

MEASUREMENT UNCERTAINTIES IN THE DETERMINATION OF THE SOUND POWER LEVEL AND EMISSION SOUND PRESSURE LEVEL OF MACHINES

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ABSTRACT

The EC Machinery Directive 89/392/EEC requires manufacturers to declare certain basic noise information about the noise emission of their products. Underpinning the Directive is a range of ISO/CEN standards specifying agreed methods of measuring sound power level and emission sound pressure level. Most of these standards have been subject to extensive revision over the past few years, and some are completely new. The standards make it clear that measurements are subject to an uncertainty which is reflected in the reproducibility of results when the standard is applied by different organisations, by different personnel, using different equipment. This report describes a programme of measurements undertaken by four laboratories on each of four different machines to test the validity of the estimates of reproducibility given in the sound power standards ISO 3744, ISO 3746 and ISO 9614-1, and the emission sound pressure level standards ISO 11201 and ISO 11202.

The report examines: the intra-laboratory repeatability of the measurements (the ability of each laboratory to produce repeatable results); the intra-standard repeatability (the repeatability of measurements made by each laboratory to each standard over a range of different conditions within the bounds permitted by the standards); and the reproducibility of the measurements (the overall dispersion of measurements made by the four laboratories). The report also analyses differences between results obtained using hemispherical and parallelepiped measurement surfaces of different sizes in different acoustical environments, and finally inter-compares results obtained using the three sound power standards and using the two emission sound pressure level standards.

With the exception of ISO 3744, the experimental reproducibility standard deviations were all within the estimates published in the standards. In general, there were no statistically-significant differences between results obtained using different measurement surfaces and distances. Inter-comparison of the three sound power standards, and the two emission sound pressure level standards, showed agreement fully consistent with the experimental reproducibilities of the standards.

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Approved on behalf of Managing Director, NPL,
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1. INTRODUCTION

The European Community is pursuing a programme to build an integrated internal market with harmonised regulations and standards, and this programme has many implications for companies which do business in Europe. The principal means of introducing these harmonised regulations and standards is through EC Directives implemented in law in each member state, underpinned by European Standards published by the European Committee for Standardization (CEN).

One of the most wide-ranging Directives affecting industrial products is 89/392/EEC¹ and its two amendments 91/368/EEC² and 93/44/EEC³ on "the approximation of the laws of the Member States relating to machinery" - the so-called EC Machinery Directive. This Directive applies to all machinery, defined as "an assembly of components, at least one of which moves, for a specific application, in particular for the processing, treatment, moving or packaging of a material". The Directive is principally concerned with the safety of machines, one aspect of which involves controlling excessive noise emission. For the first time, therefore, machinery manufacturers are being required to contribute directly to noise abatement in industry. This is done through two essential safety requirements:

- The machinery must be so designed and constructed that the risks resulting from the emission of airborne noise are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at the source.
- Specified quantitative information on airborne noise emitted by machinery under defined operating conditions must be made available by the manufacturer.

The Machinery Directive contains detailed instructions regarding the nature of the information to be provided by the manufacturer. This includes the emission sound pressure level at the work station (the position of the operator) and the overall sound power level. The decision on which of these two acoustic parameters is to be provided is made by comparing the values of the A-weighted time-averaged emission sound pressure level, L_{pA} , at the work station to thresholds specified in the Directive, as follows:

- If L_{pA} is less than 70 dB then only this fact need be stated.
- If L_{pA} is between 70 dB and 85 dB then only L_{pA} need be provided.
- If L_{pA} is greater than 85 dB, then the A-weighted sound power level, L_{WA} as well as L_{pA} must be provided.

Thus the amount of noise measurement work required to be carried out by the manufacturer is dependent on the noise level of the machine.

The "declared" noise level is defined in ISO 4871⁴ (which is in the process of revision) as a maximal statistical value that is not exceeded for a given confidence level. This

standard is a key document as it requires the addition of an uncertainty value to measured noise levels. It is unlikely that the increase in declared noise level resulting from the addition of this uncertainty will affect sales of a particular machine but, because of the criteria listed above, it may well affect the amount of measurement work required by the manufacturer. Thus it is of prime importance that the level of measurement uncertainty is carefully specified.

Although formally it is European (CEN) Standards that will underpin the noise requirements of the Machinery Directive, the work of developing these standards is being undertaken by ISO rather than CEN. The reason for this is that a whole series of standards on machinery noise measurement were published by ISO in the 1970s and 1980s, which provide a substantial basis for the standards now required by CEN. A weakness of the existing ISO standards is the way they deal with measurement uncertainty, which is generally insufficiently clear and rigorous for regulatory use. Nevertheless, the ISO standards are progressively being updated to overcome these deficiencies and to reflect improvements in measurement practice, and CEN is undertaking parallel voting on the drafts to ensure they can be adopted as European standards as soon as they are published by ISO. This approach has the advantage of bringing about harmonisation not just in Europe but worldwide, though with the disadvantage of having to carry the support of the major non-European manufacturing nations through the drafting process.

The measurement uncertainty associated with a measurement method is revealed by the reproducibility of results when a given method is applied by different organisations, by different operators, using different equipment, and will also be dependent on the desired confidence level. Even the most recent ISO standards differ in the amount of information they give on reproducibility. Some contain tables of estimated standard deviations of reproducibility (though with no indication of their source) whilst others offer no more than statements of principle.

In order to test the validity of the estimated standard deviations of reproducibility tabulated in current standards, the DTI National Measurement System Policy Unit awarded a contract to NPL in January 1993 to design and carry out a programme of inter-laboratory measurements. The objectives of the measurement programme were "to provide comprehensive and definitive data on the uncertainties in the measurement of sound power levels and emission sound pressure levels of machinery" and "to carry out an analysis of the sources of uncertainty in a form suitable for use by International Standards specifications for evaluating machinery noise emission". In particular, the project was required to investigate the reproducibility of the most up-to-date versions of the following measurement procedures:

- sound power levels according to ISO 3744, in one-third-octave bands at frequencies at least from 100 Hz to 10 kHz, and possibly extending down to a frequency of 50 Hz
- A-frequency-weighted sound power levels according to ISO 3746, in an

environment requiring approximately 7 dB correction

- sound power levels according to ISO 9614-1, in one-third-octave bands at frequencies from 50 Hz to 6.3 kHz
- A- and C-frequency-weighted emission sound pressure levels according to ISO 11201
- A- and C-frequency-weighted emission sound pressure levels according to ISO 11202, in environments requiring approximately 2.5 dB and 7 dB corrections.

All measurement were required to be traceable to UK national measurement standards, and computer software was to employ traceable analytic techniques.

This Report describes the measurement programme and analyses the results in depth to establish the intra-laboratory repeatability, intra-standard repeatability, and reproducibility of the measurements. The dependency of the results on the type of measurement surface used, the measurement distance, and the characteristics of the acoustic environment is also analysed. Finally conclusions are presented, including recommendations for amendments to the content and use of the standards.

2. BACKGROUND TO THE RELEVANT INTERNATIONAL STANDARDS

The standards being produced by ISO/CEN to support the Machinery Directive are of two types, known in European Standards terminology as B-type standards and C-type standards.

A standard that deals with the fundamental principles of a particular aspect of safety (e.g. noise emission) as applied to all types of machinery is termed a B-type standard, and these are the standards which are considered in this Report. More than a dozen B-type standards have been published or are under revision or development by ISO TC43 SC1 "Noise" (paralleled by CEN TC211 "Acoustics") specifying the basic principles for measuring machinery noise emission.

A standard that is both specific to a particular aspect of safety and to a particular class of machines (e.g. brush saws) is termed a C-type standard. C-type standards draw upon the general principles given in B-type standards, but specify the detailed operating conditions of the machinery during the safety tests. A large number of C-type standards dealing with the noise emission of particular classes of machines are under production by various Technical Committees in ISO and CEN. These were not considered in the current study.

The two noise emission quantities specified by the Machinery Directive are the emission sound pressure level at the work station and the overall sound power level. The relevant B-type standards for measuring these quantities have been grouped by ISO into three series of standards, as follows:

- the ISO 3740 series of standards, ISO 3740 - 3747⁵⁻¹² for determining the sound power level of noise sources using sound pressure
- the ISO 9614¹³⁻¹⁵ series of standards for determining the sound power level of noise sources using sound intensity
- the ISO 11200 series of standards, ISO 11200 -11204¹⁶⁻²⁰, for determining the emission sound pressure level at the operator position (work station).

The relevance of these standards is discussed in the following sub-sections.

2.1 THE ISO 3740 SERIES

This series of standards describes the "classical" methods for determining the sound power of noise sources based on measurements of sound pressure.

ISO 3740 gives guidelines on the use of the standards in the series.

ISO 3741, ISO 3742 and ISO 3743-1 and ISO 3743-2 offer methods based on measurements at locations more or less remote from the source in a reverberant environment. However, they require the use of qualified test rooms which are only

available in specialised laboratories, and were therefore not included in the current study.

ISO 3744, ISO 3745 and ISO 3746 offer methods based on measurements over a surface enveloping the source in an anechoic or hemi-anechoic environment, in which the requirements of the test site are specified in terms of an environmental correction factor (termed K_2 in the standards). ISO 3745 gives so-called grade 1 accuracy and considers both hemi-anechoic and anechoic environments, but because of the specialised nature of the test room required is seldom used for routine industrial measurements. It was therefore excluded from the study.

ISO 3747 is an in-situ comparison method but uses a reference sound source and is rather cumbersome. Consequently it is very little used, and because of the difficulty of defining a common acoustic environment it also does not lend itself to the scrutiny of an intercomparison.

For these reasons, the investigation was required to focus on ISO 3744 and ISO 3746. A summary of these two standards is given in Table 1, and briefly described below.

Table 1. Summary of the requirements of ISO 3744 and ISO 3746

	ISO 3744	ISO 3746
test environment	Enveloping surface method over reflecting plane, indoors or outdoors	
environmental correction, K_2	≤ 2 dB	≤ 7 dB
size of source	limited only by available test environment	
noise character	any	
background noise	≥ 6 dB	≥ 3 dB
number of measurement points	≥ 9	≥ 4
instrumentation	IEC 651, IEC 804, IEC 225	IEC 651, IEC 804

ISO 3744 has been up to now the most widely used standard of the series. It is an enveloping surface method of grade 2 accuracy and is applicable as long as the environmental correction for the test site is not larger than 2 dB. Out-door sites, large rooms or rooms with acoustical treatment are normally qualified. The standard has provisions for cases where more than one reflecting plane is present and has microphone positions which are consistent with those specified in ISO 3746. The standard specifies instrumentation and methodology for noise measurements to be made in one-third octave bands from 50 Hz to 10 kHz or A-weighted.

ISO 3746 is structurally similar to ISO 3744 but is of grade 3 accuracy and can be used in any room as long as the environmental correction is less than 7 dB. Unlike ISO 3744, this standard only deals with A-weighted levels.

Both these standards permit measurements to be made using either a hemisphere or a parallelepiped as the enveloping surface. A wide range of surface sizes may be chosen. There is however, a minimum surface area which is governed by the dimensions of the machine. The machine dimensions are described in the standards in terms of the size of the "reference box" and d_0 , the "characteristic dimension". The reference box is a hypothetical surface which is the smallest rectangular parallelepiped that just encloses the source and terminates on the reflecting plane. The characteristic dimension is half the length of the diagonal of the box consisting of the reference box and its images in adjoining reflecting planes. The radius, r , of the hemispherical measurement surface must be greater than or equal to twice the characteristic dimension and not less than 1 m. For the parallelepiped surface the measurement distance d (the perpendicular distance between the reference box and the measurement surface) must be at least 0.25 m. Typical measurement configurations for a hemispherical surface and for a parallelepiped surface are shown in Figures 1 and 2 respectively.

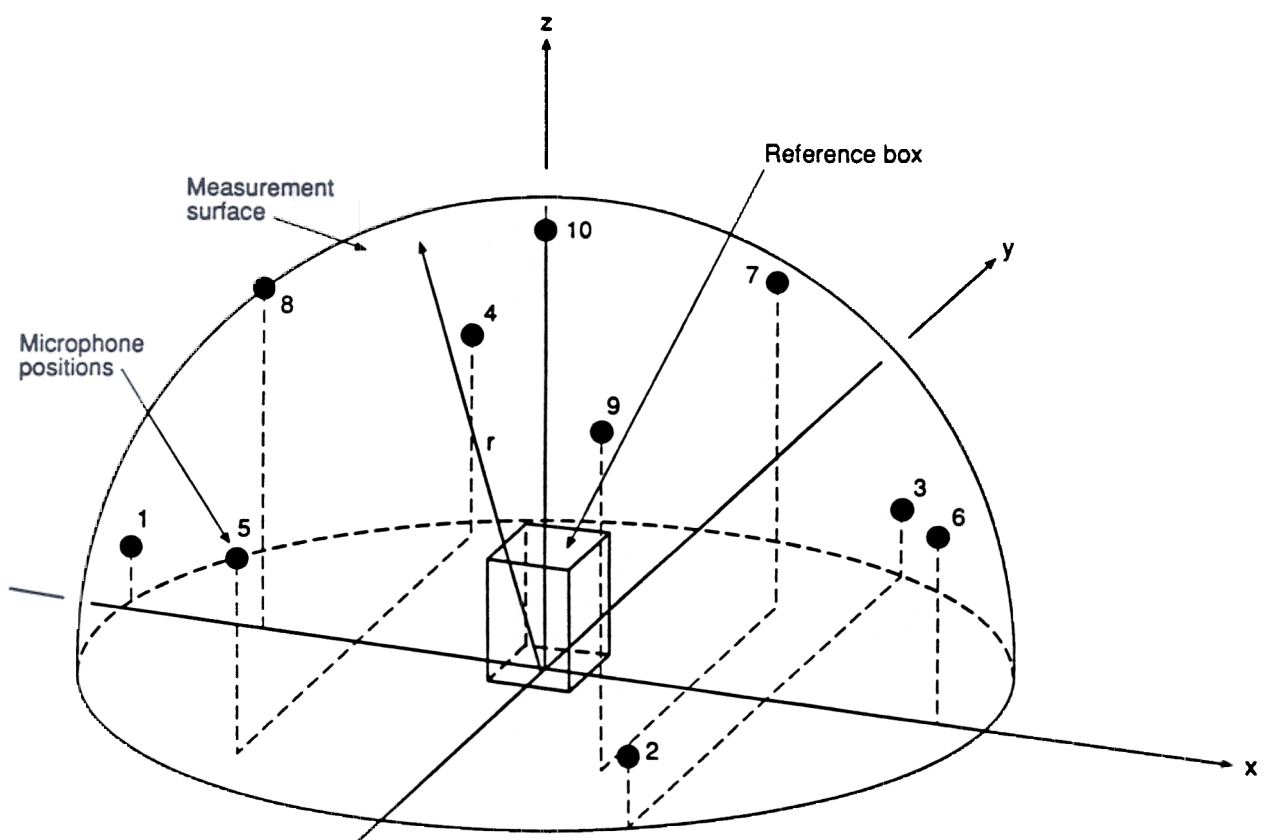


Figure 1. Typical hemispherical measurement surface

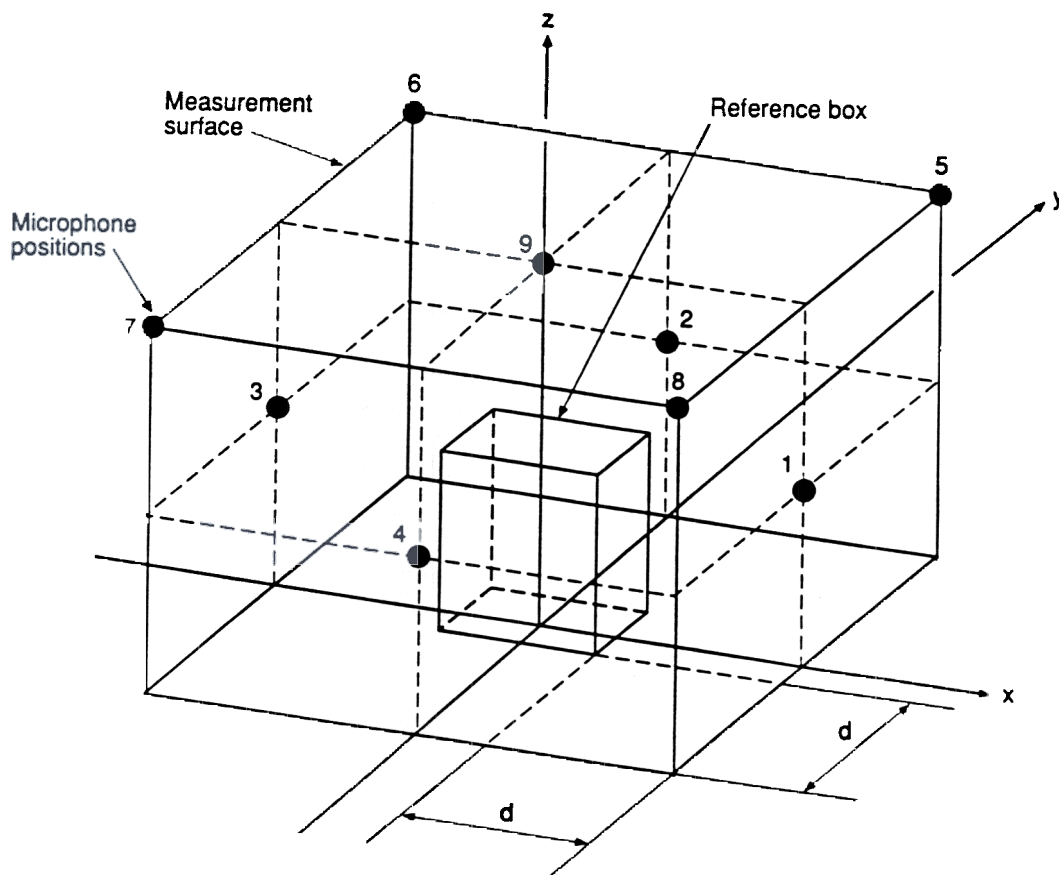


Figure 2. Typical parallelepiped measurement surface

2.2 THE ISO 9614 SERIES

This series of three standards (produced as three parts of ISO 9614) offers enveloping surface methods of measuring sound power using the sound intensity technique. ISO 9614-1 and ISO 9614-2 are published and ISO 9614-3 is under development. The requirements of this series of standards are not readily tabulated, but a brief outline is given below.

ISO 9614-1 considers discrete positions of the intensity probe on the measurement surface. The method requires many probe positions and the grade of accuracy achieved (up to grade 1) is dependent on the values of a number of so-called field indicators which examine various aspects of the source and measurement configuration. Restrictions on test environment, noise source size and character and background noise are more relaxed than those that apply to the ISO 3700 series. However, because of difficulties involved with phase matching of the microphone pair in the intensity probe there is an upper one-third octave band frequency limit of 6.3 kHz.

ISO 9614-2 offers a method in which the intensity probe is continuously scanned over the measurement surface. Whilst this provides a much faster measurement procedure

it is difficult to achieve a steady scan rate and it only gives grade 3 accuracy. It was, therefore, excluded from this investigation.

