to that of the sound level meter at that frequency. However, in the 63Hz centre–frequency band, for example, the ear's response is down by around 26 dB, so the 'A' filter takes off 26 dB in that centre–frequency band.

Although each frequency is considered independently in terms of its weighting, the levels can be logarithmically added to give an overall 'A'-weighted figure that best represents the response of the ear. This concept is widely used in environmental measurement and acoustic engineering. Most sound level meters will carry out this adjustment and can give linear and 'A' –weighted values in dB (see Table 1.4 below).

Table 1.4 — 'A'- weighting adjustment for octave bands (examples rounded to nearest dB)

Octave band centre–frequency (Hz)	'A' weighting adjustment in dB	Example linear sound level	'A' –weighted sound level
31.5	-39.4	63	24
63	-26.2	62	36
125	-16.1	68	52
250	-8.6	58	49
500	-3.2	50	47
1k	0	53	53
2k	+1.2	51	52
4k	+1.0	42	43
8k	-1.1	31	30
16k	-6.6	24	17
	Overall	**70 dB**	**58 dBA**

1.3.2 Low–frequency noise

Weighting networks cont.

The 'A'-weighting frequency network applies the highest attenuation to low frequencies (for example, 39 dB in 31.5Hz centre–frequency band). When measuring noise with a high content of low–frequency energy, 'A'-weighting can give non-representative results. In other words, it may not give sufficient emphasis to the "annoyance" value of the low frequencies. Consequently there is a growing trend to use "linear" noise levels (that is, with no frequency weighting at all) when quantifying a low–frequency noise source. This is a valid technique, but generally requires specialist advice.

1.3.3 Noise–rating curves

Noise Criterion (NC) curves were developed in the United States for setting noise limits in offices. Subsequently, Noise Rating (NR) curves were developed in Europe for more general use. The curves specify limiting sound pressure levels in each separate octave band. Although it is more usual to set noise limits in 'A' –weighted dB and to specify that the noise should have no discernible tonal character, some acousticians favour the use of NR curves and some NR –based limits may be encountered in existing conditions or limits.

1.4 Statistical and energy-based noise parameters

1.4.1 Quantifying a varying sound level

Noise levels are rarely constant because the overall sound pressure is often the result of numerous different sources of noise, each of which may be varying in strength from one instant to the next. Exceptions tend to be when one particularly constant source is very loud compared to the rest (for example, close to an extract fan in a factory wall) or when all noise sources are far away from the receiver (such as in the bedroom of a remote house at night). Therefore noise levels are usually quantified over a specified period. The time period will vary according to the nature of the noise, but is normally one hour during the day and five minutes during the night. The definitions of these terms can be found in British Standard 4142:1997 *Method for rating industrial noise affecting mixed residential and industrial areas*, (Reference 4).

1.4.1.1 L_{Amax} and L_{Amin}

Noise parameters

The simplest statistical parameters are the maximum level (L_{Amax}) and the minimum level (L_{Amin}) during the measurement period. The L_{Amax}, is often used as a measure of the most obtrusive facet of the noise, even though it may only occur for a very short time and is the level of the maximum Root Mean Square reading. L_{Amin} is rarely used, but can be a useful way of identifying a constant noise amongst other intermittent noises. The time weighting response of the sound level meter (fast (F), slow (S) or impulse (I)) should also be specified to make the reading meaningful, which is reported as $L_{AF,max}$ in dB, for example.

1.4.1.2 L_{pk}

Unlike the L_{Amax}, the L_{pk} is the peak noise level and is the highest level of noise measured, before the signal is processed in the RMS detector, so it is a true peak of the noise level. The L_{pk} is often reported as a linear reading, but is sometimes 'C' weighted and is used to assess the possibility of hearing damage in industrial situations and is reported as $L_{C,Pk}$ or $L_{L,Pk}$.

1.4.1.3 Percentile parameters

Percentile parameters, L_n values, are useful descriptors of noise. The L_n value is the noise level exceeded for n per cent of the measurement period, which must be stated. The L_n value can be anywhere between 0 and 100. The two common ones are discussed below, but sometimes other values will be encountered. The time period of the measurement should be specified, together with the time of day and day of the week.

$L_{A90,T}$

The most commonly used percentile level is the $L_{A90,T}$,which is the 90th percentile level and is the level exceeded for 90 per cent of the time, T. It will be above the L_{min} and has been adopted as a good indicator of the "background" noise level. It is specified in BS 4142:1997 as the parameter to assess background noise levels. Whilst it is not the absolute lowest level measured in any of the short samples, it gives a clear indication of the underlying noise level, or the level that is almost always there in between intermittent noisy events. BS 4142:1997 advises that the measurement period should be long enough to obtain a representative sample of the background level.

$L_{A10,T}$

$L_{A10,T}$ is the 10th percentile, or the level exceeded for 10 per cent of the time, and was used for road traffic noise assessments since it had been shown to give a good indication of people's subjective response to noise. Although the L_{Aeq} has largely superseded its use for traffic (see below), $L_{A10,T}$ may still be found in acoustic reports discussing road traffic noise. It is still used to assess traffic noise to determine eligibility for noise–insulation grants where a road is altered or a new one proposed. The $L_{A10,T}$ can be useful in assessing the overall noise climate, for example, if the $L_{A90,T}$,$L_{A10,T}$ and $L_{Aeq,T}$ are all within a few dB, then this indicates that the noise source is fairly constant.

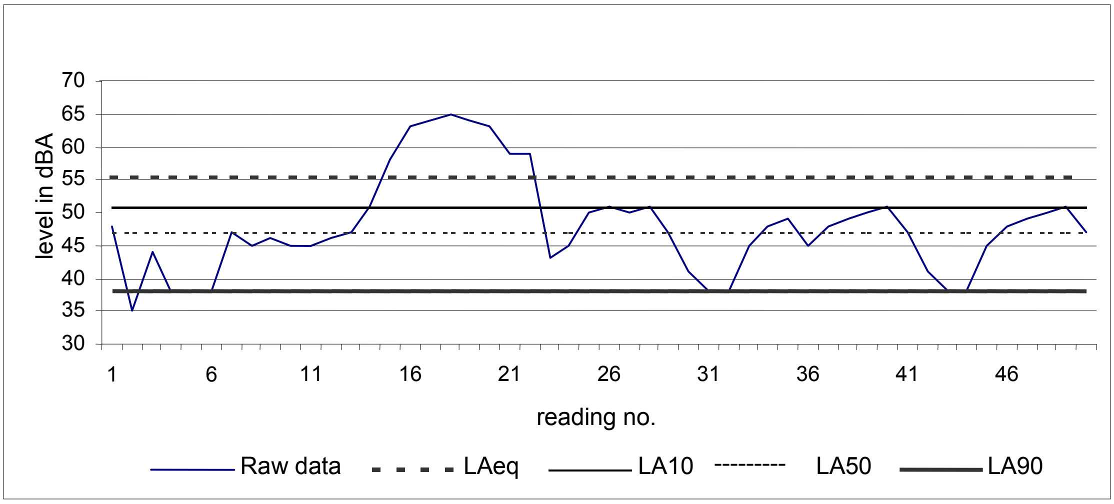


Figure 1.8 — Graph of 60 sound level measurements taken every second

Noise parameters cont.

The graph in Figure 1.8 above clearly shows that the $L_{A90,1min}$ is the lowest statistical reading, and that the $L_{A10,1min}$ is higher and the $L_{A50,1min}$ lies between them.

1.4.1.4 $L_{Aeq,T}$ (Equivalent continuous sound pressure level)

$L_{Aeq,T}$ is the equivalent continuous sound pressure level and is a form of "average" level – an average energy level of all the sampled levels. To take account of the logarithmic nature of the decibel scale of sound, however, it is the logarithmic average and not the more familiar arithmetic average.

The ambient sound level is usually measured as an $L_{Aeq,T}$ and is made up of all the sound in an area from sources near and far.

$L_{Aeq,T}$ is the sound level, that, if generated continuously, would give the same energy content over a specified time period T as the fluctuating sound being measured. It is the most widely used parameter for assessing environmental noise.

Looking at the graph above the $L_{Aeq,1m}$ is 56dB for the period in question and it is heavily influenced by the one incident between readings 16 and 21, which could have been a vehicle passing. In this case 1 minute has been chosen for simplicity, but selecting an appropriate duration for 'T' will depend on a number of factors. The nature of the source being measured, the time of day and the purpose of the measurement are all relevant.

If the noise is steady, a relatively short measurement period will be sufficient to characterise it. If it fluctuates randomly or has cyclical elements, then a longer measurement period will be required to obtain a representative sample. Furthermore, if the noise is steady, the $L_{Aeq,T}$ and the $L_{n,T}$ s (for example, $L_{A90,T}$, $L_{A10,T}$) will be within a few dB. Some standards specify a measurement period, but 15 minutes is often adequate to obtain repeatable results. Choosing a measurement period is a balancing act; it has to be long enough to be representative, but if it is too long the level may be influenced by other noise events, such as aircraft flyovers. If the objective is to measure the level of a noise source underlying an intermittent noise, a useful technique is to "pause" the sound level meter during noisy events. Clearly, only part of the noise climate is being quantified when using this technique.

One difficulty with the $L_{Aeq,T}$ is that a steady noise and a fluctuating one over the same period may have the same $L_{Aeq,T}$ value. In cases where the noise is fluctuating, the $L_{Aeq,T}$ will quite often be used in conjunction with the L_{Amax}. This would be appropriate for the fluctuating noise in Figure 1.8 above.

It may be necessary to divide the measurement time up into periods of different activity if these produce significantly different noise levels or characteristics. It is frequently necessary to consider the impact of a noise source on the local community both during the day and also at night when ambient levels are much lower and the noise source stands out far more. In these cases, both the ambient level and the noise source need to be measured. **The measurement period must always be stated when reporting the $L_{Aeq,T}$ value or statistical parameters since without the time period the value is meaningless.** The time of the day is also needed.

Noise parameters cont.

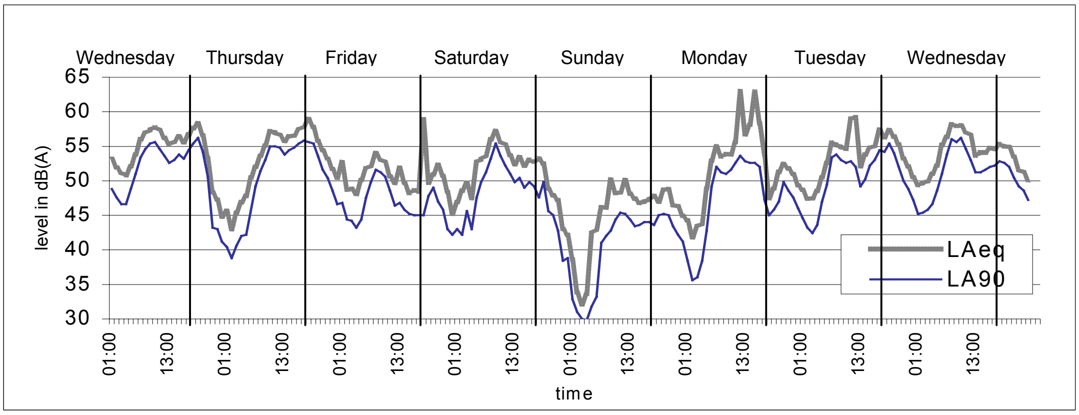
Relevant time periods can be found in BS 4142:1997 and in *Planning Policy Guidance Note 24* (PPG24), (Reference 5). PPG24 uses long time periods (07:00 to 23:00), whilst BS 4142:1997 suggests one hour for day and 5 minutes for night. BS 4142:1997 suggests that the interpretation of night will depend on local circumstances but should generally be regarded as the time when the general adult population is asleep or preparing for sleep.

1.4.1.5 Changes in background and ambient sound levels

The background sound level can vary considerably between locations and at individual locations. For example, the rural background is nearly always quieter than the urban background. The background at a location may vary with the weather (wind increases levels due to turbulence, leaves and the like) and with distant traffic flows. It is usually desirable to assess the background level at the location where a specific source may cause a problem, but this is not always possible. To overcome this, BS 4142:1997 suggests measuring background at similar locations. Although this guidance note does not specifically cover road traffic noise, this often forms a large component of background noise and is a good example of the degree to which background noise levels can vary.

Road traffic noise varies with the time of day, and the day of the week, as the traffic flow varies. Other factors affect traffic noise level, but in general there is a familiar pattern of noise levels throughout the day. Figure 1.9 depicts the $L_{A90,1h}$ and $L_{Aeq,1h}$ for each hour of the day and night for an eight-day period at an urban location about 10m from a busy 'A' class road.

Figure 1.9 — Eight days of hourly $L_{A90,1h}$ and $L_{Aeq,1h}$ readings



The following observations can be made:

- the dip in the middle of the graph, a Saturday night/Sunday morning, is not typical of the noise climate since the nearby M5 was closed to traffic for overnight maintenance;
- the levels drop in the small hours of the morning
- the Sunday levels are lower due to less traffic and a peak on Saturday morning can be seen
- the peaks in the LAeq,1h values are due to specific noisy events, such as aircraft flying over, grass cutting or other outside activities, since the LA90,1h levels do not rise
- careful examination shows the morning and evening peak rush hours for the first two days, but this is less clear later as wind raised the background level

For any particular measurement situation, there will be a range of noise parameters to choose from. Criteria used to assess noise impact have historically used a variety of indices, which make comparison difficult. In recent years, there has been a move towards using $L_{Aeq,\,T}$ wherever possible. This trend is continuing with the European Commission's work on future European noise policy (see Section 2.6).

1.5 Calculating noise levels

Calculating noise levels

Whilst measurement is clearly the best means of establishing noise levels in a particular location, this is not always possible. Similarly, it is sometimes difficult to avoid the presence of significant background noise levels when taking measurements. In these cases, it may be necessary to adjust a measured level by calculation to determine the level that is actually of interest. Some of the calculations used in sound level predictions are included below to offer guidance on the basic principles. However, sound level prediction can be a complex area and is best undertaken by experienced acousticians.

1.5.1 Adding and subtracting noise levels

Despite their log scale, sound level measurements in decibels can be added quite easily. Table 1.5 below provides an approximate method, which is often sufficient when carrying out a preliminary review of a noise report.

Table 1.5 — Adding and subtracting noise levels

Difference between the two sound levels	Quantity to be added to or subtracted from the higher level
0	3
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1
7	0.8
8	0.6
9	0.5
10 or more	0

Table 1.5 can be used to add or subtract sound levels, with the answers rounded to the nearest whole dB, for example, 60 + 62 = 64, 60 + 60 = 63

It also shows that if the $L_{Aeq,T}$ of a specific noise emission is measured, then unless it is 10dB above the residual $L_{Aeq,T}$ (that is, the ambient noise remaining when the specific noise is off) the measured value will include contributions by both the specific and the residual noises. BS 4142:1997 offers a method to take account of the ambient level in such circumstances.

Mathematically this addition is:

$$L_T = 10\text{Log}\,[10^{(Lp1/10)} + 10^{(Lp2/10)} + 10^{(Lpn/10)} + \ldots\ldots]$$

where L_T = total sound level
L_{p1} = sound level 1
L_{p2} = sound level 2
L_{pn} = sound level n

(for example, if $L_{p1,2,\&3}$ are 83, 84 and 85 dB respectively L_T = 88.85 rounded to 89dB, and check with the table above, 83 + 84 =86.5, then 86.5 + 85 = 88.8 rounded to 89dB)

The rule of thumb works well and in practice if there is a difference in level of 10dB or more the contribution of the lower source can be disregarded. Hence whenever plant sound levels are measured, they must be at least 10dB above the background, otherwise the background is contributing to the measured level.

1.5.2 Façade effects

When sound is incident on a building (or any acoustically “hard” surface) a major portion can be reflected back off the façade rather than absorbed. Thus a measurement made close to the façade will include the noise incident on the façade together with a reflected component. The reflected noise is almost like a second source of the same magnitude, and adds approximately 3 dB to the level of the noise. Measurements should be made either at a façade location, approximately 1m from the façade, or in a “free-field” location, at least 3.5m away from any reflective surface (apart from the ground). If the receiver is the occupier of a building, it is the level at the façade, usually 1m in front of it, that should be measured. BS 4142:1997 and BS 7445:1991 offer precise guidance on measurement protocols.

1.5.3 Distance attenuation

Calculating noise levels cont.

The sound level falls with increasing distance from the source. The principal reason is the wave front spreading and for a point source the "inverse square law" applies — doubling the distance from a point source produces a reduction in sound level of 6dB.

Consideration of line sources is largely restricted to traffic and railway noise. In these cases, sound is dissipated over a cylinder, rather than a hemisphere. If the distance from the source doubles, then the sound pressure halves, that is, 3dB per doubling of distance.

ISO 9613:1996 Acoustics – *Attenuation of sound during propagation outdoors*, offers detailed advice on distance attenuation and provides algorithms for the effects of atmospheric absorption, ground effect, reflections and screening, as well as the geometric divergence or wave–front spreading (Reference 6).

Most industrial sources will be point sources. However, if the source is a long one, such as a conveyor or a line of roof fans, the line source reductions will apply. Generally, if the distance from the source to the receiver is less than three times the length of the source, it will behave as a line. Beyond three times its length, it will behave as a point source. However, the cut-off is imprecise and in such cases measurements should be taken to validate calculations.

1.5.3.1 Prediction of the noise level at the receiver

Where it is not possible to measure at the receiver, it may be necessary to calculate the level at the receiver from that measured in another location. For straightforward situations, the methods below can be used. They can also be used for spot-checking predictions. In general, if a comparable measurement location can be used that is the same distance from the source as the receiver, and has the same screening and ground effects, then no correction will be needed. If measurements are made on the site boundary, it may be necessary to correct for the additional distance to the receiver. This is sometimes relatively straightforward provided there are no buildings or barriers in the pathway.

In the case of a point source, the equation is:

$$L_{p2} = L_{p1} - 20\log(r2/r1)$$

where L_{p2} = sound pressure level in dB at distance r2 in metres

and L_{p1} = sound pressure level in dB at distance r1 in metres

(for example, if Lp1 is 75dB, R1 is 50m and R2 is 200m then Lp2 = 75-20log(200/50) = 75-12 = 63dB)

In simple terms, the sound level from a point source drops by 6dB per doubling of the distance.

In the case of a line source, the equation is:

$$L_{p2} = L_{p1} - 10\log(r2/r1)$$

The sound level now drops by only 3dB per doubling of the distance. A line source has to be at least three times as long as the distance between the source and receiver, otherwise it behaves as a point source.

1.5.3.2 Predicting noise level at a distance using plant noise output data

Another method of calculating a noise level at a receiver uses the sound power level of the source as opposed to the sound pressure level at a specific distance. The prediction of noise emitted by plant and machinery at a distance using the sound power level supplied by manufacturers is useful for planning purposes. It can also be used to predict the outcomes of changes to plant layout, operating procedures and addition or substitution of equipment before changes are made. The following basic equation is used:

$$L_p = L_w - 20\text{Log } r - 11$$

where L_{p1} is the sound pressure level at a distance of r metres from the source

and L_w is the sound power of the source

and if the ground between the source and the receiver is hard (for example, paved) the correction of 11 becomes 8, since the sound that would have been absorbed is reflected so the sound only "fills" half the volume, i.e. a hemisphere as opposed to a sphere.

The above equations do not take account of the many other environmental factors that can affect predictions over distance, including:

- the weather
- air absorption

- source strength variation
- ground attenuation effects
- barriers and reflections

Calculating noise levels cont.

More detailed information can be found in BS 5228:1997 *Noise and vibration control on construction and open sites*, which gives methods of calculating some of these effects (Reference 7). For other situations, the principles of ISO 9613:1996 or other recognised methods should be followed (see Section 2.4). In general terms, the above effects increase with distance; the magnitude of the effect depends upon the frequency of the sound. The effects tend to be greater at high frequencies and less at low frequencies.

Remember that the effect of trees as a noise barrier is often overestimated by non-acousticians. Some noise experts suggest that a tree belt must be more than 100m thick and very densely planted before any significant excess attenuation is achieved. However, trees may have a significant psychological effect by blocking the noise source from sight when in leaf. They may also provide some masking when rustling in the wind.

High-level noise sources, such as roof fans, can often cause off-site noise problems. The sound may spread over large distances since ground and barrier effects may be very small. These sources may be difficult to identify at ground level on the installation since their building may provide significant shielding at the on-site receiver position.

Bear in mind that the above methods are simple “rule of thumb” ones. The prediction of sound levels is a complex subject that should only be undertaken by trained and competent personnel.

2 Measurement and evaluation of noise

2.1 Background

In making an application for a Permit, section 2.9 of the sector-specific or the general sector guidance should be consulted, supported by the information given in section 2 of Part 1 of this document (Reference 1) and H1, *Environmental Assessment and Appraisal of BAT* (Reference 22).

Noise impact assessment

This requires an initial assessment of the risk to sensitive receptors and, if shown to be necessary by the level of risk, a more detailed assessment of the impact should be undertaken. Bear in mind that the amount of detail and the effort expended should be proportionate to the degree of risk involved. It will often be appropriate to undertake an initial subjective assessment to identify those areas that need to be considered in more detail.

The same requirement for an initial risk assessment to indicate whether more detailed impact assessment is necessary will apply to an application for a substantial variation where there is likely to be an increase in noise emissions.

This section may be helpful in providing further advice on such assessments, or for investigating noise issues at any other stage.

Having considered the procedures for taking measurements and the relevant methodologies in section 2.3, the wider application of assessing the impact of specific activities or operations on a site-wide basis is considered below. Where and when to measure is discussed, how many measurements to take and how to use the information to serve the purpose of the survey. The purpose is generally to identify sources, quantify emissions and/or consider control options.

There are a number of approaches to noise impact assessment. The method adopted will depend on the purpose of the assessment and its scope – from a site-wide survey to a specific plant or operation.

Section 2.4.1 outlines a strategy for a full site investigation as a tool for identifying options for noise control. The same chain of actions and decisions, however, are equally applicable to smaller-scale noise issues. Where British Standards or other recognised guidance covers aspects of the work, it is advisable to follow these. Indeed Permit conditions will usually specify which standard to use when undertaking compliance monitoring.

