Institute of Acoustics

Proceedings
Volume 22 Pt 4 2000

Power to the People
The measurement of sound power

National Physical Laboratory
Teddington, Middlesex

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Published by:
The Institute of Acoustics, 77A St Peter's Street,
St Albans, Herts AL1 3BN
Tel 01727 848195 Fax 01727 850553
e-mail: ioa@ioa.org.uk
The Institute is a Registered Charity No. 267026.

Printed by:
Rayross Print Factory, 96 Duke Street,
Liverpool. L1 5AG.
Tel: 0151 708 0590 Fax: 0151 709 0759

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Proceedings of the Institute of Acoustics

THE NOISE EMISSION IN THE ENVIRONMENT BY EQUIPMENT FOR USE OUTDOORS DIRECTIVE 2000/14/EC

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1. INTRODUCTION

This paper describes the new Directive relating to the noise emission in the environment by equipment for use outdoors. This Directive will replace the current noise emission legislation and covers 57 types of outdoor equipment first placed on the market or put into service within the Community. The obligations of this Directive apply to manufacturers or their authorised representatives established within the EC. It will not be applied retrospectively nor is it 'in use' legislation.

2. CURRENT EUROPEAN LEGISLATION

There are currently 7 product specific Directives as listed below setting noise emission limits for about 10 types of outdoor equipment. These Directives require EC type examinations by Approved Bodies as the means of conformity assessment.

- 84/533/EEC (compressors)
- 84/534/EEC (tower cranes)
- 84/835/EEC (welding generators)
- 84/536/EEC (power generators)
- 84/537/EEC (concrete breakers and picks)
- 84/538/EEC (lawnmowers)
- 86/662/EEC (hydraulic excavators, rope-operated excavators, dozers, loaders and excavator-loaders)

When the new Directive becomes mandatory on 3 January 2002, these Directives will be repealed, type examination certificates issued will become invalid, and Approved Body status will cease.

3. THE NEW DIRECTIVE

3.1 Aims of the New Directive

The European Commission Green Paper on Future Noise Policy (COM(96) 540 final) identified noise in the environment as one of the main local environmental problems in Europe. The Commission announced its intention in the Green Paper to propose a framework directive to control the noise emission of more than 50 types of equipment used outdoors.

The aims of the proposed Directive were, and still are:

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- to remove technical barriers to trade arising out of member States' differing noise requirements for outdoor equipment.

- to simplify existing legislation by creating a framework for future noise reduction as and when developments in technology allow, as well as broadening the scope of Community legislation with regard to noise emissions from outdoor equipment.

- to protect the health and well-being of citizens by reducing overall noise exposure and noise nuisance caused by outdoor equipment.

3.2 Main Requirements of Directive 2000/14/EC

The main requirements of the new Directive are to measure the noise levels of 57 types of equipment and to fix labels showing the "guaranteed" noise levels of each machine. The Directive also sets noise limits for 22 of the 57 categories, which are laid down in two stages. Many of these categories subject to noise limits already have limits set under the current legislation.

Article 12 lists the 22 categories of equipment that are subject to noise limits together with a table denoting the permissible sound power levels. These categories of equipment require the services of a Notified Body. Article 13 lists the remaining 35 categories of equipment that require noise labelling only and do not require the services of a Notified Body.

Annex III of the Directive lays down the methods of measurement of airborne noise that shall be used for the determination of the sound power levels of equipment covered by the Directive. For the purposes of the Directive, "sound power level LWA" means the A-weighted sound power level in dB in relation to 1 pW as defined in EN ISO 3744:1995 and EN ISO 3746:1995.

3.3 Scope of the Directive

Equipment subject to noise limits and noise marking as listed in Article 12 of the Directive are as follows:

Builders' hoists for the transport of goods (combustion-engine-driven)
Compaction machines (only vibrating and non-vibrating rollers, vibratory plates and vibratory rammers)
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)
Excavator-loaders (<500 kW)
Graders (<500 kW)
Hydraulic power packs
Landfill compactors, loader-type with bucket (<500 kW)
Lawnmowers (excluding: agricultural and forestry equipment; multi-purpose devices, the main motorised component of which has an installed power of more than 20 kW)
Lawn trimmers/lawn edge trimmers
Lift trucks, combustion-engine driven, counterbalanced (excluding "other counterbalanced lift trucks" with a rated capacity of not more than 10 t)
Loaders (<500 kW)