At the start of this project, ISO 9614-3 was only at the stage of an ISO proposed work item and so was excluded. The major objective of the proposed part three to ISO 9614 is to provide a grade 1 measurement via a refinement of the field indicators for spatial and temporal variation of sound intensity.

2.3 THE ISO 11200 SERIES.

These standards offer a number of different methods for measuring the emission sound pressure level at work stations.

ISO 11200 gives general guidance on the choice of the appropriate method from those offered in the rest of the series.

ISO 11201 gives an engineering-grade (grade 2) measurement method with prescribed environmental conditions. No environmental correction is required. Its application is limited to machinery operating, indoors or outdoors, in an essentially hemi-anechoic acoustic field with no reflecting objects in the neighbourhood apart from the reflecting floor.

ISO 11202 offers an easy but survey-grade (grade 3) measurement method with prescribed environmental conditions. A local environmental correction is determined using a very simple procedure; its magnitude is limited to a maximum of 2.5 dB. This method is used in industrial situations where a machine cannot operate in an environment that can be defined acoustically and the manufacturer chooses not to use ISO 11204.

ISO 11203 does not require the measurement of emission sound pressure level at the work station but describes how it can be derived from sound power level, and so is not included in the inter-comparison.

ISO 11204 describes a sophisticated method with prescribed environmental conditions that, for machines with a low directivity index, can provide grade 2 accuracy results in a wide range of acoustical environments. To achieve this accuracy the method requires a series of sound pressure measurements around the machine, unlike the standards described above which only require a single measurement at the work station. From this series of measurements a local environmental correction is determined.

A summary of the requirements of the two standards under scrutiny in this Report (ISO 11201 and ISO 11202) is given in Table 2 together with details for ISO 11204 for comparison purposes.

Table 2. Summary of the requirements of ISO 11201, ISO 11202 and ISO 11204.

	ISO 11201	ISO 11202	ISO 11204
test environment	indoors or outdoors		
environmental correction	≤ 2 dB (not applied)	≤ 7 dB (≤ 2.5 dB applied)	≤ 7 dB (applied)
source size	limited only by test environment		
noise character	any		
background noise	≥ 6 dB	≥ 3 dB	≥ 6 dB
measurement points	work stations and other specified positions (usually up to 4)		
instrumentation	IEC 651 class 1 IEC 804 class 1 IEC 225 class 1 IEC 942 class 1	IEC 651 class 2 IEC 804 class 2 IEC 942 class 1	IEC 651 class 1 IEC 804 class 1 IEC 225 class 1 IEC 942 class 1
acoustic metric	$A, C_{peak}, 1/3$ oct	A, C_{peak}	$A, C_{peak}, 1/3$ oct

The microphone positions for the 11200 series of standards depend on the type of machine and are generally related to the location of the machine operator. For the purposes of the measurements carried out in this intercomparison the microphone positions are those recommended for unattended machines. Here measurements are made at four locations, shown in Figure 3.

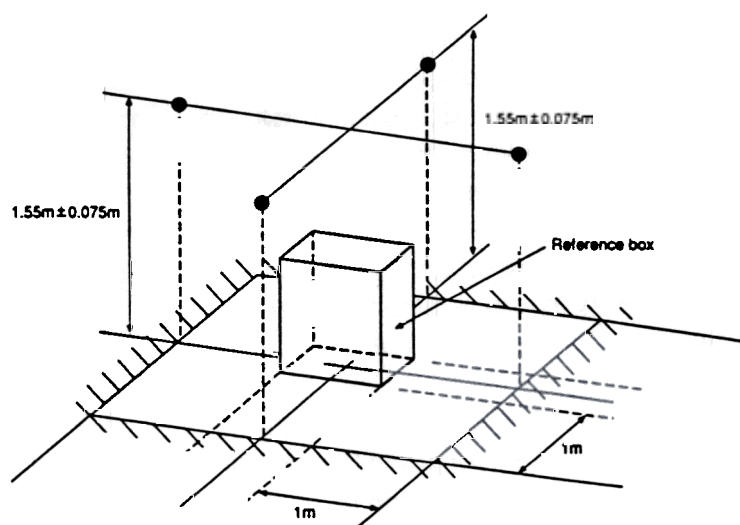


Figure 3. Microphone positions for the 11200 series of standards

3. PROGRAMME DESIGN CONSIDERATIONS

3.1 REPRODUCIBILITY TESTING

The first objective of the project was to acquire definitive data on the uncertainties in the measurement of noise emission 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 programmes were drawn up, following the guidance of ISO 5725²¹ which deals with experiments to determine reproducibility of measurements, to provide the best balance between the number of repeated measurements, number of machines to be tested and number of laboratories performing the tests. The programmes described in Section 4 contain the minimum number of test condition combinations that will permit a statistically significant assessment of the contribution of each measurement condition to reproducibility uncertainties. The greater the number of results determined for variations of a particular condition (for example changing the measurement distance, or employing different observers), the greater the statistical confidence there is in determining the influence of the particular condition on the measurement uncertainties.

3.2 MACHINE TYPES

The standard deviations of reproducibility required for incorporation into standards must be applicable to all types of noise source covered by the standards. For meaningful data to be produced, noise emission from a range of widely-used machinery types must be investigated. The variety of noise sources to which the standards are applicable requires that measurements are made on several machines having a range of different sizes, mechanisms and non-uniform acoustic directivity patterns. Reference sound sources, which have very stable output levels and simple omni-directional directivity patterns, are unsuitable for the determination of measurement uncertainties of "real" machines.

A number of machine types with a range of characteristics, which are likely to give rise to the greatest values of uncertainties were identified. Four were used in the test programme and are described in sub-section 4.1. The same machines were used in all the tests, in order to achieve consistency of results.

3.3 SELECTION OF MEASUREMENT ORGANISATIONS

Measurements made by only one or two teams of observers, or at only one test site, or with only one set of apparatus, would not be sufficient to obtain reproducibility uncertainties. Thus, it was necessary to recruit other independent laboratories to the project, and to obtain a statistically valid assessment of reproducibility uncertainties it was considered necessary to involve at least three laboratories in addition to NPL.

Six organisations were invited by NPL to tender to undertake a specified programme of measurements based on the standards listed in Section 1 on the four selected machines. They comprised laboratories holding NAMAS-accreditation for measurements of machinery noise and other organisations with appropriate facilities and experience in machinery noise measurement. In selecting the organisations which carried out the measurement work, the following factors were considered:

- past experience in machinery noise determination,
- qualification of test environments and facilities,
- suitability of test equipment available to the laboratory,
- tendered price.

Three were selected and awarded sub-contracts, having satisfied NPL that they would be capable of carrying out the whole programme. In fact from Section 7 it can be seen that the measurement programme was completed with only minor omissions.

The three laboratory sub-contractors were supervised by NPL through regular contact and by scrutiny of test results submitted for analysis.

3.4 MEASUREMENT METHODS

Five measurement methods were evaluated during the project: ISO 3744, ISO 3746, ISO 9614-1, ISO 11201 and ISO 11202. Measurement methods that involve scanning along fixed paths around the noise source require cumbersome equipment and are rarely used so, where the standards provided scanning and discrete options, measurements were made at discrete points.

Several of the standards were still in the process of development, or undergoing extensive revision, at the start of the measurement programme, so the methods used were taken from the latest Draft International Standard versions available. The laboratory sub-contractors were provided by NPL with copies of these drafts, together with instructions on measurement surfaces, measurement positions, data recording, etc. These instructions are reproduced in Appendix 1.

All the standards have now been published (some at the end of 1995) and it is these published versions which are cited in Section 13. There are no material differences between the drafts used and the final published versions.

3.5 DATA STORAGE AND SOFTWARE

Measured data from each laboratory were stored on a set of 21 floppy discs, supplied and formatted by NPL, using Statistical and Presentation Software Systems (SPSS) Data Entry II (one set for each laboratory). The statistical analysis described in Section 9 was performed using the SPSS statistical analysis package. Data Entry II is a stand-alone module of this analysis package. Sets of pre-formatted discs and comprehensive instructions (see Appendix 2) were issued to the three sub-contracted organisations to ensure compatibility of presentation and speed of analysis of the measured data.

4. EXPERIMENTAL PROGRAMME

This Section describes the four noise sources used and gives details of the measurement programme undertaken by the four laboratories (including NPL). Measurements were made on the machines first at NPL and then sequentially by the other three laboratories. A small number of measurements were carried out by NPL on all four machines during the programme and at the end as a check on the stability of the sources; no significant variation in sound power level was detected.

4.1 NOISE SOURCES

Tests were conducted on four machines supplied by NPL, comprising (a) an electric drill, (b) a diesel-engined electrical power generator, (c) a two-stroke petrol-engined lawnmower, and (d) a diesel-engined air compressor. The drill, which required a 240 V mains electrical supply, was provided with a mounting stand. The generator, lawnmower and air compressor were all used free-standing on the floor of the test area. Their approximate overall sizes are shown in Table 3. Brief details of each machine are given in sub-sections 4.1.1 to 4.1.4. In all cases the information given was extracted from the manufacturer's instruction book. The other three participating laboratories were supplied with these instruction books and were advised to consult them if there was any doubt regarding the operation of any of the machines.

Table 3. Approximate machine dimensions.

Machine	Dimensions (m)		
	Side-to-side	Front-to-back	Height
(a)	0.3	0.05	0.3
(b)	0.5	0.7	0.7
(c)	0.5	0.7	0.4
(d)	1.2	1.6	1.2

4.1.1 Electric drill [machine (a)]

Manufacturer: Black & Decker.
 Type: BD163V 550 Watt.
 Power requirement: 240 volt, 50 Hz electrical supply

The drill was fastened to a Black & Decker drill stand which was securely fixed to a wooden base plate of dimensions 300 mm x 250 mm x 20 mm. The drill was operated in the non-hammer mode with the speed trigger secured full in (maximum rpm).

Electrical power generator [machine (b)]

Manufacturer: Lombardini (engine).
 Type: GLD360.
 Manufacturer: Markon Engineering (generator).
 Type: B31B.
 Manufacturer: Clarke Power (rectifier).
 Power requirement: diesel fuel, SAE grade 15/40 oil.

Some preparatory checks were advised; check the oil level using the dip-stick and top up as required and, if necessary, clean the air filter. The engine has a starting pull cord and instructions were given on its use. Before commencing measurements the engine was allowed to idle for a few minutes by keeping the throttle lever at its highest position. During measurements the engine was operated at the maximum power setting with the throttle lever fixed at its lowest position.

Two-stroke petrol-engined lawnmower [machine (c)]

Manufacturer: Siag (lawnmower).
 Type: Harry.
 Manufacturer: Briggs and Stratton (engine).
 Type: 2 Stroke/4 HP.
 Power requirement: Unleaded petrol in 50:1 ratio with a two stroke oil rated TC-W.

The lawn mower is a rotary mower with no forward drive as is usual with cylinder mowers. Instructions on starting the engine were supplied to each organisation. These included ensuring that the underside of the mower deck was clean and the rotary cutter free of obstructions. Two sets of notches were cut into the speed control lever housing and during measurements the speed control lever was positioned between them. This resulted in an engine speed of 2000 rpm. Trials showed that small variations (larger than would be expected due to human error) in control lever position around the "notches" did not alter the engine speed.

Diesel-engined air compressor [machine (d)]

Manufacturer: Atlas Copco.
 Type: XAS 35 Air Compressor.
 Power requirement: diesel fuel, SAE 15/40 motor oil, hydraulic oil of ISO recommended viscosity of VG32

Several preparatory checks were recommended and are listed below:

- ensure the engine oil level reaches the upper mark on the dip-stick,
ensure the compressor oil level indicator is within the displayed “green range”,
drain water or sediment from the fuel filter until clean fuel flows from the drain cock,
- empty the vacuator valve of the air filter,
- check the air intake vacuum indicator.

A starting procedure was also specified

- open an air inlet valve,
move the side panel toggle switch to “1”, the “charge” and “engine oil pressure” lamps light,
press and hold the start button until both lamps go out,
once the engine runs smoothly, close the air outlet valve and allow a couple of minutes for the engine to warm up.

The acoustic measurements could then proceed.

4.2 MEASUREMENTS ACCORDING TO ISO 3744

Measurements to this standard may be carried out in a hemi-anechoic room or an outdoor space fulfilling the acoustic environment requirements of the standard. Because of the low noise level of the electric drill some measurements were carried out in a hemi-anechoic room. The other three machines all produce exhaust gases and so were tested outdoors. The laboratories determined the environmental correction factor for each environment using a calibrated reference sound source or assumed K_2 was less than 0.5 dB, and therefore negligible, in accordance with Annex A of ISO 3744.

Sound pressure levels were required to be measured with frequency weighting A and in one-third octave bands at mid-band frequencies from 50 Hz to 10 kHz, on three hemispherical measurement surfaces of radii listed in Table 4, and on three parallelepiped measurement surfaces.

Table 4. Measurement radii, r , for the hemispherical surfaces used for ISO 3744.

Machine	r_1 (m)	r_2 (m)	r_3 (m)
(a)	1.0	1.25	1.5
(b)	2.0	4.0	6.0
(c)	2.0	4.0	6.0
(d)	4.0	6.0	8.0

The number of measurement positions for each hemispherical measurement surface

was typically 10.

The measurement distances and typical numbers of measurement positions for the parallelepiped measurement surfaces are listed in Table 5.

Table 5. Measurement distances, d , and typical numbers of measurement positions for parallelepiped measurement surfaces used for ISO 3744.

Machine	Number of measurement positions			
	$d_1 = 0.25 \text{ m}$	$d_2 = 1.0 \text{ m}$	$d_3 = 1.5 \text{ m}$	$d_4 = 2.0 \text{ m}$
(a)	14	9	9	-
(b)	37	9	-	9
(c)	21	9	-	9
(d)	61	21	-	9

4.3 MEASUREMENTS ACCORDING TO ISO 3746

Sound pressure levels were measured with frequency weighting A on the three hemispherical measurement surfaces listed in Table 4, using typically 4 measurement positions, and three parallelepiped surfaces, using the measurement distances and typical numbers of measurement positions given in Table 6.

Table 6. Measurement distances, d , and typical numbers of measurement positions for parallelepiped measurement surfaces used for ISO 3746.

Machine	Number of measurement positions			
	$d_1 = 0.25 \text{ m}$	$d_2 = 1.0 \text{ m}$	$d_3 = 1.5 \text{ m}$	$d_4 = 2.0 \text{ m}$
(a)	8	5	5	-
(b)	20	5	-	5
(c)	12	5	-	5
(d)	33	12	-	5

When designing the measurement programme the original intention was for each machine to be tested in two acoustic environments, one requiring an environmental correction for A-weighted measurements, K_{2A} , within the range 2.0 dB to 2.5 dB and the other requiring a correction within the range 4.5 dB to 5.5 dB, where K_{2A} is determined in accordance with clause A.3.1 of ISO 3746 using a calibrated reference sound source.

However, these acoustic environments were difficult to achieve in practice and so environmental corrections outside these ranges were accepted.

4.4 MEASUREMENTS ACCORDING TO ISO 9614-1

For measurements to this standard the specifications for Engineering grade (grade 2) accuracy were followed.

The sound intensity instrument (comprising the probe and processor) required for measurements to ISO 9614-1 is a Class 1 instrument according to IEC 1043²². Laboratories generally sought the guidance of the manufacturer or supplier of the instrument for information on performance.

Each machine was tested in two acoustic environments, one being the same hemi-anechoic environment (either a room or outdoors) used for the measurements according to ISO 3744, and the other being the environment used for the measurements according to ISO 3746 with a nominal environmental correction factor of between 4.5 dB and 5.5 dB.

Sound intensity levels were measured in one-third-octave bands of mid-band frequencies from 50 Hz to 5.0 kHz, on one parallelepiped measurement surface only, selected to fulfil the requirements of the standard. The number of measurement positions used by the laboratories varied between the different machines, and ranged from 10 to 50.

4.5 MEASUREMENTS ACCORDING TO ISO 11201

Each machine was tested in the same acoustic environments used for the measurements according to ISO 3744.

Time-average sound pressure levels with frequency weighting A and peak sound pressure levels with frequency weighting C were measured at four positions only, in accordance with clause 11.5 of the standard.

4.6 MEASUREMENTS ACCORDING TO ISO 11202

Each machine was tested in the same two acoustic environments used for the measurements according to ISO 3746.

Time-average sound pressure levels with frequency weighting A and peak sound pressure levels with frequency weighting C were measured at four positions only, in accordance with clause 11.5 of the standard.

5. EXPERIMENTAL INSTRUMENTATION

There is an inherent requirement for all instrumentation to adhere to the specifications described in the various standards under examination. All organisations showed compliance and provided evidence of calibration certificates where required. The equipment used by each organisation, as supplied in their measurement reports, is listed below.

EQUIPMENT USED BY LABORATORY 1

Real time frequency analyser	Brüel & Kjær type 2144
½ inch condenser microphone	Brüel & Kjær type 4165
½ inch condenser microphone	Brüel & Kjær type 4181 (matched pair)
Windscreen	Brüel & Kjær type UA 0237
½ inch microphone preamplifier	Brüel & Kjær type 2639
Microphone power supply	Vinculum type M591
Sound intensity probe set	Brüel & Kjær type 3548
Sound intensity calibrator set	Brüel & Kjær type 3541
Sound level calibrator	Brüel & Kjær type 4228
Multi-frequency calibrator	Brüel & Kjær type 4226
Reference sound source	Brüel & Kjær type 4204

5.2 EQUIPMENT USED BY LABORATORY 2

Real time frequency analyser	Brüel & Kjær type 2144
½ inch condenser microphones	Brüel & Kjær type 4181 (matched pair)
½ inch condenser microphone	Brüel & Kjær type 4165
Electronic calibrator	Brüel & Kjær type 4230
Sound intensity calibrator	Brüel & Kjær type 3541
Sound source	Brüel & Kjær type ZI0055
Reference sound source	Brüel & Kjær type 4205
Anemometer	Casella type deuta
Whirling hygrometer	Casella

EQUIPMENT USED BY LABORATORY 3

Real time frequency analyser	Brüel & Kjær type 2144
½ inch condenser microphone	Brüel & Kjær type 4165
½ inch microphone preamplifier	Brüel & Kjær type 2619
½ inch condenser microphone	Brüel & Kjær type 4181 (matched pair)
Sound intensity probe set	Brüel & Kjær type 3548
Precision sound level meter	Brüel & Kjær type 2231
½ inch condenser microphone	Brüel & Kjær type 4155

Reference sound source	Brüel & Kjær type 4204
Sound intensity calibrator set	Brüel & Kjær type 3541
Sound level calibrator	Brüel & Kjær type 4230

5.4 EQUIPMENT USED BY LABORATORY 4

Sound level meter	Brüel & Kjær type 2231m
Sound level calibrator	Brüel & Kjær type 4230
1/3-octave filter set	Brüel & Kjær type 1625
Windscreen	Brüel & Kjær type UA 0237
Reference sound source	Brüel & Kjær type 4205

6. EXPERIMENTAL LOCATIONS

The acoustic environments are specified in the various standards. The requirements for each standard under consideration in this Report are briefly outlined in the following four sub-sections together with a short description of the experimental locations used by each laboratory.

