

THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

# **A Guide to the use of *EEMUA 140 Noise procedure Specification***

**PUBLICATION 141**

**Edition 3**



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## ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

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## Preface

This Guide is intended to facilitate the use of EEMUA Publication 140: Noise procedure Specification.

All mandatory requirements are included in the Specification document and this Guide is purely illustrative. The Guide is based on the experience of the plant operating companies of the EEMUA membership and although requirements and procedures will vary from plant to plant, the material in this Guide should prove helpful in any case where noise limits have to be set and complied with in the petroleum, petrochemical, power generation and allied industries.

The Guide is in three parts:

### Part 1: Selection of noise limits

This is intended primarily for the Principal<sup>1</sup>, to give guidance in the selection of noise limits appropriate to any particular locality or requirement. It may be of some value to the Contractor<sup>2</sup> in giving an explanation of how the noise limits set for a particular contract are derived.

### Part 2: Measuring noise from equipment

Specification EEMUA 140 contains a number of procedures for measuring the sound power levels of equipment and this part gives a general description of how to apply them. It is intended to give guidance to the contractor for ordering equipment and to the equipment vendor<sup>3</sup> for providing suitable information on his equipment.

This edition also recognises the recent advances made in sound power determination using the sound intensity method. The International Organization for Standardization (ISO) has recognised the complementary role of this technique to the more traditional procedures based on sound pressure measurement. A description of this is provided.

### Part 3: Noise control in plant design

This is intended to be of value to both the principal and the contractor on a project in assisting common understanding in the interpretation and application of the Noise Procedure Specification EEMUA 140 and the noise limits set for the particular project. It gives guidance on the collection and handling of noise data and presents a logical procedure to be followed in design. It includes examples of steps which have to be taken with typical items of plant and draws attention to many points which will have to be considered in any plant design. It is not a complete textbook of acoustic design but is a guide to the application of standard acoustic concepts and techniques.

---

<sup>1</sup> The Principal is defined as that party responsible for placing the order for a plant

<sup>2</sup> The Contractor is defined as the party which carried out the design, engineering, procurement, construction and commissioning of a plant on an order from the Principal

<sup>3</sup> The Equipment Vendor is defined as the party which manufactures or supplies equipment to perform the duties specified by the Contractor



# 1 Selection of noise limits

## 1.1 Introduction

EEMUA Publication 140 is purely a procedural Specification as its title implies. It does not set noise limits because the acceptable limit for any location will depend on factors relevant both to that location and the intended use of the machinery. From the Principal's point of view, rather than create blanket noise limits for classes of equipment, the specification should be driven by the noise level experienced by the recipient. The Principal's aim is not to reduce equipment noise to minimal levels but to reduce it to an acceptable standard<sup>4</sup>. For neighbourhood noise the acceptable level depends on the locality; for work area noise and accommodation noise it will also depend on exposure patterns and on the health and welfare practices of the employer.

This Guide is intended to assist in the selection of noise limits appropriate to the situations most likely to be encountered in the petroleum, petrochemical, power generation and allied industries. It gives a brief presentation of the principal conclusions which may be drawn from the literature, legislation, and from the practices and experience of EEMUA members.

## 1.2 The selection of limits

### 1.2.1 General

It is impossible to define the correct limit with complete confidence and precision; the best one can do is to review available data and evidence and then choose a limit which appears to suit the situation and satisfies statutory or local authority requirements. In some countries (for example, the UK) it may be possible to negotiate an acceptable limit for neighbourhood noise with the local authority; but in others the local authority imposes a limit which is not subject to negotiation.

The selection of noise limits for a neighbourhood area must be based on statistical evidence. The subjective response of people to noise varies widely and there is a considerable difference between the noise level which will arouse general hostility and that which everyone will accept in any particular locality. The level of complete acceptance will itself be particularly variable, since it is determined by only one person in any case. In addition, the noise level which generates hostility or which is accepted can be expected to vary with the nature of the locality. When considering hearing-damage risk, it is found that physiological response to noise is widely variable between different people, so it is impossible to forecast the precise effect that any particular noise exposure pattern will have on the hearing of a particular person.

The correctness of a noise limit, therefore, cannot always be precisely evaluated, even in retrospect. If an unacceptable number of complaints is received from the public or an unacceptable degree of hearing loss among employees is found to occur, the noise limit set was too high; but if there is no such result the limit may have been correct or even too low. If it was too low, some or all of the money spent on noise control was wasted.

---

<sup>4</sup> EEMUA recommends the UK threshold for requiring hearing protection (80dB) as a sensible level to aim for with the understanding that depending on the machinery, this may not always be reasonable or even practical.

