

THE ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

Noise procedure Specification

PUBLICATION 140

Edition 3

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ENGINEERING EQUIPMENT AND MATERIALS USERS ASSOCIATION

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Preface

This Specification defines the procedures for controlling noise in plant and equipment for use in power generation, petroleum, petrochemical and other industries. It applies both to the design and construction of new plants and to the modification of existing plants where noise reduction is required. Noise control is a continuing process which starts at the earliest stage of design and carries on throughout the operation of the plant. It is a process which requires close co-operation between the Principal, Contractor and Equipment Vendor as defined in Section 1.2. This Specification deals primarily with the stages up to the commissioning of the plant or equipment. However, it is sufficiently comprehensive to provide guidance on noise control during operations, particularly in the diagnosis of sources of neighbourhood nuisance.

The acquiring and reporting of noise data in a standard manner is a key feature of design for noise control and is a field in which there is a need for uniformity. This Specification is therefore intended to provide standard methods in which this can be achieved.

Although the measurement and calculation procedures in this Specification are practicable and adequate for use in most cases, special situations may be encountered where they cannot be employed precisely as specified. In such cases it may be necessary to modify the procedures. An explanation of the theory and philosophy behind the procedures is therefore included so that a consistency of approach and accuracy can be maintained. Some special cases of noise-level prediction - particularly indoor situations where enclosures or screens are to be employed - are beyond the scope of this specification, and the methods of calculation described in standard texts should be employed.

This guide is the Third Edition of EEMUA Publication 140. The aim of this revision is to make reference to the latest standards and to ensure that the most up to date advice and guidance is given. It describes the principles to be applied in selecting noise limits and gives worked examples of the calculation methods.

Chapter 1 defines the scope of the Specification and the division of responsibilities between the three main parties in a construction project: the Principal, Contractor and Equipment Vendor. In any given project there may be contractual requirements which define in detail the relationship between these parties, particularly with reference to performance guarantees, and it is not within the scope of this Specification to provide a precise legal contract for the project. Nevertheless, the general framework given here defines the essential features of any such contract. The notation and terms used in this Specification have been chosen as far as possible to be in accordance with current international practice.

Chapter 2 defines the measurement and reporting of equipment noise. Its aim is to specify measuring procedures which can be used in the practical situations encountered in plants and factories. These procedures are based on the use of a precision sound-level meter equipped with octave-band filters and an accelerometer; equipment which could be readily available in plants and factories. They include a correction for semi-reverberant environments; for small sources this is derived from readings on two measuring surfaces (so that no special equipment is required). Where this is not practicable, alternative methods are proposed which are based on the use of a partial second surface or the Room Constant, in descending order of merit.

The preferred measuring surface is a hemisphere in which the source is small in relation to the measuring distance; this is called the 'small-source method'. The use of this method is not determined by the physical size of the source but by the nature of the environment - the absence of high background noise and of physical obstructions, so that measurements can be made sufficiently far from the source.

Where it is not possible to get far enough away from the source - because of background noise or physical obstructions - it is necessary to measure in the geometric near field of the source. This means that the source dimensions are large compared with the measuring distance, so it is called the 'large-source method'. The preferred measuring surface is then the conformal surface (a cuboid with rounded corners and edges). But if the source radiates unevenly it is necessary to divide this into separate surfaces (called 'measuring surface zones'), to calculate their sound-power levels individually, and then to add them up. There are still some sources which do not suit this method - usually they have identifiably separate radiating components - and these have to be treated as a composite of sources, using the small-source or large-source methods as appropriate. A procedure is also given for determining the sound-power levels of linear sources.

When using the large-source method, a correction should be applied for the geometric near-field error of the sound-pressure level measurements and suitable values are given for this correction. For convenience these are quoted in terms of the ratio of surface areas rather than the angular terms from which they were calculated.

The preferred method for determining sound-power levels is from measurements of sound-pressure level, but where this is not possible - due to high background noise - a procedure is proposed for using vibratory - velocity levels, derived from measurements of vibratory velocity or acceleration. A flow chart is provided for the various choices in the determination of sound-power level.

Chapter 3 describes the calculation methods to be used for handling the test data. This includes the derivation of sound-power levels to define the noise emission of equipment items and the use of this information to estimate noise levels in the work area and the neighbourhood.

It is considered that the procedures described in this Specification will determine the sound-power level with an accuracy of ± 3 dB at the 95% confidence limit. This is likely to be acceptable for most engineering purposes. Where a higher precision is required the procedures of ISO 3741:2010⁽¹⁾ to ISO 3747⁽⁷⁾ should be used. Each of the intervening Standards is listed in the References (1 to 7) at the back of this Publication.