Mobile cranes
Motor hoes (< 3 kW)
Paver-finishers (excluding paver-finishers equipped with a high-compaction screed)
Power generators (<400 kW)
Tower cranes
Welding generators

Equipment subject to noise marking only as listed in Article 13 of the Directive is as follows:

Aerial access platforms with combustion engine
Brush cutters
Builders' hoists for the transport of goods (with electric motor)
Building site **band saw machines**
Building site **circular saw benches**
Chain saws, portable
Combined **high pressure flushers and suction vehicles**
Compaction machines (only explosion rammers)
Concrete or mortar mixers
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 tanks or silos** 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, counterbalanced (only "other counterbalanced lift trucks" with a rated capacity of not more than 10 t)
Mobile waste containers
Paver finishers (equipped with a high-compaction screed)
Piling equipment
Pipelayers
Piste caterpillars
Power generators (≥ 400 kW)
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 mixers
Water pump units (not for use under water)

Definitions for each type of equipment can be found in Annex I of the Directive.

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3.4 Conformity Assessment Procedures

Annex V of the Directive lists the Internal control of production procedure. This is the self-certification route to compliance for equipment subject to marking only (listed in Article 13). Manufacturers must draw up and keep technical documentation. Manufacturers must also affix the CE marking and indication of the guaranteed sound power level and draw up an EC declaration of conformity. There is no requirement for Notified Body intervention in this module.

Annex VI of the Directive lists the Internal control of production with assessment of technical documentation and periodical checking procedure. This procedure is for equipment subject to limits (listed in Article 12). The requirements are as in Annex V, but the manufacturer must submit the technical documentation to a Notified Body for confirmation of compliance. Product testing by the Notified Body not generally necessary. Further evaluation is required by the Notified Body by periodical checks during production to verify continuing compliance of the products.

Annex VIII of the Directive lists the Unit verification procedure. This procedure is for equipment subject to limits (listed in Article 12). A Notified Body undertakes an examination on a single unit and provides a certificate of conformity if the equipment meets the provisions of the Directive. The manufacturer affixes the CE marking and indication of the guaranteed sound power level and draws up an EC declaration of conformity.

Annex VIII of the Directive lists the Full quality assurance procedure. This procedure is for equipment subject to limits (listed in Article 12). The manufacturer must operate an approved quality assurance system for design, manufacture and final product inspection. A Notified Body assesses the manufacturer's quality assurance system in relation to the provisions of the Directive. The manufacturer affixes the CE marking and indication of the guaranteed sound power level and draws up an EC declaration of conformity.

3.4 Notified Bodies

As stated in the section, Notified Bodies will be involved in three of the four conformity assessment procedures. The DTI will appoint Notified Bodies in the UK. The United Kingdom Accreditation Service (UKAS) will assess potential Notified Bodies and monitor appointed Notified Bodies on behalf of the Secretary of State for Trade and Industry. Assessment of applicants will be against the Interim Guidelines for Organisations seeking Notified Body status to undertake Noise Emission Testing, Inspection and Certification.

3.5 Timetable

There are three key dates concerning the Directive:

- 3 July 2000 - The Directive was adopted and entered into force.
- 3 July 2001 – National legislation must be implemented. The 6-month transition period commences whereby manufacturers may either apply the provisions of the new Directive or legislation currently in force. The DTI must appoint some UK Notified Bodies by this date so that UK manufacturers will not be disadvantaged or be forced to use the services of Notified Bodies appointed in other member States.

- 3 January 2002 - The provisions of the Directive become mandatory.

3.6 Associated Work

Since the Directive's adoption, the DTI have commenced an awareness campaign via mail shots to companies, trade associations and other interested parties informing them of the new legislation and availability of DTI Guides. They have also given presentations to industry.

The DTI are now drafting the Regulations that will implement Directive 2000/14/EC. It is hoped that the draft Regulations will go out to public consultation in December 2000. A major issue in the implementation will be who enforces the Regulations in the UK.

3.7 Available Publications

The following publications are available from the STRD website:

www.dti.gov.uk/strd/

or DTI Publications Orderline:
Tel: 0870 1502 500
Fax: 0870 1502 333

- Guidance notes on the Directive - URN 00/525
- A Guide for Manufacturers to the evaluation of uncertainties - URN 00/605
- Interim Guidelines for Organisations seeking Notified Body status to undertake Noise Emission Testing, Inspection and Certification – URN/526

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UKAS and The Noise Emission Directive

M S Shipton United Kingdom Accreditation Service, Feltham

1. INTRODUCTION

At the request of the various UK regulatory authorities, such as DTI, DETR and HSE, UKAS provides assessment services to assist those authorities who are required to make appointments of conformity assessment bodies (CABs) under the requirements of the regulations which implement EC directives or other measures. The provision of these services is in line with the requirements of the DTI/UKAS Memorandum of Understanding.