There is extensive literature on the subject and several standards, or proposed standards, have been produced. At first sight the literature is highly conflicting, but within reasonable bands of tolerance a fair amount of agreement emerges. Although it is impossible to set limits which are unarguably precise and correct, one can use the available data and evidence to set limits which will probably prove satisfactory in any particular situation.

### 1.2.2 Legal requirements

The recommendations given in this Guide are considered to be the best that can be made in the context of existing law in the United Kingdom and take into account the latest (2013) published technical information. In other countries the same recommendations may be generally appropriate, modified as necessary by such legal limits as may apply locally.

In the UK there are several legislative documents relating to industrial noise; they deal with both neighbourhood noise and work-area noise. The major legislative instruments for neighbourhood noise are:

- Part III of the Environmental Protection Act 1990<sup>(1)</sup>, as amended by the Noise and Statutory Nuisance Act 1993<sup>(2)</sup>, which requires local authorities to serve abatement notices where the noise emitted from any premises, or from vehicles, machinery and equipment in the street, constitutes a statutory nuisance.
- Part III of the Control of Pollution Act 1974<sup>(3)</sup>, which gives local authorities powers to control noise from construction sites, and also introduced the concept of the Noise Abatement Zone (NAZ).
- Statutory Instruments 1976 No.37, The Control of Noise (Measurements and Registers) Regulations 1976<sup>(4)</sup>.
- Statutory Instrument 2005 No. 1643, The Control of Noise at Work Regulations 2005<sup>(5)</sup> which is used by environmental health officers and inspectors of the Health and Safety Executive (HSE) to control work area noise.

No quantitative statutory limits are set for neighbourhood noise, although boundary noise limits are often set as a condition of planning consent for new works. These limits may include restrictions on construction noise in addition to noise from works in operation. To assist control bodies set neighbourhood-noise limits and monitor them, several additional documents exist <sup>(6),(7),(8)</sup>. Quantitative neighbourhood noise limits can, however, be imposed for both new and existing plants outside the umbrella of planning consents by the imposition of noise abatement zones at the discretion of control bodies.

The legal limits on the levels of noise to which workers may be exposed, which take into account the effect of wearing hearing protection, must not exceed:- 87dB(A) for daily or weekly personal noise exposure ( $L_{EP,d}$  or  $L_{EP,w}$ ); and 140dB(C) for peak sound pressure ( $L_{Cpeak}$ ).

The Noise at Work Regulations also apply to offshore installations and were implemented in February 1998 under Statutory Instruments 1997 No. 1993 The Offshore Electricity and Noise Regulations 1997<sup>(9)</sup>.

### 1.2.3 Specifying noise limits: sound levels and octave-band levels

Noise limits may be expressed as sound-pressure levels in octave bands or in overall dB(A) sound levels (Note that it is now standard practice to use the term 'sound-level' for A-weighted sound-pressure levels and this terminology is used throughout this Specification and EEMUA 140). The dB(A) figure is used both for neighbourhood noise and work-area noise in accordance with ISO, BSI, and UK Government standards.

Neighbourhood noise limits should be based on background-noise measurements at the site; if these are not available a notional background level may be derived, depending on the environment of the site. Measurements of background noise are therefore frequently made only in dB(A), but it is recommended that octave-band levels should also be measured and the noise limits for the plant should be based on them and quoted in octave bands. It is particularly important to use octave-band limits when the plant is known to emit noise in the 31.5 Hz octave band because a noise limit derived from a dB(A) value, using an A-weighting curve, can give a noise level in this band which may cause a nuisance in the neighbourhood (see Section 1.3.4.2(v)).

Whether the plant noise limits are set in dB(A) or not, it is necessary to work in octave-band levels for design purposes because the acoustic properties of materials and the attenuation of sound with distance are frequency dependent, so all noise test data must be recorded in octave bands. Also, when designing for noise control it is convenient to use octave-band values as design limits rather than dB(A) values because this assists identification of the controlling frequencies or controlling noise sources in a complex plant.

If the overall limit is set in dB(A) this should be converted to an octave-band spectrum before design work is commenced. All calculations can be made in octave bands, and the final octave-band levels can then be recombined to compare with the overall limit set (If the overall limit is set in octave bands anyway, this conversion is not necessary). The eight octave bands 63 Hz to 8 kHz are adequate for most oil industry applications although it may be desirable to use the 31.5 Hz octave band when there are any major combustion-noise sources present, such as gas turbines, fired heaters, low-speed internal-combustion engines, and ground flares.