The following list outlines potential reasons for undertaking assessment work, although there can obviously be a degree of overlap and ultimately there will be a large element of site–specificity in whatever action is taken.

i) Related to the effect on sensitive receivers:

- assessment of harm potential (possibly as part of a complaint investigation), estimating the likelihood of complaints arising or grounds for reasonable cause for annoyance
- assessment of absolute noise levels
- investigation of the nature and degree of tonal, impulsive or other features of the noise emitted from a source

ii) Predictive:

- assessing the impact of a new activity or changes to an activity or the addition of abatement equipment, (see Section 2.5).

iii) Determining trends:

- regular long-term monitoring strategy to look at trends, or short samples over a long period - i.e. increase or decrease with time. (Unlikely to be continuous monitoring, but more likely to be sample or check monitoring at a specific number of times or days a year).

iv) Determination of compliance with Permit conditions:

- extent and frequency of any alleged or actual breaches and the circumstances relating to those breaches.

v) Risk assessment/environmental impact assessment:

- to support a Permit application a statement of the noise impact of a site and associated history will be required. Additionally, the application will have to demonstrate that BAT has been achieved, or how it is to be achieved. The requirements are set out in the IPPC Guidance note H1 and the relevant sector-specific guidance note (Reference 22);
- to provide background information for setting appropriate conditions
- to respond to a Permit condition requiring additional information
- to ascertain the level of control required or achieved, as a result of actions taken

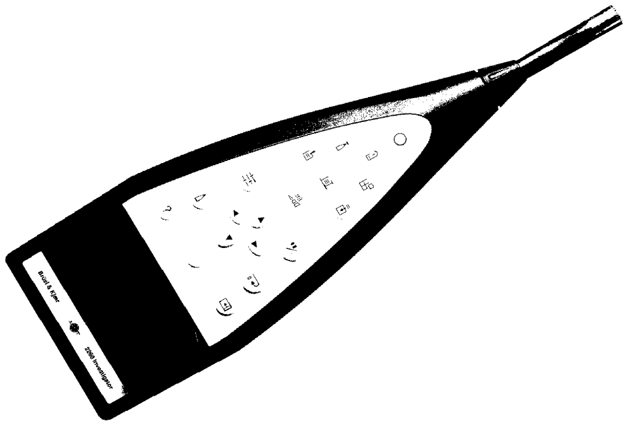
2.2 Equipment for measurement of noise & vibration

2.2.1 Sound level meters (SLMs)

Sound measurement equipment

A number of different types of noise measurement equipment are commercially available with various levels of sophistication. The range includes instruments that are capable of measuring basic time varying sound pressure level and those which are capable of calculating statistical noise indices over time. *Integrating* or *integrating averaging sound level meters* will measure the 'A'-weighted equivalent sound level, $L_{Aeq,T}$. S*tatistical sound level meters* will calculate the statistical noise measurement parameters such as $L_{A90,T}$, $L_{A10,T}$, $L_{Amin,T}$, $L_{Amax,T}$ and usually the $L_{Aeq,T}$. Sound level meters, microphones and calibrators have to comply with a range of national and international standards and in the United Kingdom Type 1 (or Class 1), referring to the relevant British or ISO standard, should be used for environmental noise measurement by both the Operator and the Regulator. SLMs are designed for field use but nevertheless are delicate electronic instruments and must be treated as such, not least of all because of their prices (starting at around £2,000 and rising to £10,000), with microphones and calibrators costing around £500 each (2002 prices).

Figure 2.1 – A statistical sound level meter



Basic instruments may need to be manually interrogated and the results read off and recorded manually. More sophisticated models may be equipped with a data logging facility and a link to a PC for sound recording. This will allow the meter to be set up to take one sample over a pre-defined period, store the result in its memory, start another measurement, and repeat the process continuously.

A frequently required feature is the ability to analyse the sound in octave bands or 1/3rd octave bands. Many instruments contain integral frequency filters. Frequency band analysis is particularly useful if noise contains distinctive tonal components. It is also useful to know the frequency content of a noise source when calculating noise attenuation from screens, enclosures etc. and when considering ground absorption in predictions, as all these effects are frequency dependent.

Modern sound level meters usually have a wide dynamic range of around 80dB and can measure peak levels of over 140dB. This means that they can measure background ($L_{A90,T}$) levels of say, 30 dB and still capture $L_{Amax,}$ levels of over 100 dB. The measurement scales go down as low as 20dB, but some meters may produce electrical noise which, when combined with thermal noise from some microphones, can start to influence the results, so in practice any level measured below 25dB should be viewed with caution. Manufacturers should be consulted if in doubt.

Most SLMs can be mains or battery powered, however care must be taken in the choice of batteries. Rechargeable ones are not suitable since their power dips rapidly as they approach the end of their charge and data could be lost. High quality alkaline batteries are recommended; poorer quality ones, or standard dry cells often have a reduced life and poorer performance in cold weather.

Each sound level meter comes equipped with a microphone that, for calibration purposes, is an integral part of the meter. Modern microphones are quite robust, but nevertheless are vulnerable to moisture and mechanical mistreatment. Provided they are treated correctly, microphones are durable and reliable. If the protection grid has to be removed the very fragile foil diaphragm should not be touched under any circumstances. Modern microphones are normally ½ inch diameter pre-polarised condenser microphones with a high dynamic range (18 to 148 dB) and a wide frequency response (8Hz to 16kHz).

Free-field microphones supplied with sound level meters are built with internal corrections (in the microphone), which compensate for their disturbing presence in the sound field, providing they are pointed at the noise source. At other directions they will not do this properly. Therefore the microphone should (from a true acoustic point of view) be pointed at the noise source to work correctly. In practice this correction is only necessary for noise source frequencies above about 2kHz, and

Sound measurement equipment cont.

hence, if the noise source does not have such frequencies (which is not always known), or you are far enough away that the higher frequencies have been attenuated, then the microphones can be pointed in any direction. However, for good acoustic measurement practice they should always be pointed at the source.

Each microphone is slightly different and a specific correction factor may have to be manually input into some older sound level meters to ensure accurate readings. More modern ones automatically adjust for the correction.

If long–term monitoring is being carried out, the meter should be in a weather–tight box and extension leads used for the microphone. Additionally, in the case of unattended or long–term monitoring, the microphone itself should be protected from the elements by using the manufacturer's outdoor microphone kit.

2.2.1.1 Calibration

The relevant British Standards require that the sound level meter should be calibrated in the field with its specific acoustic calibrator before and after each series of measurements. In practice this means at least every time the SLM is switched on and off. Additionally, if long–term monitoring is being undertaken, the meter must be calibrated at regular intervals. All the calibration levels must be recorded. If they vary before or after the monitoring, the results may have to be disregarded or treated with caution. Fortunately, this rarely happens.

A typical field calibrator is battery operated and produces an electronic tone of 94dB SPL at 1000Hz.

Each sound level meter system should consist of the meter itself, together with a dedicated calibrator and microphone.

In addition to the field calibration above, an accredited laboratory must calibrate SLMs and calibrators periodically. BS 7580:1997 *Specification for the verification of sound level meters* requires that sound level meters should be verified every two years (Reference 8). Also, the calibrators must be calibrated at least once a year. If a sound level meter, or calibrator has been subject to accidental damage, or has been ill-treated (for example, dropped, banged or subject to moisture), consideration should be given to re-calibration. Calibrators and sound level meters should also be calibrated after undergoing repair likely to affect performance. The calibration of both the meter and the calibrator must be traceable to national standards. In the United Kingdom, acoustic calibration laboratories are National Accreditation of Measurement and Sampling (NAMAS) accredited through the United Kingdom Accreditation Service (UKAS) and the relevant national metrology institute is the National Physical Laboratory. Additionally, should an opportunity arise between calibrations to check one meter against another, this should be undertaken and recorded. Furthermore, if there is reason to doubt the results then clearly the meter should be checked, possibly by careful comparison with another meter and if necessary sent for calibration. Note that even in very close proximity sound level meters may not give precisely the same reading, but the results should be consistently within 1 or 2 dB.

2.2.2 Sound recording

In some circumstances, tape recorders provide a useful means of recording noise or a noise event for later analysis. This is useful when the event is rare, short–lived, or when it is expensive to repeat a certain operation for measurement purposes. An audio recording must always be calibrated even if used only for subjective assessment or as an aid when writing a report following a site visit. Audio recording for analytical purposes can be accurate in expert hands. However, measurements taken from any tape recording system cannot be regarded as being of "Type 1 (or any other grade) accuracy". Type 1 accuracies can only be obtained from a sound level meter complying to that category in compliance with the relevant British and International Standards for Sound Level Meters. Digital Audio Tape (DAT) recorders have now replaced traditional tape recorders, but do not conform to the sound level meter standards. Mini discs are not suitable due to limitations in the dynamic range and electronic compression.

Some meters are able to switch a tape recorder into record mode, and to start internal analysis software, during noise events above a specified level and duration. This again allows measurements to be made of occasional events without an Operator needing to be present.

It is often useful to record the variation in noise over time in a graphical form. This has traditionally been undertaken by calibrating a paper trace so that it displays a time history of the sound pressure level. However, with advances in electronics, graphs showing noise variation over time can be prepared electronically for presentation in reports. There is a range of software available to graphically present results and carry out post–measurement calculations. The more advanced ones allow individual events to be marked to identify the source of a particular noise level.

2.2.3 Determining the contribution of different sources

When it is important to determine the contribution from a particular plant item to the total noise output, more complex measurements may be required, particularly if the plant cannot be switched on and off to repeat measurements. Sometimes a combination of measurements with a sound level meter made close to a different, but identical, plant together with the appropriate calculations can be used to predict the contributions.

In a crowded plant area, an intensity meter may be used. This technique may be useful, for example, where it is necessary to estimate the effect of silencing a particular machine located amongst other noise sources. This type of meter is very directional, to the extent that noise contributions from other plant in the area can be virtually eliminated. Although generally available, this type of meter is very expensive and may be complex to use. However, in the hands of an experienced and skilful user, intensity meters can identify the noise output of plant items in terms of their individual sound power level, to demonstrate that it would be useful to focus noise control effort on certain key sources. The accuracy of results in all cases will also depend on practical constraints such as access limitations to key plant that could make it difficult to take appropriate measurements.

An alternative technique for prediction is to group noisy activities together if they cover a relatively small area. Measurements can then be made, or predictions undertaken. If it is necessary to reduce the noise emissions from the group source, then more detailed investigation can take place. This approach can reduce the amount of work since, if a group is not causing an off-site problem, and BAT is being employed, no more work is needed on those sources within the group; however, this procedure must be used with care.

2.2.4 Vibration measurement

Vibration measurement

Vibration measurements are unlikely to be required in the majority of environmental situations since most of the vibration–sensitive uses of buildings are likely to be far enough from the plant to avoid vibration. However, in some of the more traditional manufacturing areas, with heavy presses located in buildings adjacent to other businesses or residential properties, some problems may arise.

Vibration monitoring is complex and there are many potential problems, such as choice of measurement point, amplification of the building, the mounting of the accelerometers used and the analysis techniques employed. As indicated in section 1.1.3, specialist advice should be sought where vibration measurement is required.

2.3 Measurement techniques

2.3.1 Where to measure

Measurement locations

In the case of compliance monitoring, measurement positions should be as close as possible to the positions specified in the conditions attached to the Permit. If these locations are no longer accessible or relevant, then consideration must be given to varying the affected condition.

For new proposals, extensions or alterations, Part 1 (Permitting and regulation) of this guidance offers advice on the choice of the location at which to specify Permit conditions; one of the key aspects that may influence this choice is the ability to carry out meaningful monitoring (Reference 1). Since the concern is impact upon the sensitive receptor, the preferred technique has to be to assess and measure at that receptor. This would then enable a receptor level to be set, or a suitable level calculated for a boundary or other appropriate measurement location.

The choice of measurement position will depend very much upon local circumstances, including the sensitive receptor to be protected.

For the location of specific measurement points, refer to BS 4142:1997 (Reference 4) and to BS 7445:1991 (Reference 2).

Part 1 of this guidance discussed the circumstances that would point towards choosing the boundary or the receptor for the setting of Permit levels.

2.3.2 Measurement procedures

Measurement procedures

At the time of preparing this guidance, the Agency is examining, with the Institute of Acoustics, the requirements for qualifications and experience of people undertaking sound level measurements under the MCERTS scheme.

Sound level meters are prone to slight changes in sensitivity under differing climatic conditions and ***it is important that all equipment is calibrated so that measurements are robust.*** In any event, sound level meters may only be accurate to within ± 2 dBA, when all the allowable variations are taken into account. The calibration of noise equipment should be checked on-site before and after measurement with an acoustic calibrator.

Standard measurement methodologies for noise measurement are contained in BS 7445:1991 and in BS 4142:1997. The relevant conditions can be summarised as follows:

- measurements should be taken 1.2 – 1.5m above the ground
- precautions should be taken to minimise the influence of wind (use a windshield), and of heavy rain falling on the microphone windshield and nearby surfaces (generally do not take measurements in the rain and when roads and so on are wet)
- minimise the effect of electrical interference due to power cables, radio transmitters and the like (use equipment that is CE compliant) but be alert for inconsistent or unusual results
- if measurements have to be made above ground level, the microphone should be positioned 1m from the façade of the building
- measurements should not be made if the average wind speed exceeds 5 m/s
- measurements should either be taken under free-field conditions (more than 3.5m from any reflecting surface) or at 1m from the facade of a building and results treated accordingly (when a noise source is incident on a façade, the effect of reflected noise from the façade is generally to increase the “façade level” measured at 1m by 3 dB)

Note: B&K 2238 Sound Level Meters and B&K 4231 Calibrators issued to Regulatory officers comply with the relevant standards.

All measurement conditions should be recorded and any deviations from the relevant British Standards justified, for example, shortening a measurement period due to rain or an extraneous noise source. For Regulatory staff, the requirements for contemporaneous notebook entries should be adhered to. Appendix 3 gives an example of a report form that can be used for recording noise complaints and measurements. This will also serve as an *aide mémoire* for best practice. The aim should always be to ensure that measurements could be repeated at a later date at the same location.

It is not anticipated that internal measurements will be made for the purposes of IPPC. In cases where this becomes necessary, specialist advice should be sought.

Environmental noise measurements can be influenced by:

- the weather

- source strength variation
- ground attenuation effects
- barriers and reflections
- time of measurement and duration

Measurement procedures cont.

These are discussed below.

Weather

Wind and temperature gradients and changes in relative humidity can affect noise propagation. Fog, thick mist and snow may also affect the noise levels that are recorded, although theoretically their effects are very small. Subjectively the effects seem quite significant, but this is probably due to less or slower moving traffic resulting in lower ambient noise levels.

Wind may affect the results by causing rustling of foliage, buffeting the microphone or enhancing or inhibiting the propagation of sound. The use of a windshield over the microphone will help to reduce wind noise, but measurements should not be taken if the wind speed is above 5 m/s. Wet roads can elevate noise levels produced by high-speed traffic. Dry weather and calm conditions are preferred.

Temperature and humidity can affect the air absorption, although in practice these effects are often much less than those of distance barriers, wind and the like and are unlikely to have a significant effect, especially at low frequencies. However, under some conditions, such as temperature inversions, sound propagation can become very complex and result in localised focussing of noise. Noise can also appear to becoming from above rather than directly from the source.

Source strength variation

Variations in operating patterns of the installation should be considered when taking measurements. The measurement should be taken over a period that is sufficient to obtain a representative sample. If the noise is intermittent or cyclic, a number of cycles may need to be recorded, including the noisiest operational modes. Records of operational conditions during measurements should be obtained from the Operator of the facility.

Ground attenuation effects

The presence of acoustically *"soft"* ground can lead to a reduction in noise level at the receptor due to absorption of noise energy by the ground, particularly where propagation distances are high. Examples of acoustically *"soft"* ground are grassed areas, areas under crops, and forests with ground covering vegetation. Areas that are concreted or otherwise sealed, and areas of water (unless frozen and covered with snow!) are acoustically *"hard"*. The proportion of hard and soft ground between the source and the receptor point should be noted. If the effect is seasonal due to variations in ground cover, measurements may need to be taken at a time when ground cover is at a minimum, if this corresponds to a time when public reaction is likely to be highest. Alternatively, measurements could be made close to items of plant and a prediction could be made with no attenuation factor for ground attenuation included. This would indicate the highest likely noise levels that would be experienced at the receptors. Extrapolated levels may be subject to some uncertainty and predicted results are often quoted along with an estimate of accuracy. Ground attenuation has little effect on high-level sources, when the receiver has a clear line of sight to the source, although the precise effect depends upon the angle of view. Ground effect is greatly reduced or even eliminated where an acoustic barrier is in place.

Barriers and reflections

Barriers can reduce the noise level at the monitoring point, especially if the source is out of direct line of sight. This can result in unrepresentative levels if the receiver does not have a similar line of sight obstruction. Similarly, reflections to a monitoring point may increase the level being monitored.

Time of measurement and duration

The time when measurements are made may affect the noise levels that are measured. If a survey is intended to establish background noise from which noise limits will be derived for a new facility, the following should apply:

- the survey should include noise measurements at all the likely operational times of the plant; day, evening, weekend and night, although in practice in the case of a 24hr operation the night–time levels will often be the limiting factor
- night–time measurements should normally be made between 01:00 to 04:00 hours, Sunday to Thursday (when traffic noise and other human activity is at its lowest)
- if the maximum difference between the new noise level and background noise level is expected to occur during a time other than at night, a further survey should be carried out during that period.

Measurements should be carried out over a sufficient period of time to establish representative noise levels, and if necessary, maximum noise levels, from the facility. It is good practice to repeat measurements in order to improve confidence in the results because of all the factors described above. Remember that the impact of an installation is likely to be greatest when the background sound levels are lowest. The lowest background levels typically occur when the weather is very still and calm, with little cloud cover.

2.3.3 Relevant methodologies for measurement and evaluation

Measurement methodologies

The measurement and evaluation of noise and vibration is covered in a number of British Standards. These give guidance on a wide range of related topics including equipment types, calibration, measurement techniques and locations and also the interpretation of data.

Wherever possible a recognised method should be followed as closely as possible. Deviations from the recommended approach should be recorded and justified. There may be a number of reasons for departing from the method, such as access, meteorological difficulties or intrusive ambient noise levels. However, where the interferences will make the results unfit for their intended purpose, measurements should be repeated.

The British Standards that may be relevant to measurement of noise from industrial activities include:

- BS 4142:1997 *Method for rating industrial noise affecting mixed residential and industrial areas* (Reference 4)
- BS 5228:1997 *Noise and vibration control on construction and open sites* Parts 1 to 5 (Reference 7)
- BS 7445:1991 *Description and measurement of environmental noise* Parts 1-3 (Reference 2)
- BS 8233:1999 *Sound insulation and noise reduction for buildings – Code of Practice* (Reference 10).

Other documents, that may be useful are:

- *CONCAWE The propagation of noise from petroleum and petrochemical complexes to neighbouring communities* 1981 (Reference 11)
- The Engineering Equipment and Materials Users Association (EEMUA) *Noise procedure specification and guide 140 and 141* (1985) (Reference 12)
- *Minerals Planning Guidance MPG11* (1993) (Reference 13)
- *Planning Policy Guidance Note PPG24* (1994) (Reference 5)
- ISO 9613-2 1996 *Attenuation of sound during propagation outdoors* (Reference 6)
- World Health Organisation *Guidelines for Community Noise* (1999) (Reference 14)
- *Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001* (Reference 15)
- *Internal Guidance for the Regulation of Noise at Waste Management Facilities under Waste Management Licensing Regulations* (awaiting publication) (Reference 16).

The most commonly used documents are outlined below and more information is contained in Appendix 2.

2.3.3.1 *BS 4142:1997 Method for rating industrial noise affecting mixed residential and industrial areas*

BS 4142:1997 describes a method for assessing industrial and background noise levels outside residential buildings and for assessing whether the industrial noise is likely to give rise to complaints from the occupiers of residential buildings. This methodology has been derived specifically for use in the mixed residential/industrial situation, but is often wrongly used in other situations. The standard predicts the likelihood of complaints arising from existing and new noise sources. It should be used and read in conjunction with BS 7445:1991.

This standard is widely used and an understanding of the methodology is essential for those undertaking sound level measurements. A worked example is given in Appendix 2, together with a more detailed discussion of the requirements and constraints of the standard.

2.3.3.2 BS 5228:1997 Noise and vibration control on construction and open sites

BS 5228:1997 provides guidance on the control of noise from construction and open sites. It also provides guidance on the prediction of noise from other sites within the scope of the standard. The prediction method is the most helpful part in terms of IPPC and Waste Regulation. It could be used to predict noise at open sites, particularly landfill and quarry sites. Although other methods require the use of frequency analysis, BS 5228:1997 allows for the use of 'A' –weighted levels, which is likely to make it easier to apply in practice. However, care must be taken since it does not specifically take account of tonal elements in a noise source.

Measurement methodologies cont.

2.3.3.3 BS 7445:1991 Description and measurement of environmental noise, Parts 1-3

BS 7445:1991 covers in detail the measurement procedures, the descriptors and reporting information for environmental noise measurements and is generally consistent with BS 4142:1997 except in the application of rating levels, and more detail on suitable weather conditions. Where a rating level is used, the approach in BS4142:1997 is more appropriate for industrial noise.

2.3.3.4 BS 8233:1999 Sound insulation and noise reduction for buildings – Code of Practice

Planning Policy Guidance PPG24 suggests that BS 8233:1987 should be used if it is necessary to consider noise levels within non-residential buildings. This has now been replaced by a 1999 version. The guidance offers advice on the control of noise in and around buildings. It offers straightforward and outline guidance on noise matters, but focuses on noise within buildings and the insulation offered by buildings.

2.3.3.5 **CONCAWE** *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities 1981*

CONCAWE prepared this paper to clarify some contradictions in prediction. It was originally written to predict noise emissions from petroleum and petrochemical plant, but it has been extensively used in other industrial situations.

2.3.3.6 **The Engineering Equipment and Materials Users Association** *Noise procedure specification and guide 140 & 141 (1985)*

The EEMUA describes a methodology for measuring noise from plants, and using prediction to investigate the effect of implementing noise control. It also suggests low–frequency noise limits that may be appropriate for some sources.