Appendix F provides a standard procedure for calculating neighbourhood noise which can be used as the basis for a contractual guarantee on whether the plant has met the neighbourhood-noise requirements. Other methods of assessing attenuation from ground and weather effects are currently available, or may be developed; but measurements around a number of plants indicate that this procedure estimates the long-term median (L_{50}) noise level in the neighbourhood to ± 5 dB(A) with about 90% confidence. For more detailed calculations refer to ISO 9613⁽⁸⁾.

Chapter 4 describes the procedure for specifying the noise limits for a complete plant. This would be used by the Principal as part of the general plant specification for the Contractor. Appendix D gives a model format for specifying noise limits for a plant and further details can be found in ISO 15664:2001⁽⁹⁾.

Chapter 5 describes the procedure for specifying noise limits for individual items of equipment and would be used by the Contractor in ordering equipment. He would derive the equipment noise limits from the complete plant limits specified by the Principal on the basis of his general design for noise control. Appendix D also gives a model format for specifying equipment noise limits.

Chapter 6 defines the requirements for assessing equipment sound-power levels and the noise levels of a complete plant for acceptance purposes.

Notes on Third Edition

This Publication was first published in 1971 as OCMA Specification NWG-1 Procedural Specification for Limitation of Noise in Plant and Equipment for Use in the Petroleum industry. In 1972, after OCMA had become part of EEMUA, it was renamed and published as EEMUA Publication 140 Noise Procedure Specification.

Edition 2 of EEMUA Publication 140 was published in 1988 and included new technical material that had been published in the intervening years and a more complete version of the calculation procedures. It also acknowledged its relevance to other industries beyond the petroleum and petrochemical industries.

This Publication is the third Edition of Publication EEMUA 140. It has been brought up to date and includes reference to many modern international standards that have been published since the last Edition. It should be read in combination with EEMUA Publication 141 "Guide to the Use of the Noise Procedure Specification."

1. Introduction and use of Specification

1.1 Scope

This is a specification of the procedures which apply to noise control in the selection and installation of all plant equipment. It indicates the method of specifying maximum acceptable noise levels for plant and equipment, describes acceptable methods of tests for determining noise emission from equipment, and gives a guide to methods of calculation and presentation of data. It does not set noise limits because the acceptable limit for any location will depend on factors relevant to that location. Noise limits may also vary over the course of time as new information becomes available on the physiological effects of noise. The noise limits are the responsibility of the Principal.

Noise levels may be considered under the following headings:

- Hearing conservation.
- Speech and work interference.
- Community reaction.
- Accommodation.

1.2 Division of responsibilities

The division of responsibilities in the application of this Specification should be as stated in this Section unless otherwise specified in the contract or agreed by the Principal.

1.2.1 The Principal

For the purpose of this Specification the Principal is defined as that party responsible for placing the order for a plant, specifying the technical requirements of the plant, and ultimately paying for its design and construction.

The Principal should be responsible for the following:

Specifying the following requirements for the complete plant:

- The broad-band noise limits and the required additional restrictions for noise character under the headings in Section 1.1. He may specify community noise levels as sound power levels for the complete plant or as sound-pressure levels at designated locations.
- Any special noise limits which may be required for certain abnormal operating conditions of limited duration. These may include construction, start-up and emergency conditions.
- The areas and times in which the noise limits are to be met.
- Whether compliance with the noise limits should be determined by direct measurements or by calculation. Where test measurements are to be made, the Principal should provide information on any background noise from sources outside the plant under consideration or agree a method for determining this and correcting for its effect. Unless otherwise specified

by the Principal, the procedures and values in this Specification are to be used for all measurements and calculations.

- Specifying the procedure and requirements for the acceptance of the complete plant.

1.2.2 The Contractor

For the purpose of this Specification 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. In some cases the Principal may undertake all or part of the responsibilities of the Contractor. The Contractor should be responsible for the following:

Obtaining the necessary information relating to the noise levels generated by equipment in the contract. This information may be derived from one or more of the following sources:

- Calculation based on theoretical or standard procedures.
- Test and calculations carried out by the Equipment Vendor.
- Test carried out by, or on behalf of the Contractor.
- Test and calculations from other sources agreed by the Principal to be reliable.

The accuracy of the data and calculations based thereon. The Principal's approval should be obtained for any deviation from the procedures prescribed in Chapters 2 and 3 of this Specification and the relevant Appendices.