Noise Rating (NR) curves, e.g. Noise and Vibration - Offshore Technology Report 2001/068<sup>(10)</sup>, are sometimes used to derive plant-noise limits in octave bands. The usual practice is to take the octave-band levels of the Noise-Rating curve which is numerically 5 below the dB(A) value; for example, the octave band levels of NR 50 would be used to represent 55dB(A). However, with the increased use of dB(A), an octave band spectrum based on the A-weighting curve should preferably be used. The overall dB(A) level of an eight-octave spectrum which precisely matches such a curve is 9dB above the 1 kHz band level. In practice, however, a plant-noise spectrum will never precisely match the A-weighting curve and if a curve is selected such that the plant-noise spectrum just touches it in any band, then the plant-noise level in dB(A) is likely to be numerically about 5 higher than the 1 kHz level of this curve<sup>(10)</sup>.

Thus there are two methods for converting a limit in dB(A) to an octave-band spectrum limit for use in this Specification:

- i. select the NR curve numbered 5 less than the dB(A) limit; or
- ii. derive a spectrum based on the A-weighting curve which has a 1 kHz level 5 less than the dB(A) limit (the A-weighting in each octave-band can be added to the 1 kHz level to derive the curve).

Either method is valid but the A-weighting spectrum is recommended for future use. To illustrate the application of these methods, Table 1 below shows the octave-band values obtained by each of them to meet a limit of 55dB(A).

**Table 1 Octave-band limits to give approximately 55dB(A)**

| Octave band, Hz    | 31.5 | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
|--------------------|------|----|-----|-----|-----|----|----|----|----|
| NR spectrum, dB    | (85) | 75 | 66  | 59  | 54  | 50 | 47 | 45 | 44 |
| dB(A) spectrum, dB | 89   | 76 | 66  | 59  | 53  | 50 | 49 | 49 | 51 |

It must be recognized that the values given in Table 1 are not precise equivalents, but are octave-band limits, which if just met, may be expected to give an overall level of about 55dB(A). The precise dB(A) equivalent of any particular noise must be calculated by the following method:

- i. Apply the A-weighting shown in Table 2 below to each octave level

**Table 2 A-scale weighting in octave bands**

| Octave band, Hz | 31.5 | 63  | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
|-----------------|------|-----|-----|-----|-----|----|----|----|----|
| A-weighting, dB | -39  | -26 | -16 | -9  | -3  | 0  | +1 | +1 | -1 |

- ii. Add the eight (or nine where appropriate) octave-band levels:

- (a) one by one, using Figure 7 of EEMUA 140 or
- (b) by using the formula

$$L_A = 10 \log \left( \text{antilog} \frac{L_{1A}}{10} + \dots \text{antilog} \frac{L_{9A}}{10} \right)$$

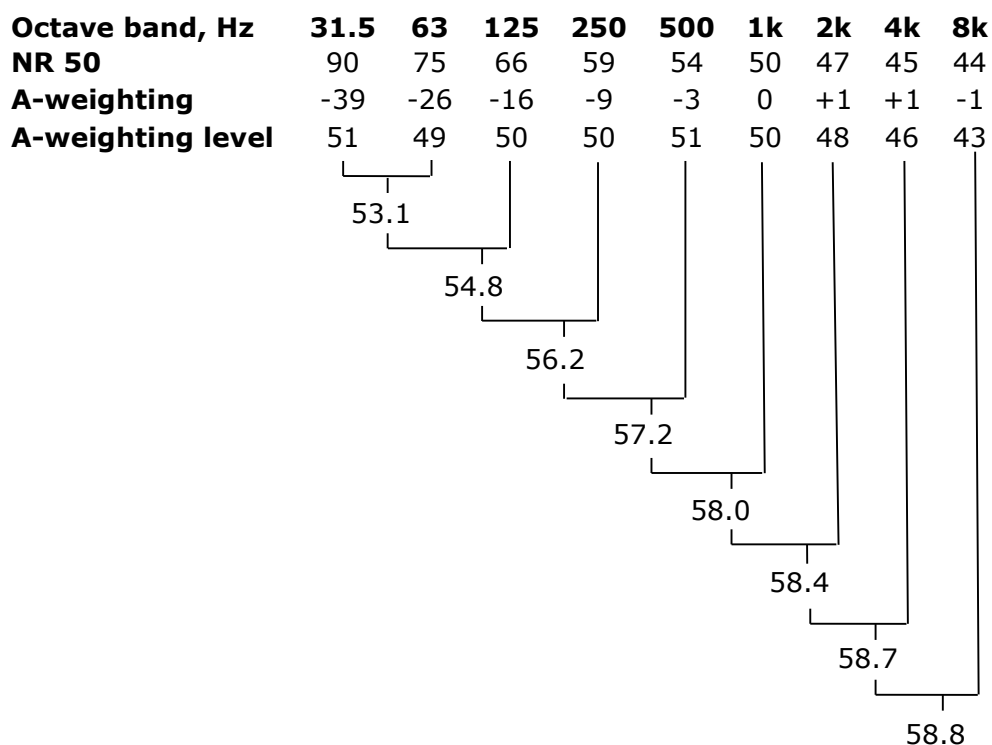
where

$L_A$  is the overall sound level in dB(A)

$L_{1A}$  is the A-weighted sound level in the first octave band etc.