6.1 MEASUREMENTS TO ISO 3744

The test environment that is applicable for measurements made in accordance with this International Standard is an essentially free field near one or more reflecting planes (indoors or outdoors). As far as practicable, the test environment shall be free from reflecting objects other than a reflecting plane so that the source radiates into a free field over a reflecting plane. The standard describes methods to determine the environmental correction factor, K_2 . As for measurements made according to ISO 3744, K_2 must be numerically less than or equal to 2 dB.

ISO 3744 locations used by laboratory 1

Two measurement locations were used, one indoor the other outdoor. The indoor location was used for all the measurements carried out on the electric drill and was a hemi-anechoic room that satisfies the requirements of ISO 3745 which addresses precision methods of measuring sound power. The outdoor location was used for all measurements on the other three machines. The outdoor location consisted of a large flat surface covered with concrete to a depth of at least 200 mm and approximately 50 m square with no sound-reflecting surfaces.

ISO 3744 locations used by laboratory 2

Measurements on all four machines were undertaken in the middle of a car park. The A-weighted environmental correction factor was estimated as less than 0.5 dB. The nearest sound-reflecting object for all the tests was a minimum of three times the greatest distance from each machine centre to the lowest measurement position. In the case of tests on the largest machine (the compressor), the greatest distance from the centre of the machine to the measurement location was 7.9 m at a height of 0.6 m above the ground, and the nearest sound-reflecting object was a minimum of 24 m away.

6.1.3 ISO 3744 locations used by laboratory 3

Three measurement locations were used. The values of the environmental correction factors for each location were measured and all were less than or equal to 2 dB. Brief descriptions of each location and a summary of measurements carried out are listed

below

- A) Part of the flat roof of an office building. This comprised a flat concrete roof of area 110 sq m which was overlaid with 50 mm thick concrete slabs to produce the reflecting plane.

Drill	All measurements
Generator	2 m hemisphere. All parallelepipeds
Lawnmower	2 m hemisphere. All parallelepipeds

- B) On a forecourt. This comprised of a concrete drive with a smaller adjacent area of tarmacadam with an effective area of approximately 140 sq m.

Compressor	0.25 m and 1 m parallelepiped.
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- C) Part of a large car park. This comprised an area of concrete blocks, large enough to allow measurements over the largest enveloping surface on the compressor.

Generator	4 m and 6 m hemispheres
Lawnmower	4 m and 6 m hemispheres
Compressor	2 m parallelepiped and all hemispheres

6.1.4 ISO 3744 locations used by laboratory 4

All measurements were carried out on a purpose built noise test pad. The “pad” area was 25 m square with an adjoining concrete access road and surrounded by a flat grass area with no reflecting obstructions for a further 20 m beyond the limits of the concrete surface.

6.2 MEASUREMENTS TO ISO 3746

The test environments that are applicable for measurements made in accordance with this International Standard include a flat outdoor area or a room which meets specified requirements on the environmental correction factor, K_{2A} . Procedures are described in the standard for determining the magnitude of K_{2A} to account for deviations of the test environment from the ideal hemi-anechoic condition. For this International Standard K_{2A} must be numerically less than 7 dB. In the experimental programme described in this report two environments are required, one with a value of K_{2A} of approximately 2.5 dB, the other a higher value of approximately 5 dB (see sub-section 4.3).

ISO 3746 locations used by laboratory 1

The measurements were carried out in three areas, indoors, outdoors and in a semi-indoor location. The indoor location was a brick walled room with a "lino" floor and a false ceiling constructed of acoustic panels. The room has a floor area of 6 m x 10 m and is 2.5 m high. The machine was positioned approximately in the centre of the floor area and a number of reflectors positioned to achieve the required value of K_2 . For the outdoor location, the machine was positioned close to a brick facade, 5 m high and 7 m wide. The measurement area was open on the other three sides and covered by a metal corrugated roof some 5 m above the concrete covered ground surface. The semi-indoor location consisted of a room with metal cover to all surfaces. The room had a floor area of approximately 10 m x 15 m and was 4 m high. Measurements were made towards one corner of the room adjacent to an area approximately 4 m square in one wall that was open to the outside. For the electric drill all low K_2 -factor measurements were carried out indoors, and high K_2 -factor measurements in the semi-indoor area. For the other three machines the low K_2 -factor measurements were performed on the outdoor site and the high K_2 -factor measurements at the semi-indoor location.

ISO 3746 locations used by laboratory 2

The majority of measurements were undertaken outdoors in selected areas around an office building. Except for the drill, the low K_2 -factor measurements were carried out with the machine as close as possible to one side of the building consisting of a brick facia to a height of approximately 14 m. Almost parallel to this facia and 8 m away was a 2 m-high concrete panelled wall. The high K_2 -factor measurements were carried out in a corner, as close as possible to the internal apex, with the two adjacent surfaces consisting of 14 m-high brick walls, one with a 2 m wide fire door. The measurements on the drill were carried out in a steel container 3 m wide, 3 m high and 6 m long fitted with a wooden floor.

6.2.3 ISO 3746 locations used by laboratory 3

Measurements were made using a range of sites that included reverberant chambers [R], a hemi-anechoic chamber [H] and outdoor environments [O] with additional absorptive and/or reflective materials in proximity in order to achieve the acoustic environments required. The type of site used for each measurement is shown in Table 7. Descriptions in parentheses are for the higher K_2 factors.

Table 7 Sites used for ISO 3746 by laboratory 3 (dimensions in metres)

	HEMISPHERE		PARALLELEPIPED	
	RADIUS	SITE	DISTANCE	SITE
DRILL	1.0	R (R)	0.25	H (R)
	1.25	O (R)	1.0	O (R)
	1.5	O (R)	2.0	O (R)
GENERATOR	2.0	R (R)	0.25	R (R)
	4.0	O (R)	1.0	O (R)
			2.0	O (R)
LAWNMOWER	2.0	R (R)	0.25	R (R)
	4.0	O (R)	1.0	R (R)
			2.0	O (R)
COMPRESSOR	4.0	O (R)	0.25	R (R)
			1.0	O (R)
			2.0	O (O)

6.2.4 ISO 3746 locations used by laboratory 4

All measurements were conducted on the outdoor site described in sub-section 6.1.4. The K_2 -factor requirements (high and low, see sub-section 6.2) were achieved by the use of moveable reflectors. These reflectors were constructed from sheets of plywood each with a separate support structure giving great flexibility in positioning. The two environments were set up using a combination of the number of reflectors and their position.

6.3 MEASUREMENTS TO ISO 9614

Within certain limitations, outlined below, there are no restrictions on the test environment that is applicable for measurements made in accordance with this International Standard. The only requirements are that the test environment shall be such that the principle upon which sound intensity is measured by the particular instrument employed, as given in IEC 1043, is not invalidated. If substantial quantities of absorbing materials are part of the source under test, high levels of extraneous

intensity (see ISO 9614-1, clause 5.2) may lead to an erroneous estimate of the sound power. There is, therefore, a requirement that every effort be made to minimise the level of extraneous intensity. There are also restrictions on air pressure, temperature and wind speed. Finally the configuration of the test surroundings shall, as far as possible, remain unchanged during the performance of a complete measurement. All the environments described in sub-sections 6.1 and 6.2 comply with these requirements and have, therefore, been used for the measurements detailed in sub-section 4.4.

6.4 MEASUREMENTS TO ISO 11201

The test environments that are suitable for measurements to this International Standard are a flat outdoor area or an indoor space that provides an essentially free field over a reflecting plane. The environmental correction factor must not exceed 2 dB and no corrections to measured data are permitted. For measurements to this standard the locations described in sub-section 6.1 were used.

6.5 MEASUREMENTS TO ISO 11202

The test environments that are suitable for measurements to this International Standard are essentially the same as those described in sub-section 6.2, which restricts the value of the environmental indicator (K_2) to a maximum of 7 dB. However, the standard restricts the magnitude of the correction that can be applied to measured data to 2.5 dB. All the test environments described in sub-sections 6.1 and 6.2 are suitable for this standard and have all been used.

7. INTRA-LABORATORY REPEATABILITY

All four laboratories completed the full programme of sound power and emission sound pressure level measurements using the standards requiring measurements of sound pressure. One laboratory did not carry out the part of the programme requiring measurements of sound intensity.

All four laboratories presented their data on the disks supplied using the data entry system described in Appendix 2 together with written reports describing experimental details.

The data on the floppy disks were transferred to a single spread sheet file in the SPSS analysis software and examined in order to account for individual erroneous data entries caused by typing errors etc. The resulting valid as-measured data are summarised in the tables given in Appendix 3. There is a set of tables for each standard listed in sub-section 3.4. Each table lists the mean value of the three repeated measurements carried out by each laboratory together with its associated standard deviation for one machine and one measurement configuration, for each one-third octave band, A- and C- weighting as appropriate. Each standard deviation tabulated in Appendix 3, therefore, shows the ability of one laboratory to carry out three nominally identical measurements to a specified standard, using a specified measurement surface and distance, in a specified environment. Thus these standard deviations represent what we shall term the "intra-laboratory repeatability" of the measurements. The repeatability of the measurements to each of the standards by each laboratory, taken over all measurement surfaces, distances and environments (the intra-standard repeatability), and the reproducibility of the measurements (taken over all laboratories), will be discussed in Section 8. The statistical significance of variations in results with machine type, and with measurement surface, distance and environment, is considered in Section 9.

It should be noted that all tabulated data in this Report have been exported from the SPSS spreadsheet which used some coded information; these codes are used in the tables and are explained with the appropriate data in Appendix 3.

7.1 INITIAL OBSERVATIONS ON ISO 3744 RESULTS

The results listed in Appendix 3.1 are the means and standard deviations of each laboratory's repeat measurements (calculated from a total of 7200 sound power determinations, themselves the result of 72000 sound pressure level measurements including all measurement distances and surfaces. The original measured data are shown in Figures 4 to 7, one figure for each machine, with the four laboratories represented by different symbols. It can be seen that for all machines there is a data scatter in all bands, with a range of approximately 10 dB; for A-weighted levels this reduces to about 4 dB. The low-frequency data for the drill in Figure 4 show a very large variation due to the effects of background noise. It is clear that either the

background noise corrections in ISO 3744 do not adequately account for background noise, or the data should not have been reported (because the difference between background noise and machine noise was less than 6 dB - see ISO 3744, clause 4.3). Whatever the reason, these low frequency results are used with care in the analyses in this Report. The intra-laboratory repeatability standard deviations listed in Appendix 3.1 exhibit a slight dependence on frequency, generally increasing at lower and higher frequencies. However, the standard deviations (a total of about 2400) are generally less than 0.5 dB and the majority are less than about 0.3 dB. Standard deviations of the A-weighted measurements are shown in Table 8. The overall mean standard deviation is 0.18 dB, distributed such that about half the means are less than this value.

Table 8 Standard deviations of A-weighted measurements to ISO 3744, averaged over all measurement distances

surface	1				2			
lab	1	2	3	4	1	2	3	4
machine	standard deviation							
1	.27	.32	.10	.02	.22	.15	.26	.05
2	.08	.21	.14	.11	.18	.06	.09	.16
3	.12	.09	.31	.25	.15	.07	.30	.11
4	.52	.13	.28	.24	.35	.13	.23	.10

It is interesting at this point to consider the magnitude of the difference between sound power levels determined using hemispherical surfaces and those obtained using parallelepiped surfaces. Values averaged across the three measurement distances are shown in Table 9. The average of the differences shown in Table 9 is just over 0.5 dB, and can be seen to vary between machine and laboratory.

Table 9. Difference between hemispherical and parallelepiped A-weighted sound power determinations according to ISO 3744

lab	1	2	3	4
machine	mean difference (parallelepiped-hemisphere) dB			
1	1.15	-1.01	0.56	1.93
2	1.0	-0.6	1.0	0.9
3	-0.4	-1.5	-0.7	0.6
4	1.08	-1.7	0.67	4.87