The determination of all areas where the relevant noise limits would be exceeded if standard equipment was used, and in all such areas the selection of the most economic method of meeting the limitations, subject to the approval of the Principal. The Contractor should take into consideration the effects of reverberation, equipment mounting and neighbouring equipment to ensure compliance with the Principal's noise limits. He should also take into consideration the requirements for dealing with narrow-band and impulsive noise. Corrective action may take one or more of the following forms:

- Selection of low-noise equipment.
- Modification of design to reduce the noise at source.
- Alteration of plant layout and orientation of directional sources.
- Enclosure of equipment or working areas.
- Screening equipment from the working areas.
- Fitting silencers.
- Acoustic lagging.

The determination of suitable sound-power level limits for equipment items where appropriate (see Chapter 5) in order to achieve the work area and community limits set by the Principal, subject to the requirements above.

The preparation of noise data sheets for the requisition of equipment and the checking of noise data supplied by Equipment Vendors.

When required by the Principal, the preparation of reports giving sufficient data and calculations to demonstrate to the satisfaction of the Principal that the plant

design meets the requirements of this Specification. Such reports should define the measures proposed for reducing noise and should include all of the noise test data obtained, together with data received from other sources. They should also indicate clearly those areas where it does not appear practicable to meet the noise limits.

Ensuring the sound levels from any reasonable operating condition up to the maximum design load should meet the noise limits. These conditions should include regeneration, low load, recycle, start-up, shutdown and other abnormal but expected modes of operation.

Estimating the sound levels radiated from piping and vessels connected to noisy equipment such as valves or compressors.

Taking corrective action if the acceptance tests for the plant show that the specified noise levels have not been met. Such action should have the approval of the Principal.

1.2.3 The Equipment Vendor

For the purpose of this Specification the Equipment Vendor is defined as the party which manufactures or supplies equipment to perform the duties specified by the Contractor. He may manufacture the equipment himself or assemble packages of equipment from other suppliers. The Equipment Vendor should provide the following information:

- Sound-pressure levels at 1m from the surface of his equipment under free-field conditions, and at the operator's position, if any. This information is to include both average and maximum noise levels.
- The sound power level of this equipment under agreed operating conditions. This may be determined by the methods in Chapter 3 or by a test method agreed with the Principal. The determination may be affected by the equipment mounting or by associated equipment and details of this should be provided.
- Any special characteristics of the noise emission such as narrow-band or impulsive noise.
- Where noise tests can only be made under semi-reverberant conditions, the test data should be corrected to free-field data. If this is not possible, a note should be made that the data provided may be higher than free-field data. The corrections used and the method of calculation should be given in the test report.
- For equipment such as compressors or valves where a considerable portion of the noise it generates is radiated by the connected piping, the Equipment Vendor may quote the sound-power level per unit length of pipe upstream and downstream of the equipment, together with the diameter and schedule of the pipe for which the data apply.

Alternatively he may quote the in-pipe sound-power levels at the suction or discharge of his equipment. For tests on pipes connected to pumps or compressors it is necessary to ensure that the measurements are not

influenced by noise from external loads such as valves; for example, by using low-noise valves; and

- He should indicate all modifications to standard equipment necessary to meet the noise limits set by the Contractor. Alternatively he may advise the Contractor on appropriate methods for reducing the noise from standard equipment when this does not meet these noise limits. Any modifications to the equipment should not conflict with the requirements of other specifications for the equipment.

1.3 Special consideration

In certain circumstances the available noise data may be inadequate for detailed calculations and design. In such cases, provided that there is no reasonable method of obtaining the required data, the Principal may approve a particular design and layout and equipment selection, and be responsible for the resulting noise levels.

When it is necessary to make use of data obtained from another test method (Section 1.2.3, second bullet point) it should be at least as accurate as the corresponding measuring procedure in this Specification and the results should be given in octave bands. In particular, the relevant near-field and environmental corrections should be applied, and the operating conditions of the equipment under test should be appropriate. These should be agreed with the Principal.

1.4 Notation and definitions

The following notation is used in this Specification:

d	Measuring distance	(m)
D	Directivity index	(dB)
D ₀	Typical source dimension	(m)
E ₁	Geometric near-field correction	(dB)
E ₂	Environmental correction	(dB)
E ₃	Conformal surface correction	(dB)
f	Frequency	(Hz)
F	Correction for area of conformal surface	
I	Reference intensity level	(Watts/m ²)
I ₀	Reference intensity level	(Watts/m ²)
I _{ni}	Intensity level normal to the i th surface element	(Watts/m ²)
K	Attenuation factor	(dB)
L _I	Sound Intensity level	(dB)
L _{eq}	Equivalent continuous sound levels	(dB)
L _p	Sound pressure level	(dB)
$\bar{L}_p$	Mean sound pressure level	(dB)
L _p [*]	Directional sound pressure level	(dB)
L _v	Vibratory velocity level	(dB)
$\bar{L}_v$	Mean vibratory velocity level	(dB)
L _w	Sound power level	(dB)
I _n	Dimension of reference surface	(m)
log	Logarithm to base 10	
N	the number of elements in the measurement mesh	