- (c) by using intensity levels as set out in various standard texts.

For example, using the first method, calculate the dB(A) level corresponding to the octave-band spectrum of NR 50.



Thus a noise spectrum which matches NR 50 in all octave bands would be equivalent to 59dB(A). In practice such a spectrum rarely occurs and the average difference is usually 5.

For convenience, the octave-band levels appropriate for use with some typical overall dB(A) levels are given in Table 3.

**Table 3 Octave-band equivalents to sound levels in dB(A)**

| Overall limit, dB(A) | Octave band, Hz |     |     |     |     |    |    |    |    |
|----------------------|-----------------|-----|-----|-----|-----|----|----|----|----|
|                      | 31.5            | 63  | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
| <b>90</b>            | 124             | 111 | 101 | 94  | 88  | 85 | 84 | 84 | 86 |
| <b>65</b>            | 99              | 86  | 76  | 69  | 63  | 60 | 59 | 59 | 61 |
| <b>60</b>            | 94              | 81  | 71  | 64  | 58  | 55 | 54 | 54 | 56 |
| <b>55</b>            | 89              | 76  | 66  | 59  | 53  | 50 | 49 | 49 | 51 |
| <b>50</b>            | 84              | 71  | 61  | 54  | 48  | 45 | 44 | 44 | 46 |
| <b>45</b>            | 79              | 66  | 56  | 49  | 43  | 40 | 39 | 39 | 41 |
| <b>40</b>            | 74              | 61  | 51  | 44  | 38  | 35 | 34 | 34 | 36 |
| <b>35</b>            | 69              | 56  | 46  | 39  | 33  | 30 | 29 | 29 | 31 |

## 1.3 The use of noise limits in the EEMUA Specification

### 1.3.1 General

This Section of the Guide gives more detailed information and recommendations on the selection of noise limits for the various classes of noise encountered on

typical oil industry plant. It is intended to amplify Chapter 5 of EEMUA Publication 140 and assist completion of the data sheets in Appendix D.

### 1.3.2 Hearing conservation noise limits

#### 1.3.2.1 Legal noise limits in the UK

The Control of Noise at Work Regulations 2005, Statutory Instruments 2005 No. 1643<sup>(5)</sup> sets legal limits on the levels of noise to which employees may be exposed. These take into account the effect of wearing hearing protection, and must not exceed:-

- 87dB(A) for daily or weekly personal noise exposure ( $L_{EP,d}$  or  $L_{EP,w}$ );
- 140dB(C) for peak sound pressure ( $L_{Cpeak}$ ).

A "daily personal noise exposure" means the level of daily personal noise exposure of an employee taking account of the level of noise and the duration of exposure and covering all noise including any exposure to peak sound pressures.

#### 1.3.2.2 General work area noise limits

These are defined by the lower and upper exposure action levels of 80dB(A) to 85dB(A) for a daily or weekly personal noise exposure<sup>(5)</sup>. Despite the adoption of exposure action levels it is not possible to determine whether or not exposure at these levels will in practice result in any hearing loss.

It is not possible to define precisely the degree of hearing damage which is 'significant'; this is essentially an arbitrary decision. Standards for hearing conservation are generally based on the assumption that hearing loss at frequencies higher than the range required for understanding speech is not significant, and that noise induced loss at lower frequencies will not occur in isolation.

Prior to 2013, a difference of opinion existed as to the precise frequency range which was considered and what represented 'significant' loss. This was resolved with the withdrawal of BS 5330:1976<sup>(11)</sup>. The international Standard ISO 1999:2013<sup>(12)</sup> is now the accepted method.

The UK Health and Safety Executive Research Report<sup>(13)</sup> reviews and compares these standards. Analysis of data presented in both standards show the desirability of reducing noise exposure to an equivalent continuous noise level 85dB(A), for an 8-hour exposure, but diminishing returns set in rapidly below this level. Noise below about an equivalent continuous-noise level 80dB(A) entails negligible risk over and above the ravages of time and the auditory hazards of normal life. It must be recognized, therefore, that noise exposure between the lower and upper exposure action values of 80dB(A) to 85dB(A)<sup>(5)</sup> are not necessarily safe levels but merely a compromise between reasonable practice and an acceptable risk.

Thus it is clear that routine audiometry is a necessary part of any hearing conservation programme, so that the more sensitive people can be identified and protected at an early stage. If such a programme is used, then an exposure limit of 85dB(A) represents acceptable risk. But where routine audiometry is not used, a lower exposure limit of 80dB(A) would be a preferable target.