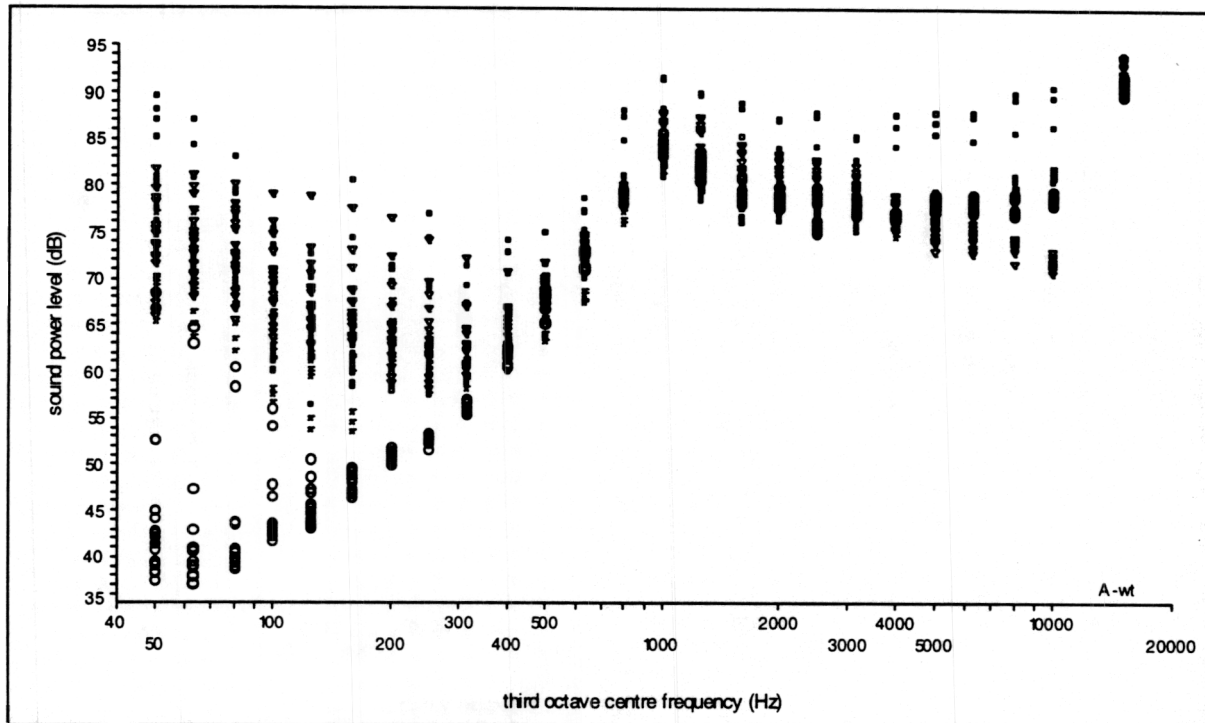


Figure 4 As-measured sound power levels to ISO 3744 for the drill

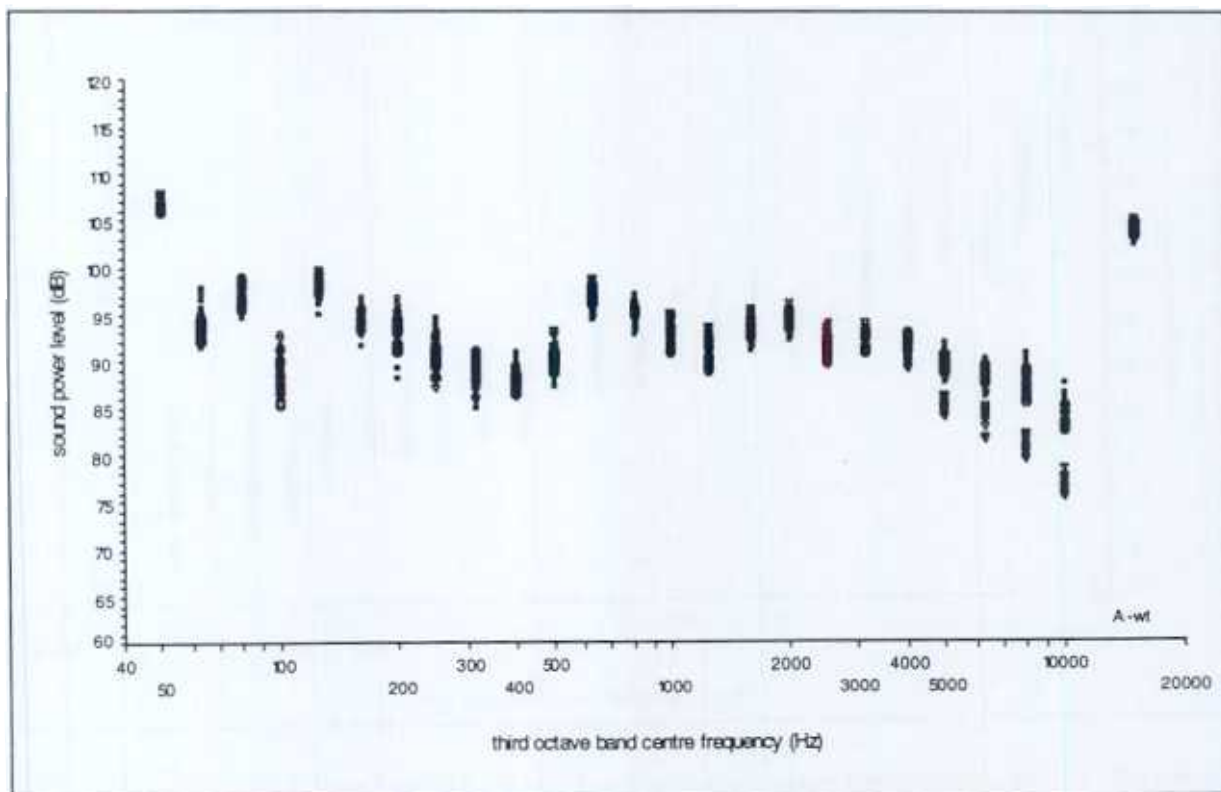


Figure 5 As-measured sound power levels to ISO 3744 for the generator

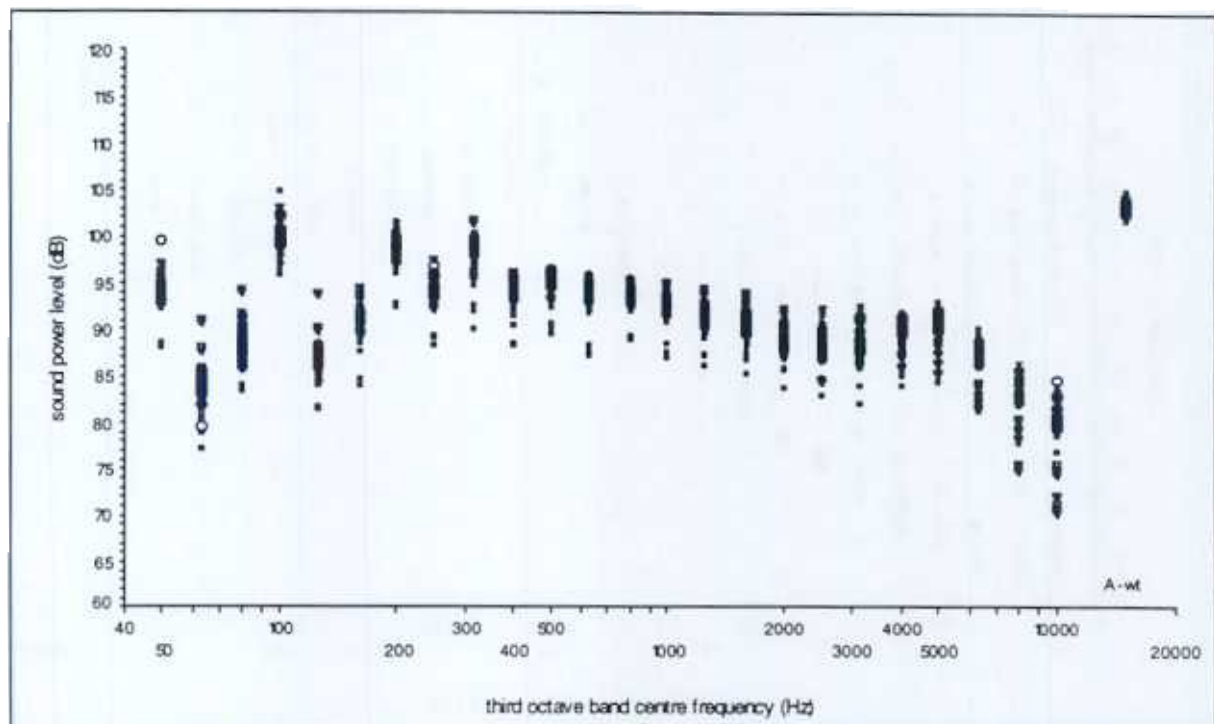


Figure 6 As-measured sound power levels to ISO 3744 for the mower

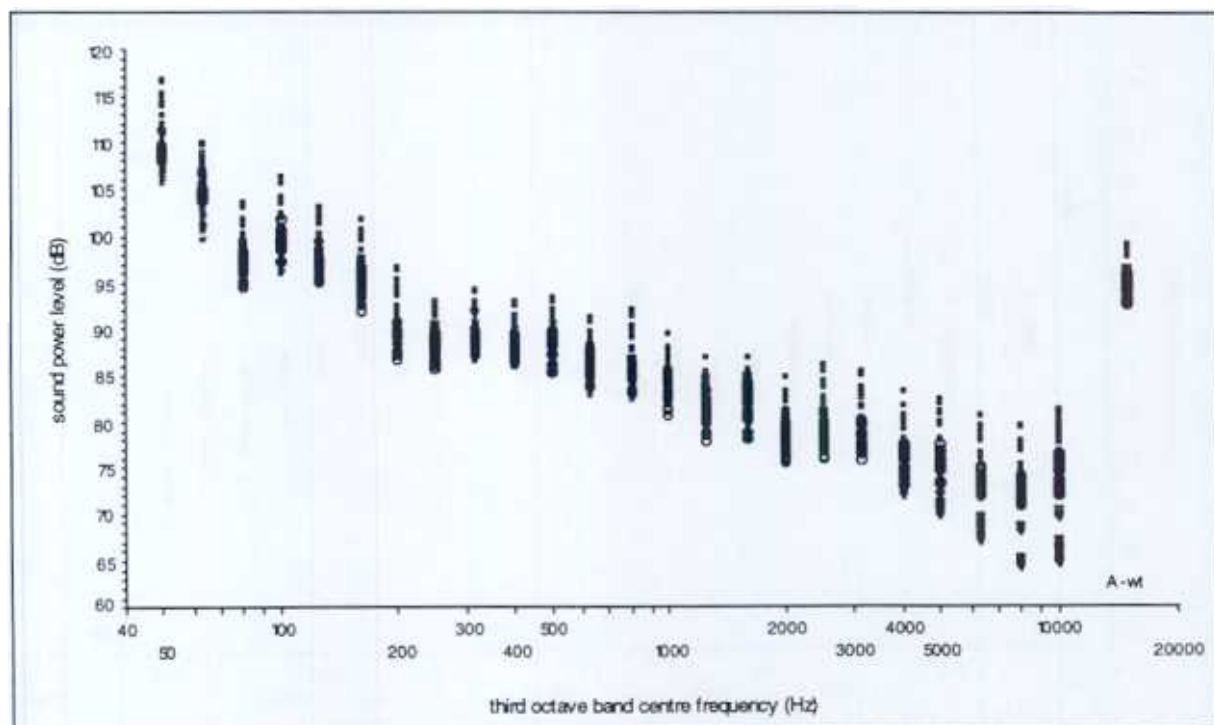


Figure 7 As-measured sound power levels to ISO 3744 for the compressor

7.2 INITIAL OBSERVATIONS ON ISO 3746 RESULTS

The results listed in Appendix 3.2 are the means and standard deviations of each laboratory's repeat measurements (for this standard only A-weighted sound power levels are determined). The original measured data are shown in Figures 8 to 11, one figure for each machine, with the two acoustic environments represented by different symbols. It can be seen that for all machines there is a data scatter with a range of approximately 4 dB. This is similar to the A-weighted data shown in the ISO 3744 scatter plots (Figures 4 to 7). Values of standard deviation averaged across distance are shown in Table 10 for the two acoustic environments. It can be seen that the values of standard deviation are similar for both environments and for all four machines with an overall average of 0.15 dB. This value is comparable with the value of 0.18 dB calculated for ISO 3744.

Table 10 Standard deviations for measurements to ISO 3746, averaged over all measurement distances

lab	1	2	3	4	1	2	3	4
surface	1				2			
machine	mean standard deviation (dB), environment 2							
1	0.09	0.18	0.07	0.07	0.08	0.15	0.10	0.10
2	0.08	0.02	0.06	0.08	0.09	0.06	0.07	0.05
3	0.22	0.08	0.12	0.08	0.20	0.18	0.07	0.12
4	0.04	0.14	0.02	0.07	0.13	0.19	0.16	0.06
Machine	mean standard deviation (dB), environment 3							
1	0.15	0.26	0.13	0.06	0.17	0.20	0.15	0.25
2	0.13	0.18	0.09	0.18	0.17	0.24	0.15	0.10
3	0.16	0.10	0.24	0.07	0.28	0.23	0.06	0.06
4	0.10	0.15	0.21	0.12	0.14	0.06	0.13	0.09

To permit a comparison with the data shown in Table 9, the difference between sound power evaluations using hemispherical measurement surfaces and those using parallelepiped surfaces is shown in Table 11, averaged across both environments.

Table 11. Difference between hemispherical and parallelepiped A-weighted sound power determinations according to ISO 3746

lab	1	2	3	4
machine	mean difference (parallelepiped-hemisphere) dB			
1	1.72	-2.2	0.51	2.47
2	0.36	-0.80	0.56	0.76
3	-1.32	0.10	0.05	1.56
4	1.79	0.23	0.15	4.17

The average of the differences shown in Table 11 is just over 0.6 dB, and can be seen to vary between machine and laboratory. The statistical significance of variations of sound power levels with machine type and measurement configuration is considered in Section 9.

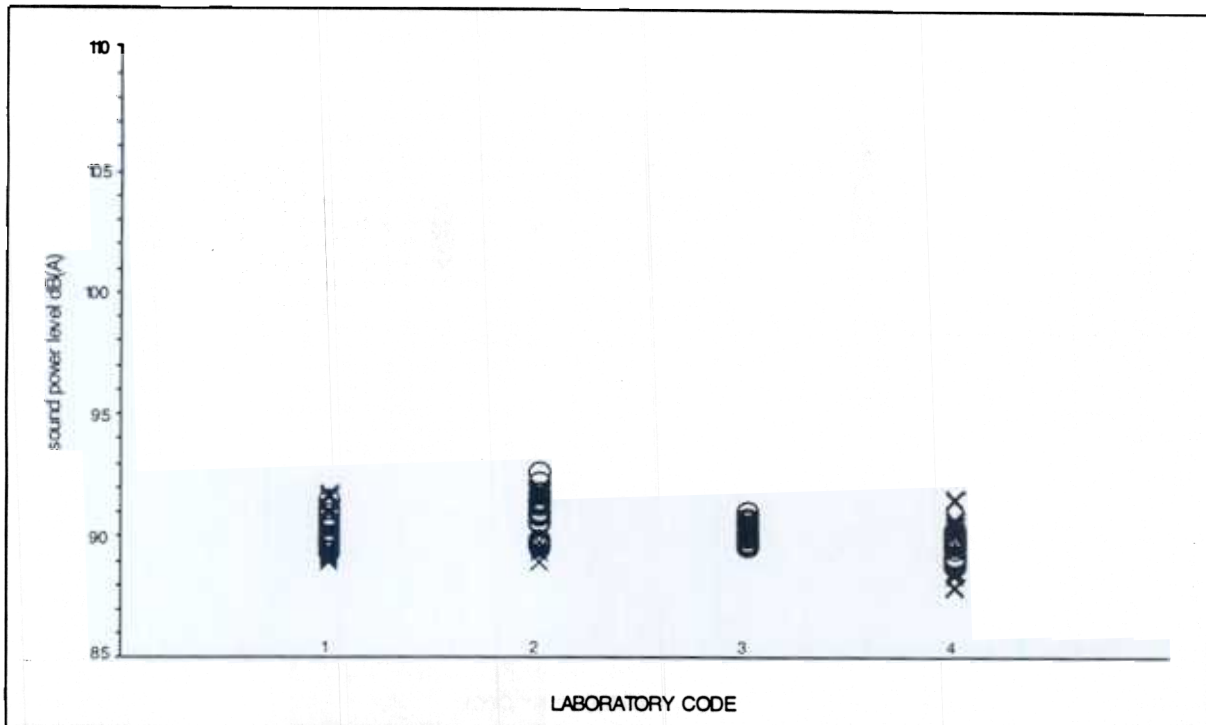


Figure 8 As-measured sound power levels to ISO 3746 for the drill

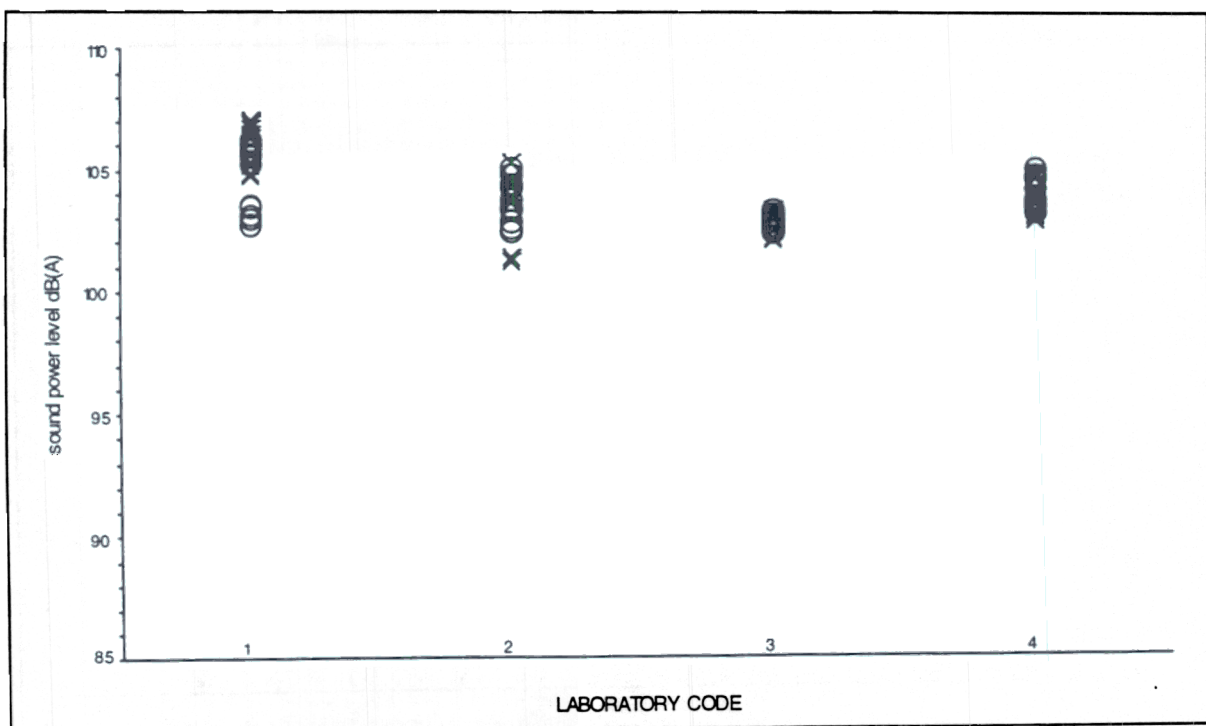


Figure 9 As-measured sound power levels to ISO 3746 for the generator

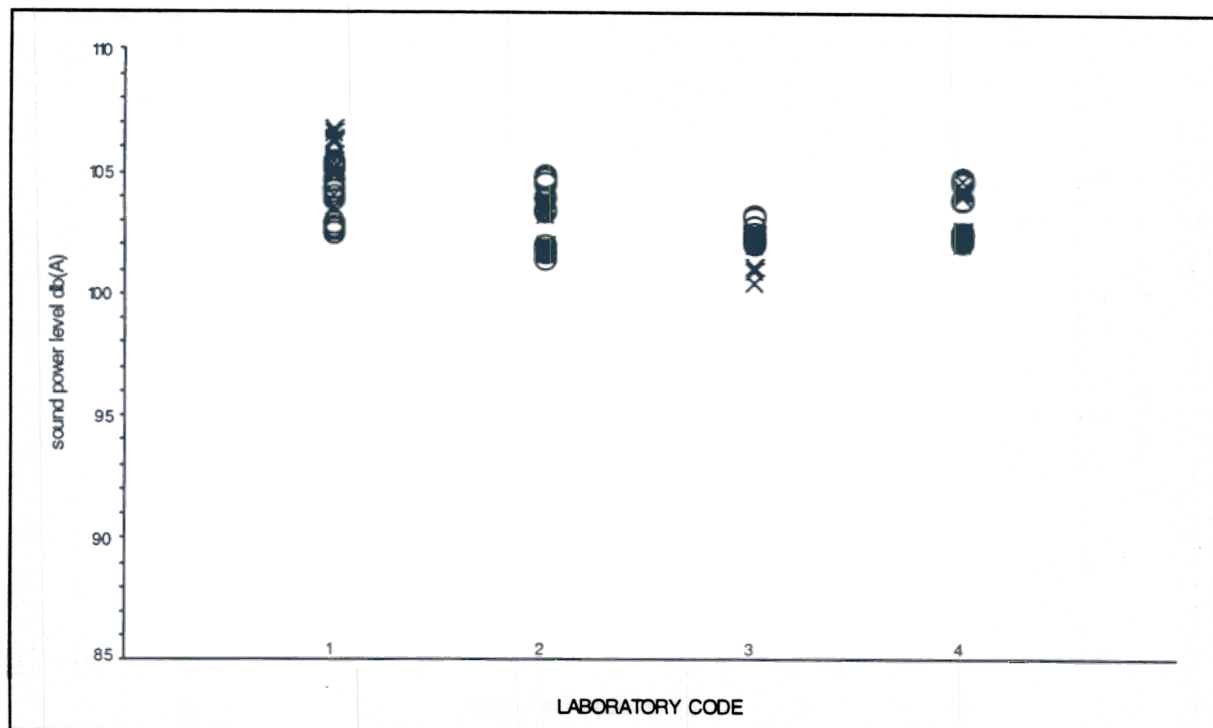


Figure 10 As-measured sound power levels to ISO 3746 for the mower

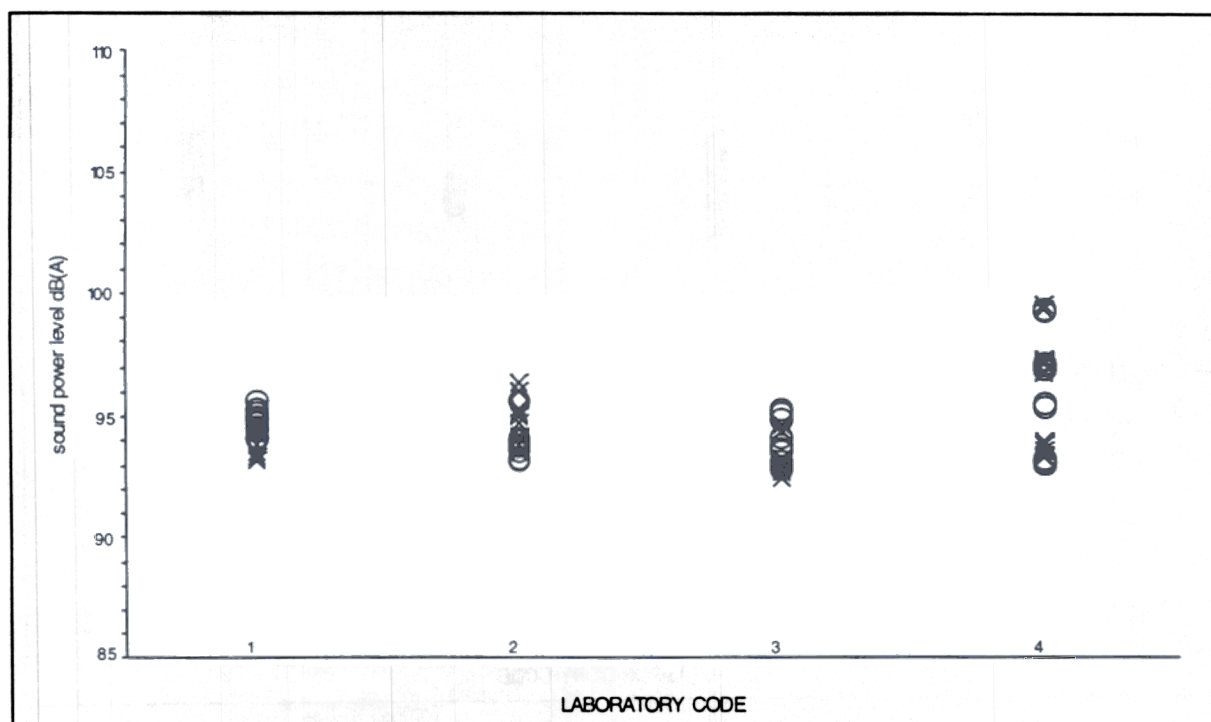


Figure 11 As-measured sound power levels to ISO 3746 for the compressor

7.3 INITIAL OBSERVATIONS ON ISO 9614 RESULTS

The results listed in Appendix 3.3 are the means and standard deviations of each laboratory's repeat measurements. For this standard data is only available from three laboratories. The original measured data is shown in Figures 12 to 15, one figure for each machine. It can be seen that for all machines there is a scatter of data in all bands, with a range of approximately 5 dB; for A-weighted levels this reduces to about 3 dB. As was discussed in Section 7.1, the low-frequency data for the drill in Figure 12 shows a very large variation due to the effects of background noise. The intra-laboratory repeatability standard deviations listed in Appendix 3.3 are essentially independent of frequency, but there is perhaps a slight increase at low frequencies. However, the standard deviations (a total of about 600) are generally less than 0.5 dB and the majority are less than about 0.3 dB (very similar to the ISO 3744 data). Considering only standard deviations of A-weighted levels (values averaged across both environments are shown in Table 12) the overall mean is 0.22 dB distributed such that about half are less than this mean value.