UKAS assistance on the appointment of CABs is provided in two forms

a) A specific (and ongoing) assessment process of a CAB is undertaken against requirements for appointment developed by the regulator. Following a successful initial assessment a recommendation for appointment is made by UKAS and, following appointment by the regulator, a surveillance and reassessment process is implemented.
b) The regulator may choose to make an appointment without further reference to UKAS on the basis of a UKAS (or other) accreditation.

This lecture deals with the Type a) appointment process, as applied, to the directive 'The Noise Emission in the Environment by Equipment for use Outdoors Directive 2000/14/EC. The essence of the process is that UKAS assesses against specified requirements or guidelines and makes a recommendation for appointment. The responsible government department always retains the responsibility for making the formal appointment.

2. BASIS FOR ASSESSMENT

The regulators, with the assistance of UKAS, develop guidelines or equivalent documents for the assessment of the potential appointed bodies. These guidelines provide the detail underpinning the minimum criteria for appointment given in the regulations or directives and relate the conformity assessment activity to the relevant EN45000 series standards, to the essential health and safety requirements and to product standards where they exist. Whilst the guidelines make it clear that accreditation is not mandatory they use the EN 45000 series standards as the basis for assessment.

UKAS is required to assess against the requirements of the guidelines and to provide a view on the status of applicants against the requirements of the guidelines and then to make a recommendation to the competent authority on the applicant's overall competence in respect of the specified conformity assessment duties and proposed technical scope of work.

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3. ACCREDITATION AND REGULATORY APPOINTMENTS

UKAS complies with EU policy and the policy of the relevant UK competent authority in undertaking assessment work in support of directives and other UK regulatory appointments. In assessing for regulatory appointments UKAS does not insist on accreditation, does not add requirements to those of the guidelines but nonetheless uses the criteria in the relevant EN45000 series standard as far as practicable.

In many cases the requirements of the legislation make the provision of services by a formally appointed body the only legal route by which conformity assessment services can be provided within the UK or the EU. In such cases UKAS does not offer an overlapping voluntary accreditation for the activities described in the regulations. Accreditation can of course continue to be granted in the usual way against relevant product or laboratory standards or QA Scopes that fall both within and outside the regulations.

The lecture will describe in more detail some of the processes in making recommendations to the DTI under the Directive.

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NEW STANDARDS FOR DETERMINATION OF SOUND POWER LEVELS

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1. INTRODUCTION

The methods available by which the sound power levels of noise sources can be determined fall into two groups, one using measurements of sound intensity and the other using measurements of sound pressure. It may be that at some time in the future, sound intensity methods will come to be used for all applications where the sound power level is required to be known, since they evaluate energy flow directly and they have certain practical advantages. However, at present, the great majority of sound power level determinations made for use in noise declaration and verification are obtained using sound pressure, and this appears likely to continue to be the case for some time yet.

The standard methods in use for sound power determination using sound pressure are the international standards ISO 3741 through ISO 3747. This series of standards has undergone major revision during the past ten years, and indeed this process is not yet quite completed. Even so, the basic structure of the standards remains unchanged from that originally laid down during the 1970s. The seven methods are identified with the different kinds of environment where they are applied, and they are also broken down by three grades of accuracy. Users of the standards find this variety confusing. Moreover, an aspect increasingly important to regulations on machinery noise emission, that of measurement uncertainty, is dealt with in a way that is unsatisfactory from several respects. This paper outlines proposals which have been made to ISO for a completely new series of standards with a simplified structure and addressing measurement uncertainties more adequately.

2 – THE PROPOSED STANDARDS

The titles proposed for the new series of standards are as follows:

ISO xxxx1 Noise emitted by machinery and equipment – Determination of sound power levels and sound energy levels using sound pressure – Laboratory methods for reverberation rooms.

ISO xxxx2 Noise emitted by machinery and equipment – Determination of sound power levels and sound energy levels using sound pressure – Laboratory methods for free-field and hemi-free-field rooms.

ISO xxxx3 Noise emitted by machinery and equipment – Determination of sound power levels and sound energy levels using sound pressure – Methods for a free space over a reflecting surface.