If a plant is successfully designed so that it nowhere exceeds 85dB(A), the work patterns in the oil industry are likely to result in a daily or weekly personnel exposure of less than 85dB(A). However, to achieve such a successful design some allowance must be made in the selection of design limits to take into account errors in design (due to inadequate data, for example) and the subsequent deterioration of equipment.

For design purposes the selected plant limit should be converted to an octave band spectrum by one of the methods outlined in Section 1.2.3.

### **1.3.2.3 Use of hearing protection**

The UK Statutory Instruments 2005 No 1643<sup>(5)</sup> states that a person who is likely to be exposed to noise at or above a lower exposure action value has the right to request personal hearing protectors. If it is not possible to reduce the levels of noise by other means to below an upper exposure action value, personal hearing protectors must be provided and worn.

### **1.3.2.4 Restricted areas**

Hearing damage risk is a function of noise level and duration of exposure. It can be argued that there is some merit in taking advantage of this fact and permitting a higher noise level in areas where people will work for only short periods.

The UK Statutory Instruments 2005 No 1643<sup>(5)</sup> states that if any person is likely to be exposed to noise at or above an upper exposure action value for any reason, then

- i. the area is designated a Hearing Protection Zone;
- ii. the area is demarcated and identified by means of the sign specified for the purpose of indicating that ear protection must be worn;
- iii. access to the area is restricted where this is practicable and the risk from exposure justifies it;
- iv. so far as is reasonably practicable, precautions are needed to ensure that no person enters that area unless that person is wearing personal hearing protectors.

The experience of some companies is that if it is worth reducing work-area noise at all then it is worth reducing it to the unrestricted exposure limit.

Where the reduction of work-area noise is not practical, other hearing conservation measures should be taken, such as the mandatory wearing of personal hearing protection.

It must be appreciated, however, that the acoustic performance of personal hearing protection is limited, particularly at low frequencies, and may not guarantee a personal exposure of less than 85dB(A) at the ear. In this case there is no option but to limit the time of access to the area. Hearing protection should be carefully chosen to be adequate for the spectrum and level of the noise.

### 1.3.2.5 Narrow-band noise in work areas

The extent of hearing damage caused by narrow-band noise is not well established although recent studies<sup>(14)</sup> suggest that damage occurs in different areas to that encountered by exposure to white noise, and multi-frequency noise encountered under most industrial circumstances. The extent of the damage depends on the frequency of the noise and increases with intensity at the centre frequency.

There is a case for reducing narrow-band noise in work areas because of its annoyance to personnel and reduction in work efficiency. Two approaches are possible for suppressing narrow-band noise:

- *To use any available broad band noise to mask the narrow band noise.*

The degree by which the narrow-band noise needs to be suppressed depends on frequency because the perceptibility of narrow bands against masking noise varies with frequency. It also depends on the bandwidth of the narrow band component, but for design purposes it is convenient to consider the narrow-band component as a pure tone. This represents the worst case - although not an infrequent one - and so may involve some overdesign. But any rigorous treatment requires the use of narrow-band analysis and a more complicated calculation procedure.

Where masking noise is used for suppressing narrow-band noise it should be noted that the reductions recommended in Table 4 for work area noise differ from those for neighbourhood noise given in Table 6. The neighbourhood values are considered to be unnecessarily severe for work-area noise, where the objective is to avoid the prominence of narrow-band noise rather than to obtain complete inaudibility.

The sound-pressure level from a noise source containing a narrow-band component should therefore be suppressed in accordance with one of the following options:

- **New narrow-band noise source added to an existing plant** - In this instance the broad-band noise available for masking can be measured and the noise limits for the narrow band noise source should be suppressed below this broad-band noise in the appropriate frequencies by the amount given in Table 4.
- **New plant - including a known narrow band noise source** - For this case the broad-band noise available from the plant for masking will have to be calculated. The noise limits for the narrow-band noise source should then again be suppressed below this broad-band noise in the appropriate frequencies by the amount given in Table 4.

**Table 4 Suppression of narrow bands in work area noise**

| Octave band, Hz          | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
|--------------------------|----|-----|-----|-----|----|----|----|----|
| Required suppression, dB | 0  | 0   | 0   | 4   | 6  | 7  | 7  | 3  |

- To reduce by a nominal amount the noise limit for the octave bands in which the noise appears.

This is a common approach to the control of interference and hearing damage risk from noise characteristics; the usual recommendation is to reduce the overall noise limit by 5dB(A). However, as it is only that part of the noise containing the characteristic which matters, it is reasonable to reduce the limit only for the octave bands where it appears.

This approach is not to be recommended in general, but it may be necessary to adopt it when there is no masking noise in the vicinity. It will only give a limited alleviation of annoyance to personnel and in some cases a greater reduction may be necessary.