2.3.3.7 Minerals Planning Guidance MPG11 (1993)

MPG11, which is currently under review, describes the Government's policy on noise from surface mineral workings. It notes that waste–disposal sites *may* share many common features with surface mineral working, and suggests that Operators and planning authorities *may* wish to take account of the principles set out in the guidance. However, where the waste disposal is an integral part of a mineral operation, MPG11 states that it is expected that its guidance will be followed. Hence the principals in MPG11 do not automatically apply to landfill operations. However, when setting limits and/or conditions for such facilities, Regulators should be guided by requirements of the appropriate internal noise guidance and the sector-specific guidance. MPG11 recommends the use of BS 5228:1984 to predict noise levels.

2.3.3.8 Planning Policy Guidance PPG24 Planning and Noise

PPG24 outlines the Government's view on noise and planning. The guidance focuses on the planning of new noise-sensitive development in already noisy environments where the principal source is road, rail or air transport (PAN 56 in Scotland and TAN 11 in Wales are similar). In the case of proposed noise-producing development affecting existing noise-sensitive premises, PPG24 advises that British Standard BS 4142:1990 can be used, (now superseded) within its own terms of reference, to predict the likelihood of complaints. It strongly suggests, however, keeping noisy activities and noise–sensitive uses apart. PPG24 also states that for specific advice relating to landfill operations, MPG11 should be used. As mentioned above, though, the appropriate internal noise guidance and sector-specific guidance should be used by Regulators in the setting of conditions and limits in licences and Permits. MPG11 in turn advocates using BS 5228:1984 for application to such activities (now superceded by later versions).

2.3.3.9 ISO 9613-2 1996 Acoustics - Attenuation of sound during propagation outdoors

This standard offers complex guidance on calculating the propagation of noise outdoors. It shows how to calculate the effect of many factors including barriers, ground absorption and air attenuation. ISO9613 is also the basis for many computer-based modelling packages.

2.3.3.10 Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001

These regulations implement the EU Noise Directive 2000/14/EC, which replaces a number of previous ones and seeks to harmonise noise emission from specified plant and equipment used outdoors. The regulations offer guidance on levels and the measurement of sound power level is referenced to relevant ISO Standards. The directive specifies noise–emission standards and noise marking for one range of equipment, and for a second group requires only the marking of noise emission. The details of the equipment covered by the lists are included in Appendix 2.

2.3.3.11 World Health Organisation *Guidelines for Community Noise (1999)*

Measurement methodologies cont.

In late 1999, the World Health Organisation proposed guidelines for community noise. If the daytime and evening L_{Aeq} for general steady, continuous noise in an outdoor living area exceeds 55 dB, then there is likely to be serious annoyance. If this value drops to 50 dB, then the annoyance factor becomes moderate. The guidelines also considered noise levels at which sleep disturbance would not take place. The guidelines suggest that an internal $L_{Aeq,8hr}$ not greater than 30 dB for continuous noise is needed to prevent negative effects on sleep. This is equivalent to a façade level of 45 dB $L_{Aeq,}$ assuming open windows or a free-field level of about 42 dB L_{Aeq}.

2.3.3.12 *Agency Internal Guidance for the Regulation of Noise at Waste Management Facilities under Waste Management Licensing Regulations*

This document offers guidance relevant to waste management facilities, which fall within the waste-management licensing regime. Some of this guidance will be useful in other outdoor situations, which are subject to integrated control under the PPC Regulations. It will be subject to review when the specific requirements relating to those activities that will move from the waste-management licensing regime to the integrated pollution control regime become clearer.

2.4 Investigation and assessment of noise impact

2.4.1 Noise assessment strategy

2.4.1.1 Background

Noise impact assessment

Whatever the scale of the issue under investigation, the overall aim will be to define and carry out a cost-effective and structured investigation to obtain meaningful information relating to the source(s) of noise. The investigation may necessitate sound level monitoring. The sources should be prioritised and decisions made relating to the level and type of controls required. Action plans can then be drawn up and the appropriate trials or work undertaken.

Once the assessment work is complete and mitigation measures have been put into place, ongoing monitoring, maintenance and feedback arrangements are vital to sustained improvement. These form the cornerstone of a Noise Management Plan (see Appendix 4).

2.4.1.2 Survey methodology: process or site survey

The methodology described below is generic and could be applied, with appropriate modification, to a range of activities, both enclosed and open-air, which produce noise. Similarly, it could be applied to a single source in its simplest form, or to an entire process or site with the intention of producing an integrated noise control strategy.

The key components of noise assessment, that is, the stages involved in identifying sources, quantifying emissions and assessing control requirements are shown in Figure 2.2 and are described in generic form below.

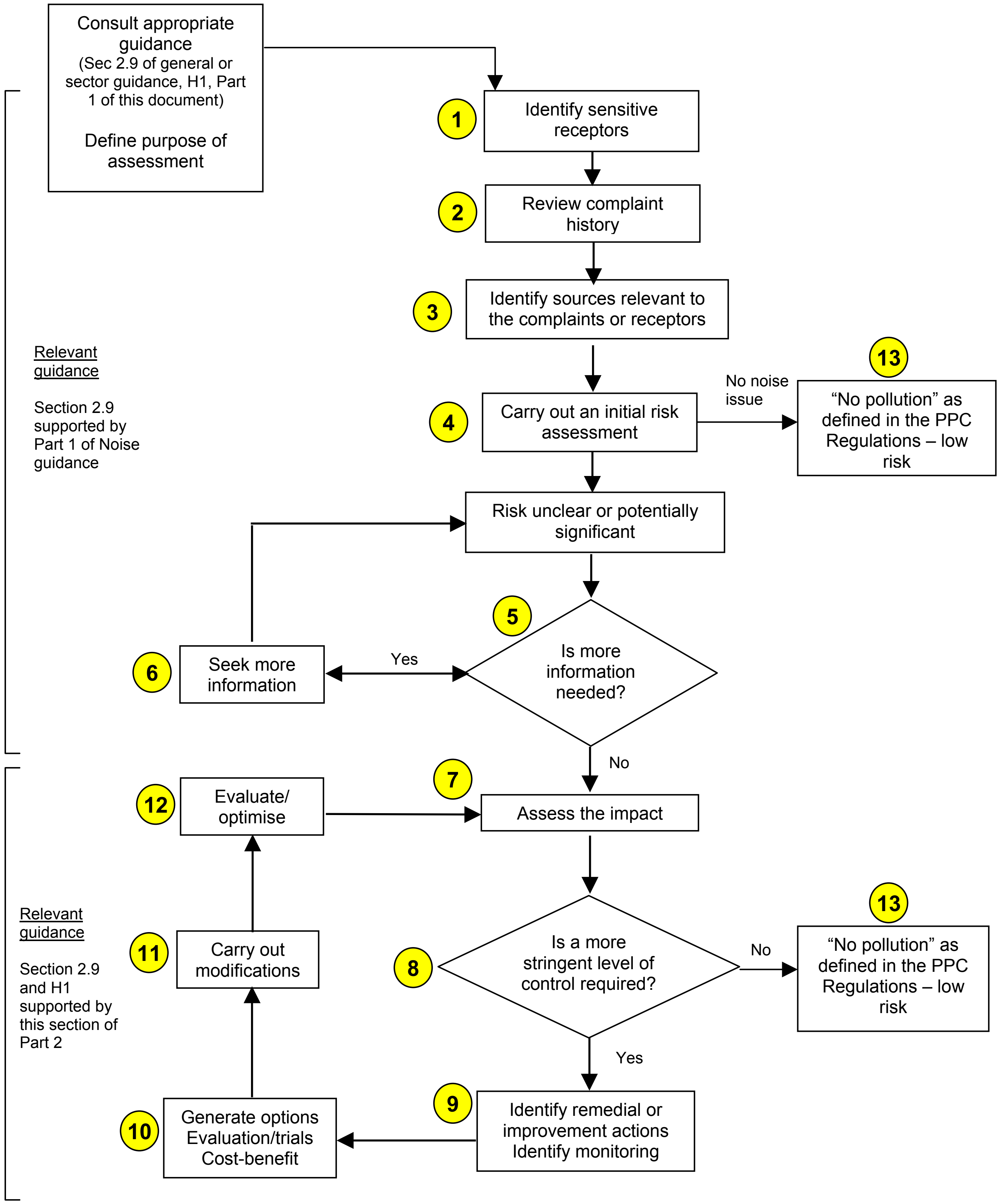


Figure 2.2 – Key components of a noise assessment

Key to Figure 2.2

1. **Identify the sensitive receptors**

With reference to Section 2.1 consider and identify the sensitive receptors or receivers and the relevant locations. Examine the site and the area, including reference to plans and future planning proposals.

2. **Review complaint history**

A history of complaints may indicate that noise is causing annoyance at sensitive receptors, but lack of complaint does not necessarily imply there is no noise problem. However, the outcomes of action taken by the local authority are very important when using complaint information. Determine if the complaints are, or are likely to be, justified by comparison with BS 4142:1997 or other relevant criteria.

3. **Identify the sources relevant to the complaints or receptors**

Once a particular site or activity has been identified as the cause of the noise emission, the precise source or sources must be identified. A number of sources can generally be identified by a systematic “walk-around”. The source(s) may be immediately apparent, but it is important to consider the less obvious. Running through process–flow diagrams might identify these. Again take care to ensure that the suspected major noise source is not masking another source that may be only slightly quieter. Also ensure that the “walk-around” takes place during typical operations and that all the significant, or potentially significant, noise sources are operating. This may include alarm testing.

In addition to the primary process or activity, operations to consider may include:

- raw materials, unloading and handling
- transfer processes — vehicles, conveyors
- heating and combustion or steam-raising plant
- washing, cleaning and maintenance operations (particularly compressors)
- abatement plant — associated pumps and air–moving fans
- start-up and shut-down operations
- emergency releases — particularly high–pressure releases
- cooling, refrigeration, or air–handling plant

It is often possible to reduce or prevent off–site noise problems without needing complex solutions. Taking simple actions such as tightening loose connections, replacing covers, closing doors and programming an adequate standard of maintenance can effect improvements.

4. **Carry out an initial risk assessment**

The aim of a risk assessment is primarily to consider the risk of an impact on the environment of a particular emission (generally, in this case, the degree of offence to human senses).

At this stage the aim should be to determine whether:

a) the risk is not significant and no further action is required in relation to noise

b) there is insufficient information for the noise to be assessed

c) more work is required to assess the information provided

5. **Is more information needed?**

The following information will normally be required for each source:

- the precise nature of the noise source
- the noise level at the sensitive receptors
- a characterisation of the source — type of sound, frequency spectrum, duration, time of day, fluctuation of emission
- the proximity, direction and sensitivity of receptors, that is, the local community (on a large site this may vary considerably for different sources)

The following site-specific information will typically be required:

- the local topography — relative location of valleys, hills, buildings or other features that affect the propagation of noise from the source to the receiver
- the prevailing meteorological conditions, including the most frequent wind direction
- the nature and character of the locality, for example, industrial, residential, rural, mixed
- the noise climate of the locality, including levels where appropriate and sources

Key to Figure 2.2 cont.

In assessing the risk of an impact, account will have to be taken of the likely noise emissions and the location of the noise sensitive receptors. Advice on this is offered in Part 1 of this document (Reference 1, Section 2.4).

6. **Seek more information**

   If necessary use the standard procedures to obtain further information until sufficient is available to assess the noise impact.

7. **Assess the impact**

   An assessment of the impact of the noise should be made using the information gained in steps 1 – 6 above. The assessment will be very site–specific and will depend upon many of the factors discussed in this guidance. Generally speaking, more data will be needed to assess an impact than to assess the risk of an impact.

   At a basic level the sources can be ranked in a number of ways:

   - by noise level
   - by rating the level in accordance with BS 4142:1997
   - by the distance from the sensitive receptors, or proximity to the site boundary — or likelihood that the noise will travel long distances (for example, low–frequency noise) might be used to give an estimation of the impact
   - sources that operate at night or at weekends
   - the source associated with the worst complaint record
   - threat of Regulatory action, or previous Regulatory action where the problem may have relapsed

   The worst-case situation should also be considered in the determination of impact. Operations such as start-up and shut–down, pressure release, cleaning and maintenance (including routine heavy-duty maintenance, annual maintenance during shut–down) and emergency releases should be considered.

   This will allow sources to be ranked in terms of risk and indicate priorities, allowing an action list to be drawn up.

   To summarise – the noise impact will depend upon many factors including the difference between the off-site noise and the existing background sound level, the nature of the noise, its frequency, duration, and the times of day that exposure occurs.

8. **Is a more stringent level of control required?**

   To address this issue it will be necessary to identify the required end-point or desired noise output from the process at the sensitive receptors. To achieve this, each source may have to be addressed individually.

   The performance required to achieve a reduction in emissions will be determined by Permit conditions, and the need to achieve BAT for a particular operation, in addition to meeting the main criteria as set out in Part 1 of this document, *Regulation and Permitting*, Section 1.2: IPPC Requirements for Noise (Reference 1).

   Many noise issues can be addressed in a straightforward way, for example, through a high level of equipment servicing and maintenance. Then the opportunity for reducing emissions from the remaining sources should be assessed against:

   - opportunities for reduction by changing the way the plant is operated — throughput, timing, maintenance, change in materials or process parameters, additional training of Operators and the like
   - attenuation of noise at source by better design or redesign, renewal of noisy plant or retrofitting acoustic measures to existing plant
   - improved containment — keeping doors and windows closed, repairing buildings, automatic roller doors, containing transfer lines or conveyors, keeping covers on machinery
   - using barriers such as buildings, stockpiles, acoustic fences, and earth bunds

   Noise control measures should not impede any emergency releases or exits where this would have safety implications. Design of high-pressure relief systems to minimise noise is discussed in 3.4.3.1.

   The above techniques are covered in detail later in this document.

Key to Figure 2.2 cont.

9. **Identify remedial or improvement actions**

   For each option, an assessment of the costs and benefits should be undertaken to inform the final selection. In many cases the decision will be straightforward, but in others it will not be clear-cut. Several factors may have to be balanced. Noise must also be balanced alongside other emissions and environmental impacts in determining BAT for a particular installation. Conflict between noise and other pollutants is rare however, and it is normally a balance of costs and benefits. Refer to Part 1 of this note *Regulation and Permitting* (Reference 1) and IPPC Guidance Note (H1 – *Environmental Assessment and Appraisal of BAT*) (Reference 2).

   Maintenance and training requirements should also be factored into the decision–making process.

   Based on the choices made, a timetable of work can be drawn up. It may be appropriate to undertake trials, possibly fairly early in the decision-making process. These may range from temporary adjustments in operating parameters to the installation of pilot plant to test the effectiveness of a proposed noise reduction option.

   Procedures for maintenance, monitoring and review should be included in a noise control strategy for the installation or site, which covers both short- and long-term requirements for the operation as a whole. See Appendix 4.

10. **Generate options, evaluation/trials, cost-benefit**

    The main thrust of this will come from the Operator in consultation with the Regulator. The identified options may become Permit conditions or part of an upgrade or improvement programme.

11. **Carry out modifications**

    These works will be carried out by, or on behalf of, the Operator. Where new equipment is being installed, it is often appropriate to carry out proving trials as early as possible to measure the sound pressure levels and compare them with those predicted by the manufacturer or specified by the Operator in a contract. There are often benefits in undertaking such tests before the equipment leaves the manufacturer's premises, wherever possible.

12. **Evaluate/optimise**

    Again the evaluation and optimisation will be carried out by the Operator, but the results of trials and other actions will be forwarded to the Regulator for reassessment.

13. **No pollution as defined in the PPC Regulations**

    The PPC Regulations define pollution as "emissions which may be harmful to human health or the quality of the environment, cause offence to any human senses or impair or interfere with amenities and other legitimate uses of the environment". Further guidance on the interpretation of this can be found in Part 1 of this note *Regulation and Permitting* (Reference 1).

2.5 Prediction of noise

Noise prediction

Simple predictions of noise can be based upon relatively straightforward equations and principles. However, detailed noise prediction and modelling requires the use of computers and commercially available prediction or mapping software.

Noise predictions can be useful in three circumstances:

- at a proposed facility where noise must be quantified before construction to ensure that no noise problems will arise from the installation once it is operational, and to allow Permit noise limits to be set if necessary
- at existing installations where the effectiveness of various noise control techniques needs to be reviewed and to establish a "target" Permit level that takes BAT into account
- at existing installations where changes to operations or the process are proposed

It should, however, be noted that accurate predictions rely on good software with accurate inputs, and these inputs are often the weakest link in the predictions. In most cases, predictions will need to be "calibrated" with some sound level monitoring at the same or similar operation. Some software may contain bugs, so it is important not to rely blindly on the figures. It is often worth checking some predictions with the rule of thumb methods.

In some situations prediction can be more accurate than measurement since only the contribution of the process is predicted. With measurement, the sound levels may include other significant noise sources that may influence the results, such as a busy nearby road or motorway.

Noise-modelling capabilities are currently being developed by the Regulator with a view to providing a national facility for in-house expertise in this field. As this expertise develops, and as noise modelling is developing generally, further advice will become available. Where applications include predictions based on noise modelling, seek advice from the Agency local noise contacts.

As accurate predictions rely on accurate input data and use of an appropriate methodology, answers to the following questions may be useful in assessing the validity of predicted noise levels. This checklist is taken from a report on *The Use of Sound Power Levels in Noise Modelling* prepared by Casella Stanger on behalf of the Environment Agency (Reference 25).

- Has a suitable site visit been carried out to collect input data and measure background noise levels?
- Have external source noise levels been correctly evaluated?
  - For example, use of manufacturer's L_w data; measured L_p; do the figures look sensible?
- Has noise breakout from buildings been correctly evaluated?
  - For example, accurate assessment of internal noise levels; use of correct building attenuation figures; correct surface areas of building elements used; acoustically weak areas identified.
- Have the correct sound level meters been used and octave–band measurements made?
- Is the modelling method appropriate and does it follow known standards or empirical formulae?
- Has the geographical and topological data been input correctly into the model?
  - For example, correct scale, alignment and terrain data.
- Have the physical elements been input correctly into the model?
  - For example, buildings/barriers included and correct height; ground effects accounted for.
- Has the noise source data been input correctly into the model?
  - For example, sound power, or sound pressure and "on-time" corrections. Has the source type been described correctly?
  - For example, point, line, area sources and directivity.
- Has the calculation grid been set up appropriately?
  - For example, adequate resolution.
- Have the correct receptors been chosen?
  - For example, right locations, heights, and the effects of façades and barriers considered
- Are individual noise sources being modelled correctly?
  - For example, consider sources in isolation, check appropriateness of distance attenuation, barrier effects and the like.
- Finally, do the results appear reasonable?

2.5.1 Methodology

Noise prediction cont.

Several models are commercially available in the United Kingdom and some acoustic consultancies have prepared their own software. Most of the prediction methods are based on one of the following procedures or papers:

- ISO 9613-2 1996 *Acoustics - Attenuation of sound during propagation outdoors* (Reference 6)
- CONCAWE *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities* 1981 (Reference 11)
- The Engineering Equipment and Materials Users Association (EEMUA) *Noise procedure Specification 140 and 141*(1985) (Reference 12)
- BS 5228:1997 Part 1 *Noise control on construction and open sites* (Reference 7)+

Check that the method on which the model is based is relevant to the specific case under investigation. Predictions calculated with a program that does not state which standard it is based on, or the margin of error, should be treated with caution.

For industrial noise it is preferable to use those following the principles of ISO 9613-2 1996, although the use of the CONCAWE and EEMUA methods can also give valid predictions.

The Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001 offers detailed advice on the assessing sound power levels and refers to relevant ISO standards (Reference 15).

In some cases, those based on BS 5228:1997 may be appropriate for outdoor or straightforward sites where factors such as ground absorption and air absorption are not critical to the assessment. It is a broadband method, that is, the noise is not predicted at each octave band and then summed, which could lead to inaccuracies. However, it will often provide a quick method of carrying out an initial assessment. For instance, the ground absorption factors in BS 5228:1997 are intended for use with construction plant. Hence if the frequency spectrum of the noise source differs from that of construction and demolition plant, errors may be introduced into the predictions.

Whilst noise from mechanical plant can generally be quantified quite reliably, the prediction of variable noise sources, such as gas flares, may only be accurately achieved by consulting the methods developed in specialist research papers. These specialist areas are not generally included in the computer programs. However, useful information can be gained from considering measurements taken at similar units in operation elsewhere.

At existing plants, a combination of modelling and measurement can be the most effective approach. Measurements can be made to establish the noise output from the facility. If changes to a particular plant item are being considered, the effect of replacing it with a quieter item can be predicted. Predictions are required only for the equipment items that may be subject to change using this method.

Prediction is a specialist area, but if carried out correctly it can be accurate and the findings resilient to scrutiny.

2.6 Future trends

Future EU and Government policy

As part of the closer co-operation with other European countries, harmonisation of noise appraisal methods has been the subject of investigation by working groups drawn from EU member states.

It is also possible that the EU will propose noise targets. However, local input will probably be required to establish suitable levels from industry.

2.6.1.1 European Directive relating to the assessment and management of environmental noise (noise mapping) (Reference 17)

This directive requires noise mapping for agglomerations of 250,000 inhabitants or more, major roads, major railways and major airports, within a set timetable and at a later date for agglomerations of 100,000 inhabitants. The maps will be published on the Internet and in hard copy. In due course a noise strategy will be required setting long– and medium–term goals for reducing exposure to the major noise sources above, **including industry**. The precise mechanism of the implementation is presently unclear.

For noise mapping, a standard noise description parameter is used known as the day-evening-night level L_{den} or (LDEN) in dB. The default values for day, evening and night are 0700 to 1900, 1900 to 2300 and 2300 to 0700 respectively, however in respect of southern European countries evening can be defined as a period in the afternoon. To work out the L_{den} value, 5 dB is added to the evening value and 10dB to the night value and these weighted values are added to the daytime value. Although the unit is unfamiliar to most UK acousticians, it has been used widely in parts of Europe for several years.

$$L_{den} = 10 \log 1/24 \left[(12*10^{Lday/10}) + (4*10^{(Levening+5)/10}) + (8*10^{(Lnight+10)/10}) \right]$$

Where the L_{day} $L_{evening}$ and L_{night} are the A-weighted average levels for the relevant period averaged over a year and are defined in ISO1996-2: 1987.