p	Sound pressure	(N/m ²)
p_o	Reference sound pressure	(N/m ²)
Q	Ratio of the measuring surface to the reference surface	
r	Radius	(m)
R	Room constant	(m ²)
t	Time period	
T	Total observation time	
S	Surface area	(m ²)
S_i	area of the i^{th} surface element	(m ²)
v	Vibration velocity	(m/s)
v_o	Reference vibratory velocity	(m/s)
W	Sound power	(W)
W_i	partial sound power of the i^{th} element	(Watts)
W_o	Reference sound power	(W)
σ	Radiation ratio	
α	Sound absorption coefficient	
θ	Angle	(rad)
λ	Wave length	(m)

The following definitions apply to this Specification:

Acoustic near field	is defined as the region near a noise source where particle velocity and pressure are not in phase.
Conformal surface	is a form of measuring surface which is at a distance, d , from all points on the reference surface.
Crude sound-power	is the sound-power level obtained from a measuring surface before the application of the environmental correction.
Cuboid	is a rectangular parallelepiped.
Directional sound-pressure	is the sound-pressure level in free field at any distance from the equipment in the specified direction.
Directivity index	of a small source in a particular direction is the difference between the directional sound-pressure level L_p^* and the mean sound-pressure level $\bar{L}_p$ at the same distance.

$$D = L_p^* - \bar{L}_p$$

For a large source it is the difference between the sound-power level in a particular direction and the total sound-power level source.

Equivalent continuous sound level is the level of a steady sound that has, over a given period, the same energy as the fluctuating sound in question.

Free field is defined as that part of the sound field where the effects of its boundaries are negligible.

Note: where the effects of the boundaries are constant, such as above a continuous reflecting plane, the sound levels may be treated as if in a free field and corrections made as necessary.)

Geometric near field is defined as the region near a noise source where measuring distance from the reference surface is less than the maximum linear dimensions of the source or reference surface element.

Impulsive noise When a noise contains significant irregularities, such as bangs, clanks, or thumps, or if the noise is only existent momentarily and is of a character to attract attention, then it should be considered as impulsive for the purpose of this Specification.

Measuring distance is the distance between the point on the measuring surface where the measurement is made and the nearest point on the reference surface.

Measuring surface is an imaginary surface on which measurements are made. Its relation to the reference surface is defined in the appropriate test procedure.

Measuring surface zone is that part of the total measuring surface of a source over which the variation in sound pressure level is less than 6 dB(A). It may consist of one plane or curved surfaces.

Narrow-band noise When the noise from a source contains a pure tone or narrow-band component which is noticeable to the ear as a noise of distinguishable pitch, and which represents a dominant feature of the total source noise, then the source noise should be regarded as containing narrow-band noise for the purpose of this Specification.

Note: Where there is doubt about the subjective assessment of narrow-band

noise it should be resolved by narrow-band analysis, using an instrument with a band width not more than 10 Hz or 1%, whichever is the less (See Appendix E).

Octave bands

refer to the preferred octave frequency bands EN ISO 266:1997⁽¹⁰⁾.

Reference surface

is the smallest possible imaginary parallelepiped enclosing the sound and terminating on the ground (excluding re-entrant sections and minor protuberances which are not significant emitters of noise).

Sound level

is the A-weighted overall sound-pressure level.

Sound intensity level

is defined as $10 \log (I/I_0)$ in dB where I is the sound intensity in watts/m^2 , and I_0 is the reference sound intensity of 10^{-12} watts/m^2 .

Sound-power level

is defined as $10 \log (W/W_0)$ in dB where W is the sound power in watts, and W_0 is the reference sound power of 10^{-12} watt.

Sound-pressure level

is defined as $20 \log (p/p_0)$ in dB where p is the measured sound pressure in N/m^2 and p_0 is the reference sound pressure of 2×10^{-5} N/m^2 .

Vibratory-velocity level

is defined as $20 \log (v/v_0)$ where v_0 is the reference velocity of 5×10^{-8} m/s.

Note: This is not the preferred reference velocity required by EN ISO 1683:2008⁽¹¹⁾ but it is the most suitable value for relating vibratory-velocity levels with sound-power levels.

Work area

is any position not less than 1m from equipment surfaces which is accessible to personnel, or any position where an operator's ear may be exposed to noise in the normal course of duty. It includes any platform walkway or ladder.

2. Measurement and reporting of equipment noise

2.1 Measuring equipment

Sound pressure measurements should be made with a sound-level meter to EN 61672⁽¹²⁾ (Precision), Grade 1 equipment with band filters to EN 61260⁽¹³⁾.