Table 12 Standard deviations of A-weighted measurements to ISO 9614-1, averaged over both environments

lab	1	2	3
machine	mean standard deviations (dB)		
1	0.14	0.37	0.13
2	0.01	0.21	0.32
3	0.19	0.24	0.15
4	0.33	0.35	0.25

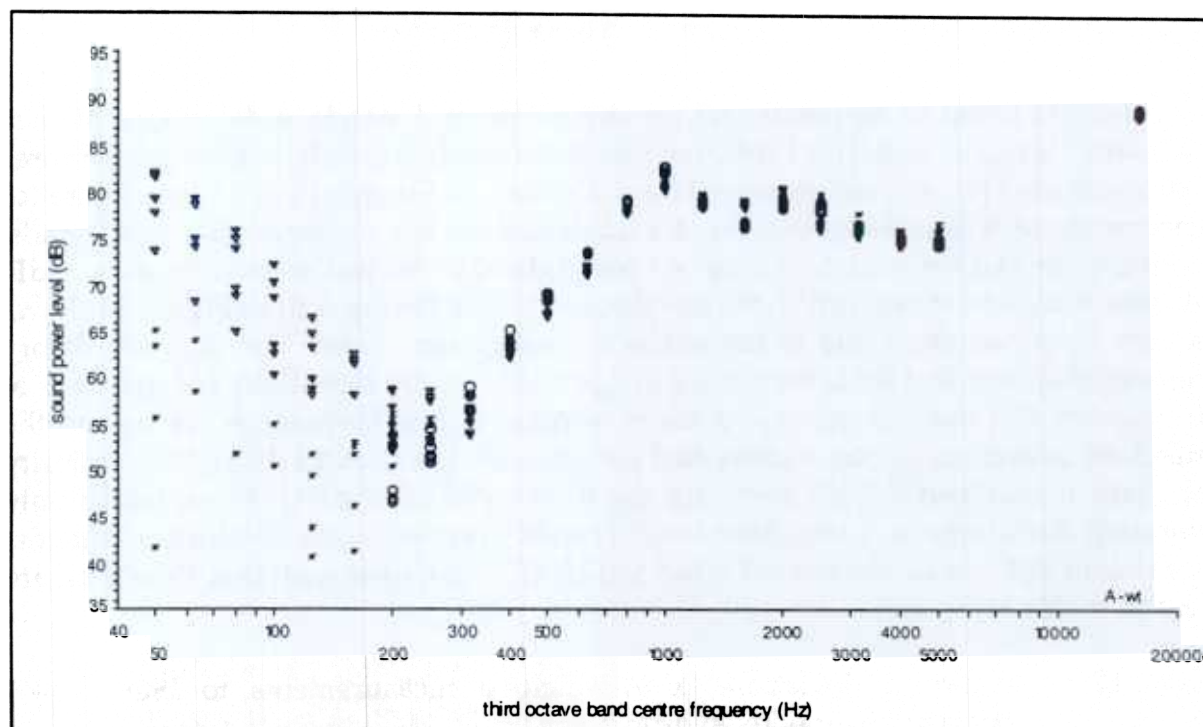


Figure 12 As-measured sound power levels to ISO 9614-1 for the drill

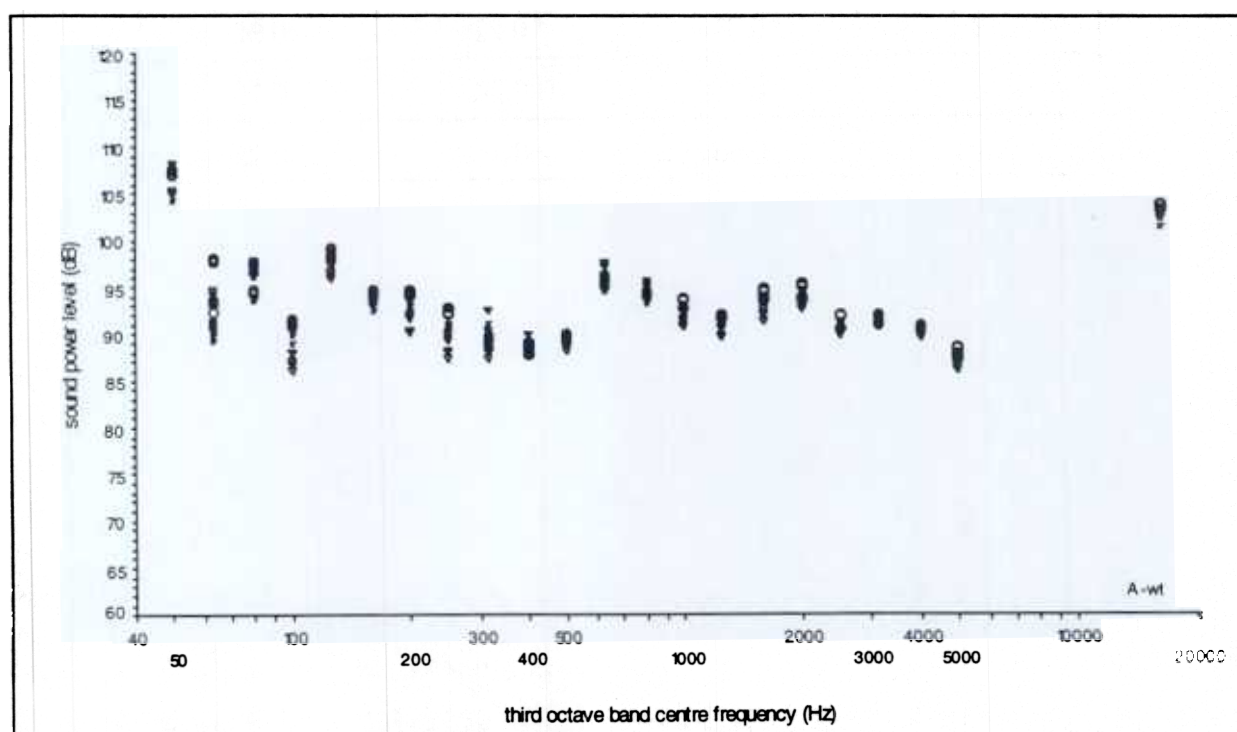


Figure 13 As-measured sound power levels to ISO 9614-1 for the generator

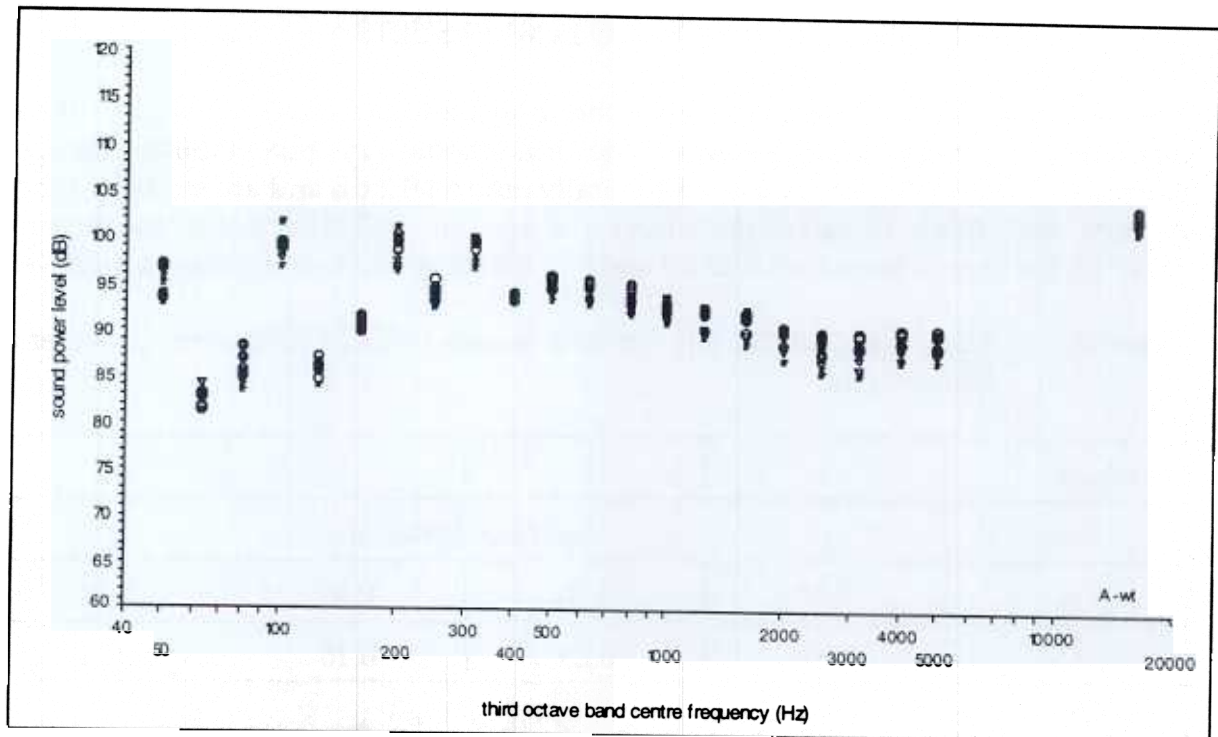


Figure 14 As-measured sound power levels to ISO 9614-1 for the mower

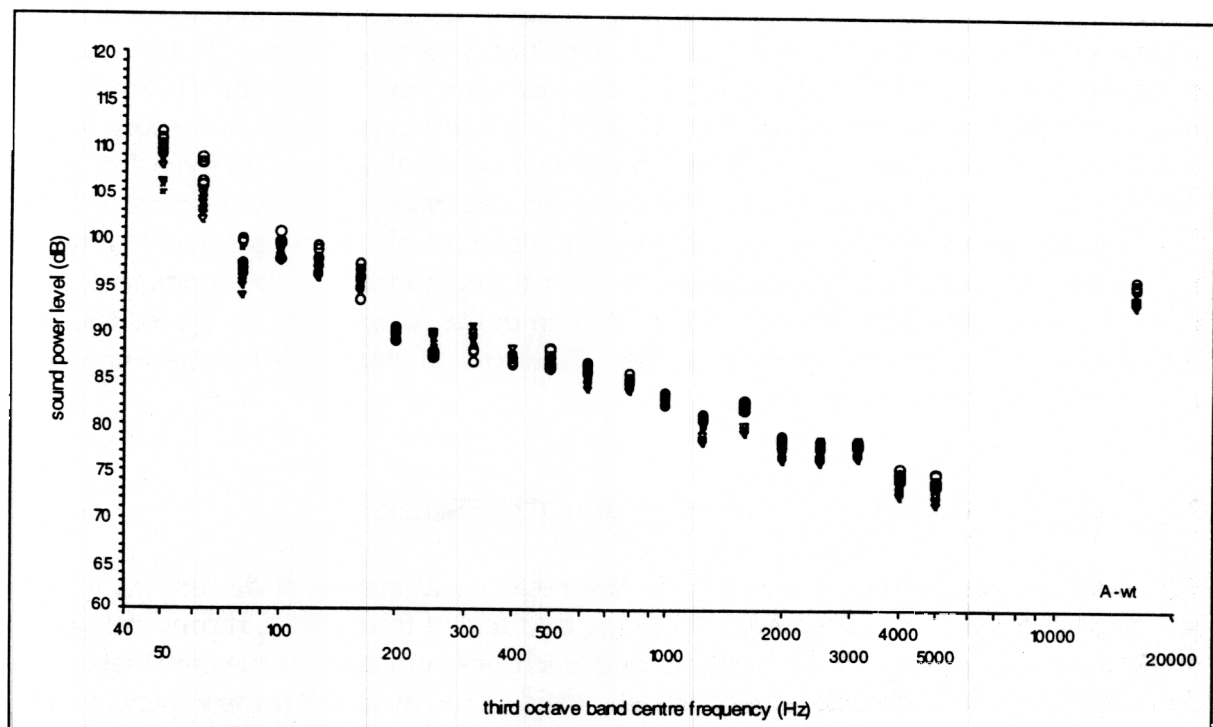


Figure 15 As-measured sound power levels to ISO 9614-1 for the compressor

7.4 INITIAL OBSERVATIONS ON ISO 11201 RESULTS

The results listed in Appendix 3.4 are the means and standard deviations of each laboratory's repeat measurements. The intra-laboratory repeatability standard deviations listed in Appendix 3.4 are generally around 0.2 dB and are similar for both A- and C-weighting. Standard deviations averaged over all laboratories are shown in Table 13; the overall means are 0.23 dB and 0.21 dB for A- and C-weighting respectively.

Table 13 Standard deviations for measurements to ISO 11201, averaged over all laboratories

machine	1	2	3	4
Wtg	standard deviations			
A	0.17	0.10	0.30	0.34
C	0.31	0.23	0.10	0.21

It can be seen from the data in Appendix 3.4 that there is a difference of approximately 12 dB between the C-weighted values reported by laboratories 1 and 2 with those reported by laboratories 3 and 4. This is the result of different interpretations of the meaning of "C-weighted peak emission sound pressure level" as required by ISO 11201. Laboratories 1 and 2 assumed the level measured was the maximum in the machine cycle and used a C-weighting with rms detection, whereas laboratories 3 and 4 used a peak detection. This difference in detection will result in a 3 dB difference for a sinusoidal signal but for the machines considered in this report the difference is in excess of 10 dB, as shown in Appendix 3.4. The definition given in paragraph 3.3.2 of ISO 11201 is as follows, "*peak emission sound pressure level, $L_{p,peak}$ in decibels: The highest instantaneous value of the emission sound pressure level determined over an operational cycle.*". The use of "instantaneous" implies the method used by laboratories 3 and 4 is the one required by the Standard. The inclusion of "over the operational cycle" tends to confuse rather than help the user. To avoid this confusion in the future, it is suggested the peak detection requirements are specified in the 11200 series of standards by reference to the appropriate IEC document.

7.5 INITIAL OBSERVATIONS ON ISO 11202 RESULTS

The results listed in Appendix 3.5 are the means and standard deviations of each laboratory's repeat measurements. There are two sets of four tables, representing data for A- and C-weighting for each of the four machines, and each of the eight tables has data for the two acoustic environments used. The intra-laboratory repeatability standard deviations listed in Appendix 3.5 are generally around 0.2 dB and are similar for both A- and C-weightings, although there are a few large values for C-weighting, for both environments. Standard deviations averaged over all laboratories are shown

in Table 14; the overall means (combining both environments) are 0.12 dB and 0.32 dB for A- and C-weighting respectively, the larger value for C-weighting being due to a few large values of standard deviation (see Appendix 3.5). It can be seen from Appendix 3.5 that there is a difference between the data reported by laboratories 1 and 2 and those reported by laboratories 3 and 4. The probable reason for this difference has been discussed in Section 7.4.

Table 14 Standard deviations for measurements to ISO 11202, averaged over all laboratories

machine	1		2		3		4	
environment	2	3	2	3	2	3	2	3
Wtg	mean standard deviations							
A	0.08	0.05	0.10	0.09	0.17	0.16	0.10	0.20
C	0.82	0.13	0.45	0.35	0.14	0.22	0.18	0.24

8. INTRA-STANDARD REPEATABILITY, AND REPRODUCIBILITY

The results of the raw repeated measurements underpinning the means and standard deviations listed in Appendix 3 can alternatively be combined, for each standard and each laboratory, to yield overall means and standard deviations, taken over all measurement surfaces, distances and environments. These standard deviations show the robustness of the standard when one laboratory uses a range of different measurement surfaces, distances and environments permitted by the standard. Thus they represent what we shall term the “intra-standard repeatability” of the measurements.

The raw results can also be combined to give grand mean levels and standard deviations, taken over all laboratories. In this case, the standard deviations show the extent to which measurements on a given machine, carried out to a given standard, can be reproduced in different laboratories. Thus, they represent the reproducibility of the measurements.

8.1 ISO 3744 MEANS AND STANDARD DEVIATIONS

Overall mean values of sound power level and associated intra-standard repeatability standard deviations are shown in Tables 15 to 18. Here each standard deviation corresponds to an overall mean value that is calculated from eighteen determinations of sound power provided by each laboratory, representing three determinations for each of three hemispherical radii and three determinations for each of three parallelepiped measurement distances. Thus the intra-standard repeatability standard deviations are an indication of the variability of sound power determinations that result from the numerous measurement configurations that are permitted by ISO 3744 and not just a reflection of the precision of the laboratory carrying out the measurements (as is the case for the intra-laboratory repeatability standard deviations listed in Appendix 3.1, discussed in Section 7.1).

It can be seen from the four tables that the standard deviations are generally around 1 dB with lower values of the order 0.5 dB and values approaching 2 dB not uncommon. This represents a considerable increase when compared with the data discussed in Section 7.1. This increase is the result of the range of measurement distances and surfaces involved in the averaging process.