### 1.3.2.6 Impulsive noise in work areas

It is not possible to set precise values for required suppression because, in addition to the variables of pitch and intensity, there is the further variable of intensity-time relationships. It is suggested that for practical purposes a suppression of the impulsive noise component 5dB(A) below the total noise level will probably be adequate.

There are several methods for measuring impulsive noise, but there are inadequate data available on how such measurements could be utilized for the purposes covered by the Specification. In those cases where impulsive noise dominates, e.g. where mechanical handling plant or impact tools are used, the owner may consider it advisable to obtain specialist advice.

### 1.3.2.7 Summary of recommendations for hearing conservation noise limits

Unless the Principal has any reason for choosing other values, it is recommended that the following should be used:

- Absolute limit: 125dB(A) for accessible positions  
120dB(A) for accessible positions near infrequent sources.

*Note: These limits would only be legal within the UK if:- the limiting exposure value of 87dB(A) was not exceeded, there was in place mandatory use of hearing protection and that all the accessible positions were designated as hearing protection zones.*

- General work area: Use 85dB(A) (for design purposes convert to octave-band spectrum based on A-weighting). The determination of exposure values and routine audiometry tests of personnel may be required as this equates to the "upper exposure value".
- Narrow-band noise: preferably suppress narrow-band component below actual broad-band noise level (calculated or measured) by the amounts

given in Table 4; alternatively reduce limit for total noise by 5dB in any octave band containing narrow-band noise.

- Impulsive noise: suppress impulsive noise component 5dB(A) below basic limit.
- Personal hearing protection (by means of ear defenders or ear plugs) must be worn in areas where it is impracticable to meet the general work-area limit<sup>(5)</sup>. Such areas should be kept to a minimum.

### 1.3.3 Speech and work interference noise limits

#### 1.3.3.1 General

It is generally accepted that a noise level up to the general work-area limit will not affect appreciably the performance of simple manual, clerical or technical work, though it may affect the performance of more demanding work. The most evident effect of noise on work is through speech interference, but noise is significant also as a facet of comfortable working conditions.

Selecting speech and work-interference noise limits in all these cases is purely a matter of judgement; there is no clear definition of acceptability of noise level for an office. The recommended limits in Table 5 are considered to be reasonable, and not at all extravagant. In plant control rooms, for example, 55dB(A) might be preferred if a higher standard of comfort is required.

**Table 5 Speech and work-interference noise limits**

| Type of area                                                                                                      | Limit, dB(A) |
|-------------------------------------------------------------------------------------------------------------------|--------------|
| Workshop and machinery buildings where communication is necessary                                                 | 70           |
| Workshop offices, plant offices, plant control rooms, and other areas where telephonic communication is necessary | 55-60        |
| General offices (also plant offices where meetings are held)                                                      | 50           |
| Private offices and small conference rooms                                                                        | 45           |
| Offices and conference rooms where a high standard is required                                                    | 35           |

Comfort as well as ease of communication should be considered, so narrow band and impulsive noise should be allowed for as previously under hearing conservation noise limits.

This is particularly important in offices and conference rooms and of some importance in the other classes.

### 1.3.3 Recommendations for speech and work interference noise limits

- Recommended speech and work-interference noise limits for the various classes of work area are given in Table 5.
- Appropriate corrections should be made, when required, for narrow-band or impulsive noise, using the values recommended in Table 4.

### 1.3.4 Neighbourhood noise limits

#### 1.3.4.1 General

Limits of acceptability for neighbourhood noise cannot be set with the same confidence as limits for work-area noise. Response to such noise is based almost entirely on subjective reaction; that is, annoyance (which cannot be directly measured) rather than hearing damage or masking of speech (which can be measured to a useful degree of accuracy by direct means).

#### 1.3.4.2 Noise limit in dB(A)

It is usually uneconomic to control noise to such a level that no complaints at all may be expected, although very low limits may sometimes be required by planning authorities. More normally the design neighbourhood noise limits are set low enough such that any resentment as may occur is not particularly deep or widespread. This means that complaints may occur from time to time, and it is recommended that a company employee be made responsible for investigating them.

Whichever approach is adopted, for an established site, noise surveys and analysis of complaints (if any) will give useful guidance; for a new site a survey of background noise is recommended. In each case a neighbourhood noise limit can then be derived in dB(A) by applying BS 4142:1997 (although this still leaves a margin of choice due to different interpretations of its recommendations).

The BS method is applicable to any location and the procedures in the standard can be followed to enable the likelihood of complaints concerning noise from an installation to be predicted. It should be noted that the standard does not consider either the level of general community annoyance or the economic aspects of noise control, and several problems arise when applying it:

#### i. Background noise level

BS 4142:1997 recommends the use of the background noise level that is exceeded for 90% of the time period being considered (the 'L<sub>90</sub>') as a criterion against which the plant noise can be judged. This may be inappropriate in areas where the typical background noise level is very low (less than 25dB(A)) or where a new plant is so large as to completely change the character of the area in which it is sited.