Sound pressure measurements made with instruments to EN 61672 (Industrial Grade) Grade 2 or 3 may be accepted only if the Principal agrees that it is unreasonable or impracticable to obtain readings with a precision instrument.

The 'slow' meter response setting should be used.

More sophisticated equipment may be used provided that it can give equivalent readings to those of a precision sound-level meter and octave-band analyser; for example, a narrow-band analyser may be required in some circumstances (see Appendix E).

The microphone should be orientated so that the angle of incidence of the sound waves is that for which it is calibrated, as specified by the manufacturer.

When measurements are made outdoors or around ventilating equipment, the use of wind screens on the microphone is recommended. An appropriate correction to the readings should be made according to the manufacturer's instructions.

The sound power level for equipment can be determined from sound pressure measurements or from sound intensity measurements. Sound intensity measurements should be made with an instrument to IEC 61043:1993⁽¹⁴⁾ in either one-third octave or octave bands filters to EN 61260.

2.2 General requirements for measurements

The following points should be observed at all times when noise measurements are made.

2.2.1 Measurements

The terms 'readings' or 'measurements' will at all times imply separate measurements in each of the eight octave frequency bands centred on 63, 125, 250, 500, 1k, 2k, 4k and 8k Hz and in overall dB(A). Additional readings may be made in the 31.5 and 16k Hz bands if required by the Principal. The readings in octave bands should be un-weighted.

Note: In some countries it is the practice to use weighted octave-band levels and such values should be corrected for use in calculations according to this Specification.

2.2.2 Sound-level meter and sound intensity meter calibration

The sound-level meter should be calibrated immediately before and after use, using a standard acoustic calibrator approved for the meter. A maximum difference of 1 dB between the two calibration readings and an error of not more

than ± 1 dB between each and the quoted sound level of the calibrating source should be deemed acceptable.

The sound intensity meter should be checked for proper operation prior to each series of measurements using the manufacturer's procedures or by following the procedures provided in the measurement standards (ISO 9614⁽¹⁵⁾ series).

2.2.3 Measurement of background noise

Whenever possible, measurement of background noise should be made when the equipment under test is not operating. Minimum of four measurements of background noise, spaced equally around the equipment at approximately the same distance as for the source noise measurements, may then be made. When any background measurement is within 6 dB of the total noise level (background noise level measurement should be made for each point of total-noise measurement).

2.2.4 Measurement of fluctuating noise levels

Where the sound-pressure levels fluctuate, the average or most common level with the meter on 'slow' response should be recorded. If the range of fluctuation is greater than 6 dB, the maximum and minimum levels should also be recorded and a level 3 dB below the maximum should be used for design purposes. For slow fluctuations (for example, where there are discrete modes of operation) or for intermittent noise the equivalent continuous sound level (L_{eq}) should be derived (see Section 3.1.6).

2.2.5 Test conditions

Operating conditions for the tests should be selected beforehand and should be kept constant during each test.

2.2.6 Precision

Measurements should be recorded to the nearest 1 dB.

2.3 Sound-pressure level measurements

For the purpose of calculating work-area noise limits (see Chapter 4) sound-pressure levels should be measured at 1 m from the equipment surface and at the operator's position where applicable. Readings should be taken at a minimum of four positions equally spaced around the equipment at 1.5 – 2 m above the working floor level. The positions chosen should include the position of the highest noise level. These sound-pressure level measurements and any others made around the equipment to determine sound-power levels can be used directly for determining work-area noise levels near the equipment (see Section 3.3.2).

2.4 Sound-power level determination for equipment

ISO 3740:2000⁽¹⁶⁾ provides guidelines for the determination of the sound power levels of noise sources based on the methods described in ISO 3741:2010 to ISO 3747 and ISO 9614-1:1993, ISO 9614-2:1996 and ISO 9614-3:2002, which together embrace all types of machinery, equipment and acoustic environments.

ISO 3741 to ISO 3747 describe methods, with precision grade, engineering grade or survey grade, using sound pressure level measurements in different types of environment.

ISO 9614-1:1993, ISO 9614-2:1996 and ISO 9614-3:2002 describe sound intensity methods, each with precision grade, engineering grade or survey grade accuracies, employing different measurement sampling techniques. The methods are well suited in the presence of high background noise generated by sources other than that under test and by sound reflections by the environment

Figure 5 provides guidance on which of the Standards is the most appropriate choice for determining the sound power level of a noise source.