Table 15 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 3744 for the drill

machine	Drill							
lab	1		2		3		4	
freq (Hz)	Mean	sd	Mean	sd	Mean	sd	Mean	sd
"A" wtg	90.86	0.66	92.78	0.91	90.18	0.37	90.9	1.57
50	44.37	9.16	73.43	4.52	70.5	3.29	81.66	5.84
63	42.78	8.06	74.36	3.65	70.56	3.54	74.11	5.46
80	42.89	6.24	72.6	4.09	68.89	3.2	72.69	4.62
100	44.78	4.01	69.42	4.24	63.87	3.84	65.03	4.71
125	45.19	2.02	68.23	4.15	61.42	4.03	64.48	4.09
160	47.77	1.05	67.13	3.71	61.18	3.53	63.8	5.54
200	50.65	0.55	64.26	4.68	63.34	2.34	61.85	4.32
250	52.72	0.39	63.24	4.34	60.92	1.78	62.46	5.89
315	56.36	0.62	63.39	3.1	59.65	2.09	61.77	3.81
400	61.81	0.9	64.57	2.33	63.68	1.76	65.2	3.7
500	67.18	1.51	68.88	1.09	67.16	2.09	68.37	2.88
630	72.49	0.9	73	0.92	70.41	1.73	73.88	2.47
800	78.75	0.57	79.22	0.65	77.66	0.96	80.9	2.93
1000	84.3	0.74	86.55	1.17	82.32	0.57	83.65	3.29
1250	82.06	1.07	85.42	1.59	79.71	0.42	81.18	3.72
1600	79.62	1.28	82.93	1.11	79	0.78	79.73	3.88
2000	78.66	0.71	82.29	0.79	79.98	0.78	79.46	3.27
2500	77.34	1.7	80.61	1.55	78.14	1.09	78.34	4.04
3150	77.91	0.67	80.24	1.07	77.33	0.46	77.74	3.25
4000	77.03	0.25	76.88	1.21	75.89	0.67	78.19	3.76
5000	78.17	0.46	75.17	0.89	77.44	0.53	79.42	3.56
6300	78.36	0.6	74.43	0.98	77.43	0.3	78.87	3.78
8000	78.19	0.93	73.79	0.64	79.46	0.39	80.54	3.83
10000	78.7	0.38	72.14	0.71	81.24	0.43	80.79	3.9

Table 16 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 3744 for the generator

machine	generator							
lab	1		2		3		4	
freq (Hz)	Mean	sd	Mean	sd	Mean	sd	Mean	sd
"A" wtg	104.3	0.55	104.58	0.47	103.56	0.59	104.47	0.62
50	106.41	0.41	107.16	0.57	107.11	0.5	106.76	0.85
63	93.7	0.8	93.78	0.56	92.52	0.63	95.32	1.43
80	96.97	1.07	96.73	0.93	97.52	0.76	96.8	1.36
100	88.03	1.51	89.34	1.06	88.14	1.72	89.57	1.57
125	98.37	0.47	98.43	0.9	97.22	0.66	98.21	1.11
160	94.45	0.64	94.24	0.7	94.06	0.82	95.46	1.31
200	92.99	1	93.71	1.08	93.94	0.92	93.87	2.44
250	90.78	0.86	90.99	1.59	91.08	1.41	91.83	1.81
315	89.31	0.88	88.58	1.21	88.78	0.8	88.7	1.85
400	87.79	0.61	88.36	0.86	88.07	0.75	89.26	2.39
500	90.18	0.61	91.66	1.13	90.3	0.85	89.93	1.32
630	96.91	0.58	97.43	0.96	95.47	0.45	96.21	0.96
800	95.44	0.29	95.75	0.51	94.02	0.44	96.13	0.74
1000	92.77	1.26	94.33	0.72	91.84	0.8	93.73	1.15
1250	90.78	1.14	92.77	0.72	90.24	0.99	91.55	1.17
1600	93.45	0.66	94.86	0.56	92.62	0.86	93.21	1.22
2000	94.53	0.66	95.03	0.75	93.29	0.58	94.6	0.91
2500	91.67	0.74	92.15	1.23	92.85	0.78	92.76	0.73
3150	92.57	0.86	92.72	0.81	93.16	0.52	92.53	0.84
4000	92.47	0.47	90.51	0.72	90.92	0.45	92.32	0.9
5000	89.83	0.47	85.63	0.76	88.76	0.53	90.35	1.01
6300	88.8	0.57	84	1.07	87.79	0.94	88.57	1.13
8000	87.59	1.17	81.31	0.96	87.11	0.63	89.55	1.06
10000	83.87	0.92	76.9	0.86	84.29	0.72	86.21	2.85

Table 17 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 3744 for the mower

machine	mower							
lab	1		2		3		4	
freq (Hz)	Mean	sd	Mean	sd	Mean	sd	Mean	sd
"A" wtg	103.42	0.41	103.43	0.75	102.87	0.66	103.65	0.69
50	94.22	1.43	94.57	1.26	94.84	1.25	93.03	2.36
63	83.61	1.27	85.27	2.69	84.11	0.77	81.76	2.16
80	88.66	1.34	89.02	2.54	88.27	1.09	87.77	2.14
100	100.38	1.07	101.13	1.3	99.21	1.72	100.5	2.59
125	86.91	0.74	88.02	2.42	85.97	1.18	85.79	2.11
160	91.21	0.5	92.39	1.57	90.63	1.02	89.18	2.48
200	98.9	0.62	98.96	0.78	99.88	1.17	97.12	2.54
250	94.88	0.89	94.61	1.46	93.44	1	93.04	1.98
315	98.97	0.53	99.34	2	97.55	1.33	95.89	2.25
400	94.56	0.64	95.12	0.81	93.93	0.49	92.2	1.9
500	95.76	0.54	94.71	0.87	94.42	0.6	94.14	2
630	94.48	0.77	95.22	0.34	93.24	0.67	93.35	2.79
800	93.87	0.47	94.42	0.8	92.9	0.54	93.38	2.08
1000	92.79	0.45	94.02	0.76	92.15	0.67	91.97	2.09
1250	91.68	0.65	93.44	0.93	90.89	0.96	90.84	2.03
1600	90.71	0.69	91.94	1.25	90.33	1.24	90.06	2.04
2000	89.15	0.87	89.6	1.71	89.09	1.26	89.22	2.09
2500	88.24	0.99	87.99	1.79	90.22	1.17	88.47	2.22
3150	88.87	1.06	87.6	0.72	90.12	1.16	88.05	2.47
4000	90.59	0.61	87.56	0.82	89.63	1.11	89.45	2.3
5000	91.3	0.59	87.83	1.62	90.45	0.71	89.89	2.47
6300	87.66	0.68	83.18	1.03	87.43	0.7	86.99	2.47
8000	83.35	0.85	77.44	2.23	83.93	1.19	82.57	3.68
10000	80.59	1.33	73.18	2.06	81.56	1.33	80.01	1.96

Table 18 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 3744 for the compressor

machine	compressor							
lab	1		2		3		4	
freq (Hz)	Mean	sd	Mean	sd	Mean	sd	Mean	sd
"A" wtg	94.62	0.97	95.67	0.52	93.84	0.45	96.28	2.56
50	108.83	0.43	109.46	0.89	107.9	1.5	112.86	2.56
63	104.57	0.39	105.67	1.16	103.94	2.22	106.56	2.46
80	96.84	1.23	97.24	1.09	97.06	0.86	99.04	2.64
100	99.6	1.21	100.19	0.56	97.67	1.12	101.94	2.32
125	96.85	0.63	98.08	0.95	96.54	1.11	99.92	2.27
160	94.64	1.27	95.84	1.43	94.14	1.02	98.11	2.13
200	89.14	1.22	89.64	1.1	89.11	0.84	92.95	1.97
250	88.22	1.14	89.73	0.7	87.87	1.27	90.07	2.42
315	88.56	0.81	90.02	0.98	88.77	1.17	90.7	2.76
400	88.12	0.79	88.33	0.71	87.93	1.37	90.11	1.89
500	87.97	1.27	88.46	0.61	88.06	1.55	89.61	2.69
630	86.03	1.18	87.21	0.58	85.44	1.19	87.54	2.68
800	85.17	1.04	86.6	0.51	84.3	0.95	87.65	2.66
1000	83.49	1.25	84.92	0.6	82.92	0.65	85.65	2.57
1250	81.08	1.43	83.54	0.59	80.05	0.66	83.01	2.69
1600	81.99	1.82	84.02	0.77	80.7	0.83	83.19	2.71
2000	78.12	1.28	79.54	1.01	77.32	0.83	80.83	2.65
2500	78.13	1.35	79.18	0.96	79.11	0.85	81.7	2.84
3150	78.17	1.26	79.37	0.76	79.01	0.84	80.89	2.82
4000	75.63	1.41	73.32	0.74	75.4	0.69	79.05	2.71
5000	75.58	1.2	71.06	0.66	75.72	0.48	78.67	3.05
6300	73.71	1.15	68.54	0.74	73.54	0.57	76.89	3.02
8000	72.66	1.18	65.54	1.45	73.01	0.34	75.87	2.93
10000	74.23	1.59	66.93	1.66	75.61	0.6	77.58	3.23

To enable a comparison with the data shown in Table 8 the standard deviations of A-weighted values are assembled in Table 19.

Table 19 Intra-standard repeatability standard deviations for A-weighted measurements to ISO 3744

Lab	1	2	3	4
machine	standard deviation			
1	0.66	0.91	0.37	1.57
2	0.55	0.47	0.59	0.62
3	0.41	0.75	0.66	0.69
4	0.97	0.52	0.45	2.56

The average of the standard deviations shown in Table 19 is 0.8 dB, which is a considerable increase over the corresponding value of 0.18 dB for the data in Table 8.

Grand mean sound power levels averaged across all laboratories, all measurement distances and both surfaces and the associated reproducibility standard deviations for each machine are listed in Table 20. It can be seen that there is an increase in the magnitude of the standard deviations, compared with Table 19, as here the data from all laboratories are combined. Generally the standard deviations are around 2 dB (with the exception of the low frequency data for the drill, see Section 7). However, the standard deviations increase with frequency above about 4 kHz to approximately 4 dB at 10 kHz. The average value for A-weighted levels is 1.1 dB.

To permit a clearer view of these general trends and to facilitate a comparison with the estimates of reproducibility standard deviation published in ISO 3744, the data in Table 20 are displayed in Figure 16. Variations in standard deviation between machines can be clearly observed from Figure 16. The data for the drill are shown as filled squares and should be ignored at frequencies below 500 Hz (see Section 7.1). The shaded area represents the ISO 3744 estimates; all data points are expected to lie in this shaded area. It can be seen that at frequencies below about 400 Hz measured values are below the ISO estimates, between 400 Hz and 4 kHz it is machine dependent, but the data is generally greater than the values in ISO 3744, and at higher frequencies the ISO limits are clearly far too low. It must be borne in mind that these reproducibility data are calculated from numerous measurement configurations. To investigate how these data would change if they were separated into individual configurations the calculations were repeated and the resultant selective reproducibility data are shown in the six plots of Figure 17 (where "s" is surface and "d" is distance or radius). The data in Figure 17 show a considerable scatter and there is no indication of a reduction in the magnitude of the reproducibility standard deviation.

Table 20 Grand mean sound power levels and associated reproducibility standard deviations for measurements according to ISO 3744

machine	GENERATOR				MOWER		COMPRESSOR	
freq (Hz)	Mean	Std	Mean	Std	Mean	Std	Mean	Std
A-wt	91.18	1.37	104.23	0.68	103.34	0.69	95.1	1.67
50	67.49	15.28	106.86	0.67	94.17	1.75	109.76	2.43
63	65.45	14.31	93.83	1.35	83.69	2.24	105.18	2.01
80	64.27	13.33	97.01	1.08	88.43	1.89	97.54	1.81
100	60.78	10.39	88.77	1.61	100.3	1.87	99.85	2.09
125	59.63	9.56	98.06	0.95	86.67	1.93	97.85	1.9
160	59.67	8.29	94.55	1.04	90.86	1.93	95.68	2.14
200	59.62	6.45	93.63	1.51	98.71	1.77	90.21	2.08
250	59.61	5.61	91.17	1.49	93.99	1.57	88.97	1.77
315	59.20	3.73	88.84	1.26	97.94	2.13	89.51	1.82
400	59.61	2.68	88.37	1.44	93.95	1.55	88.62	1.53
500	67.9	2.11	90.52	1.2	94.76	1.29	88.52	1.79
630	72.45	2.06	96.5	1.06	94.07	1.68	86.56	1.79
800	70.13	1.96	95.34	0.95	93.64	1.28	85.93	1.98
1000	84.2	2.34	93.17	1.37	92.73	1.41	84.24	1.83
1250	82.00	2.95	91.34	1.38	91.71	1.63	81.92	2.11
1600	80.62	2.61	93.54	1.18	90.76	1.54	82.47	2.11
2000	80.1	2.2	94.36	0.97	89.27	1.53	78.95	2.08
2500	79.61	2.64	92.36	1	88.73	1.81	79.53	2.13
3150	79.61	2.07	92.74	0.79	88.66	1.76	79.36	1.89
4000	77	2.13	91.56	1.08	89.31	1.74	75.85	2.6
5000	77.55	2.4	88.64	1.98	89.87	1.99	75.26	3.2
6300	77.27	2.6	87.29	2.16	86.32	2.31	73.17	3.43
8000	73	3.04	86.39	3.24	81.82	3.41	71.77	4.2

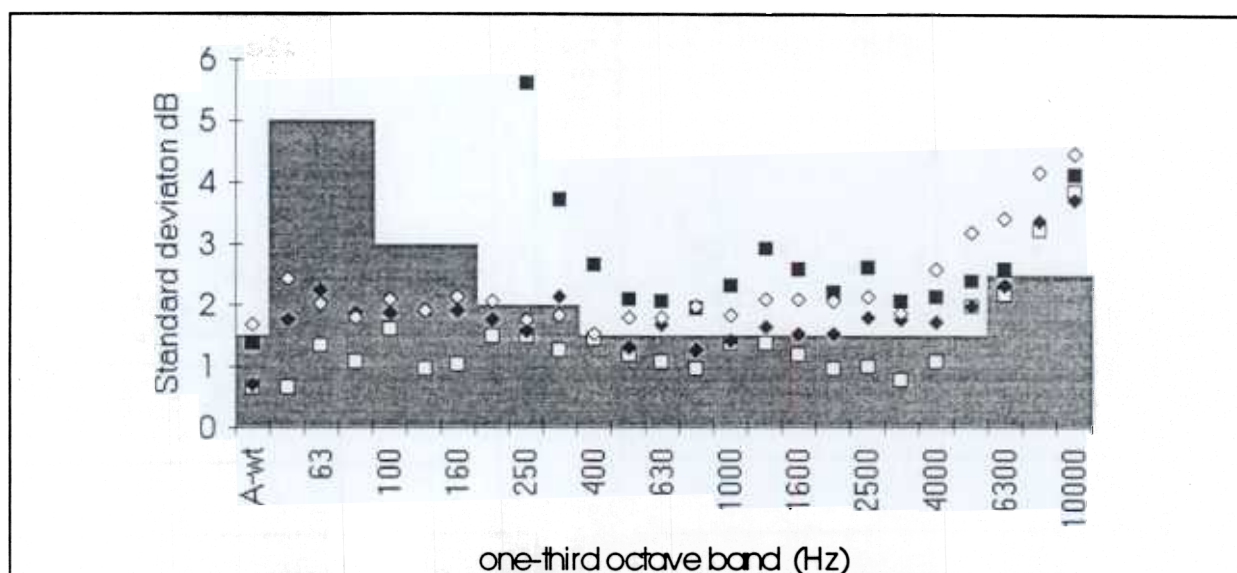


Figure 16 Measured reproducibility standard deviations for ISO 3744 compared with the ISO 3744 document estimates (shaded mask).
Data key - ■...Drill, □...Generator, ◆... Mower, ◇...compressor

It is thought that the large reproducibility standard deviations that are shown in Figures 16 and 17 may result from the relatively large range of K_2 -factors that are deemed acceptable in ISO 3744. The only requirement is that measurements are made in an acoustical environment with a K_2 -factor less than or equal to 2 dB. No corrections to measured data to take account of the K_2 -factor are required. Values of K -factor for one-third octave bands and A-weighting were determined by the laboratories involved in the measurement programme and showed values ranging from 0.2 dB to 1.6 dB. It is clear that such large differences will result in variations in the determination of sound power level and an increase in measurement uncertainties. It is recommended, therefore, that corrections to allow for variations in acoustical environment should be required by ISO 3744.

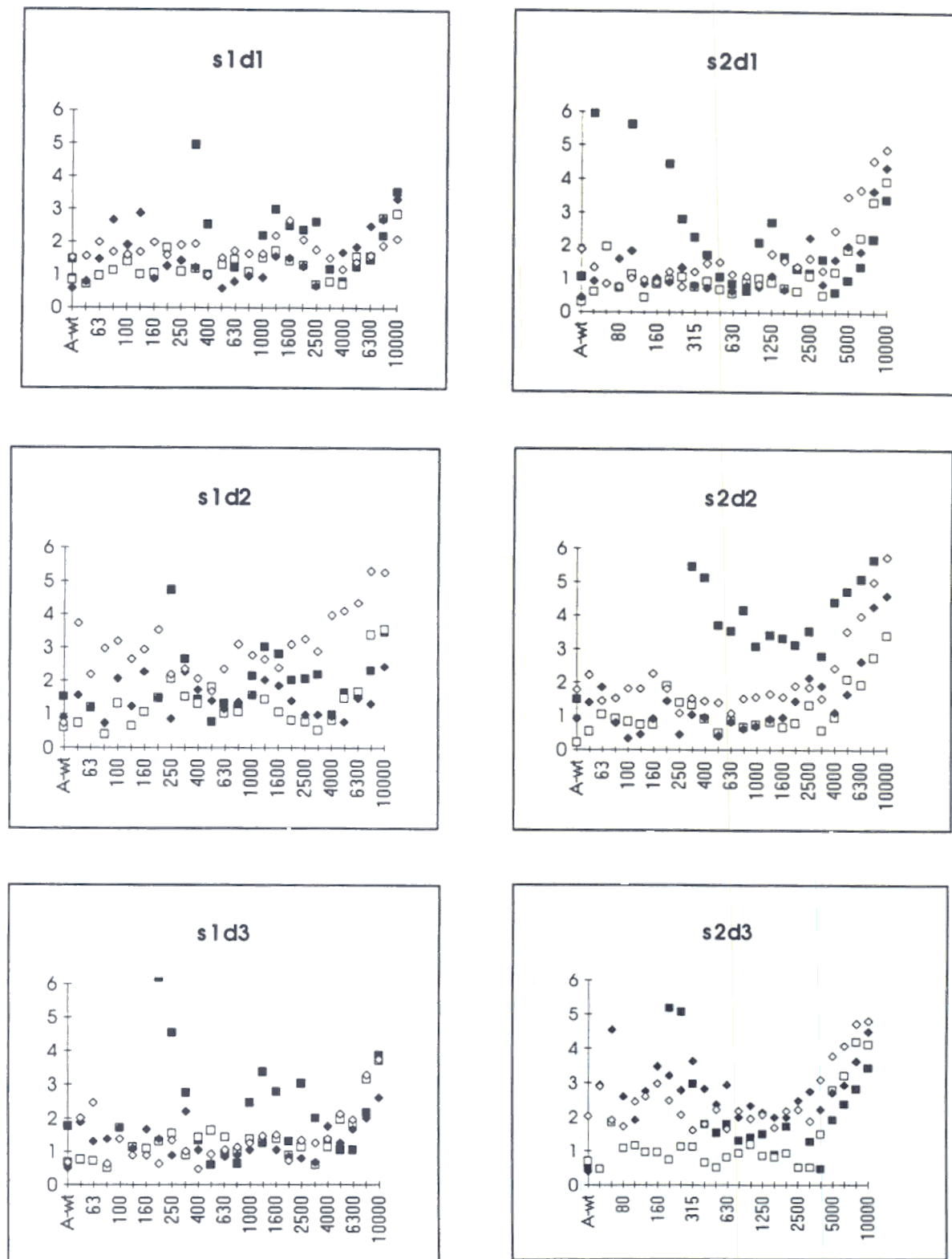


Figure 17 Measured reproducibility standard deviations for individual configurations for ISO 3744

8.2 ISO 3746 MEANS AND STANDARD DEVIATIONS

For this standard only A-weighted sound power levels are required, and so there is much less data to consider than in the previous section. Overall mean values of sound power level (averaged across all measurement surfaces and distances and both acoustic environments) and associated intra-standard repeatability standard deviations are shown in Table 21. Here the standard deviation corresponds to a mean value that is calculated from determinations of sound power provided by each laboratory, representing three determinations for each of three hemispherical radii and three determinations for each of three parallelepiped measurement distances, in each of two acoustic environments.

Table 21 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements to ISO 3746

machine	Drill		Generator		Mower		Compressor	
Lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	90.2	0.88	105.47	1.3	104.69	1.31	94.33	0.69
2	90.87	1.05	103.92	1.08	103.16	1.14	94.66	0.9
3	90.25	0.38	103.02	0.36	102.19	0.84	93.63	0.82
4	89.54	0.99	104.03	0.61	103.19	1.02	95.93	2.36

The intra-standard repeatability standard deviations are an indication of the variability of sound power determinations that result from the numerous measurement configurations that are permitted by ISO 3746 and not just a reflection of the precision of the laboratory carrying out the measurements (as is the case for the intra-laboratory standard deviations listed in Appendix 3.2, discussed in sub-section 7.2). It can be seen that there is an increase in repeatability standard deviations over those listed in Table 10: an average value of 0.98 dB compared to 0.15 dB. This is a direct result of combining all data from all measurement configurations.