For night–time impact and sleep disturbance the L_{night} will be used.

The maps are produced by computer modelling methods with base contours of the L_{den} produced for a height of 4m above the ground.

The impact upon UK Regulators has yet to be determined since the implementation of the Directive in the UK has not yet been clarified.

2.6.1.2 Ambient noise strategy

In the Rural White Paper, *Our Countryside: The Future. A Fair Deal for Rural England* issued in November 2000, the Government announced its intention to consult on a proposed national ambient noise strategy (Reference 19). Consequently in November 2001 a consultation paper entitled *Towards a National Ambient Noise Strategy* was published (Reference 24). The closing date for comments was 15th March 2002. The strategy suggests a three phase approach:

- establishing three key sets of information that is, the ambient noise climate, methods used to asses noise (particularly regarding quality of life and tranquillity) and techniques available to take action to improve the situation where bad and preserve it where good
- evaluation of options, including consideration of cost and benefits
- policies to move towards the desired outcome, which would be the National Ambient Noise Strategy

2.6.1.3 Institute of Acoustics and the Institute of Environmental Management and Assessment Guidelines on Environmental Impact Assessment

The Institute of Acoustics and the Institute of Environmental Management and Assessment are working on this guidance, which has currently been issued for public consultation. This document will cover the main features of an environmental noise assessment:

- baseline
- prediction
- assessment
- mitigation
- presentation
- follow–up

It will provide sufficient guidance to enable a reviewer to check that everything has been properly carried out in an environmental noise study. It also highlights that one single assessment method is not appropriate to all situations. When this paper is published, its relevance to the IPPC process will be assessed.

2.7 Human response

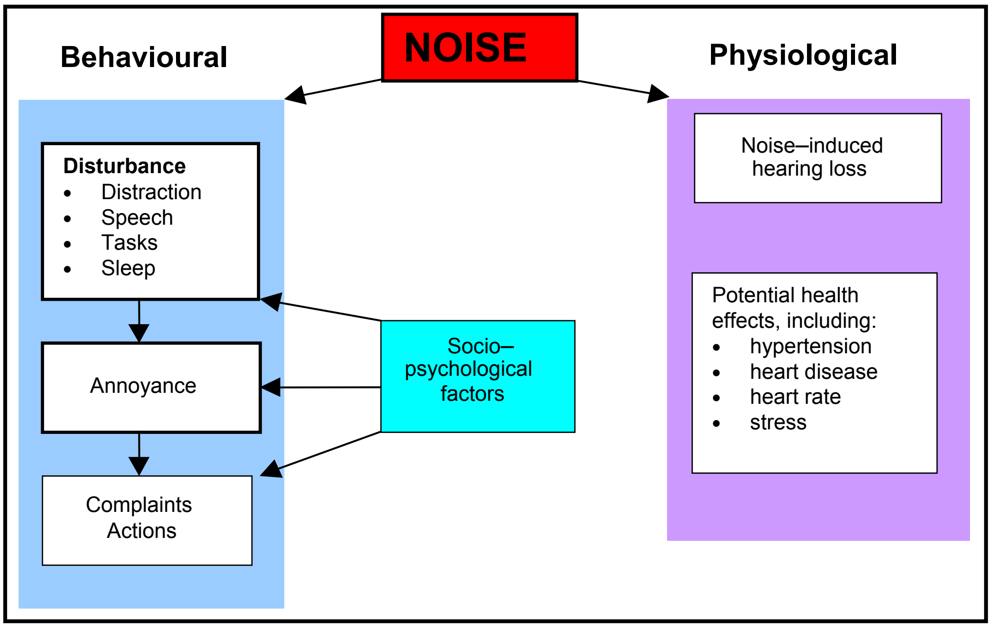
2.7.1 The effects of noise

2.7.1.1 Effects on people

Effects of exposure to noise

The effects of noise on human beings are summarised in Figure 2.3. This illustrates how noise complaints and annoyance can be caused in various ways.

Figure 2.3 — Cause and effect relationships for noise



Noise–induced hearing loss is not an issue at the exposure levels likely to be experienced by neighbours of noise–emitting facilities. The Health and Safety Executive (HSE) or the Local Authority (LA) deal with the occupational exposure risk by enforcing the Noise at Work Regulations 1989. Generally, HSE regulates noise in factories and industrial installations and the LA regulates offices, warehouses, retail and leisure premises.

The nature of the response to environmental noise — both the exposure level and the type of noise – can vary widely between individuals. There may be little or no response at all, through varying degrees of adaptation to the disturbance, to annoyance or anger. There is a distinction between disturbance and annoyance. Someone is disturbed by noise when it stops or inhibits them from undertaking an everyday activity such as concentrating while reading (distraction), hearing spoken conversation, listening to the radio or sleeping. The feeling of displeasure caused by noise is annoyance. This is often a result of disturbance and it can be influenced by socio-psychological factors, such as a bias for or against the facility or person making the noise, or the environmental expectations of an individual. Whereas disturbance can be assessed analytically, annoyance is measured by social–survey questioning, and over the years has been used as a common indicator of overall community noise impact.

There is growing concern about the non-auditory effects of noise and it is now generally accepted that high levels of unwanted noise can lead to increased stress in some people.

Some individuals may experience physical effects such as sleep disturbance or loss of appetite as a result of emotional stress. Stress-related illnesses are inherently difficult to predict and quantify across populations due to the variation in human response to noise disturbance and the wide range of other stressors to which individuals are exposed.

Some particularly sensitive people will be disturbed by very low levels of noise, even those that may be barely audible to other people. At the other extreme, some people will be very tolerant of high noise levels that would cause concern to most people. When assessing noise problems, Regulators have to be satisfied that the noise would be a problem to an ordinary person and not just to someone who has undue sensitivity. Remember that some forms of illness, including mental illness, can increase sensitivity to noise. It is also acknowledged that stress sometimes results in low tolerance of noise. Finally, when considering a noise complaint the Regulator should be aware that tinnitus (a disorder of the ear) may not just be a ringing in the ears but can be buzzing or engine sounds, either continuously or intermittently, and may be attributed to nearby industrial premises by the sufferer.

2.7.1.2 Effects of vibration

Effect of exposure to vibration

It is highly unlikely that vibration transmitted from a process will be of sufficient magnitude to cause structural damage in nearby buildings, unless the levels at source are very high and/or the source is very close to the receiver. Where vibration is thought to be having an impact on receptors, specialist advice should be sought.

2.8 Assessment of community reaction

Community assessment

This is a complex issue, often driven by multiple factors, and hence it is extremely difficult to assess community reaction to noise alone. A classic illustration of this is when people start to complain about noise, or other problems, from premises when the Operator has, or is about to lodge, a planning application for an extension. The complaints often continue until the matter has been resolved and then die down again – until another application is made! Many complaints are driven by concern regarding property values and the overall impact of an activity on an area, rather than just the noise.

The WHO guidelines for community noise drew together the conclusions of many research papers worldwide. More information can be found in Appendix 2 and Reference 14. The guidelines drew data from a number of sources, which have shown that some types of noise are more annoying than others, although there is no clear understanding of the reasons for these differences. Whilst it is possible to rank sources relating to transport — road, rail and aircraft — by their ability to cause annoyance, when one considers the very wide range of noise sources that fall within the category of "industrial noise", the situation becomes less clear. However, the following are some of the factors that may influence response:

- hours of operation (day, night, 24hr, 7day)
- continuous or intermittent sources
- nature of the noise (tones, clatters, hums and the like)
- whether or not the noise is "avoidable" as perceived by the community
- community standing of the Operator (good/bad neighbour)
- response to complaints and other problems
- odour/litter/traffic or other adverse environmental effects
- good/bad employer
- nature of the area

People are generally less tolerant of industrial and neighbour noise than transportation noise.

From a Regulatory viewpoint, complaints can serve as a useful indicator of a potential problem noise source, however the outcome of investigations into complaints may be more important, as discussed in Part 1 of this document (Reference 1). In any event, the Operator should have a complaint monitoring and response system in place.

3 Noise control – techniques and technologies

This part of the document intends only to provide an overview to demonstrate the types of solutions available. In complex situations, specialist advice should be sought to ensure that the correct option is selected.

BAT for noise and vibration

IPPC and BAT for noise and vibration

IPPC requires installations to be operated in such a way that all appropriate preventative measures are taken against pollution, in particular through the application of Best Available Techniques (BAT). BAT includes both the technology used and the way in which the installation is designed, built and operated. In deciding what level of control constitutes BAT for a given installation, a number of factors need to be considered and balanced. These include:

- costs and benefits
- the technical characteristics of the installation concerned
- geographical location
- local environmental conditions

BAT, in a general sense or at sector level, will be set out in process- or sector-specific guidance. This guidance note covers *in generic terms* a range of abatement technologies, best practice and design features that could, taking the above site-specific criteria into account, form the basis of BAT for a range of situations. In all cases, the specific requirements relating to a particular sector should be reviewed as part of the decision-making process.

Furthermore, the BAT may have to be considered for an installation that may cover more than one industry sector, for example, paper mills and on-site Combined Heat and Power (CHP) plants.

3.1 Noise control — general principles

Assuming that all management, operational and maintenance issues have been satisfactorily addressed, once noise has been generated, there are a number of physical factors involved in determining how it is propagated and how much reaches the receiver (Figure 3.1).

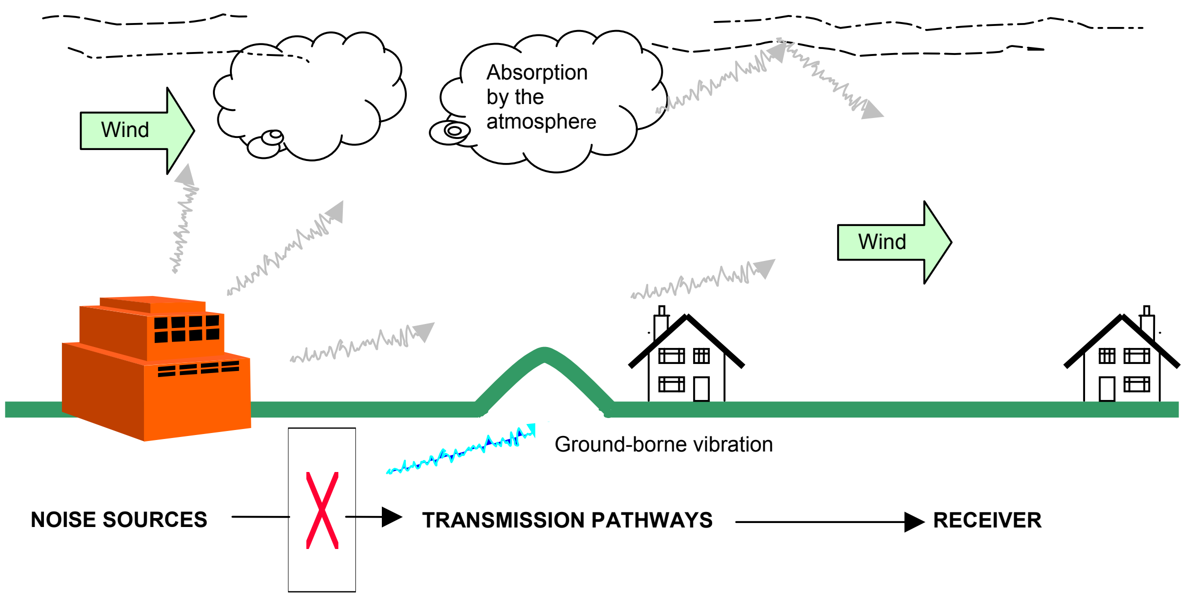
Noise levels at sensitive receptors can be minimised by:

- reduction at source
- ensuring adequate distance between the source and receiver
- the use of barriers between the source and receiver

In determining the degree of control required, it is usual to calculate or measure the sound pressure level close to the source and, knowing the desired end-point, calculate:

- the attenuation provided by the environment at the sensitive location
- the additional attenuation required

It is nearly always more cost–effective to consider noise reduction at the design stage as later modifications are often more expensive, more difficult to install and may not be as effective.



The amount of noise radiated depends on:

i) the sound power level of the source
ii) the nature of the building structure
iii) gaps in the fabric of the building
iv) the number of sources

The noise received depends on the degree of attenuation provided by:

i) distance from source
ii) attenuation provided by the type of ground
iii) screening by walls, banks, other buildings
iv) the wind direction
v) meteorological conditions, such as temperature inversions and gradients
vi) atmospheric absorption

The strength of any vibration received will depend on:

i) the strength of the source
ii) ability of the source to transmit vibration to the ground
iii) the nature of the ground — hard, soft
iv) distance of the receiver from the source
v) the continuity of the transmission route – e.g. breaks in the ground from foundations, pipes, trenches
vi) the ability of the receiver to receive vibrations, i.e. coupling to the ground or vibrating surface

Figure 3.1 — Propagation of noise from source to the community

3.2 Attenuation of noise — general principles

3.2.1 Natural attenuation

Noise attenuation principles

Sound passes through the air as a pressure wave. In open space the amplitude of that pressure wave will naturally reduce as it moves from source to receiver through three principal mechanisms:

- spherical spreading — the natural dilution of the sound energy as it is spread over a widening area
- absorption by the air
- absorption by the ground

3.2.1.1 Attenuation with distance (geometric divergence or wave–front spreading) and atmospheric absorption

Spherical spreading reduces the sound energy radiating away from a point source at the rate of 6 dB for every doubling of distance from a point source and 3dB for a line source. This is a theoretical "free-field" figure and will be subject to a number of influences. These are discussed briefly below.

3.2.1.2 Atmospheric absorption

Over small distances (up to a few hundred metres) atmospheric absorption can generally be ignored, as its effect is minor compared with that of spherical spreading. However, the effect is more marked over longer distances and is frequency–dependent, with the higher frequencies being attenuated far more than lower frequencies.

It depends on temperature and relative humidity. Table 3.1 below illustrates the attenuation at 70%RH and 15 °C, which is due to absorption.

Table 3.1 — Atmospheric absorption

Octave–band centre frequency in Hz	Excess attenuation in dB km^{-1}
125	0.7
250	1.3
1k	5
4k	25

Additional effects are due to wind speed and direction, wind–speed gradient (the change in speed as the height above ground increases) and temperature gradients. Sometimes, when an atmospheric inversion occurs, refraction of the noise can take place. This results in the bending of the sound waves, causing focussing of the sound in certain areas.

3.2.1.3 Ground effect

Acoustically "soft" ground will also affect the total attenuation. Soft ground effects can produce additional attenuation of up to about 3 dB over distances of 100m. This can increase with increasing distance up to about 9 dB over 1,000m. The excess attenuation is greater the higher the frequency and is influenced by the height of propagation. Hence care has to be taken when assessing sound from sources that are either elevated or in a direct unobstructed line of sight (for example, across a valley) since in these cases the ground attenuation will be minimal.

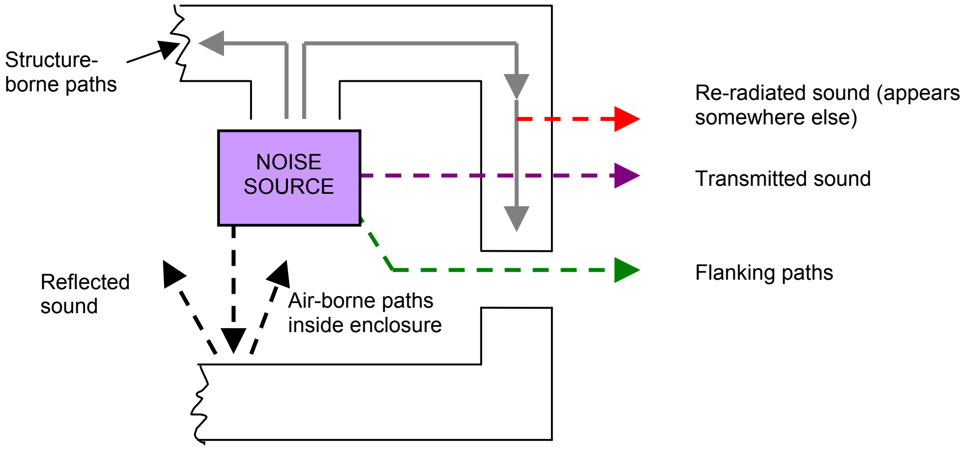
3.2.2 Attenuation between the source and receiver

If noise generation at source cannot be reduced, two methods of noise control commonly used are increasing distance or increasing attenuation. *Increasing distance from source to receiver is usually only possible at the planning stage, but is often the most effective solution*. Increasing attenuation is commonly achieved by enclosing of the noisy processes or by using barriers. Barriers work by increasing the path length (the distance the noise has to travel from the source to the receiver) and by providing acoustic shadow to the receiver. Hence they have to be close to the source or receiver to be effective.

3.2.2.1 Sound attenuation through structures

Sound incident on a solid structure, such as a wall, has one of four paths to follow. It is either reflected back away from the wall, it passes directly through the wall or it passes along the wall and may be radiated away from its structure somewhere else (the so called *re-radiated* noise path). Noise may also pass around the end of the wall or over the top to form another *flanking path*. Each of these paths and their effect on the attenuation provided by the structure is considered below.

Figure 3.2 — Types of sound transmission pathways in machinery



Noise attenuation principles cont.

i) **Reflected sound** can lead to reverberant noise if the source is enclosed. This can be reduced by using absorbent materials.

ii) **Flanking paths** allow sound to pass along a structure and be re-radiated elsewhere. Noise can also diffract around the edge of a structure or barrier.

iii) **Transmitted sound** is where the energy travels through the structure itself, then emerges at the other side as sound.

3.2.2.2 Sound attenuation by barriers

The degree of attenuation afforded by a barrier depends on the frequency of the noise, the increase in path distance and the effect on the line of sight of the source from the receiver. The use of barriers results in the loss of ground attenuation and this may sometimes result in disappointing barrier improvements. Barriers have to be continuous and solid. Suitable ones include a double-skinned overlapping solid timber (at least 25mm thick), solid masonry or earth banks. BS5228:1997 (Reference 7) suggests that the minimum mass of a barrier should be 7 kg/m^2. Lightweight woven panels are not suitable as noise barriers. Barriers can also take the form of earth bunds. A combination of a bund with an acoustic fence on top often provides a good acoustic barrier, enabling a suitable height to be achieved at a reasonable cost and without using up too much space. When barriers are used, care must be taken to ensure that the noise does not reflect off the barrier to a solid reflecting surface and then back to the receiver over or around the barrier. This can almost negate the effect of the barrier.

There are formulae for calculating barrier effects relative to the frequency of the sound and the path difference. In general terms, if a barrier removes a source completely from the line of sight, then a reduction of 10dB is a reasonable estimate. If the source is only half obscured, then the reduction is only 5dB. However, the maximum attenuation that can be afforded by a barrier is 20dB. Low frequency sound, particularly, can diffract over and around the ends of a barrier, hence barriers must be longer than the source to be shielded.

3.2.3 Acoustic properties of materials

3.2.3.1 General

It is the mass of a material that serves to attenuate sound through frictional losses and generally the greater the mass the greater the attenuation (see 3.2.3.2 below). However, this attenuation depends on the frequency of the sound. Higher frequencies are absorbed more easily than low frequencies. As a result, a common feature of noise control is that it is nearly always more difficult to attenuate low–frequency noise than high–frequency noise. This problem is accentuated when a long propagation distance is involved because air absorption will affect higher frequencies far more than lower ones. The result is that low–frequency noise tends to “travel” further than high frequency noise.

3.2.3.2 Classification of acoustic materials

Materials that are used for noise control purposes can be divided into several broad classifications, although some materials have properties belonging to more than one class:

i) sound insulating, resisting or blocking

ii) sound absorbing

iii) damping

Noise attenuation principles cont.

i) Sound insulating

The ability of a material to reduce sound passing through it is given in terms of the Sound Reduction Index (SRI). This varies across the frequency spectrum for a given material. Sound insulating materials tend to be of high mass and impervious — the greater the mass, the harder it is to set it into vibration and therefore more difficult to transmit sound.

Materials with the best (highest) SRI have high mass and low stiffness. Lead sheet has a high SRI for its thickness and brickwork also has a high SRI. Double–skin constructions are frequently used to give a good degree of insulation whilst keeping the weight down.

The relationship between sound reduction, mass (M) — in terms of mass per unit area and frequency (f) are given in the 'Mass Law'. This provides that:

- at a given frequency, sound reduction increases by about 6 dB for each doubling of mass;
- for a given mass, the sound reduction increases by about 6 dB for each doubling of frequency.

These are idealised relationships that ignore other mechanisms that may affect attenuation. The sound insulation can be adversely affected by the stiffness of the partition and coincidence (the angle at which the sound approaches the partition). This can mean that the insulation properties do not follow the basic mass law at all frequencies. There may be critical frequencies, often in the medium– to –high frequency region, where the insulation may be considerably reduced. Furthermore, flanking transmission around or over a partition can reduce the attenuation even more.

These factors can result in a much smaller reduction than one would expect from the 'Mass Law' alone.

ii) Sound absorbing

Materials that have good sound absorption properties tend to be porous in structure, with an acoustically soft (that is, non–reflective) surface. Incident sound waves pass into the material, where they encounter resistance. The performance of a given material will vary across the frequency spectrum. Efficiency of absorption depends on factors such as thickness, density, pore size and the size of any fibres.

Effectiveness is quoted in terms of the absorption coefficient, which is the sound energy absorbed divided by the incident sound energy. Its value lies between 0 and 1, where a good absorber is close to 1 and a highly reflective surface is close to 0. The value varies with frequency.

Frequently used materials are glass wools, mineral wools and open–cell plastic foams. These are available in the form of panels, mats and lagging. There may be fire risks associated with using some materials where heat is likely to build up, or release of toxic fumes. Mineral wool is suitable for high temperature use and ceramic fibres can be used up to about 1200 -1300 °C. Some materials absorb oil, water or other fluids, which will impair efficiency and may also be a fire risk. Absorbents used to line ducts may be abraded by high–velocity airflows.

iii) Damping

The damping ability of a material is a measure of the degree to which it is able to absorb vibration energy arising from sound incident on its surface. The amount of damping provided by a given material varies across the frequency spectrum and often also varies with temperature.