Background noise level can also be highly variable from day to day and between night and day, so an indication of the range of levels can only be established after several surveys, arranged to cover a representative number of different time periods and weather conditions.

A further difficulty when considering noise levels from a continuous process plant is that, once the plant has started up, the 'background' noise level may permanently change in the immediate neighbourhood of the plant. The previous background noise level may then have less significance unless a complaint is received as soon as the plant is commissioned.

BS 4142:1997 does allow for an alternative method of deriving a 'notional background' level where it is impractical to do this by measurement; but this method is less reliable where unusually high background levels exist. However, it may, be a better criterion in areas of extremely low background (such as rural areas) where the siting of the plant has been agreed.

It must be recognized that BS 4142:1997 assumes that the measured noise is received from a specific source and this is also implied in legislation which sets noise limits for a particular plant. Such a noise level is sometimes called the 'noise immission' and it should be distinguished from the 'background noise' (which is the noise received from all sources other than the works in question) and the 'ambient noise' (which is the total measured noise level, including the specific immission and the background noise). In practice, it is often difficult to distinguish between measurements of the specific immission from a works and the background noise, particularly if continuously running measuring instruments are used and there is no subjective judgement by ear.

Experience among European refineries indicates that if the average neighbourhood noise level is 10dB(A) or more below the notional background level given by the British Standard, there is only a small risk of receiving one or more complaints; if the average noise level is 10dB(A) or more above the notional background there is a considerable chance of receiving complaints. The day-to-day variation in noise level in the neighbourhood of a refinery and the variation in response between localities is so great that available data are inadequate for any more precise predictions.

## ii. Variation in noise level

When calculating noise levels at distant neighbourhood locations, account has to be taken of the variations that will occur in practice. At a distance of 0.5 km or more from the plant, noise levels will commonly vary by about 10dB with different weather conditions; on occasions they may vary by as much as 20dB.

In Britain, the equivalent continuous sound level,  $L_{eq}$ , is the recommended measurement parameter it being measured with an integrating sound level meter complying with the Standard, BS EN 61672-1:2013<sup>(15)</sup>, which permits measurements over any time period. It is a parameter which averages the noise energy. An alternative measure is the median or 50 percentile value of a series of noise levels measured over a defined period of up to a year, and this is given the symbol  $L_{50}$ . Other points on the cumulative distribution of noise levels may also be used; for example,  $L_{90}$  and  $L_5$  (they represent levels above which 90% and 5% respectively of the measurements lie).  $L_{90}$  is used in BS 4142:1997, for example, as a

measure of background noise and  $L_5$  is sometimes used as a measure of peak noise. For further discussion of the significance of these parameters see UK government legislation (e.g. The Control of Noise Regulations 1976<sup>(4)</sup>).

Most legislation requiring noise limits does not define which of these parameters is implied. It is important in making measurements and doing calculations to decide which of them is to be compared with the noise limits set for the plant.

If the local authority has not imposed specific conditions for plant noise it is desirable to use attenuation values for design purposes which relate to common unfavourable conditions; that is, conditions which commonly occur and give median or higher noise levels, but not the highest possible. Still night conditions have often been used in the past but there is evidence to suggest that attenuation values applying when the selected neighbourhood location is downwind of the plant are also appropriate. This recognizes that some complaints may only occur on a limited number of occasions but may still be considered justifiable. In the UK, legislation requires neighbourhood noise from industrial plants to be measured under 'downwind' conditions.

The advantage of using attenuation values based upon the least favourable weather conditions is that the noise from the plant at the neighbourhood location will seldom exceed the long-term average by more than 5dB(A) so strenuous complaints are unlikely.

### iii. Plant extensions

Where the Specification is to be applied to new plant added to an existing works, a further consideration may apply. If the existing neighbourhood noise is considered to be at the tolerable limit, then the new plant must not add appreciably to this noise level. The new plant must therefore, be designed to be at least 5dB, and possibly 10dB below the existing noise level. Similarly, with a new plant which is a first stage of a large works, it may be desirable to design the first stage to a limit below the ultimate.

### iv. Low-frequency noise

Most noise sources in the petroleum and allied industries generate broad-band noise predominating in the mid and high frequencies and the British Standards method of predicting complaints is adequate.

However, it is not satisfactory for plants containing sources emitting low-frequency noise (for example, gas-turbine exhausts). If the limit is set in dB(A), this will allow a noise level in the 31.5 Hz band which may exceed the background noise in this band by up to 20dB. Experience shows that this is likely to give rise to complaints<sup>(16),(17),(18)</sup>. This is due to the fact that, at low frequencies, annoyance is not simply related to loudness levels and can be caused merely by hearing the noise. It is therefore advisable to reduce the low frequency noise in the neighbourhood due to the plant to around the hearing threshold, regardless of the existing background noise. At 31.5 Hz it is recommended that this should not exceed 60dB.