The procedures given in ISO 3741 to ISO 3747 are based on the use of a portable precision sound-level meter and are intended for use in industrial conditions such as factories or open-air plants. It is assumed that the use of special anechoic or reverberant test chambers is not practicable. Where these special chambers are available the procedures of ISO 3741⁽¹⁾, 3743⁽³⁾, or 3745⁽⁵⁾ should be used, as appropriate.

The sound-power level of a noise source is normally determined from sound-pressure level measurements on an imaginary surface enveloping the source, defined as the 'measuring surface'. In order to define the measuring surface a 'reference surface' is established which is the smallest possible imaginary cuboid just enclosing the source and terminating on the ground on which the source is mounted. Elements protruding from the source which are not major radiators of sound may be neglected.

The preferred measuring surface is a hemisphere and measurements should ideally be made under conditions of 'free field above a reflecting plane'. This means that the ground is assumed to be a flat continuous reflecting surface from the source to the measuring points; it should preferably be concrete, steel plate or wood. If such a surface is not available and the source has to stand on an absorbing surface such as gravel or grass, a note should be made in the test report. Also, there should be no reflecting surfaces present, apart from the ground, and no other sources to cause high background levels. In these circumstances, measurements can be made at such a distance from the source that its linear dimensions are small in relation to the measuring distance (see Section 2.4.1.1): the acoustic details of the source are then insignificant. Measurements made in these conditions are defined in this Specification as the 'Small Source Method' and are described in Section 2.4.1.

There are, however, many practical situations in which reflecting surfaces and high background noise cannot be eliminated and to minimize their influence it is necessary to make measurements at distances smaller than those prescribed in the small-source method; the source will then be large relative to the measuring distance. Measurements made under these conditions are defined in this Specification as the 'Large Source Method' and are described in Section 2.4.2.

It is important to verify that the test environment has met the above requirements and this should be checked as part of the procedure. This should preferably be done by using the noise emission of the source itself so that no special equipment is required; but where this is not possible a correction may be

made by other methods (see Section 2.4.1.5 for the small-source method and Section 2.4.2.6 for the large-source method). If the environment is semi-reverberant an indication of sound-power level may be obtained by the procedure described in Appendix A.

In addition there are some special techniques for determining sound-power levels which do not fall into these two categories and these are described in Section 2.4.4.

Figure 1 gives a flow chart for determining the appropriate procedure to be used.

For more details see ISO 3741 to ISO 3747.