Damping materials may be applied as a surface layer to vibrating structures and effectiveness depends on the thickness of the layer as well as the nature of the material. Alternatively, damping materials may be sandwiched in a layer between the structure and a layer of stiff material. Cast iron, manganese-copper and nylon are commonly used.

Damping of noise radiating surfaces can reduce resonance and the reductions can be quite dramatic. However, the "damper" has to be carefully selected and designed for the specific situation.

3.3 Noise control practice — management of noise

3.3.1 Introduction

Noise management

The hierarchy for control should be to:

1. ***Prevent*** generation of noise at source by good design and maintenance.
2. ***Minimise or contain noise at source*** by observing good operational techniques and management practice.
3. ***Use physical barriers or enclosures*** to prevent transmission to other media.
4. ***Increase the distance*** between the source and receiver.
5. ***Sympathetic timing and control*** of unavoidably noisy operations.

Measures for preventing or minimising noise need to be considered on a process– and perhaps a site-specific operation basis. The preliminary stages of assessing releases arising from the activity should have highlighted the main noise sources and a hierarchy for dealing with these should have been prepared.

Emphasis should be on:

- **good process design or redesign. Utilising "low–noise options", that is, design the problem out rather than relying on "end-of-pipe" abatement to deal with a noise problem**
- **good operating and management practice backed up by an environmental management system**

Noise control is a specialist area, but the sections below are intended to give an outline of the more common methods of noise control.

3.3.2 Noise control at the planning stage

For a new facility, the obvious time to consider noise control is at the initial planning stage. Similar opportunities may arise during the lifetime of a facility, when planning an extension or when old plant is being replaced. At this stage, potential noise problems can be "designed out". This approach is usually more effective, costs less and can be integrated into other elements of IPPC, such as energy efficiency.

In some cases, there will be planning restrictions governing what can be done on the site and these can limit the options for noise control. In general, however, consideration should be given to the following basic principles:

- use of inherently quieter processes
- selection of inherently quiet plant or "low–noise options"
- site layout to maximise natural screening, screening by buildings and separation distances
- orientation of directional noise sources away from sensitive receivers
- noise barriers and bunding

In the case of landfill sites, the design of the filling sequence can influence the extent of noise screening by filled material, and hence can be used to maximise screening for particular noise-sensitive areas.

Tree planting may provide effective mitigation of visual impacts, and may psychologically reduce the subjective response to the noise. Acoustically, however, this has an almost negligible affect. For example 20m of dense foliage will reduce the noise in the 4kHz octave band by 2.4 dB, but by only 0.04 dB in the 64 Hz octave band.

3.3.3 Examples of noise–management techniques

For some operational facilities there are effective ways of reducing noise simply by being aware of its presence as an issue for the site, and by adopting appropriate procedures when carrying out everyday activities. Such procedures can be collectively called "noise management" and can be particularly important where substantial noise control has been incorporated in a plant design.

3.3.3.1 Routine maintenance of plant

Noise management cont.

Noise generated in mechanical plant by the interaction of moving or rotating parts can increase over time, as these parts tend to wear. Specific acoustic attenuators may also degrade and wear out.

The following are just a few examples:

- fans can go out of balance
- bearings can wear and become noisy
- the perforations in duct attenuators can become clogged and the acoustic lining damaged
- ducts can start to rattle
- internal combustion engine silencers can break down and burn out
- acoustic doors may distort or the seals become worn
- resilient linings to hoppers may be eroded away
- acoustic enclosures (including building panels) may become damaged

All of these sources of increased noise could be avoided by ensuring a satisfactory standard of maintenance.

3.3.3.2 Good operational site practices

There are a number of common–sense procedures that can help to reduce noise emissions. Although these tend to be specific to operations at a particular facility, some common examples are listed as follows:

- closing doors and windows in noisy buildings and using acoustic enclosures
- ensuring that generator or vehicle engine hatches are kept closed
- locating mobile plant away from noise–sensitive receivers
- avoiding dropping materials from a height
- switching off plant when not in use
- stockpiling materials (for example, containers) so as to provide acoustic screening between noise sources and receivers
- careful siting, use and volume control of public address systems
- considerate behaviour by the workforce, especially at night, to avoid or minimise shouting, whistling and the like
- arranging delivery or on–site vehicle routes away from sensitive receivers
- use of "smart" reversing alarms, which produce sound at a volume relative to the background level, for example 5 or 10 dB above, rather than at a fixed volume; or using other safe systems of work which obviate the need for reversing alarms

Although the noise–reduction benefits of these practices can be difficult to quantify, they should form a routine part of best practice to reduce overall noise emissions.

3.3.3.3 Restricting operating hours

The sensitivity of neighbouring areas to noise impacts will vary with the time of day and day of the week. More stringent standards may be applied for the evening (generally taken as 1900 to 2300 hours) and night (2300 to 0700 hours) than for the daytime. The Irish EPA IPC licensing guidance on noise is in line with other guidance in suggesting a 10 dB differential between day and night in the absence of more detailed information (Reference 20). Restricting the operating hours of noisy activities can be an extremely effective way of mitigating community noise impacts and is often used, to great effect, in planning conditions for new facilities. Restricting operating hours may reduce productivity and create operational difficulties, but it need not necessarily require a cessation of all activity on the site. In some cases, it will be possible to schedule noisy operations to the less sensitive weekday daytime periods in order to keep noise emissions to a minimum at night.

In terms of pollution control, the restriction of operations should be regarded as a secondary form of control as it does not address control at source. For some operations it may, however, be appropriate.

3.3.4 Ongoing management of noise — Noise Management Plan

On some sites that are large, or complex, and on others where there is a significant noise issue, then the development of a Noise Management Plan can be a very effective tool to ensure that both the Operator and the Regulator adequately address noise issues. This is described in Appendix 4. The prepared plan may not need to include all the elements in the outline and it may also include other elements specific to the site under consideration.

3.4 Noise control practice

3.4.1 Introduction

Noise control

Before considering the subject in more detail, remember that noise cannot necessarily be addressed in isolation. For example, reducing the noise emission by a few dB may give rise to increased energy use or increase the risk of other pollution occurring. All these issues have to be considered and included in the decision process.

Additionally, noise control measures may take up operational space, which could give rise to health and safety issues in confined areas such as plant rooms. Silencers on air–handling plant can cause back-pressure, which can itself lead to increased noise elsewhere in the system, and acoustic enclosures can cause overheating. Hence the design of acoustic measures has to be undertaken by experts, often in consultation with the Operator and the manufacturer of the original item of plant.

The most common noise control methods used are known as passive noise control. However, there is a technique for noise reduction known as active noise control (ANC) or anti-noise. ANC uses modern electronics to produce an acoustic signal, similar to the problem noise, but which is out of phase, so it cancels out the original noise. It is still a developing science as processors improve.

A number of the noise control and reduction techniques described below may have to be employed to achieve BAT. However, their need may be influenced by the industry sector and the local circumstances, including the risk of environmental harm.

3.4.2 Noise–control equipment and techniques

Noise control is a highly developed industry and numerous manufacturers produce a huge range of equipment designed for particular applications. However, there are common types of equipment that use particular techniques and materials to attenuate noise. Ten generic types of noise–control equipment account for the majority of the equipment used by the noise control industry. These are listed below:

- acoustic enclosures
- acoustic louvres
- noise barriers
- acoustic panelling
- acoustic lagging
- vibration damping
- impact deadening
- attenuators
- steam and air diffusers
- vibration isolation mounts

Whilst vibration damping and isolation mounts control vibration, they can often make a key contribution to noise control.

For many noise sources there will be more than one noise–control option.

A one-page information sheet is included for each type in Appendix 5.

3.4.3 Control of noise and vibration generated by machinery and industrial processes

This section highlights a range of noise sources and outlines ways of reducing noise by design or operation, or by using noise abatement equipment.

3.4.3.1 Aerodynamic — flow noise

Noise is generated by turbulence in the flow of gases and fluids in pipes, ducts or vessels. If solids are moved, for example, in dust or waste extraction, they may cause impact noise as well as that caused by the air movement.

In general terms, the greater the turbulence the greater the noise. Hence reducing the turbulence by smoothing the flow, and reducing velocities and pressures, can be effective at reducing aerodynamic noise.

i) ***High pressure releases*** such as blow-down, exhausts, emergency pressure relief or dump systems can produce very high noise levels for short periods due to strong turbulence in the area where the emerging jet meets the surrounding air. This type of noise is broadband in character with peaks at frequencies determined by the velocity and size of the jet.

Noise control cont.

Attenuation can be achieved by using a vent silencer that forms a shroud around the area of maximum turbulence and absorbs the energy as a result of repeated internal reflection. About 18dB reduction in output (sound power) can be achieved, with the higher attenuation occurring at higher frequencies. The design will need to take into account not only the efflux velocity and the frequencies at which maximum attenuation is required, but also the permissible pressure drop. It is likely that a high-pressure drop or other restriction to the flow would be unacceptable on an emergency relief system or similar.

An alternative is to reduce the velocity of the jet (where this is feasible), by increasing the diameter or reducing the pressure. Reducing velocity reduces the turbulence and hence the noise, so increasing the diameter of the source can reduce the noise; *but* this could give rise to another noise source. Alternatively, if the expansion is located somewhere back in the system and remote from the atmospheric vent, steps can be taken to absorb the noise energy before it reaches the outlet, although this may not be suitable for an emergency relief system.

Sometimes it is possible to duct the air stream away to a remote location or to a dump tank where buildings and distance may provide some degree of attenuation; or, where control of timing is possible, to discharge at a time least likely to cause annoyance. The health and safety implications to workers, and the environmental impact of the release, will need to be considered by the Operator as well as the frequency of occurrence. Frequent operation of an emergency system may point to a need for process changes.

ii) ***Movement around restrictions or obstructions in ducts*** may also create noise. Obstructions or sharp bends can produce turbulence and lead to formation of vortices that produce noise at frequencies determined by the size and shape of the obstruction relative to the flow speed. If any of the noise peaks coincide with the resonant frequency of the system, then amplification can occur and much greater noise levels can result. The solution lies largely in system design, materials of construction and the velocity of air movement, although absorptive lagging applied to pipe work may provide some degree of attenuation.

iii) ***Gas control valves*** used on steam, gas or air systems can generate noise in the valve throat, particularly if supersonic flow conditions are achieved by the combination of flow and orifice size. Reduction of pressure is similarly better undertaken in small graduations, using several valves if appropriate, to avoid supersonic conditions. “Low noise” valves are commercially available. These contain a filter of porous material that serves to slow the velocity and reduce the turbulence around the jet.

In addition to the radiation of noise directly from the valve, associated vibration can be set up in upstream and downstream pipe work and attached structures. This can lead to noticeable "ringing" at the resonant frequency/ies of the system. Reduction can be achieved by exterior lagging of pipe work with a combination of materials with damping and insulating properties.

iv) ***Noise produced by cooling jets*** can be reduced by using a larger–diameter, lower–velocity jet to move the same volume of air. Good practice would be to optimise the combination of mass flow rate, timing and direction of flow. Low–noise nozzles are commercially available, but may suffer a degree of loss of thrust.

3.4.3.2 Fan noise

Fan noise is a commonly occurring environmental noise problem; tonal, whining or beating noises can be produced and these may be may be particularly noticeable at night.

Noise is produced primarily as a result of the turbulence produced by the fan blades and is a function of the number of blades and the fan–tip speed. This can be confined to quite a narrow frequency spectrum, and hence can be tonal in nature, but random frequency aerodynamic noise may obscure the prominence of tones. The frequency generated by the passing blades is known as the blade–pass frequency and is determined by:

$$f = \frac{nr}{60}$$

where f = the blade–pass frequency

and r = fan speed (rpm)

n = the number of fan blades

Note: Some fan manufacturers now specify speed in Hz, in which case the 60 in the formula above is not required.

For example, a fan with ten blades, rotating at 1,200 revolutions per minute (20 times per second) has a blade-pass frequency of 200Hz. Whilst noise from fans is commonly the result of complex aerodynamic effects, this fan could potentially produce tonal noise at 200Hz.

Noise control cont.

A number of multiples (harmonics) of this frequency may also be produced and can often be seen across the noise spectrum. Additional peaks may be produced by obstructions to the airflow or blade spacing irregularities.

Noise also arises from casings, motors and vibration set up in the associated ductwork. Where fans are connected to an exhaust stack, the fan noise can be radiated further afield. Where batteries of fans are operated together, a "beating" noise can arise as a result of slight variations in speed. Lack of maintenance or loss of balance due to build–up of deposits on the blades can lead to a noise problem on an otherwise satisfactory fan.

There are several aspects to fan noise control and manufacturers can often offer the solutions discussed below, but specifically designed to solve a problem. Although some of the techniques are straightforward, some solutions will require careful design and implementation. There is no substitute for careful thought and experience when it comes to selecting the right option(s) to reduce noise.

i) Fan design and selection

Ideally the fan and its installation should be designed as a complete package for a specific task. Consideration of noise minimisation should include the effect on adjacent structures. Fans generally produce less noise if operated at the optimum efficiency relative to their characteristics; this point varies according to the type of fan. It may be difficult and expensive to subsequently modify a system for lower noise output after installation.

A range of fans is available, depending upon the operational requirements. Five main fan types are:

Table 3.2 - Outline information on fan types

Fan type	Noise	Description
Centrifugal	Lower frequencies	Air enters axially and is discharged radially
Axial	Mid–range frequencies	Air enters and leaves the fan in a straight–through configuration
Mixed flow	Lower frequencies	The air path is intermediate between axial and centrifugal
Cross flow	Varied	Long cylindrical impeller with a large number of shallow blades discharging via a long slot
Propeller	Tonal peaks	Similar to an axial fan, but mounted in a ring Permitting both radial and axial discharge, higher volume and lower pressure

Nearly all fans produce tonal peaks, which can sometimes be reduced or changed very easily by altering the speed. In many cases, simple engineering solutions can be identified following investigations.

Where fans are exposed to high dust levels, erosion or imbalance can occur, so shafts should be short and routine maintenance procedures strictly followed.

Fewer larger fans operating at lower speeds produce less noise than smaller high-speed fans. Sometimes, continuous operation may cause less disturbance than intermittent; the advantages of running fewer fans continuously rather than many fans intermittently should be considered. This may be quite important for night-time operations, as the relays that start fans can be very noisy.

If fans can be located at low level, that is, on sidewalls, rather than in the roofs of buildings, ground effect and the local topography and the like will far more readily reduce the noise transmission.

ii) Resilient mounting of the fans and ductwork

Anti-vibration mountings may be required on fans to prevent noise being transmitted through the structure and re-radiating elsewhere. Ducts may have to be resiliently mounted, especially if they are to be fixed to steelwork and similar structures. Connections should be made using flexible connectors, where necessary, to avoid the transfer of noise via pipework and other services. The connectors should be checked regularly to ensure that bridging caused by a build–up of material does not occur.

The use of sheet metal, or other materials of construction that may vibrate when located in close proximity to the fans, should be avoided since the vibration may be transmitted to other parts of the structure. The use of smooth, noise–reflective surfaces will allow noise levels to build up in and around the building, whereas softer surfaces such as wood and straw will absorb sound.

Noise control cont.

Silencers

A range of silencers is available and it may be necessary to insert in-duct silencers both upstream and downstream to prevent radiation of fan noise through ductwork. These should be as close to the fan as possible (but not so close as to lead to a non-uniform air–flow velocity across the face of the silencer). Where this is not possible, the intervening ductwork should be acoustically lagged. It may also be necessary to enclose or lag the fan. Where fans are used to push gases up a stack, silencers containing absorbent material can sometimes be mounted directly on top of the stack. However, where gases are hot, wet or dirty, the infill may need to be protected.

Acoustic louvres on exhausts and inlets can greatly reduce environmental noise. However, their performance can sometimes be disappointing if their installation increases back-pressure or the velocity of the air flow.

iii) Avoidance of turbulence

The flow of air or gas into a fan should be as uniform as possible and sharp right–angle bends should be avoided in ductwork. The resistance at the inlet and exhaust should be as low as possible to avoid placing unnecessary loading on each fan. Changes of direction should be curved; silencers, fans and junctions should be sited away from bends; junctions themselves should be designed to go with the direction of flow. Rounded or bell–mouth inlets and outlets can help to ensure smooth air flow. Dampers and louvres may also create turbulence and can be significant sources of noise unless they are carefully designed, installed and maintained.

iv) Maintenance

Regular maintenance of systems is very important. Many noise complaints have been traced to worn bearings, imbalance due to erosion or damage, dust and deposits on the impeller and in the adjacent ductwork. Additionally, silencers may be damaged, eroded, corroded or clogged and flexible connectors may become brittle or stiff.

v) Active noise control

This technique could be considered in some circumstances and can be particularly effective for in–duct solutions. A microphone is installed in a duct that relays the signal to a microprocessor, which then generates the same sound signal as the source. The new signal is 180° out of phase with the original, so it cancels it out. (In other words, the peak of the new signal coincides with a trough of the old one and hence, theoretically, the effect is no pressure change.) This signal is then played through loudspeakers (often four) into the duct. The effect cancels out the noise and reductions as high as 20 dB have been reported.

vi) Fan modifications

Where a tonal noise is being generated by a fan, minor modifications to the casing, or blades, can significantly reduce the noise at a particular frequency, and can reduce the noise at a specific frequency by up to 25 dB. The cost can be quite modest, but it is a specialised technique, and care must be taken to ensure that the correct frequency is reduced, that other frequencies are not causing problems, or new ones are introduced.

3.4.3.3 Combustion noise

The noise associated with combustion processes is largely due to the unsteady burning of fuel and the gas velocity involved. There can also be noise from the induced draught fans. The design of burners and boilers is a very specialist area, but with careful thought and design, noise can be reduced at source and suitable silencers installed.

3.4.3.4 Hydraulic systems

The main source of noise in hydraulic systems is the pump, or compressors used to pressurise the system. The hydraulic mechanisms themselves are usually quiet. Pump and compressor houses can often be enclosed, with acoustic louvres being used at any air inlets and outlets.

3.4.3.5 Machine noise

Machinery noise can come from many sources. The machine itself may be inherently noisy due to gears, bearings, motors or cooling fans. Additional sources may be the material being worked, resonating and the use of hand tools, such as saws, grinders and the like. The reduction of machinery noise can be a specialist area. Some problems will require complex, purpose–built enclosures, but more simple solutions may be the correct use and speed of saw blades or the use of low–noise grinding wheels.

3.4.3.6 Impact noise

Impact noise can be divided into three types in terms of the means of production:

- impulsive action produced as part of the operation of a machine (for example, presses, drop hammers)
- incidental to machine operation (for example, hoppers, vibrating conveyors, screens)
- operating procedures, (for example, dropping steel plates, timber

This type of noise often comprises many frequencies and the solutions may range from operational ones (reducing drop heights) to mechanical ones (using resilient linings).

3.4.3.7 Noise from gas flares

Noise control cont.

See also 3.4.3.1— high-pressure releases.

The main noise-generating mechanisms of a gas flare are:

(i) The turbulent air flow caused by the high–velocity, high–temperature gas flow. Noise levels increase with increasing gas velocity and temperature. At velocities below 30m/s, noise generation is not usually a major concern. Noise caused by the turbulent airflow is generally of low frequency (below 50Hz). Consequently, flare noise can be more annoying at sensitive receptors than an ‘A’-weighted level would suggest. It can therefore be more meaningful to measure the noise using a linear scale as ‘A’-weighting tends to under–represent the effects of low frequencies.

(ii) Combustion produces low–frequency noise, below 350Hz.

(iii) Noise from injection of smoke suppressant, such as high-pressure steam, produces high–frequency noise. Steam injection also improves combustion efficiency, thereby increasing the combustion roar.

Noise levels produced by gas flares can vary widely and under some circumstances have produced sound power levels approaching 140dB (linear). This equates to around 85 dB (linear) some 200 metres away.

In addition to noise generated at the discharge point, noise tends to radiate from the ductwork or flue, although to a lesser degree.

The most effective ways to reduce noise from flares are:

(i) To reduce the high–frequency steam–jet noise. This is usually best accomplished by careful design of the injection orifices, and by using multiple, carefully sited ports. In any particular case there will usually be a number of technical issues to consider, including clogging and coke formation in particular

(ii) To slow the flow rate down. This reduces turbulence and hence creates a smoother air flow, but may not be possible for operational reasons.

Nozzles can be fitted to the discharge point to split the gas stream into a number of smaller streams. Silencers may also be fitted, to the steam injector(s) or to the discharge point, provided they can withstand the extreme environment.

Some flares operate only intermittently — this reduces the time-averaged noise levels but may produce a startle effect.

Alternatively, if safety aspects and pollution dispersion calculations allow, enclosed flares at ground level might be considered.

In general, noise-related issues associated with flaring are best addressed at the design stage, as they tend to be difficult to deal with retrospectively.

3.4.4 Control of noise from open-air operations

Outside operations

Part 1 of BS 5228:1997 offers guidance on the prediction and control of noise and vibration from construction and open sites. Parts 2 to 5 offer advice on legislation, open–cast coal sites, piling operations and surface mineral extraction respectively.

The Agency’s *Internal Guidance for the Regulation of Noise at Waste Management Facilities under the Waste Management Licensing Regulations* (Reference 16) also offers advice. Some of the suggestions may be appropriate to open-air operations other than waste management facilities, which are subject to integrated control under the PPC Regulations. It provides a framework for noise control and guidance to Regulatory officers on the issues surrounding noise and its assessment in relation to waste management facilities under the waste management licensing regime. It will be reviewed as appropriate, as will this document, when some of these facilities subsequently move to integrated control.

Many open-air operations that will fall under IPPC and those currently covered by the Waste Management Licensing system will not have the advantage of permanent buildings of solid construction to act as noise containment for activities likely to cause annoyance. A further difficulty can lie in the need to use mobile plant such as front-end loaders, power screens, crushers and the like, which are not normally enclosed.

As for other noise sources, great improvements can be achieved by ensuring a good standard of maintenance and management. A wide range of measures can be considered to reduce the impact of outside operations and the key areas are outlined below. Any modifications to plant should be done in conjunction with the manufacturers to ensure that overheating or other problems do not occur.