### 1.3.4.3 Octave-band limits

For design purposes the neighbourhood noise limit in dB(A) should be converted to octave-band limits, preferably by using the A-weighting spectrum as discussed in 1.2.3. For quick reference the octave-band equivalents given in Table 3 may be used.

### 1.3.4.4 Narrow-band noise in neighbourhood areas

Additional restrictions for narrow-band noise should always be applied to neighbourhood noise. As described previously for work-area noise, narrow-band noise can be suppressed by masking with a broad-band noise. For neighbourhood noise this approach is both preferable and more economic than reducing the noise limit for the whole plant in the octave-band(s) in which the narrow-band noise occurs.

To ensure that any narrow-band component in the noise from a particular source is not noticeable in the neighbourhood, the noise level from that source in the relevant octave bands should be suppressed below the broad-band neighbourhood noise level from the plant by the amount given in Table 6. The suppression quoted is estimated to be adequate to reduce the narrow-band noise to the threshold of perceptibility; it is based on Figure 15 (Appendix E) of EEMUA 140.

**Table 6 Suppression of narrow bands in neighbourhood noise**

| Octave band, Hz          | 31.5 | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
|--------------------------|------|----|-----|-----|-----|----|----|----|----|
| Required suppression, dB | 0    | 0  | 1   | 5   | 9   | 11 | 12 | 12 | 8  |

If the noise limit for the project or plant in question is lower than the total neighbourhood-noise level (the background noise) this suppression should be set below the background-noise level, not the project-noise level. This means that the excess of background noise level above project noise level may be subtracted from the values in Table 6.

### 1.3.4.5 Impulsive noise in neighbourhood areas

As described previously for work-area noise, it is not possible to set precise values for suppression of impulsive noise when considering neighbourhood noise. It is suggested for practical purposes that a suppression of impulsive noise by a nominal 5dB(A) below the total broad-band neighbourhood noise level will probably be adequate. Reference should be made to ISO 13474:2009<sup>(19)</sup> for further guidance.

### 1.3.4.6 Cyclic plant operation

With plant employing a cyclic operation, noise may vary appreciably with the operating cycle, and the intermittency and duration correction given in BS 4142:1997 should then be applied. In such cases, as with narrow-band noise, it may be more economical to suppress the varying noise sources adequately below the steady masking noise level so that the variation is not appreciable in the aggregate community noise.

### 1.3.4.7 Neighbourhood-noise calculations

*Note: References to Figures in this Section relate to EEMUA 140*

Where there is a choice of attenuation values Figure 13, Figure 14 and Figure 16 in EEMUA 140 should be used.

Figure 16 gives standard values assuming hemispherical noise propagation and includes the normal attenuation for atmospheric absorption for about 15°C and 70% humidity, based on Beranek<sup>(20)</sup>. Figures 13 and Figure 14 represent an assessment of the additional attenuation due to ground effects. Other guidance is now available in ISO 9613-2:1996<sup>(21)</sup>. These two graphs are based on measurements made at refineries and are broadly consistent with the literature<sup>(22),(23)</sup>. Figure 13 applies where there is flat or rising ground between the plant and the community location so that there is little direct screening of the noise sources but there is some scatter by partial screening; the line of sight is close to the ground surface and the ground is mostly unpaved. Figure 14 applies where there is screening by other plant, tankage, bund walls, scattered buildings etc., so that there is no clear line of sight and the intervening ground surface is mostly unpaved.

Although described as 'ground-effects attenuation', these graphs represent the residual attenuation after accounting for distance and air absorption in Figure 16 and they include the time averaged effect of weather. The procedure may therefore be expected to predict noise levels which correspond to a long-term average over several months (probably a level slightly higher than the  $L_{50}$  value and nearer to the long term  $L_{eq}$ ).

Comparisons of measured levels of  $L_{50}$  around several refineries and the levels calculated by this procedure indicate that the agreement is generally within about 3dB, so the procedure is still regarded as a useful assessment of attenuation<sup>(24),(25)</sup>.

The basis of calculation in this guideline is the EEMUA procedure. For other guidance consult ISO 9613 which provides a general method of calculation for the attenuation of sound propagation outdoors and/or K.J. Marsh<sup>(26)</sup> for a method of calculating neighbourhood-noise from open-air industrial plants, such as oil refineries and petrochemical plants.

Recommendations:

- Make a rough estimate of the expected neighbourhood noise levels due to the plant;
- Establish a neighbourhood-noise limit by discussion with the local authority;