Grand mean sound power levels averaged across all laboratories, all measurement distances and surfaces and both environments, and the associated reproducibility standard deviations for each machine, are listed in Table 22. It can be seen that there is a slight increase in the standard deviations compared with Table 21, as here the data from all laboratories are combined; the average standard deviation is 1.3 dB.

Table 22 Grand mean sound power levels and associated reproducibility standard deviations for measurements to ISO 3746

drill		generator		mower		compressor	
mean	s.d.	Mean	s.d.	mean	s.d.	mean	s.d.
90.22	0.98	104.11	1.26	103.31	1.4	94.64	1.64

The estimated standard deviation of reproducibility published in ISO 3746 for noise sources of the type used in this study is 4 dB. It can be seen from Table 22 that the measured values are well below this ISO estimate. The text in the standard makes it clear that standard deviations are dependent on machine type and environment and so it may turn out that if very large machines with time variable and/or impulsive noise attributes are considered the reproducibility standard deviations are larger. However, the results obtained from measurements according to this standard are impressive when compared to those obtained using ISO 3744.

8.3 ISO 9614 MEANS AND STANDARD DEVIATIONS

Overall mean values of sound power level and associated intra-standard repeatability standard deviations are shown in Tables 23 to 26. Here standard deviations correspond to a mean value that is calculated from three determinations of sound power provided by each laboratory, using one parallelepiped measurement surface in two acoustic environments. Thus the intra-standard repeatability standard deviations are an indication of the variability of sound power determinations that result from two of the measurement configurations that are permitted by ISO 9614 and not just a reflection of the precision of the laboratory carrying out the measurements (as is the case for the standard deviations listed in Appendix 3.3, discussed in Section 7.3).

It can be seen from the four tables that the standard deviations are generally around 1 dB with lower values of the order 0.5 dB and higher values approximately 2 dB (similar to the data for ISO 3744). This represents a considerable increase when compared with the data discussed in Section 7.3 where values were generally around 0.5 dB. The standard deviations for A-weighted levels are assembled in Table 27. Comparison with the data in Table 12, shows a general increase in magnitude. The average of the data in Table 12 is 0.22 dB compared to 0.44 dB in Table 27.

Table 23 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 9614-1, for the drill

machine	Electric drill					
lab	1		2		3	
freq (Hz)	Mean	Std	Mean	Std	Mean	Std
"A" wtg	88.92	0.21	88.88	0.35	88.97	0.25
50	.	.	79.55	3.29	56.47	10.6
63	.	.	75.83	4.29	61.3	3.96
80	.	.	71.52	4.24	51.8	.
100	.	.	66.37	4.78	52.8	3.11
125	.	.	61.97	3.42	46.43	5.1
160	.	.	61.42	1.64	49.04	5.06
200	49.25	3.22	55.75	2.83	54.03	2.04
250	52.17	1.28	55.73	2.62	54.95	0.59
315	57.33	1.02	55.38	1.2	58.08	0.16
400	63.83	0.83	63.73	0.78	63.78	0.17
500	69.02	0.33	67.17	0.52	68.97	0.34
630	73.83	0.08	71.8	0.37	73.43	0.14
800	79.27	0.16	78.45	0.38	78.2	0.15
1000	82.78	0.25	81.45	0.67	82.12	0.29
1250	79.28	0.29	79.3	0.49	79.12	0.51
1600	76.73	0.16	79.02	0.25	76.95	0.25
2000	79.03	0.29	79.87	0.65	79.72	0.29
2500	78.63	0.45	76.75	0.39	79.52	0.27
3150	76.63	0.2	75.92	0.32	76.8	0.54
4000	75.35	0.24	76.02	0.27	74.75	0.34
5000	74.82	0.36	75.32	0.37	76.43	0.33

Table 24 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 9614-1, for the generator

machine	generator					
lab	1		2		3	
freq (Hz)	Mean	Std	Mean	Std	Mean	Std
"A" wtg	103.83	0.3	103.17	0.38	102.72	0.59
50	107.46	0.21	106.62	1.4	105.03	0.44
63	95.6	2.67	92.63	1.91	89.53	0.37
80	95.92	1.59	97.37	0.45	95.22	1.63
100	91.31	0.22	87.07	0.73	89.8	1.11
125	98.78	0.51	97.2	0.73	98.28	0.12
160	94.56	0.28	93.78	0.5	93.52	0.54
200	94.56	0.29	91.2	0.85	93.23	0.49
250	92.64	0.25	88.97	1.05	90.75	0.27
315	89.17	0.6	89.35	1.99	90.03	0.83
400	88.6	0.51	88.83	0.76	88.42	0.44
500	89.73	0.33	89.35	0.55	89.72	0.34
630	95.67	0.35	96.93	0.69	94.98	0.22
800	94.45	0.2	95.22	0.41	93.5	0.18
1000	93.4	0.56	91.4	0.31	92.58	0.59
1250	92	0.19	90.22	0.47	91.48	0.23
1600	94.44	0.46	92.2	0.49	93.75	0.36
2000	94.71	0.84	93.53	0.43	94.07	0.22
2500	91.46	0.71	90.53	0.2	91.05	0.16
3150	91.63	0.41	91.48	0.36	91.65	0.26
4000	90.78	0.25	90.43	0.41	90.62	0.35
5000	88.1	0.53	87	0.5	87.4	0.18

Table 25 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 9614-1, for the mower

machine	mower					
lab	1		2		1	
freq (Hz)	Mean	Std	Mean	Std	Mean	Std
"A" wtg	103.51	0.59	103.03	0.69	102.15	0.69
50	95.32	1.77	95.35	1.93	93.98	1.19
63	82.13	0.7	83.22	0.61	81.57	0.59
80	86.26	1.25	85.8	1.6	85.3	1.56
100	99.55	0.26	99.25	0.64	99.65	2.36
125	86.16	0.79	86.53	0.5	85.15	0.81
160	90.92	0.59	91.22	0.39	90.63	0.56
200	99.51	0.69	97.33	0.46	100.47	0.71
250	94.6	0.78	93.97	0.48	93.27	0.57
315	99.74	0.39	100.08	0.19	97.58	0.44
400	94.01	0.41	93.97	0.29	94.4	0.18
500	95.62	0.61	94.95	0.47	94.42	0.54
630	95.43	0.41	94.32	0.58	93.58	0.35
800	94.34	0.83	93.25	0.69	92.8	0.37
1000	93.07	0.45	93.07	1.09	91.92	0.73
1250	91.86	1.11	92.15	1.22	91.03	1.3
1600	91.57	1.02	91.38	1.02	90.82	2.03
2000	90.17	0.95	90	1.07	88.95	1.96
2500	89.3	1	88.82	1.05	87.78	1.82
3150	89.57	0.68	88.17	1.04	87.37	1.73
4000	90.07	0.66	88.9	0.79	88.18	1.05
5000	89.83	0.86	89.13	0.74	87.98	0.97

Table 26 Overall mean sound power levels and associated intra-standard repeatability standard deviations for measurements according to ISO 9614-1, for the compressor

machine	compressor					
lab	1		2		3	
freq (Hz)	Mean	Std	Mean	Std	Mean	Std
"A" wtg	95.51	0.31	93.8	0.33	94.07	0.35
50	110.39	0.88	108.33	1.22	107.28	1.95
63	107.21	1.31	103.48	1.06	104.2	1.01
80	97.87	1.59	95.7	1.24	97.65	1.9
100	99.58	0.94	98.37	0.5	99.05	0.55
125	98.21	0.8	96.3	0.26	96.93	0.63
160	95.94	1.35	95.03	0.53	95.08	0.92
200	89.64	0.64	89.67	0.43	89.58	0.19
250	87.56	0.22	89.68	0.25	88.15	0.47
315	87.92	0.52	89.87	0.58	88.95	0.55
400	86.94	0.18	87.68	0.38	87.3	0.19
500	87.37	0.8	86.73	0.52	86.58	0.39
630	86.44	0.46	84.75	0.42	85.43	0.8
800	85.26	0.46	84.28	0.36	84.35	0.42
1000	83.12	0.42	83.02	0.44	82.85	0.16
1250	81.02	0.25	78.63	0.34	80.33	0.62
1600	82.44	0.42	79.98	0.35	82.08	0.38
2000	78.57	0.4	76.78	0.31	78.13	0.31
2500	78.09	0.35	76.55	0.29	78.12	0.44
3150	78.21	0.24	76.98	0.41	78	0.4
4000	74.89	0.45	73.1	0.57	74.43	0.39
5000	74.26	0.59	72.42	0.57	73.67	0.31

Table 27 Intra-standard repeatability standard deviations for A-weighted measurements to ISO 9614-1

Lab	1	2	3
machine	standard deviation		
1	0.21	0.35	0.25
2	0.30	0.58	0.59
3	0.59	0.69	0.69
4	0.31	0.33	0.35

Grand mean sound power levels averaged across all laboratories for both acoustic environments and the associated reproducibility standard deviations for each machine are listed in Table 28. It can be seen that there is a slight increase in the magnitude of the standard deviations, compared with the data in Tables 23 to 26, as here the data from all laboratories are combined.

Generally standard deviations are still around 1 dB, with the exception of the low frequency data for the drill (see Section 7) although the standard deviations increase slightly at low frequencies for the other machines as well; the average value for A-weighted levels is 0.6 dB. To permit a clearer view of these general trends and to facilitate a comparison with the estimates of reproducibility uncertainty published in ISO 9614 the data in Table 28 are displayed in Figure 18. Variations in standard deviation between machines can be clearly observed from Figure 18. The data for the drill are shown as filled squares and as can be seen, are in excess of the vertical scale at lower frequencies. The shaded area represents the ISO 9614 estimates for engineering grade measurements; all data points are expected to lie in this shaded area. It can be seen that with only two exceptions this is the case. It must be borne in mind that these reproducibility data are calculated from only one measurement surface and distance. However, the discussion in sub-section 8.1 (see Figures 16 and 17) indicates that the magnitudes of reproducibility standard deviations do not necessarily increase with an increase in the number of measurement configurations.

Table 28 Grand mean sound power levels and associated reproducibility standard deviations for measurements according to ISO 9614-1.

machine	DRILL		GENERATOR		MOWER		COMPRESSOR	
freq (Hz)	Mean	Std	Mean	Std	Mean	Std	Mean	Std
"A" wtg	88.92	0.26	103.24	0.63	102.9	0.85	94.46	0.83
50	70.32	13.62	106.37	1.31	94.88	1.69	108.67	1.89
63	72.2	7.79	92.59	3.12	82.31	0.92	104.97	1.98
80	68.7	8.4	96.17	1.56	85.79	1.45	97.07	1.81
100	62.98	7.56	89.39	1.95	99.48	1.34	99	0.83
125	55.75	8.92	98.09	0.83	85.95	0.9	97.15	0.99
160	55.79	7.31	93.95	0.62	90.92	0.55	95.35	1.03
200	53.01	3.83	93	1.52	99.1	1.47	89.63	0.43
250	54.28	2.25	90.79	1.66	93.94	0.81	88.47	0.97
315	56.93	1.45	89.52	1.27	99.14	1.19	88.91	0.97
400	63.78	0.63	88.62	0.58	94.13	0.35	87.31	0.4
500	68.38	0.96	89.6	0.43	94.99	0.72	86.89	0.66
630	73.02	0.93	95.86	0.94	94.44	0.89	85.54	0.9
800	78.64	0.53	94.39	0.77	93.46	0.91	84.63	0.6
1000	82.12	0.7	92.46	0.97	92.69	0.94	83	0.36
1250	79.23	0.42	91.23	0.83	91.68	1.24	80	1.11
1600	77.57	1.08	93.46	1.05	91.26	1.39	81.5	1.17
2000	79.54	0.56	94.1	0.72	89.71	1.43	77.83	0.85
2500	78.3	1.24	91.01	0.56	88.63	1.42	77.58	0.83
3150	76.45	0.53	91.59	0.33	88.37	1.49	77.73	0.65
4000	75.37	0.6	90.61	0.36	89.05	1.13	74.14	0.9
5000	75.52	0.77	87.5	0.62	88.98	1.13	73.45	0.92

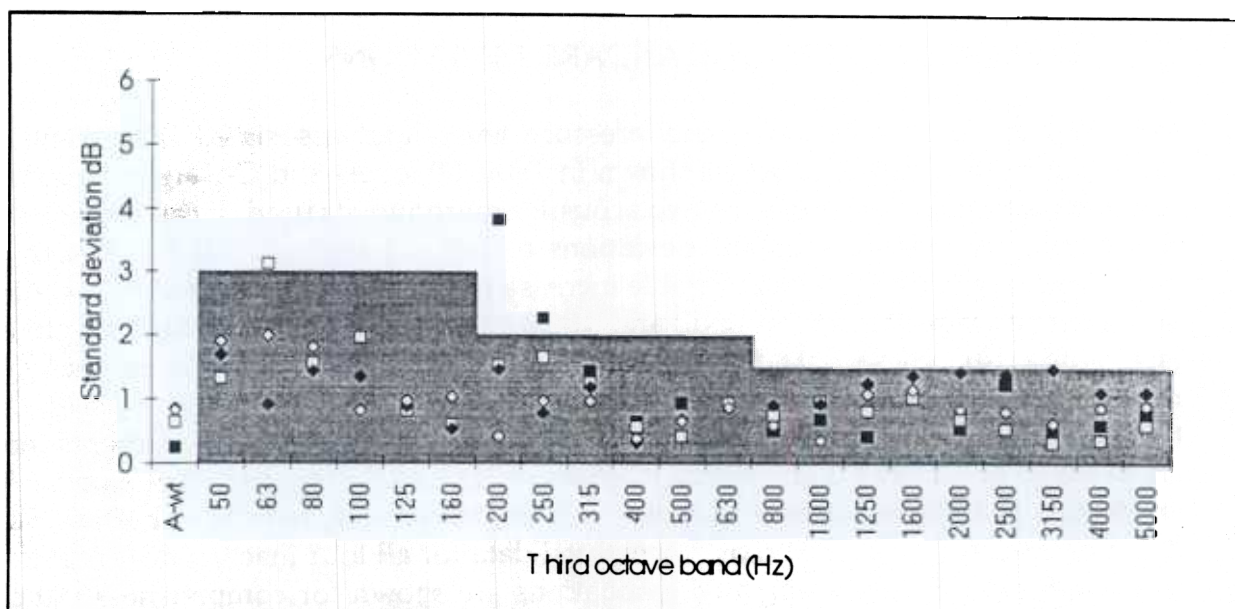


Figure 18 Measured reproducibility standard deviations for ISO 9614 compared with the ISO document estimates (shaded mask). Data key as Figure 16.

8.4 ISO 11201 MEANS AND STANDARD DEVIATIONS

As each laboratory was only required to carry out one set of measurements the results listed in Appendix 3.4, and discussed in Section 7.4, are themselves the intra-standard repeatability standard deviations for measurements according to ISO 11201. The data underpinning Appendix 3.4 have been combined to provide reproducibility standard deviations and these are shown in Table 29. It can be seen that there is an increase in the average standard deviation for A-weighted measurements from 0.23 dB in Table 13 to 0.88 dB in Table 29. The guidance given in ISO 11201 suggests that the reproducibility uncertainty should be less than 2.5 dB. It can be seen from Table 29 that measured values for all four machines are less than this value. Values for C-weighted evaluations are shown for completeness but are erroneous due to the problem relating to peak measurement discussed in sub-section 7.4.

Table 29 Grand mean emission sound pressure levels and associated reproducibility standard deviations for measurements according to ISO 11201

machine	DRILL		GENERATOR		MOWER		COMPRESSOR	
wtg	Mean	Std	Mean	Std	Mean	Std	Mean	Std
A	77	1.43	89.78	0.46	88.51	1.11	79.38	.53
C	84.59	8.32	100.44	5.79	99.87	6.04	100.1	5.19

ISO 11202 MEANS AND STANDARD DEVIATIONS

The overall mean emission sound pressure levels and associated intra-standard repeatability standard deviations shown in Table 30 for A- and C-weighting are the result of combining data from the two acoustic environments used. It can be seen that this results in average standard deviations of 1.36 dB and 1.22 dB for A- and C-weighting respectively, a considerable increase in standard deviation over the intra-laboratory average values of 0.12 dB and 0.32 dB for A- and C-weighting respectively (see Table 14). These data have been further combined to provide estimates of reproducibility standard deviation which are shown in Table 31. It can be seen that there is a slight increase in standard deviation for the A-weighted measurements (now an average of 1.7 dB). The guidance given in ISO 11202 suggests that due to the limitations on K-factor corrections reproducibility uncertainty may be as high as 5 dB. It can be seen from Table 31 that A-weighted data for all four machines are less than this value. Values for C-weighted evaluations are shown for completeness but are erroneous due to the problem relating to peak measurement discussed in sub-section 7.5.

Table 30 Overall mean emission sound pressure levels and associated intra-standard repeatability standard deviations for measurements according to ISO 11202

Machine		DRILL		GENERATOR		MOWER		COMPRESSOR	
lab	wtg	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	"A"	80.23	0.52	93.41	0.74	92.44	0.71	81.73	2.4
	"C"	80.58	0.45	97.33	0.5	96.71	0.98	96.19	1.35
2	"A"	82.51	2.76	91.13	0.37	90.72	0.61	80.27	1.16
	"C"	83.72	2.59	98.06	0.49	96.4	0.35	98.06	0.53
3	"A"	79.51	1.61	91.54	1.9	91.29	2.03	80.44	1.89
	"C"	95.4	1.79	108.77	1.59	108.92	2.53	106.21	2.03
4	"A"	80.11	2.47	92.16	1.13	90.95	0.89	79.04	0.6
	"C"	93.5	2.18	107.81	0.9	107.26	0.9	104.34	0.28

Table 31 Grand mean emission sound pressure levels and associated reproducibility standard deviations for measurements according to ISO 11202

Machine	DRILL		GENERATOR		MOWER		COMPRESSOR	
wtg	Mean	Std	Mean	Std	Mean	Std	Mean	Std
A	80.59	2.23	92.06	1.41	91.35	1.31	80.37	1.83
C	88.3	6.67	102.99	5.51	102.33	6.07	101.2	4.43

It must be remembered, however, that the estimates of measurement uncertainty published in ISO 11202 and ISO 11201 include an allowance for differences from the "true value", and not just an assessment of measurement uncertainties. In the case of the sound power standards the quoted uncertainties are assumed to be concerned with uncertainties in measurement procedures and each standard should provide the same sound power level (this is examined in Section 10). For the emission sound pressure level standards this is not the case. A comparison of the mean A-weighted data in the two reproducibility tables (Tables 29 and 31) shows differences in sound pressure level of 3.59 dB, 2.28 dB, 2.84 dB and 0.99 dB for machines 1, 2, 3, and 4 respectively. If it is assumed that the data from ISO 11201 is "correct" and these differences are added to the ISO 11202 reproducibility standard deviations, then, the estimate in the standard of a 5 dB standard deviation is still reasonable.