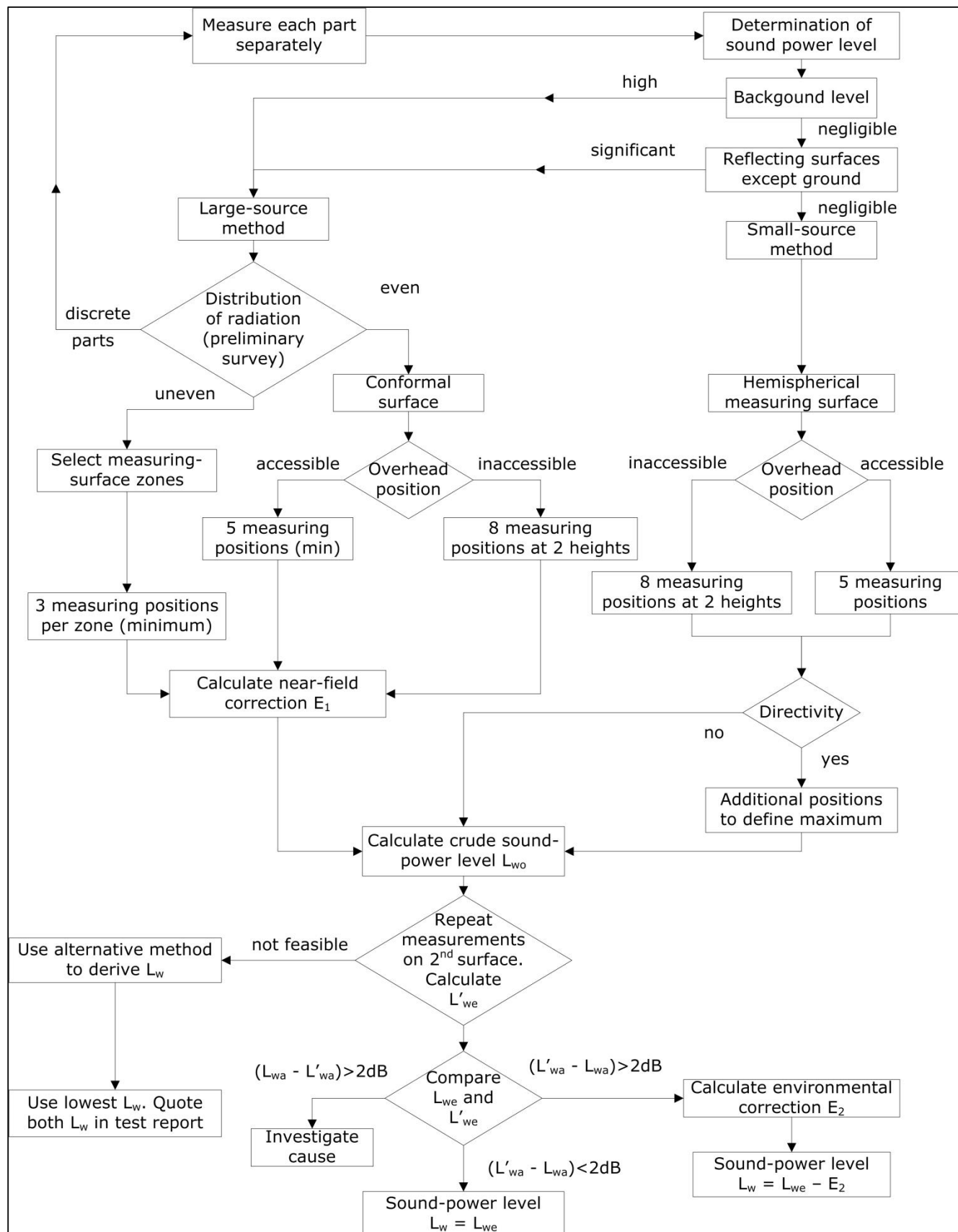


Figure 1 Flow chart for determination of sound-power level

2.4.1 The small source method

This is to be used for sources whose linear dimensions are small in relation to the radius of the measuring surface as defined in Section 2.4.1.1. The source should be mounted away from other reflecting surfaces and a check on the suitability of the environment should be made as in Section 2.4.1.5. The background noise should be measured, if possible, as described in Section 2.2.3 and the test measurements corrected as in Section 3.1.4.

The calculation of the sound-power levels is described in Section 3.2.1.

2.4.1.1 The measuring surface

For the small-source method the measuring surface is a hemisphere terminating on the ground. The radius of the hemisphere is at least twice the typical source dimension D_0 defined as

$$D_0 = \sqrt{(L_1/2)^2 + (L_2/2)^2 + L_3^2}$$

where

L_1 , L_2 , and L_3 are the length, width and height of the reference surface. The radius should be such that the hemisphere is at least 1m from the reference surface (see Figure 2(a)).

2.4.1.2 The microphone positions

Before selecting the microphone positions a preliminary survey should be made over the measuring surface with the sound-level meter set to dB(A) in order to determine whether the source has any directivity.

The microphone positions are situated on the measuring surface and a minimum of 5 positions should be used. One of these should be vertically above the source and the other 4 positions should preferably be on a circle of radius 0.92 times the radius of the hemisphere and at a height above the ground of 0.4 times the radius, spaced at 90° intervals around the source (see Figure 2(b)). If the radius is large and this microphone height is impracticable a lower height may be used with a correspondingly larger measuring circle. In any case the microphone positions should not be less than 1 m above the ground.

2.4.1.3 Omission of the overhead microphone position

If it is impracticable to make a measurement in the position vertically above the source it may be omitted. Four additional microphone positions on the measuring surface should then be used which should be at heights which are one half or double the height of the corresponding positions defined in Section 2.4.1.2. They should be at least 1 m from the ground and should be rotated 45° about the vertical axis with respect to the original positions.

2.4.1.4 Additional microphone positions

If the preliminary survey shows that the difference in sound level between any two points on the measuring surface exceeds 6 dB(A), one microphone position should be situated at the maximum and four additional positions should be used so that the positions are equally spaced around the equipment. They should

preferably be at a different height from the first 4 positions and rotated 45° about the vertical axis (see Figure 2(c)). The purpose of these extra positions is to weight out the effect of the maximum on the mean sound-pressure level.