ISO xxxx4 Noise emitted by machinery and equipment – Determination of sound power levels and sound energy levels using sound pressure – Comparison methods using a reference sound source.

None of the titles include the accuracy grade of the method, but the first two will be laboratory methods of the highest precision. All of the standards will give data on measurement reproducibility and information on factors affecting it.

ISO xxxx1 will replace ISO 3741:1999. The overall approach retains both a direct method and a comparison method, but modifications include the addition of methods for determining the sound energy level for a source which emits impulsive noise or bursts of noise, and methods for normalising sound power levels and sound energy levels to reference barometric conditions.

ISO xxxx2 will replace ISO 3745:200x. Again, methods are added for determining the sound energy level, and for normalising all levels to reference barometric conditions.

ISO xxxx3 will replace ISO 3744:1994 and ISO 3746:1996. The procedures for obtaining sound power levels and sound energy levels in frequency bands will remain as they are already, but those for determining the A-weighted levels (most commonly used for noise declaration) will be radically different. Data will be given relating the number of microphone positions on the measurement surface to the overall measurement reproducibility, for noise sources having different directivity characteristics. The experimental basis for the approach adopted is described in Richard Payne's paper to this meeting. Normalisation to reference barometric conditions is not incorporated into the method, but the range of conditions under which the method may be applied is restricted.

ISO xxxx4 will replace ISO 3743-1:1994 and ISO 3747:2000.

3. DEVELOPMENT OF THE NEW STANDARDS

Fully drafted versions of ISO xxxx1 –xxxx3 have already been presented to working group 28 of ISO/TC 43 Sub-committee 1. A draft for ISO xxxx4 is expected to be prepared during 2001.

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ASSESSMENT OF REPRODUCIBILITY UNCERTAINTIES FOR USE IN AN INTERNATIONAL STANDARD

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1. INTRODUCTION

In recent years a large number of European Directives have been published, containing requirements for determining the sound power levels of machines. The forerunner was Directive 79/113/EEC[1], which included a general method of determining the sound power level of construction plant and equipment. This was implemented by Directive 84/532/EEC[2] and several subsequent related directives, which imposed sound power limits on a wide range of machines used on construction sites. Separately from these, Directive 86/594/EEC[3] made provision for labelling household appliances with their A-weighted sound power level on a voluntary basis, and this was followed by Directive 92/75/EEC[4] which made the noise labelling mandatory. Directive 89/392/EEC[5] (the Machinery Directive) covers the safety of a wide range of machinery types, and it requires manufacturers to give information on the sound power level if the A-weighted sound pressure level at the work station of a machine exceeds 85 dB. In addition to all these, there is another new directive which addresses the noise emitted by machinery used outdoors[6]. It concerns some sixty machine types and will include some new noise limits and requires that all machines are labelled with a guaranteed A-weighted sound power level. The guaranteed level is defined as a sound power level that includes uncertainties due to production and measurement procedures.

The measurement procedures called up in the proposed new Directive are taken from the series of international standards that are concerned with the determination of sound power. In particular those that require measurements of sound pressure level around the machinery over a hypothetical surface surrounding the source. These standards are considered by many users as being too complicated and time consuming to use. The usefulness of a sound power measurement standard depends on the speed and accuracy with which results are obtained. The shape and size of the hypothetical surface and the way in which the sound field is sampled affects the accuracy and speed of the measurement. Generally, the more samples that are taken, the higher the grade of accuracy and the longer the measurement takes.

In a recent Report[7] it was proposed that a new series of sound power standards should be produced, ultimately to replace all the existing ones. The measurement method would be to relate the number of measurements of sound pressure level to the measurement uncertainty associated with the resultant sound power determination, allowing the number to be increased in order to achieve improved accuracy if required. The report provided data on measurement uncertainty based on repeatability standard deviations. However, the measurement uncertainty required for inclusion in these standards is revealed by the reproducibility of results when a given method is applied by different organisations, by different operators, using different equipment.

This paper describes a programme of inter-laboratory measurements designed to obtain estimates of the standard deviation of reproducibility. These values of reproducibility uncertainty are compared with the values obtained by Reference 7, based on repeatability data, with a view to providing uncertainty values suitable for inclusion in the proposed new series of standards.