3.4.4.1 Reduction at source

Outside operations cont.

Reduction at source by using quieter machinery or methods of working should be the preferred first course of action. This can avoid the need to construct expensive and extensive barriers. It also reduces the need for very tight site management, which in turn may allow for greater flexibility.

The following are just some of the options that can be considered:

- ensure adequate maintenance of silencers and other acoustic measures such as engine covers and the like
- replace diesel fork lifts or pumps with electric ones
- replace older site plant with modern, quieter plant
- use “smart” reversing alarms, adjust operations so as to minimise the need for reversing, use of movement sensors and lights
- instead of rolling or dropping materials off a lorry, deliveries could be paletted and unloaded using an electric fork–lift
- smooth surfaces to yards and transport areas
- use correctly specified plant rather than making do with available plant; for example, using an appropriately sized front-end loader to carry out site tasks efficiently within its design parameters will be quieter than an undersized loader
- materials should be lowered onto hard surfaces rather than dropped, and the drop height of any bulk material or components should be reduced as much as possible

3.4.4.2 Siting and use of equipment

Care should be taken to site noisy equipment away from noise-sensitive areas. Although the siting of the facility and the access roads will be considered as part of the planning application, the day–to–day location of equipment on the site and the way in which it is used is often controlled by the site Operator. The Operator can therefore play a major part in noise mitigation:

- site noisy machinery and operations as far as possible from noise–sensitive areas
- orientate plant that is known to be a directional noise source so that noise is directed away from noise-sensitive areas. (Noise transmission paths should be included in this consideration as noise may reflect off walls and the like)
- avoid idling of machines between work periods and unnecessary revving of engines
- maintain site roads in a state of good repair to reduce noise from the passage of empty vehicles
- use the of buildings on site as noise barriers

3.4.4.3 Training

The need for noise minimisation should be widely advertised on site. As part of their training, site personnel should be advised of the following aspects, particularly in relation to noise:

- the proper use and maintenance of plant and equipment to minimise noise
- the positioning of any mobile machinery to reduce noise emissions
- avoidance of unnecessary noise when carrying out manual operations and when operating plant and equipment, particularly at night

3.4.4.4 Maintenance

Regular and effective maintenance by trained personnel may do much to reduce noise from machinery. Increases in plant noise are often indicative of future mechanical failure:

- noise caused by vibrating machinery with rotating parts can be reduced by attention to proper balancing
- noises caused by friction in conveyor rollers, trolleys and other machines can be reduced by proper lubrication
- lack of maintenance may lead to overheating, resulting in engine covers being left open

3.4.4.5 Modifying existing plant and equipment

Noise from existing plant and equipment can often be reduced by modification or by applying improved sound-reduction methods:

- noise caused by resonance of cover plates can be reduced by stiffening with additional ribs or by increasing the damping effect with a surface coating of resonance damping material
- rattling noises can be controlled by tightening loose parts and by fixing resilient materials between the surfaces in contact
- using more efficient exhaust systems on internal combustion engines

3.4.4.6 Local enclosures

Outside operations cont.

It may be possible to enclose some noise sources. The extent to which this can be done depends on the nature of the machines to be enclosed and their ventilation requirements. The effectiveness of partial or full noise enclosures and screens can be lost if they are used incorrectly:

- close integral engine cover plates when plant is operating
- direct the noise being enclosed into and not out of enclosures
- there should not be a reflecting surface opposite the open side of a partial noise enclosure
- effectively sound-reduce any opening in complete enclosures, for example, acoustic louvres for ventilation openings
- the need for sound insulation for buildings housing plant may necessitate upgrading the external fabric of the building
- consider the issues of reverberation in the design and construction of any housing

3.4.4.7 Acoustic barriers and enclosures

The use of acoustic barriers was introduced in section 3.2.2.2. These can be very effective in dealing with outdoor noise propagation. Where it is not possible to reduce noise to a sufficient level at source, or by increasing the distance between the source and a noise-sensitive location, screening should be considered. The site layout can itself contribute towards the provision of useful screening. Site buildings may be grouped to form a substantial barrier separating site operations and nearby noise-sensitive locations. For some sites, earth bunds landscaped to provide a permanent feature of the environment may be used to provide screening. Acoustic barriers may be erected as an alternative to, or in addition to, earth bunds since they may be more readily moved or re-sited.

The use of barriers is a complex subject that requires careful consideration. Advice and discussion on barriers and screening is contained in Part 1 of BS 5228:1997.

Enclosures around noisy areas, such as tipping halls, need to be maintained in a good state of repair. And any access doors or other “holes” in the structure need special consideration — preferably to ensure they are facing the least sensitive areas (or those sensitive areas furthest away).

Site and building entrances should face away from sensitive areas, as it is difficult to put effective barriers where ease of entrance and egress may be the primary concern.

3.4.4.8 Other controls

It may be necessary to limit the number of vehicles admitted to a site. Restricting certain operations to particular areas and times, or limiting the throughput of a site, will also reduce noise emissions. Restrictions such as these may be the subject of conditions attached to the planning consent.

The use of public address systems and factory sirens should be carefully controlled, as should other matters that can give rise to noise, such as the use of horns.

Monitoring of noise levels at source can help to identify any increase in noise level with time and therefore allow remedial activities to be undertaken.

3.4.5 Community liaison

Community liaison committees and groups

There is no doubt that a well-run and managed local liaison committee can help Operators to live at peace with the residents. Face–to–face discussion and community involvement can often bring more tolerance to bear on unavoidable noisy operations. If, for example, the community understands why an operation has to be undertaken, why it has to be at night, perhaps, and the length of time, many potential complaints may be avoided. Furthermore, explanation of problems or difficulties that have occurred can be discussed or explained to the community. Occasional open days and similar events also promote a greater degree of understanding between the Operator and the community.

Some plants require occasional, unavoidably noisy, procedures to be followed, such as “blowing down” pressurised systems and testing emergency generators. The impact of noise from such activities can be reduced by sympathetic scheduling, during the normal working day, at set times or by warning the community beforehand. This can reduce the level of disturbance caused as people may be able to schedule noise–sensitive activities for other times. An example of this is the testing of emergency generators or alarms at weekends in commercial areas where there are no residential buildings. More generally, keeping the community aware of noise–control activities and plans can offer long-term benefits to all parties. If the duration of short–term incidents is known, often the public will be more tolerant, but it is still important to keep the number of such occasions to a minimum.

3.4.6 Complaints

Complaints

Where noise complaints are made, they must be received and treated by the Operator in a constructive manner. They can often provide the Operator with information on the main source(s) of concern and the best approach to mitigating the problem. Appendix 3 gives an example of a typical standard form to illustrate the key information that should be sought from a complainant. Very often a positive response from an Operator can defuse or remedy a situation, whereas the opposite response can provoke more complaints.

It is important to ensure that each complaint is thoroughly investigated and appropriate remedial action carried out promptly. It is essential that the complainant is kept updated of progress, particularly if the investigations and solution will take some time.

A Permit might contain specific actions to be taken in the case of complaints relating to reporting requirements, or to cessation of, or modification to, the activities or operations being carried on.

References

1. *IPPC Horizontal Guidance for Noise (IPPC H3) Part 1 — Regulation and Permitting*, Environment Agency.
2. BS 7445:1991 *Description and measurement of environmental noise*:

   Part 1. Guide to quantities and procedures, BSI, ISBN 0 580 19728 X

   Part 2. Guide to the acquisition of data pertinent to land use, BSI, ISBN 0 580 19736 0

   Part 3. Guide to the application of noise limits, BSI, ISBN 0 580 19734 4
3. *Noise at work regulations 1989*, HMSO, ISBN 0 110 97790 4.
4. BS 4142:1997 *Method for rating industrial noise affecting mixed residential and industrial areas*, BSI ISBN 0 580 28300 3.
5. Planning Policy Guidance Note PPG24: *Planning and Noise*, September 1994, DoE.
6. ISO 9613 Acoustics - *Attenuation of sound during propagation outdoors*;

   Part 1: 1993 *Calculation of the absorption of sound by the atmosphere*;

   Part 2: 1996 *General method of calculation*.
7. BS 5228: *Noise and vibration control on construction and open sites*.

   Part 1: 1997 *Code of practice for basic information and procedures for noise and vibration control*, BSI ISBN 0 580 26845 4.

   Part 2.: 1997 *Guide to noise and vibration control legislation for construction and demolition including road construction and maintenance*, BSI ISBN 0 580 26866 7.

   Part 3:1997 *Code of practice applicable to surface coal extraction by opencast methods,* BSI ISBN 0 580 26874 8.

   Part 4:1992 *Code of practice for noise and vibration control applicable to piling operations*, BSI ISBN 0 580 20381 6.

   Part 5. *Code of practice applicable to surface mineral extraction (except coal) sites,* BSI ISBN 0 580 28306 2.
8. BS 7580:1997 *Verification of sound level meters Part 1 Comprehensive procedure* BSI ISBN 0 580 20908 3.
9. BS 7385:1990 *Evaluation and measurement for vibration in buildings*.

   Part 1. *Guide for measurement of vibrations and evaluation of their effects on buildings.* BSI ISBN 0 580 190978
10. BS 8233:1999 *Sound insulation and noise reduction for buildings* BSI ISBN 0 580 33009 5.
11. CONCAWE *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities*, 1981
12. EEMUA *Noise procedure specification and guide 140 and 141*, 1985, ISBN 0 859 31078 7.
13. Minerals Planning Guidance MPG11: *The Control of Noise at Surface Mineral Workings*, DoE/Welsh Office, April 1993, ISBN 0 -11-752779-3 (currently under review).
14. *Guidelines for Community Noise*, Birgitta Berglund, Thomas Lindvall, Dietrich H Schwela © World Health Organization 1999.
15. *Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001*, SI No. 1701, HMSO ISBN 0 11 029485 8.
16. *Internal Guidance for the Regulation of Noise at Waste Management Facilities under Waste Management Licensing Regulations: Environment Agency.*
17. IPPC S0.01 *General Sector Guidance* (Version 1, August 2000), Environment Agency.
18. *Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise*. Official Journal L 189 , 18/07/2002 P. 0012 - 0026
19. Rural White Paper *Our Countryside: The Future A Fair Deal for Rural England* , Department of the Environment, Transport and the Regions, HMSO.
20. Integrated Pollution Control Licensing, *Guidance Note for Noise In Relation to Scheduled Activities*, Irish Environmental Protection Agency, 1995.
21. *Library of Licence Conditions and Working Plan Specifications* (Edition 2, August 1999), Environment Agency.
22. IPPC Guidance Note H1 – *Environmental Assessment and Appraisal of BAT*, Environment Agency, 2002.
23. Environment Agency IPPC Regulatory Guidance Series, No. 1 *Determining "Substantial Change" Under IPPC.*
24. Consultation paper *Towards a National Ambient Noise Strategy*, a Consultation Paper from the Air and Environment Quality Division, Department for Environment, Food and Rural Affairs, November 2001.
25. Report on *The Use of Sound Power Levels in Noise Modelling*, Environment Agency, March 2002.

Suggested standards or books for further reading or reference

- *Best Available Techniques for Control of Noise and Vibration*, R&D Technical Report. This work was undertaken for the Agency by ERM and partly forms the basis for this guidance, H3, Part 2. In particular, it contains a number of case studies relating to investigation and control of noise problems that do not appear in this guidance.

- BS 7445 *Description and measurement of environmental noise*:

  Part 1. *Guide to quantities and procedures*, BSI ISBN 0 580 19728 X

  Part 2. *Guide to the acquisition of data pertinent to land use*, BSI ISBN 0 580 19736 0

  Part 3. *Guide to the application of noise limits,* BSI ISBN 0 580 19734 4

- BS 4142:1997 *Method for rating industrial noise affecting mixed residential and industrial areas*, BSI ISBN 0 580 28300 3.

- Planning Policy Guidance Note PPG24: *Planning and Noise*, September 1994, DoE.

- BS 5228:1997 *Noise and vibration control on construction and open sites*, September 1994, DoE.

  Part 1. *Code of practice for basic information and procedures for noise and vibration control,* BSI, ISBN 0 580 26845 4.

  Part 5. *Code of practice applicable to surface mineral extraction (except coal) sites*, BSI ISBN 0 580 28306 2.

- Minerals Planning Guidance MPG11: *The Control of Noise at Surface Mineral Workings*, DoE/Welsh Office, April 1993, ISBN 0 -11-752779-3 (currently under review).

- HSE's Guidance HSG138 *Sound Solutions — Techniques for reducing noise at work*, 1995, HSE, ISBN 0 7176 0791 7.

- Report on *The Use of Sound Power Levels in Noise Modelling*, Environment Agency, March 2002. This work was undertaken for the Agency by Casella Stanger and forms the basis of the discussion on modelling.

- World Health Organisation, *Guidelines for Community Noise 1999*, http://www.who.int/peh/noise/guidelines2.html

- *Woods Practical Guide to Noise Control*, 4th Edition, Sharland I. Woods of Colchester, ISBN 095029411X.

Definitions

BAT	Best Available Techniques
BPM	Best Practicable Means
BS	British Standard
EEMUA	Engineering Equipment and Material Users Association
IoA	Institute of Acoustics
IPPC	Integrated Pollution and Prevention Control
LA	Local Authority
MCERTS	Monitoring Certification Scheme. The Agency is pursuing several initiatives to help improve the quality and reliability of measurement data submitted to it for assessment. Central to these is the Agency's Monitoring Certification Scheme: MCERTS
MPG	Mineral Planning Guidance
NECs	Noise Exposure Categories
Pollution	Emissions as a result of human activity that may be harmful to human health or the quality of the environment, cause offence to any human senses, result in damage to material property, or impair or interfere with amenities and other legitimate uses of the environment (Pollution Prevention and Control Regulations 2000).
Pollutant	Any substance, vibration, heat or noise released as a result of such an emission (as above) that may have such an effect (Pollution Prevention and Control Regulations 2000)
PPC	Pollution Prevention and Control
PPG	Planning Policy Guidance
SEPA	Scottish Environment Protection Agency
Substantial change	A change in operation that, in the opinion of the Regulator, may have significant negative effects on human beings or the environment. (Reference 23)
WHO	World Health Organisation

Appendix 1 — Glossary of acoustic terminology

1/3 octave band analysis:

Frequency analysis of sound such that the frequency spectrum is subdivided into bands of one–third of an octave each. An octave is taken to be a frequency interval, the upper limit of which is twice the lower limit (in Hertz).

Ambient noise *

The totally encompassing sound in a given situation at a given time, usually composed of sound from many sources near and far. Unlike the *residual noise*, the ambient noise includes the contribution from the specific noise.

Background Noise Level, $L_{A90,T}$ *

The 'A'-weighted sound pressure level of the residual noise in decibels exceeded for 90 per cent of a given time and is the $L_{A90,T}$.

dB (decibel)

The scale in which sound pressure level is expressed. It is defined as 20 times the logarithm of the ratio between the root-mean-square pressure of the sound field and the reference pressure (0.00002 N/m^2). 0 dB is the threshold of hearing, 140 dB is the threshold of pain. A change of 1 dB is detectable only under laboratory conditions. A change of 10 dB corresponds approximately to halving or doubling the loudness of sound.

dBA

A measure of the overall noise level of sound across the audible frequency range (20Hz - 20,000Hz) with a frequency weighting (i.e. 'A' –weighting) to compensate for the varying sensitivity of the human ear to sound at different frequencies. The background noise level in a living room may be about 40 dBA, normal conversation about 60 dBA, heavy road traffic at 60mph about 80 dBA, the level near a pneumatic drill about 100 dBA.

dB(C)

A measure of the overall level of sound across the audible frequency range with the 'C' frequency which is virtually linear between 50Hz and around 5kHz.

Façade Level

Noise levels at locations 1m from the façade of a building are described by the term *Façade Levels* and are subject to higher noise levels than those in open areas (free-field conditions) due to reflection effects.

Hz (Hertz)

The unit of sound frequency in cycles per second

Impulsive noise

A noise that is of short duration (typically less than one second), the sound pressure level of which is significantly higher than the background.

$L_{Aeq,T}$ *

The equivalent steady sound level in dB containing the same acoustic energy as the actual fluctuating sound level over the given period, T. T may be as short as 1 second when used to describe a single event, or as long as 24 hours when used to describe the noise climate at a specified location. $L_{Aeq\ T}$ can be measured directly with an integrating sound level meter.

Noise

Unwanted sound. Any sound, that has the potential to cause disturbance, discomfort or psychological stress to a subject exposed to it, or any sound, that could to cause actual physiological harm to a subject exposed to it, or physical damage to any structure exposed to it, is known as noise.

NR

Noise Rating curves, similar to Noise Criteria (NC) curves, form a set of noise criteria given in octave bands.

APPENDIX 1 - GLOSSARY OF TERMS

Noise–sensitive location

Any dwelling, hotel or hostel, health building, educational establishment, place of worship or entertainment, or any other facility or area of high amenity, which for its proper enjoyment requires the absence of noise at nuisance levels.

Rating level $L_{Ar\,T}$ *

The equivalent continuous 'A' –weighted sound pressure level of an industrial noise during a specified time interval, plus specified adjustments for tonal character and impulsiveness of the sound.

Residual noise *

The noise level in the area in the absence of the noise source under investigation.

Sound power level and sound pressure level

Any source of noise has a characteristic s*ound power*, a basic measure of its acoustic output, but the s*ound pressure levels* it gives rise to depend on many external factors. These include the distance and orientation of the receiver, the temperature and velocity gradients in the medium, and the environment. *Sound power*, on the other hand, is a fundamental physical property of the source alone, and is therefore an important absolute parameter, which is widely used for rating and comparing sound sources.

Specific noise level *

The equivalent continuous 'A' –weighted noise level produced by the source under investigation (that is, the specific noise source *) over a period (T) as measured at the assessment point (usually a noise–sensitive receptor) $L_{A\,eq,\,T}$.

Peak particle velocity

The rate of change of displacement of the particles in a solid medium. It is the term usually used to describe vibration in relation to activities involving blasting. Velocity will vary from zero to a maximum value — the peak particle velocity, and the units used are millimetres per second (mm/sec).

Pure tone

A sound in which the sound pressure varies regularly, at a single frequency, over time.

Vibration Regularly repeated movement about a fixed point.

VDV

Vibration Dose Value — vibration measurement parameter that combines the magnitude of vibration and the time for which it occurs. The measurement is based on a form of acceleration that is frequency weighted to reflect human sensitivity to various frequencies (see BS6472).

Note: More information on the definitions above marked with an asterisk can be found in BS4142: 1997.

Appendix 2 — British standards and other guidance

A2.1 Introduction and background

This appendix summarises the content of the key guidance documents that are relevant within the context of this guidance note, and comments upon the applicability of each. Reference should be made to the full document if there is any doubt as to scope or relevance to a particular situation.

In all cases, it is important that local conditions are taken into account. Consultation with the local authority will be helpful when determining the approach to be adopted.

A2.1.1 Planning Policy Guidance PPG24 *Planning and Noise*

(See Reference 5)

PPG 24

A2.1.1.1 Introduction

PPG24 outlines the Government's view on noise and planning and *focuses on the planning of new noise-sensitive development in already noisy environments* (PAN 56 in Scotland and Technical Advice Note (Wales) 11 in Wales are very similar) (References A.2.1 & A.2.2). It establishes Noise Exposure Categories (NECs) that are applicable when planning new residential developments affected by transport noise or by mixed noise sources in which industrial noise does not dominate.

However, these NECs cannot be used for assessing noise impacts of new or existing noise sources on existing housing. In the case of proposed noise-producing development affecting existing noise-sensitive premises, PPG24 advises that BS 4142:1997 can be used, within its own terms of reference, to predict the likelihood of complaints, and hence assist in the assessment. However, many planning authorities adopt more stringent standards than are implied in PPG24, which really only discusses the likelihood of complaints.

A2.1.1.2 Noise Exposure Categories

NECs

PPG24 does not offer a single set of criteria, but introduces the concept of NECs that provide flexibility to take account of local conditions and the needs of the local community and economy.

There are four NECs:

A. Noise need not be considered as a determining factor in granting planning permission, although the noise level at the high end of the category should not be considered as desirable.

B. Noise should be taken into account when determining planning applications and, where appropriate, conditions imposed to ensure an adequate level of protection against noise.

C. Planning permission should not normally be granted. Where it is considered that permission should be given, for example, because there are no alternative quieter sites available, conditions should be imposed to ensure a commensurate level of protection against noise.

D. Planning permission should generally be refused.

BS 4142: 1997

A2.1.2 British Standard 4142: 1997 - Method for rating industrial noise affecting mixed residential and industrial areas

(See Reference 4)

A2.1.2.1 Introduction

PPG24 suggests that BS 4142:1997 should be used to assess the likelihood of complaints from industrial sources. BS4142: 1997 describes a method for determining industrial and background noise levels outside residential properties and for **assessing whether the industrial noise is likely to give rise to complaints from residents**. The potential noise impacts of new or modified plants should be considered both in terms of BS 4142: 1997, PPG24 and the World Health Organisation guidelines.

This standard does not offer any guidance on BAT, although the alleviation of complaints should be one of the criteria considered in determining of BAT.

A2.1.2.2 Definitions used in BS 4142: 1997

BS 4142:1997 uses the following definitions:

Ambient noise
Totally encompassing sound in a given situation at a given time usually composed of sound from many sources near and far.

Background noise level $L_{A90,T}$
The 'A'-weighted sound pressure of the residual noise at the assessment position that is exceeded for 90 per cent of a given time interval, T, measured using the time weighting, F, and quoted to the nearest whole number of decibels.

Measurement time interval, T_m
The total time over which measurements are taken.

Rating level $L_{Ar,Tr}$
The specific noise level plus any adjustment for characteristic features of the noise.

Reference time interval T_r
The specified interval over which an equivalent continuous 'A'-weighted sound pressure level is determined.

Residual noise
The ambient noise remaining at a given position in a given situation when the specific noise source is suppressed to a degree such that it does not contribute to the ambient noise.

Residual noise level, $L_{Aeq,T}$
The equivalent continuous 'A' –weighted sound pressure level of the residual noise.

Specific noise level, $L_{Aeq,Tr}$
The equivalent continuous 'A'-weighted sound pressure level at the assessment position produced by the specific noise source over a given reference time interval.