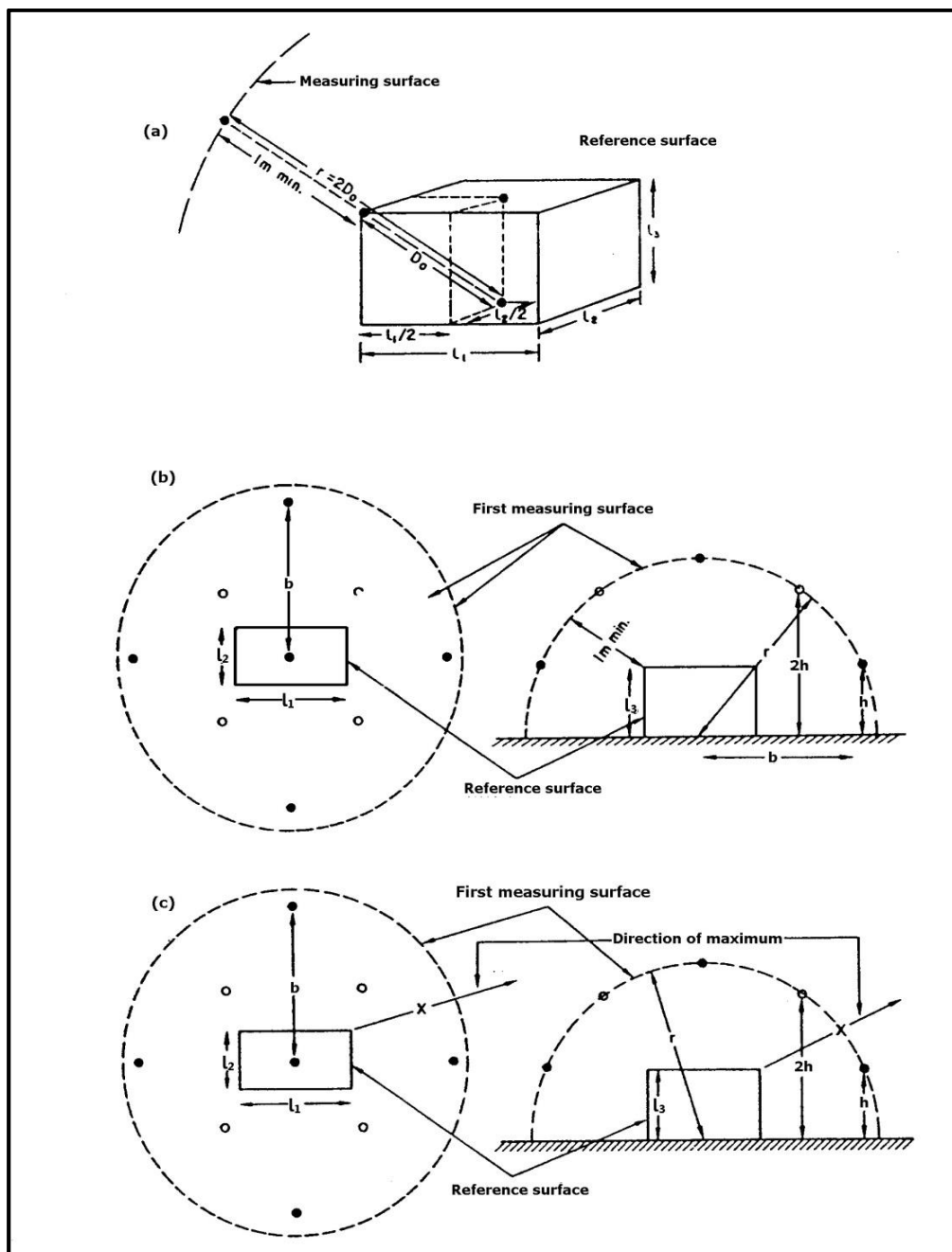
Note: These four positions may be the same as those in Section 2.4.1.3 if the overhead microphone position cannot be used.

The position of the maximum should be noted and used to derive the directivity index as described in Section 3.2.8.1.

2.4.1.5 Test environment correction

The measurements described in Section 2.4.1.1 to 2.4.1.4 should be repeated on a second hemispherical measuring surface of area approximately 4 times that of the first measuring surface. It should not be less than 3 times the area. A second set of sound-power levels should be derived from these measurements compared with the first. For distances greater than 25m a correction for air absorption will be necessary (See Figure 16).

If the second estimate of sound-power level exceeds the first estimate by more than 2 dB in any octave band, the correction of Section 3.2.3 should be applied to the first estimate (in the relevant octave band). If the difference is 2 dB or less, the first estimate should be used for sound-power level. Otherwise a correction to the measurements should be made which is derived from the mean absorption factor of the test environment (the Room Constant). This correction is based on ISO 3746⁽⁶⁾ and is described in Appendix A.



- (a) Determination of radius of measuring surface. Minimum radius of measuring surface

$$r = 2D_0 = 2\sqrt{\left(\frac{l_1}{2}\right)^2 + \left(\frac{l_2}{2}\right)^2 + l_3^2}$$

- (b) Measuring points.

- Measuring points with overhead point.

Preferred positions: $h = 0.4r$, $b = 0.9r$.

- ° Additional measuring points to replace overhead point.

- (c) Small-source method: measuring points for some with directivity.

- Basic measuring points.

Preferred positions: $h = 0.4r$, $b = 0.9r$.

- ° Additional measuring points.

X Point to measure maximum.

Figure 2 Small-source method