2. EXPERIMENTAL PROGRAMME

2.1 Reproducibility testing

The objective of the project was to acquire data on the uncertainties in the determination of sound power levels, expressed in terms of standard deviations of reproducibility. To obtain reproducibility uncertainties it is necessary for the noise emission levels of a particular noise source to be measured,

by the same method,
by different laboratories (in different locations),
by different personnel,
using different measurement apparatus,
at different times.

The test programme was drawn up, following the guidance of ISO 5725-2[8] which deals with experiments to determine reproducibility of measurements, to provide the best balance between the number of repeated measurements (**three**) and number of laboratories (**four**) performing the tests with statistical confidence and measurement effort.

2.2 Noise source considerations

Thirty-two noise sources (actual machines and specially constructed devices) were used in reference 7 with a range of Directivity Index from 0.8 dB to 8 dB and an estimate of measurement uncertainty was associated with each. The purpose of the current series of measurements is to assess how these estimates compare with reproducibility values. However, because of the logistical difficulties involved with using such a large number of noise sources, it was decided to limit the number of noise sources to just three: a reference sound source with an A-weighted Directivity Index of 0.8 dB and a specially constructed source with Directivity Index of 6.9 dB, to examine the extremes of the Directivity Index range and a diesel-engined electrical power generator (Directivity Index of 1.3 dB) to include data for a real machine.

2.3 Measurement methods

The Standard generally used as the basis for all sound power determinations is ISO 3744:1994[9], and the proposed EC Directive concerning the noise from equipment used outdoors generally requires the use of a hemispherical enveloping surface. So, it was decided to concentrate the measurement effort on sound power levels determined according to ISO 3744 using a hemispherical surface. For the purposes of this paper only A-weighted sound pressure levels are considered. The number of measurement positions used for each hemispherical measurement surface was twenty and each sound power level determination was repeated three times in order to assess measurement repeatability. Sound power levels determined using this 20-microphone array were used as reference levels to which data from other arrays and configurations (see sub-Section 2.4) are compared and furthermore, are assumed to be true values. Measurements were made on all three noise sources by each Laboratory over a two week period with an overall measurement period of about two months. Measurements were also carried out by one of the Laboratories on all noise sources at each laboratories test site as soon as practicable after each had completed the required measurements. These measurements were performed to check on the long term stability of the noise sources and also permitted an estimation of uncertainties associated with the differing measurement sites. These uncertainties are a half way house between repeatability- and reproducibility-conditions and should provide information as to the contribution of variations resulting from differing sites and differing measurement laboratories to the final reproducibility variance. In this paper these uncertainties are termed "intra-site" repeatability.

2.4 Spatial sampling

From the sound pressure level measurements made using the twenty microphone positions, values of sound power level may be calculated for several microphone position sub-sets. Seven microphone position sub-sets were used in Reference 7 and may be briefly described as follows:

Twenty positions — The key and additional positions of ISO 3744
One array

Ten positions — The 10-key positions or the 10-additional positions of ISO 3744
Two arrays

Six positions — Six positions on each of the three complete hemispherical arcs
Three arrays, described as 6 (opp)

Four positions — All four positions at different heights
Six arrays

Three positions — All three positions at different heights
Six arrays, described as 3 (120)

Three positions — Three positions, two on one half-hemispherical arc and one on the opposite half-hemispherical arc
Six arrays, described as 3 (opp)

One position — Each of the twenty ISO 3744 positions
Twenty arrays

3. EXPERIMENTAL RESULTS

3.1 repeatability uncertainties

The average of the four Laboratories A-weighted repeatability uncertainties are shown in Table 1 for each sound source.

Table 1 Standard deviations of A-weighted repeatability uncertainties (expressed in dB).

	Number of measurement positions						
Machine	20	10	6 (opp)	4	3 (opp)	3 (120)	1
RSS	0.04	0.04	0.05	0.07	0.07	0.07	0.11
Generator	0.04	0.06	0.07	0.06	0.10	0.08	0.14
Box	0.06	0.08	0.10	0.13	0.15	0.14	0.16

An examination of these average values shows that repeatability uncertainties are generally less than 0.2 dB and for the reference 20-microphone array are of the order 0.05 dB. Values for all three noise sources tend to increase as the number of microphone positions is reduced. However, it can be seen that this increase is only of the order 0.1 dB when the number of microphones is reduced from twenty to one.

3.2 Intra-site uncertainties.

There is a variation in sound power determination between sites, with a range of 0.59 dB, 0.68 dB and 0.94 dB for the reference sound source, generator and box source respectively. If it is assumed

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