Specific noise source
The noise source under investigation for assessing the likelihood of complaints.

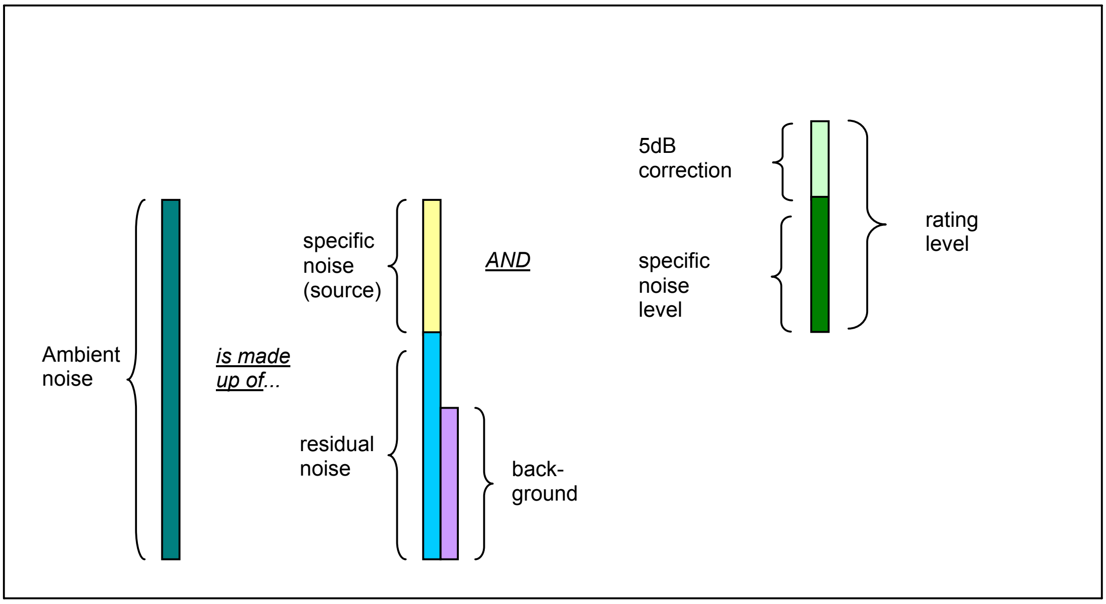


Figure A2.1 — Relationship between different BS 4142 parameters

BS 4142: 1997 cont.

The BS4142: 1997 assessment methodology involves the following procedure:

- measure the background ($L_{A90,T}$) sound level, in the absence of the new noise source, at the noise-sensitive receptors
- measure the noise levels attributable to the source of interest to the sensitive receptor as an $L_{Aeq,T}$ (using the procedures set out in the standard)
- correct the noise levels for duration and character, to produce the rating level ($L_{Aar,T}$). (The correction for tonal, impulsive or any distinctive character in the noise source is +5dB)
- assess the likelihood of complaints by subtracting the measured background noise level from the rating level

The interpretation of the difference between the *rating level* and the *background noise level* is shown in Table A2.2, but can only be done after carrying out the steps detailed in Section 10 (h to m) of the standard. The greater the positive difference, the greater the likelihood of complaints.

Table A2.2 - Interpretation of noise–level difference

Difference in noise level (dB)	Significance
Around +10	Complaints are likely
Around +5	Marginal
-10	Positive indication that complaints are unlikely

A2.1.2.3 Application and discussion

BS 4142: 1997 requires that daytime assessments are based on the $L_{Aeq,T}$ from the noise source over a period of 1 hour, while at night-time an assessment period of 5 minutes is specified. Section 10 of the standard details the information that shall be reported for a full assessment. This includes:

- the source(s) under investigation
- subjective impressions
- measurement locations
- sound level measuring instruments used
- field calibration details
- weather conditions
- date(s) and time(s)
- specific noise level(s)
- measurement time intervals
- reference time intervals
- rating level
- background noise level

- excess of rating level over background

BS 4142: 1997 cont.

Table A2.2 is useful in determining the likelihood of complaints in a given situation, but if it is to be used to determine an acceptable noise Permit level, then great care is needed. This British Standard is commonly misused in this way, if figures are taken directly from it. When used for assessing acceptable noise limits, several factors that are unique to the local situation must be considered, including:

- the levels of ambient noise in the area
- the types and characteristics of noise present
- the planning setting with regards to other future noise sources
- local opinion on the noise environment

Taken at face value, Table A2.2 could be interpreted to indicate that if a new noise source has a level between 10 dB below and around 5 dB above the existing background noise level, complaints are not likely to be received hence, implicitly, such a level is “acceptable”. In this sense, BS 4142:1997 offers limited guidance because this range of levels is wide. There are many factors, including local conditions and site-specific circumstances, that will help determine where in this range “acceptability” lies. The following examples illustrate some situations where certain interpretations of the standard could be misleading.

Where background noise levels are very low (below 30 dB) and rating levels very low (below about 35 dB), the standard warns that the guidance may not apply. Applying a -10 dB limit of below $L_{Aeq,\ night}$ 20 dB to ensure a positive indication that complaints are unlikely would therefore be inappropriate.

A new type of noise may be clearly discernible above a very different type of background noise, (for example, distant traffic that tends to form a steady broadband noise). In such cases, a limit of background +5 dB for a new source may not be appropriate.

Bear in mind that a study by the National Physical Laboratory in 1995 showed that the rating method of BS 4142:1990 generally gives a good indication of the likelihood of complaint (in 80 per cent of the cases reported), (Reference A2.3). However, this implies that the method was wrong in the remaining one in five cases. (Note: there was no change in this respect between the 1990 version and the 1997 version). Also the study showed that under–prediction of complaints occurred in some cases including low–frequency noise, impulsive noise and tonal new noise.

Adopting the +5 dB “marginal” case as acceptable may be inappropriate if there is a likelihood of other future developments adding to ambient noise levels. This is the so-called “creeping background” (or more correctly creeping ambient) concern that sometimes arises around developing industrial areas. This concern can be valid in some cases, but in others it may not be so serious

If little future development is expected, adopting a cautious approach of setting the Permit level at -10 dB may be unnecessary, depending on other local factors, particularly if ambient noise levels are low in absolute terms.

Finally, in situations where there is a history of noise disturbance from whatever source, the local community may have become “sensitised” to noise impacts. In such cases the “average” dose-response relationships that form the basis of noise standards may not hold and there may be more complaints. In such cases, limits at the lower end of the BS 4142: 1997 range may be more appropriate, depending on other local factors.

Of course, all these local factors interrelate, so it is not possible to offer prescriptive guidance on how to apply BS 4142:1997. It must, however, be used with care if numerical noise conditions are attached to Permits and when assessing the noise impact of an installation.

Ahead of any internally developed protocols, bear in mind the following few points when undertaking and reporting sound level measurements and assessments. Reference should be made to BS 4142: 1997 for the measurement protocols and the measurements should normally be carried out only by a suitably qualified person, (for example, someone holding the IoA Certificate of Competence in Environmental Noise Measurement or higher). The ten points outlined in Table A2.3 should be used as an *aide memoire*:

BS 4142: 1997 cont.

Table A2.3 - Points to note when using BS4142

Advice	Clause in BS4142:1997
Only measure if the weather is suitable (no rain, wind $<5ms^{-1}$)	5.4
Calibrate SLM before and after measurements and record readings	5.1
Select the correct measurement period for the specific, residual and background levels	6.2 7.1.2
Measure at least 3.5m from reflecting surfaces and 1.2 – 1.5m above ground levels	5.3
Ensure all the information is reported	10
Describe the nature and characteristics of the specific noise source	10
Describe the main sources of the residual and background noise	10
Correct measured level of the specific noise source for effects of the residual noise	6.3.3
Correct the measured level for the duration or “on-time”	6.3.7 to 6.3.14
Consider the corrections for acoustic features	8

A2.1.2.4 BS 4142 Worked example

BS 4142: 1997 worked example

An industrial premises has a compressor that runs for 15 minutes in each hour during the normal working day and it produces audible noise at nearby residential property. The background and residual noise were measured for 15 minutes, immediately after completion of one cycle. The sound level from the compressor was measured for the full 15-minute cycle, and finally a repeat 15-minute ambient and background sound level was measured. The background and residual noise before and after the compressor cycle were, after correction to the nearest whole dB, the same. The sound of the compressor had no audible characteristics at the measurement location.

It is assumed that all the measurements have been made and reported in accordance with the requirements of the standard.

Table A2.4 - Use of BS4142

Description	Parameter	Value	Clause	Comment
Measured noise level of the compressor	$L_{Aeq,15min}$ dB	56	6.3	Compressor running
Residual noise level	$L_{Aeq,15min}$ dB	51	6.3	Compressor not running, to enable the appropriate correction to be made for the ambient noise level
Correction for residual noise level	dB	-2	6.3.3 Table 1	Since the residual noise level is within 10 dB of the measured level the latter must be corrected to allow for the contribution the residual noise has made to the measured level
Corrected measured level	$L_{Aeq,15min}$ dB	54	6.3.3	
Specific noise level	$L_{Aeq,1hr}$ dB	48	6.3.13	The measurement has to be corrected to 1 hour since the compressor runs 15 minutes in each hour (Correction = 10Log(15/60) = -6 dB)
Acoustic feature correction	dB	0	8.2	There are no acoustic features, hence no 5dB adjustment is added
Rating level	$L_{Aeq,1hr}$ dB	48	8.2	
Background sound level	$L_{A90,15min}$ dB	42	7.3	Background sound level measured between compressor cycles
Excess of rating over background	dB	6	9	CONCLUSION Assessment indicates marginal significance

BS 4142: 1997 Worked example cont.

Discussion:
If the noise had an acoustic feature (whine, hiss, screech, hum, bang, click, clatter or thump), then the rating level would increase by 5dB. The excess over background would then be 11 dB and the conclusion would be that complaints are likely.

A2.1.3 British Standard 5228: *Noise and vibration control on construction and open sites*

(See Reference 7)

BS 5228

BS 5228 has five parts:

- Part 1. *Code of practice for basic information and procedures for noise and vibration control* (1997).
- Part 2. *Guide to noise and vibration control legislation for construction and demolition including road construction and maintenance* (1997).
- Part 3. *Code of practice applicable to surface coal extraction by opencast methods* (1997).
- Part 4. *Code of Practice for noise and vibration control applicable to piling operations* (1992).
- Part 5. *Code of practice applicable to surface mineral extraction (except coal) sites* (1997).

The standard forms a series of codes of practice for construction sites. However, sections of Part 1 provide useful guidance for any situation where noise is generated by plant outdoors, for example on landfill sites. The bulk of Part 1 provides a method of calculating noise from construction plant, including:

- tables of source noise levels
- methods for summing up contributions from intermittently operating plant
- a procedure for calculating noise propagation, over “soft” or “hard” ground
- a method for calculating noise screening effects
- a way of predicting noise from mobile plant, such as those on haul roads

Part 1 also provides guidance on the following subjects for construction sites that may also be useful in other outdoor situations:

- legislative background
- community relations
- training
- noise and vibration neighbourhood nuisance
- project supervision
- control of noise and vibration

On the last subject, the standard gives examples of the noise control achievable through various methods (such as exhaust silencers and enclosures). It also gives diagrams illustrating simple designs of noise enclosures and barriers that can be built and used on construction sites.

In summary, BS 5228 provides guidance that may be useful when predicting noise and considering noise–control techniques for plant operating outdoors, in particular for landfills.

A2.1.4 British Standard 7445: 1991 – *Description and measurement of environmental noise*

(See Reference 2)

BS 7445: 1991

BS 7445: 1991 (equivalent to ISO 1996) gives general guidance on measuring environmental noise and reporting noise levels. ISO 1996 is, at present, under revision, but the standard is currently in three parts:

- Part 1 *Basic quantities and procedures*
- Part 2 *Acquisition of data pertinent to land use*
- Part 3 *Application of noise limits*

The standard sets out various definitions and protocols. The following guidance on tonality is particularly useful:

BS 7445: 1991 cont.

"In some practical cases a prominent tonal component may be detected in one-third octave spectra if the level of a one–third octave band exceeds the level of the adjacent bands by 5 dB or more, but a narrow–band frequency analysis may be required in order to detect precisely the occurrence of one or more tonal components in a noise signal. If tonal components are clearly audible and their presence can be detected by a one–third octave band analysis, the adjustment may be 5 – 6 dB. If the components are only just detectable by the observer and demonstrated by narrow–band analysis, an adjustment of 2 – 3 dB may be appropriate".

The key requirements of the standard have been incorporated into this guidance and in the sample reporting forms in Appendix 3.

A2.1.5 Minerals Planning Guidance MPG 11

(See Reference 13)

MPG11

MPG11 is being revised and consultation on the revision is taking place, but the date for the issue of the revised guidance (if any) is not yet known.

MPG11 describes the Government's policy on noise from surface mineral workings. MPG11 notes that waste–disposal sites share many common features with surface mineral working, and much of the advice contained in the guidelines is appropriate to noise control of such operations. MPG11 goes on to say that Operators and local planning authorities may wish to take account of the guidelines and, where waste disposal forms an integral part of a mineral site, it is expected that they should be covered by MPG11. Hence MPG11 does not automatically apply to stand–alone landfill sites, but it may be useful for assessing the noise from landfill operations that will fall to integrated control under the PPC Regulations. However, *the appropriate internal noise guidance and sector-specific guidance should be used by the Regulator in determining BAT and in setting installation-specific conditions and limits under PPC.* MPG11 recommends the use of BS 5228 to predict noise levels.

Three issues are addressed in MPG11:

i) Impact on dwellings

ii) Impact on gardens and open space

iii) Temporary operations such as bund formation and spoil removal

In general, MPG11 provides absolute limits, however Paragraph 25 does state:

> "…. these guidelines recommend a procedure for setting limits, but recognise that each case should be treated on its merits, having particular regard to the circumstances of the potential site and its surrounding area..."

This is an important point to remember in that, whilst a limit is suggested, each site must be considered critically. So the guidance in MPG11 does provide scope for site-specific limits as necessary.

The planning guidance document suggests "free-field" noise limits. The basic criterion it recommends for daytime operations is a nominal noise limit of 55 dB $L_{Aeq,1h}$ at noise–sensitive properties used as dwellings.

Areas of land that the public use for quiet relaxation, public gardens and open space should be considered as noise–sensitive, whereas sports fields may not warrant any further noise protection. The perception of noise impact affecting open spaces and parkland is different to that affecting dwellings and generally a less stringent limit would be justified. MPG11 suggests a limit of 65dB$L_{Aeq,1h}$ for the normal working day and 55dB$L_{Aeq,1h}$ outside of this time, measured at the boundary of the open space/parkland. Some areas, such as nature reserves or ornamental gardens, may require specific consideration and these should be examined in conjunction with all relevant bodies. Conversely, footpaths and bridleways should not normally be considered noise–sensitive.

It is recognised that in the case of quieter rural areas, where a 55 dB $L_{Aeq,1h}$ limit would exceed the existing background level by more than 10 dB, a lower limit may be appropriate. It is recommended that a limit below 45 dB $L_{Aeq,1h}$ is not normally used, since 45 dB $L_{Aeq,1h}$ "should prove tolerable to most people in rural areas". A night–time limit of 42dB$L_{Aeq,1h}$ is also suggested.

MPG11 also states that it will often be necessary to raise the noise limits to allow for temporary but exceptionally noisy phases in the mineral extraction operation that cannot meet the limits set for routine operations. Any higher noise limit, as well as the duration of any such temporary phases, should be agreed between the Mineral Planning Authority (MPA) and the mineral Operators, taking account of local circumstances.

To allow the operation of a landfill site, it may be necessary to allow increased noise limits for certain defined operations over specific time periods. For example, during the construction of noise bunds or the removal of overburden, MPG11suggests a limit of 70dB$L_{Aeq,1h}$ (during the working day) for periods of up to eight weeks per year.

EU Outdoor equipment directive.

A2.1.6 *Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001* (See Reference 15)

The regulations do not apply to plant and equipment placed on the market before 3 July 2001. The following two lists of equipment come within the scope of the regulations:

Equipment that has to comply with sound power output limits and has to be marked in a specified manner:

- builders' hoists for the transport of goods (combustion-engine-driven)
- compaction machines
- compressors (<350 kW)
- concrete-breakers and picks, hand-held
- construction winches (combustion-engine driven)
- dozers (<500kW)
- dumpers (<500 kW)
- excavators, hydraulic or rope-operated (<500 kW)
- excavators-loaders (<500 kW)
- graders (<500 kW)
- hydraulic power packs
- landfill compactors, loader-type with bucket (<500 kW)
- lawnmowers (excluded are agricultural and forestry equipment; multi-purpose devices, the main motorised component of which has an installed power of more than 20kW)
- lawn trimmers/lawn–edge trimmers
- lift trucks (only combustion-engine driven counterbalanced lift trucks)
- loaders (<500 kW)
- mobile cranes
- motor hoes (<3 kW)
- paver-finishers
- power generators (<400kW)
- tower cranes
- welding generators

Equipment that must have the sound power level marked in the specified manner:

- aerial access platforms with combustion engines
- brush cutters
- builders' hoists for transporting goods (with electric motor)
- building–site band saw machines
- building–site circular saw benches
- chain saws, portable
- combined high–pressure flushers and suction vehicle;
- compaction machines (explosion rammers only)
- concrete or mortar mixes
- construction winches (with electric motor)
- conveying and spraying machines for concrete and mortar
- conveyor belts
- cooling equipment on vehicles
- drill rigs
- equipment for loading and unloading silos or tanks on trucks
- glass recycling containers
- grass trimmers/grass–edge trimmers
- hedge trimmers
- high–pressure flushers
- high–pressure water jet machines
- hydraulic hammers
- joint cutters

- leaf blowers
- leaf collectors
- lift trucks, combustion–engine driven
- mobile waste containers
- paver-finishers (equipped with a high-compaction screed)
- piling equipment
- pipe layers
- piste caterpillars
- power generators (>400kW)
- power sweepers
- refuse–collection vehicles
- road–milling machines
- scarifiers
- shredders/chippers
- snow-removing systems with rotating tools (self-propelled, excluding attachments)
- suction vehicles
- trenchers
- truck mixes
- water–pump units (not for use under water)

A2.1.7 World Health Organisation *Guidelines for Community Noise*

(See Reference 14)

WHO Community Noise Guidelines

In late 1999 the World Health Organisation proposed guidelines for community noise. These suggest that to protect the majority of people from being seriously annoyed during the daytime, the L_{Aeq} in outdoor living areas should not exceed 55 dB. If this value drops to 50dB, then the annoyance factor becomes moderate for most people. The guidelines also considered noise levels at which sleep disturbance may take place. The guidelines suggest that an internal L_{Aeq} not greater than 30 dB for continuous noise is needed to prevent negative effects on sleep. This is equivalent to a façade level of 45 dB $L_{Aeq,}$ assuming open windows or a free-field level of about 42 dB L_{Aeq}. (It has generally been assumed that an open window provides 10 – 15 dB of attenuation, and the WHO guidelines assume the higher attenuation of 15dB). If noise is not continuous, then the internal level required to prevent negative effects on sleep is an $L_{Amax,fast}$ of 45 dB. For sensitive people, lower levels may be necessary. Hence for sleep disturbance, the continuous level as well as the number and level of noisy events should be considered.

However, one difficulty with the guidelines is that they discuss general outdoor noise and do not focus on the specific issues of industrial noise. Hence it is possible that for specific industrial sources levels lower than those identified by WHO may give rise to annoyance if ambient levels from other sources are lower still. This is addressed by implementing BS4142: 1997. For industrial noise, undoubtedly the excess of the noise over the background noise is a key issue and an indicator of likely noise impact.

Table A2.5 — WHO table of health effects

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50	16	-
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening	35	16	
	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School classrooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	During class	-
Pre-school Bedrooms, indoors	Sleep disturbance	30	Sleeping-time	45
School, playground outdoor	Annoyance (external source)	55	During play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time	30	8	40
	Sleep disturbance, daytime and evenings	30	16	-
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial, shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Outdoors in parkland and conservation areas	Disruption of tranquillity	#2		

#1: as low as possible;
#2: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low.

Appendix references

A.2.1 The Scottish Office, *Planning Advice Note PAN 56*, April 1999.
A.2.2 Planning Guidance (Wales), *Technical Advice Note (Wales) 11*, October 1997.
A.2.3 Study of the application of British Standard BS4142:1990 *Method for rating industrial noise affecting mixed residential and industrial areas* (The Datasheet Study), Nicole Porter, National Physical Laboratory, May 1995.

Appendix 3 — Example of reporting forms (complaints and survey)

Table A3.1 - Typical form for reporting a noise complaint

Noise complaint report form	Date:	Ref. No.	
Name and address of complainant			
Tel no. of complainant			
Time and date of complaint			
Date, time and duration of offending noise			
Weather conditions (e.g., dry, rain, fog, snow)			
Wind strength and direction (e.g.,light, steady, strong, gusting)			
Complainant's description of noise (e.g., hiss, hum, rumble, continuous, intermittent)			
Has complainant any other comments about the offending noise?			
Any other previous known complaints relating to installation (all aspects, not just noise)			
Any other relevant information			
Potential noise sources that could give rise to the complaint			
Operating conditions at the time offending noise occurred (e.g., flow rate, pressure at inlet and pressure at outlet)			
Action taken:			
Final outcome:			
Form completed by		Signed	

Table A3.2 - Noise Measurement Reporting Form — Sheet 1 — Site data and the like

Note: the letters in the boxes refer to BS4142:1997 Section 10

Operator				Permit number	
				Date (g)	
		Start time(g)		Finish time (g)	

Instruments (d & e)	Cal. level		Cal. level	
Instruments	Make	Model	Serial No	Calibration date
SLM				
Calibrator				
Microphone				

Description of sound source (a)

Description of monitoring location(s) (c)	Subjective impressions (b)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Name		Signed	

Table A3.3 — Noise Measurement Reporting Form — Sheet 2 — Sound monitoring data

	Premises							Weather (f)				Date:
No.	Location	Start	Stop	LAeq	LA90	LA10	LAmax	Wind dir.	Wind speed	Temp.	Rain etc.	Comment, acoustic features etc (k)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Name:	Signed:	Date:

Notes:
The barometric pressure may be obtained from the nearest met. station, allowing for any difference in altitude.
An anemometer should be used to measure wind speed, but the table below may be used as a guide for informal measurements. However, a compass should be used to assess the direction.

Force	Description	Conditions	Min MPH	Max MPH	Min kmh^{-1}	Max kmh^{-1}	Min ms^{-1}	Max ms^{-1}
0	Calm	Smoke rises vertically	0	1	0	2	0	0
1	Light air	Smoke drifts	1	3	2	5	0	1
2	Slight breeze	Leaves rustle; vane moved by wind	4	7	6	11	2	3
3	Gentle breeze	Leaves in constant motion; light flag extended	8	12	13	19	4	5
4	Moderate breeze	Raises dust and loose paper; small branches move	13	18	21	29	6	8
5	Fresh breeze	Small trees sway; crested wavelets on inland water	19	24	31	39	8	11

Table A3.4 — Noise Measurement Reporting Form — Sheet 3 — 1/3rd Octave data

Permit number	
Date	

Centre frequency	1	2	3	4	5	6	7	8	9	10
dBA										
dBLin										
16										
20										
25										
31.5										
40										
50										
63										
80										
100										
125										
160										
200										
250										
315										
400										
500										
630										
800										
1										
1.25										
1.6										
2										
2.5										
3.15										
4										
5										
6.3										
8										
10										
12.5										
16										
20										

Name:		Signed:	

Appendix 4 — Noise Management Plan

This appendix should be read and interpreted in conjunction with the information on application requirements given in Section 2.9 of the General Sector Guidance (Reference 17) or the appropriate Sector Guidance.

This appendix provides an outline of a noise management plan – and the supplementary information that may be requested by the Regulator to augment this. It can be adapted for use in specific circumstances as a Regulatory and operational tool. Some sections may be excluded and others expanded, depending on the specific issues that need to be covered. However, a noise management plan and supplementary information will only normally be required - *where the degree of risk justifies its use* to control noise emissions. In the majority of cases it is anticipated that conditions will be sufficient.

The aim of the plan is to consolidate the noise issues on a site to assist the Operator in complying with Permit conditions and to assist the Regulator in enforcement and complaint responses. A well-prepared plan can save time for both the Regulator and the Operator when responding to problems and can help to ensure a prompt remedy to noise problems. In addition, the use of a comprehensive noise management plan is good practice for any Operator who has noise problems or could give reasonable cause for annoyance at sensitive receptors.

Who writes the plan, and when is this done?

Where there are known noise problems associated with an installation, the Operator would normally be asked to submit the supplementary information as part of his application. During the pre-application discussions with the Operator, the need for this would be identified and the Operator would be expected to discuss the responses/actions with the Regulator prior to submission. Effective liaison and exchange of information with the local authority will be important at this time, as described in Part 1 of this document (Reference 1). During the determination process, any additional comments from the public consultation process can be incorporated. The finalised plan is developed, with actions and outcomes agreed between the Operator and Regulator. This then forms the basis of ongoing control of noise and elements should be incorporated into on-site procedures as appropriate, or into an environmental management system.

What is the status of a noise management plan?

Since the need to provide supplementary information will either be identified in pre-application discussions, or will be required by the Regulator as additional information by means of a Schedule 4 Notice, the draft plan may form part of the application and therefore forms a part of the Permit. As it forms part of the application, it will appear on the public registers.

How can the plan be amended?

Changes to the agreed plan should be discussed with the Regulator and, where changes have been agreed, the plan will have to be varied according to the normal procedure. Changing the plan would not of itself constitute a substantial change, but the actions leading to the need for change (for example, the addition of new plant or modification to existing plant) resulting in an increase in noise emissions, may constitute a substantial change. The description of substantial change can be found in the document *Environment Agency IPPC Regulatory Guidance Series, No. 1, Determining "Substantial Change" Under IPPC* (Reference 23) or the Scottish Executive/SEPA document *The Pollution Prevention and Control (Scotland) Regulations 2000 a practical guide*.

Compliance with a noise management plan

The Operator is expected to follow the agreed plan and to update it, as appropriate, in consultation with the Regulator. Failure to follow the outcomes or actions identified, which then becomes manifest as a breach of a noise condition or as an inspection failure (for example, failure to keep the appropriate records, failure to keep to maintenance schedules and the like), would in itself be a breach of the requirement to maintain and follow the agreed plan.

The noise management plan template on the following pages includes some of the information required to be submitted as part of the application, however Operators may also find it useful in assisting to direct or prioritise activities relating to noise control. The information in Table 2.9.3 is only *required* for complex and/or high noise–risk installations.

Noise Management Plan – to be read in conjunction with Sec 2.9 of the General Sector Guidance or the appropriate Sector Guidance

The level of detail given should correspond to the risk of giving *reasonable cause for annoyance* at sensitive receptors.

Table 2.9.1 Receptors (scaled maps and site plans should be provided as appropriate to show relative locations of receptors, sources and monitoring points)

Receptor	Receptor reference	Distance to installation boundary/sources	Background noise level at each receptor		Specific noise level at each receptor when installation is operating	
Type, extent, size			Day time	Night time	Day time	Night time

Table 2.9.2 Noise sources (Information relating to individual sources and emissions)

Identify sources of noise and/or vibration	Source reference	Describe the nature of the noise or vibration	Contribution to overall emission
List each source considered to be insignificant – by process or activity if divided in this way. Mobile sources should also be identified with their areas of use		Include hours of operation for non-continuous, infrequent or seasonal activities. Note any distinctive characteristics e.g., clatter, whine, hiss, screech, hum, bangs, clicks, thumps or tonal elements	This relates to the relative risk associated with each source in terms of impact at sensitive receptors. Categorise each as high or medium.

Table 2.9.3 Demonstration of BAT

Source reference	Are abatement and actions taken to prevent or minimise emissions BAT?	Actions to be taken to meet BAT and timescales
	Demonstrate that arrangements are BAT for the installation (see sector guidance and H3 for indicative BAT requirements)	Identify proposals for improvement or issues that need to be addressed to meet BAT, with time scales for implementation

Table 2.9.4 Supplementary information required for complex and/or high–risk installations

This is an additional requirement which *should be submitted only where its need is identified in discussions with the Regulator*.
It may also be useful to any Operator who has noise problems or could cause noise and/or vibration-related annoyance in assisting to direct or prioritise activities.

Source	Potential failure scenarios	What measures have been put into place to prevent the failure or to reduce the impact?	What is the environmental impact/outcome if there is a failure?	What actions are taken if this occurs and who is responsible?
	Consider all reasonably foreseeable scenarios that could increase noise to a level where it could affect sensitive receptors or lead to non-compliance with a Permit condition	For example, closing doors, visual inspections, routine maintenance through to withdrawing machinery from service or stopping the activity altogether	Include likely duration, noise level or increase in noise level (at source or receptor) and any characteristics. If immediate action cannot be taken the reasons should be noted. Where complaints are likely it should be agreed with the Regulator.	For example, the requirement to contact the Regulator should an event occur , or internal actions such as reporting requirements, verbal or written, dealing with complaints etc.

Any other relevant information not specifically detailed above could be given or referenced here e.g. monitoring schedules, alarm-testing arrangements, maintenance procedures etc.

Maintenance of the logs/records is normally expected:

- **Log of processes and checks carried out to minimise noise emission from normal operations**
  This includes planned maintenance, visual inspections and checks.

- **Log of processes and checks carried out to minimise noise emission from failures and other factors**
  This includes reactive maintenance where required to address increased noise or vibration emissions, replacement of equipment and the like.

- **Log of monitoring and compliance checks undertaken**
  Note: The operational log should normally be completed within 14 days of taking the measurements or actions.
  All sound level monitoring to be undertaken and reported in accordance with the relevant British Standard.

Appendix 5 — noise control equipment and techniques

Sheet 1 — Acoustic enclosures

Picture used with the permission of Industrial Acoustics Ltd

Acoustic enclosures form a complete box around a piece of equipment and include acoustics doors, windows and attenuated ventilation or cooling systems.

Description

Where equipment can operate in a confined space it can be completely enclosed by high performance metal acoustic panels. Doors, windows and other openings require special attention and proprietary enclosures ensure optimal design. Openings to provide adequate air flow for cooling are usually the acoustically weak points and high performance attenuators are required.

Vibration isolation is usually required between the equipment and the floor.

Application

Generators, compressors, pumps, process equipment requiring substantial attenuation but minimal access and maintenance.

Performance

Around 20 dBA limited mainly by silencing of openings and doors.

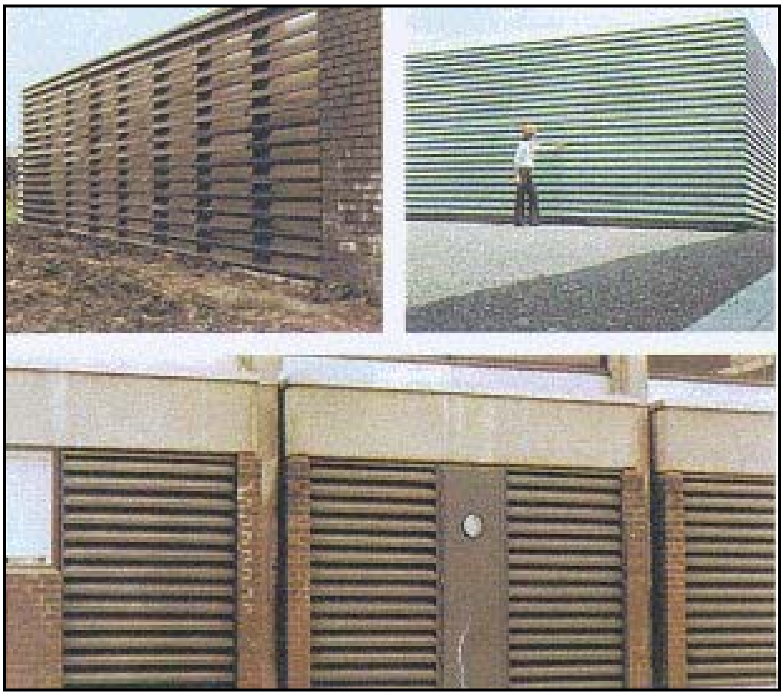
Cost

Enclosures with surface areas of 30 m^2, installed with attenuators:

20 dB - £3,000 to £7,000

Sheet 2 - Acoustic louvres

Acoustic Louvres are similar to weather louvres but have sound absorbent material often on the underside behind a perforated sheet. And they provide additional attenuation of noise that passes through them.



Description

Acoustic Louvres can be used to replace weather louvres in building openings to reduce noise transfer to outside. Alternatively free-standing acoustic louvres can be placed around external equipment that requires air flow for cooling. Air is allowed to flow between the louvre blades, but noise is attenuated by absorptive material within each blade.

Acoustic louvres can produce high pressure drops to the air flowing through them which may create heat load problems to the plant.

Application

Chillers, compressors, pumps, heat pumps, other external equipment requiring air flow.

Performance

Low frequency performance is limited. The noise path over the top of a louvre screen will usually limit performance to up to about 10 dBA.

Cost

Single acoustic louvres - £300 / m^2
Back to back louvres - £400 / m^2

Sheet 3 - Noise barriers

Acoustic barriers are solid structures located close to equipment to provide acoustic screening between source and receiver.

Picture used with the permission of Industrial Acoustics Ltd

Description

Noise barriers can be made from acoustic panels, but usually brick/ block walls or solid wooden fences are adequate unless reverberation behind the barrier is a concern. Barriers require a minimum surface density of around 7kg m^{-2} so that noise passing through the barrier is attenuated to below that passing over the top. Barriers are most effective when located close to the noise source and can be painted or landscaped to minimise visual impact. Transparent materials have also been used. Earth bunds can be effective barriers, trees cannot. Barriers must be solid without any holes or openings.

Application

Most noise sources close to the ground.

Performance

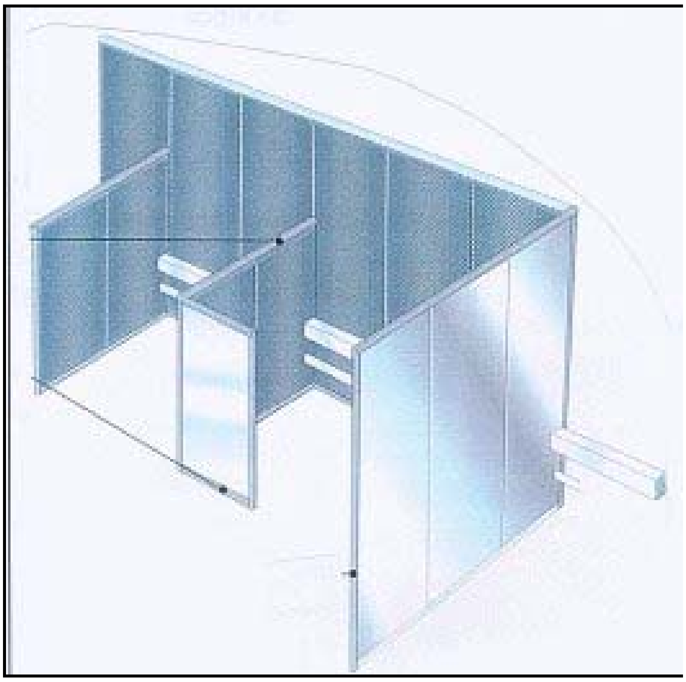
Performance increases with the difference between the direct path (through the barrier) and diffracted noise path over the top edge of the barrier. When the line of sight from noise source to the receiver is just broken there is a 5 dBA attenuation and when the source is completely hidden from view this rises to 10 dBA. Up to 15 dBA can be achieved with very large barriers and is rarely practicable, unless it is shielding afforded by a building.

Cost

Noise barrier fences 2 m high cost from around £160 per linear meter, but can be considerably more expensive if they are tall or made from superior materials.

Sheet 4 — Acoustic panelling

There are many types of acoustic panels, but most are designed to absorb sound incident from one side.



Description

Acoustic panels are generally 40–200mm thick and are made from a sandwich of coated steel sheets, with a mineral fibre in-fill. On one side of the panel, the metal sheet is perforated to allow sound to pass inside, where it is absorbed by the in-fill material. Acoustic panels can be designed to offer very high attenuation to noise transmission that is better than an equivalent solid structure of the same weight. Also, their absorptive properties are used to control reverberation in confined spaces.

Application

Acoustic panels are the building blocks of many acoustic products. Used alone, they can replace conventional walls or partitions, or they can be used to line plant rooms within existing structures.

Performance

Attenuation to sound transmission can be up to about 10–20 dBA.

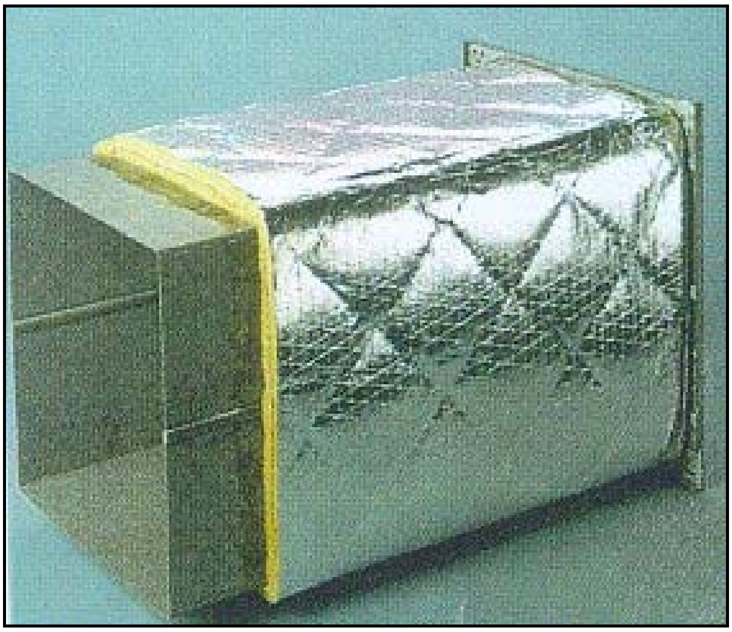
Absorption can be more than 90 per cent at middle and high frequencies.

Cost

Acoustic panels need not be expensive, but prices increase if attractive finishes are required. £100-150 / m^2

Sheet 5 — Acoustic lagging

A flexible material wrapped around noise sources in the same way as thermal lagging.



Description

Acoustic lagging is generally made of a laminated quilt comprising a tough outer skin, mineral fibre quilting and a heavy (often lead) internal layer providing mass. Such lagging is flexible and can be fitted around complex shapes and is ideal for sealing holes and gaps around solid acoustic elements. A similar product can be hung as acoustic curtain around plant that is moved frequently or in very confined spaces.

Application

Lagging to pipes and ducts. Sealing around most acoustic installations.

Acoustic curtain for pumps, fans, hand tools and the like.

Performance

10 – 15 dBA

Cost

Relatively expensive per unit area, but generally used in small quantities. £15-30 per m^2

Sheet 6 — Vibration damping

Damping materials applied as an adhesive, flexible “putty” or sheeting to vibrating metal sheeting.

Description

Metal sheeting has a tendency to “ring” when vibrated by heavy machinery. Large, unsupported areas of metal can be very efficient at converting vibrational energy into audible frequencies and radiating noise, rather like a loud speaker cone. Casings and guards can be damped using various damping or “anti-drumming” compounds.

Application

Casings and guards to most machinery, for example, conveyors, pumps. Rotating parts.

Performance

Performance varies, but 10 dBA is achievable. Damping of machinery casing is most effective on large areas of thin gauge metal.

Cost

Variable depending on product.

Sheet 7 — Impact deadening

Noise generated by impacts on metal surfaces, such as loading material into dump trucks, can be reduced by applying a resilient surface treatment.

Description

Deadening materials can be useful on metal floors, chutes or containers, but there are practical problems with wear and tear. For metal floors, blended resin compounds have been developed that damp noise generated by trolley wheels and foot falls whilst offering adequate grip, strength and weatherproofing. Metal chutes and lorry holds can be surfaced with abrasion-resistant rubber to reduce noise generated by material impacts. Resilient materials can also be used to help reduce noise generated by inherently noisy material, such as barrels, scrap metal and pipes.

Application

Metal floors or wall coverings in warehouses or industrial stores.

Lorries, metal chutes, hoppers.

Performance

Impact noise can be reduced by 10 dBA or more.

Cost

Metal floor treatment — approximately £66 per m^2.

20 tonne dump truck — £26,000.

Sheet 8 — Attenuators

Attenuators are designed to allow air to flow between a series of *splitters,* which absorb noise. They come in all shapes and sizes.

Description

Attenuators can be part of a ducted air–flow system or can be inserted in a wall, partition or enclosure opening. Several splitters divide the air flow. Splitters comprise perforated metal or rigid mesh enclosing an acoustic in-fill, which is generally some form of mineral fibre. Problems include degradation of the in-fill material and pressure loss (energy consumption) due to restricting the air–flow. Excessive air flow speed can regenerate noise. These problems do not prevent attenuators being very widely used in industry.

Application

Standard attenuators: heating, ventilation and air–conditioning systems, fans.

Specialist attenuators: as used on motor vehicles, modified materials allow high temperature and corrosive gas discharges to be silenced.

Performance

Performance is a function of attenuator length and the ratio of the cross-sectional areas of the splitters and the whole attenuator. Up to 20 dBA.

Cost

Approximately £250-400 /m^3.
Specialist applications can be very expensive.

Sheet 9 — Steam and air diffusers

Metal fittings attached to the outlets of high–pressure steam or air discharge

Description

Steam traps and compressed air valves, used in petrochemical, food and other process plants to release excessive pressure, generate noise because of the high pressure and velocity of the discharge. The discharge flow can be passed through a diffuser of enlarged diameter filled with a flow–resistant material such as stainless steel wool to slow down the gas speed, thus reducing noise generation.

Application

Steam and high–pressure air system discharges.

Performance

Performance is best at mid to high frequencies and typically gives up to about 15 dBA.

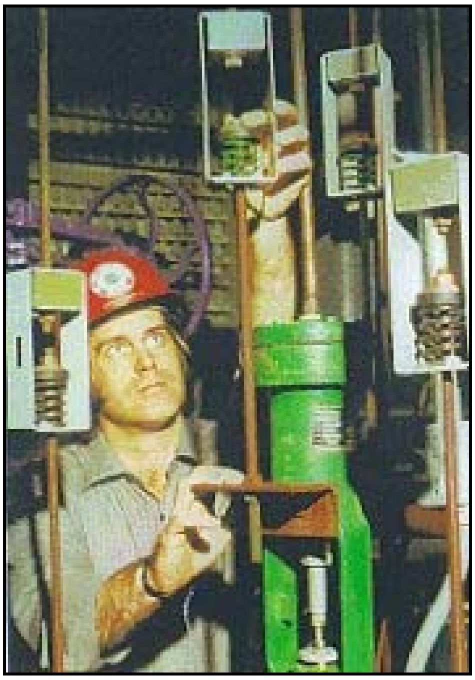
Cost

Simple steam trap diffuser — approximately £20 each.

Specialist compressed air attenuators can be expensive.

Sheet 10 — Vibration isolation mounts

Spring or rubber mounts located between vibrating plant and their supporting structure reduce the transfer of vibrational energy into the structure where it may be transferred and re-radiate as unwanted noise.



Description

Stiff springs or low–compliance rubber/neoprene pads are housed in metal retaining fittings, forming a mount or hanger to which the plant is bolted. The mount is designed to be deflected under static load and to absorb the predominant frequencies at which the plant oscillates. In practice, this means selecting a mount that has a natural frequency is well below the driving frequencies in the plant. Poor installation can lead to flanking paths, poor performance or amplification.

Application

Vibration isolation mounts can be fitted to most mechanical equipment, including pumps, fans, generators, compressors, and also to pipes and ductwork.

Performance

Vibration isolation can be almost complete for correctly selected mounts. Installation is harder for large, heavy plant and performance can be compromised at lower frequencies. Noise–reduction performance will depend on the surrounding structure and its noise transfer and radiation characteristics.

Cost

Modest costs for simple installations requiring typically 4 – 10 mounts, depending on loading and support requirements.