It is clear that if the procedures detailed in ISO 11204 were followed (see subsection 2.3) and a more representative correction for K-factor applied, then the estimates of emission sound pressure level would be more accurate and the assessment of measurement uncertainty calculated in this Report would remain essentially unchanged.

9. ANALYSIS OF VARIANCE

In the previous two Sections the standard deviations of intra-laboratory repeatability, intra-standard repeatability and reproducibility have been determined. Differences resulting from variations in measurement configuration have been observed. However, the statistical significance of these configuration differences and between-laboratory differences needs to be investigated in order to assess the implications for measurements made according to the Standards considered in this Report. For instance if the difference between measurements made using hemispherical surfaces and those made using parallelepiped surfaces is statistically significant then it may be possible to account for the variation in sound power level by the use of a correction factor or, a more probable outcome, to restrict measurements to a particular surface. This assessment has been carried out using of an analysis of variance, which is one of the tools incorporated in the SPSS software package.

In order to determine statistical significance it is necessary to determine whether the observed differences in the sample means, described in previous Sections, resulting from different types of measurement configurations (or from measurements made by different laboratories) can be attributed to a natural variability between the sample means or whether they come from populations that have different means. The statistical technique used in this report is the SPSS procedure called ANOVA. The technique examines the variability of measured data within each chosen group and the variability between the group means. Based on these two estimations of variability the F-statistic is computed and from a comparison with tabulated values of the F distribution it is possible to draw certain conclusions about the group means. This is achieved by testing the null hypothesis, which in this case is that the data from the two groups are from the same population. The F-statistic is calculated from the ratio of the within-group and between-group mean squares and has a value between zero and unity. If the null hypothesis is true then these two mean squares are close to one another and the ratio will be close to unity which indicates no significant difference between the two groups.

In the analyses carried out in this report the data from two groups are considered to be significantly different if the value of the F-statistic is less than 0.05. This is equivalent to the 95% confidence interval used in the standards under consideration. A statistical analysis has been carried out on the data obtained using each standard considered in this report and results are discussed in the following four sub-sections.

9.1 STATISTICAL ANALYSIS FOR ISO 3744

Initially three statistical analyses were carried out to examine the significance of differences between sound power determinations made by the four laboratories. These analyses were continued with an examination of the differences between measurement configurations. This consisted of two analyses for surface differences and two analyses for distance (or radii) differences. All these analyses are described below, and for each, tables of the F-statistic are shown for each of the four machines together with a

graphical representation of statistical significance at the 95% level. The tables may be used to estimate statistical confidence at other levels.

9.1.1 ISO 3744, between-laboratory differences, all data.

The first of the initial set of analyses examines the value of the F-statistic for the differences between laboratories using all measured data (effectively an examination of the data used to assess reproducibility standard deviations). Results are listed in Table 32. Here all the repeat measurements are combined for both surfaces and all distances. It can be seen that the F-statistic is generally approaching zero in all frequency bands. A graphical representation showing which of these values of F-statistic are statistically significant at the 95% level is displayed in Figure 19. In this figure a “box” represents a statistical significance. It can be clearly seen that the difference between laboratories is statistically significant for A-weighted levels for all machines and in all but a few frequency bands.

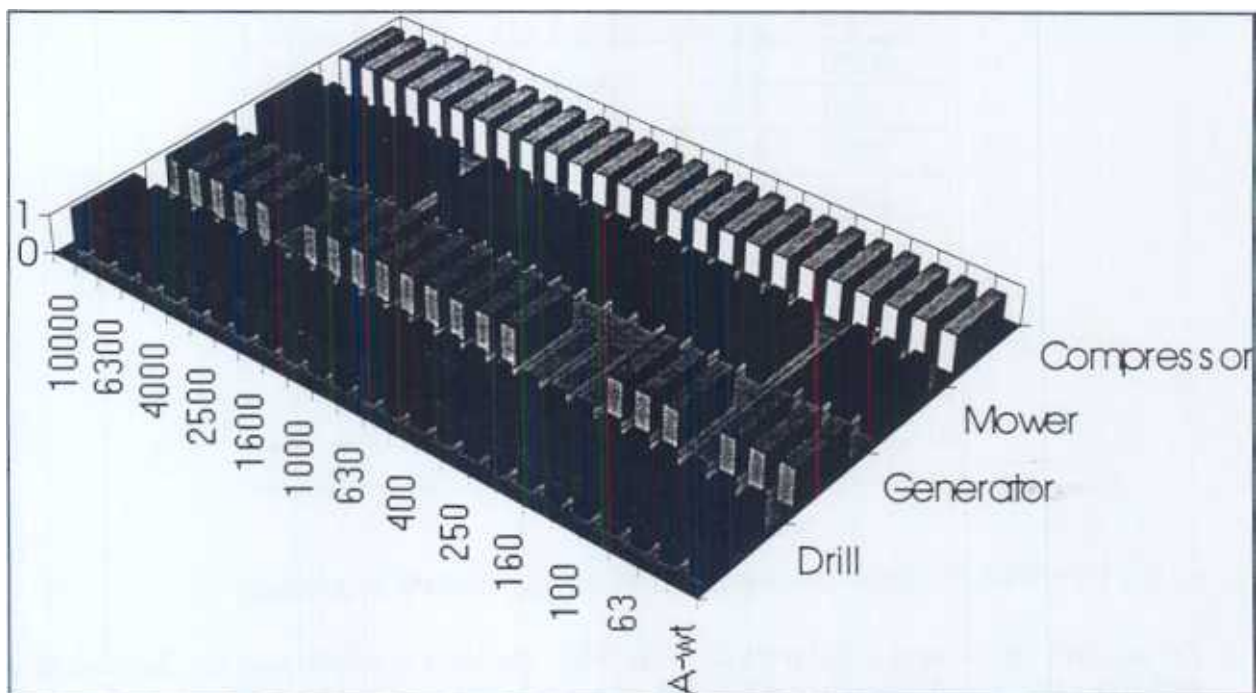


Figure 19 Statistical significance of between-laboratory differences, all data, for ISO 3744. Based on Table 32.

Table 32 F-statistic for between-laboratory differences, all data, for ISO 3744

machine	1	2	3	4
freq (Hz)	F Statistic			
"A" wtg	0	0	0.0042	0
50	0	0.0012	0.0082	0
63	0	0	0	0.0002
80	0	0.1165	0.2315	0.0004
100	0	0.0027	0.0154	0
125	0	0.0001	0.0009	0
160	0	0.0001	0	0
200	0	0.2169	0	0
250	0	0.1645	0.0003	0
315	0	0.3169	0	0.0003
400	0.0004	0.0119	0	0
500	0.0244	0	0.0005	0.0195
630	0	0	0.0003	0.0005
800	0	0	0.0017	0
1000	0	0	0	0
1250	0	0	0	0
1600	0	0	0.0007	0
2000	0	0	0.7608	0
2500	0.0009	0.0004	0.0003	0
3150	0	0.0666	0	0.0001
4000	0.0116	0	0	0
5000	0	0	0	0
6300	0	0	0	0
8000	0	0	0	0
10000	0	0	0	0

9.1.2 ISO 3744, between-laboratory differences, divided by surface.

The second analysis is similar to the above but the data for each surface (hemisphere and parallelepiped) have been treated separately. The objective here is to assess the possibility that the differences between laboratories are the result of one type of surface having particularly large variations. The values of the F-statistic are shown in Table 33 and those that are significant at the 95% level are displayed in Figure 20. It can be seen that there are statistically significant differences for both surfaces. It cannot be concluded, therefore, that one surface provides more reproducible data than the other.

Table 33 F-statistic for between-laboratory differences divided by surface for ISO 3744

machine	1		2		3		4	
surface	1	2	1	2	1	2	1	2
freq(Hz)	F Statistic							
A-wt	0	0.0051	0	0.0001	0	0.001	0	0
50	0	0	0	0	0.0018	0.008	0	0
63	0	0	0.0001	0	0.1266	0	0.003	0
80	0	0	0.0119	0.0787	0.31	0.097	0.134	0
100	0	0	0.0002	0.33	0	0.492	0	0
125	0	0	0.0077	0.0042	0.0013	0.034	0.004	0
160	0	0	0.0103	0.0165	0	0.019	5E-04	0
200	0	0	0.1552	0.0495	0	0.107	0	0
250	0	0	0.0001	0.0044	0.0005	0.018	0.003	0
315	0	0	0.0154	0.0807	0.0002	3E-04	0.051	0
400	0	0.0041	0	0.8474	0	0	0.03	0
500	0.1345	0.0312	0	0.4048	0.0032	0.004	0.055	0
630	0	0.001	0	0	0	0.001	0.018	0.0001
800	0	0.0019	0	0	0	0.109	0.003	0
1000	0	0.0235	0	0	0	0.034	0.021	0
1250	0	0.0032	0	0.0004	0	0.057	0.002	0
1600	0	0.0865	0	0	0	0.342	0.01	0
2000	0	0.0175	0	0	0	0.126	0.009	0
2500	0	0.2367	0	0	0.1084	1E-04	0.005	0
3150	0	0.0652	0.0074	0.0016	0.0138	5E-04	0.018	0
4000	0.0002	0.0157	0	0	0	0.004	1E-04	0
5000	0	0.0002	0	0	0	0	0	0
6300	0	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0	0

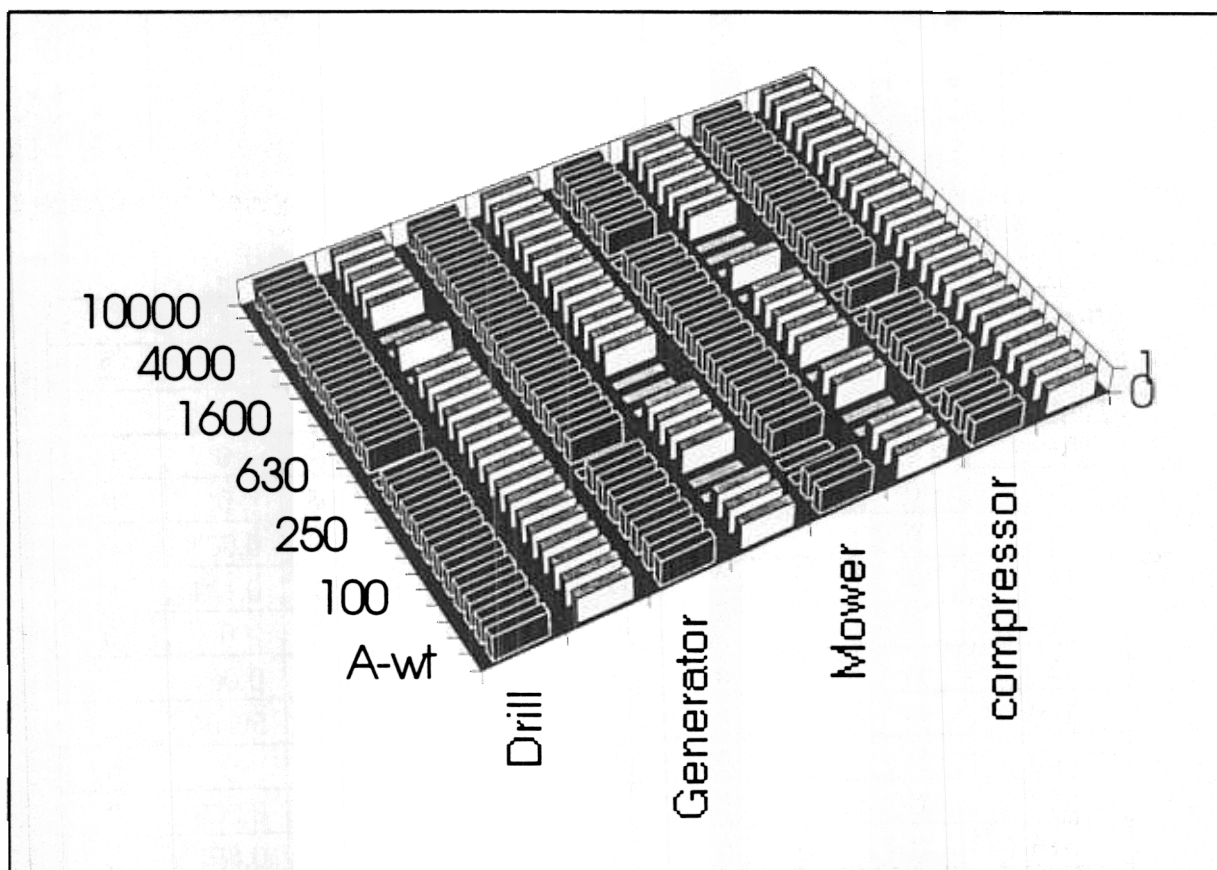


Figure 20 Statistical confidence of between-laboratory differences, data divided by surface, for ISO 3744. Based on Table 33.
Dark boxes are for hemispherical surfaces, light for parallelepiped.

9.1.3 ISO 3744, between-laboratory differences, divided by surface and distance.

The third and final analysis in this initial set has a further division of data. Data from each surface are again considered separately but here each distance (or radius) is also separated. Thus the difference between laboratories for a particular measurement configuration can be assessed. This analysis generates somewhat more data than the previous two analyses and so the F-statistic is listed in two Tables 34a and 34b, with the corresponding graphical representation in Figures 21a and 21b. In these two figures the boxes (representing 95% statistical significance) change hue from dark to light, for the smallest distance (radius) through to the largest distance (radius). An examination of the two figures shows that there is a statistical significance for A-weighted levels at all distances for both surfaces and for all machines. It can, therefore be concluded that there is not a preferred distance (or radius), each one used in this study providing data with essentially the same reproducibility.

Table 34a F-statistic for between-laboratory differences, divided by surface and distance for surface 1

surface machine distance	1											
	1			2			3			4		
	1	2	3	1	2	3	1	2	3	1	2	3
freq (Hz)	F Statistic											
"A" wtg	0	0	0	0	0	0	0.0081	0	0.0015	0	0.0004	0.0001
50	0	0	0	0	0.0002	0	0.011	0.0001	0.1899	0.0017	0	0
63	0	0	0	0.0061	0.0721	0.0467	0.3505	0.1523	0.0808	0	0	0
80	0	0	0	0.0383	0.0114	0.0005	0.0041	0.201	0.2957	0.0002	0	0.0504
100	0	0	0	0.1438	0.0003	0.0094	0.0074	0.0001	0	0	0	0.0011
125	0	0	0	0.5034	0.0096	0.0002	0.0013	0.0026	0.0001	0.0002	0	0
160	0	0	0	0.4156	0	0.0003	0.5709	0	0	0.0001	0	0.0013
200	0	0	0	0.6259	0.0013	0.0061	0.0002	0.0001	0.0002	0	0	0.0184
250	0	0	0	0.6549	0.0007	0	0.0101	0.0002	0.0004	0	0	0.0014
315	0	0	0	0.0374	0.0395	0.0095	0.0002	0	0	0	0	0.0005
400	0.0009	0	0	0.0002	0.0509	0.0001	0.0147	0.0002	0	0.0001	0	0.3393
500	0.001	0.0059	0.0066	0.0001	0.0008	0	0.4085	0.0011	0.001	0.0001	0	0.0139
630	0	0.0001	0	0	0.0008	0	0.1029	0.023	0	0	0	0.0004
800	0	0	0	0.0204	0.0007	0.0014	0.0317	0.0004	0	0	0	0.001
1000	0	0	0	0.0002	0	0.0001	0.0088	0.0001	0	0	0	0
1250	0	0	0	0	0	0	0.0003	0	0	0	0	0.0004
1600	0	0	0	0	0	0	0.0003	0.0007	0.0001	0	0.0002	0.0032
2000	0	0	0	0.0001	0.0002	0.0001	0.0039	0.002	0.002	0.0001	0	0.1207
2500	0	0.0017	0	0.0131	0.196	0	0.7082	0.0238	0.0082	0	0	0.0017
3150	0	0.0006	0	0.0001	0.0095	0	0.0031	0.0668	0.0419	0.0003	0	0.0019
4000	0.0001	0.0157	0	0.0389	0.0005	0	0.0007	0.0176	0	0.0001	0	0.0016
5000	0	0.0042	0	0.0001	0	0	0.001	0.062	0	0.0005	0	0.0001
6300	0	0.0086	0	0.0001	0	0	0.0001	0	0	0	0	0
8000	0.0001	0	0.0001	0	0	0	0.0001	0.0003	0	0.0001	0	0
10000	0	0	0	0	0	0	0.0001	0	0	0	0	0

Table 34b F-statistic for between-laboratory differences, divided by surface and distance for surface 2

surface machine distance freq (Hz)	2											
	1			2			3			4		
	1	2	3	1	2	3	1	2	3	1	2	3
F Statistic												
"A" wtg	0	0	0	0.0004	0.0127	0	0.0003	0	0.0002	0	0	0
50	0.0596	0	0	0.0003	0.3861	0.0902	0.0017	0	0	0.0007	0.0001	0
63	0.0634	0	0	0	0.0013	0.0011	0.0267	0.027	0	0.097	0	0
80	0.0209	0	0	0.0001	0.7338	0.0399	0.0032	0.077	0.0002	0.1963	0.0008	0.0015
100	0.0007	0	0	0.0012	0.0586	0.0179	0.0001	0.4531	0	0.0374	0.0012	0
125	0.0003	0	0	0.2608	0.4075	0.0012	0.0666	0.174	0.0001	0.001	0.0001	0
160	0	0.0002	0	0.0019	0.1582	0.0125	0.0013	0.0252	0	0.0049	0.0004	0
200	0	0	0	0.1714	0.0002	0.0106	0.0024	0.0466	0	0.0097	0.0006	0
250	0	0	0.0023	0.0002	0.0004	0.0005	0.0046	0.002	0	0.2038	0.0046	0
315	0	0	0.0005	0.0121	0.0243	0.0208	0.0025	0.0558	0	0.099	0	0.0001
400	0.0255	0	0.0144	0.0115	0.029	0.6897	0.0008	0.1649	0	0.0286	0.0001	0
500	0.0072	0	0	0.1866	0.3649	0.1719	0.0001	0.1552	0	0.1458	0.0036	0
630	0.1046	0	0	0.1356	0.0344	0.0001	0.033	0.0002	0	0.4178	0.0018	0.0001
800	0.4773	0	0	0	0	0.0001	0.0069	0.0101	0	0.2831	0.0004	0
1000	0	0.0001	0	0	0.0056	0.0002	0.0008	0.0974	0	0.053	0	0
1250	0	0	0	0.0011	0.0081	0.0029	0.0001	0.0206	0	0.0006	0.0002	0
1600	0.0257	0	0	0.0005	0.0097	0.0014	0.0012	0.0128	0	0.0147	0.0045	0.0001
2000	0.0131	0	0	0.0098	0.011	0.0001	0	0.0024	0.0001	0.0223	0.0001	0
2500	0.0082	0	0.0577	0.0002	0.0002	0.0005	0	0.0001	0	0.015	0	0
3150	0.0136	0	0	0.1816	0.0553	0.0009	0.0001	0.0011	0	0.044	0	0
4000	0.1673	0	0.0095	0	0.0098	0	0	0	0.0015	0	0.0002	0
5000	0.008	0	0	0	0	0	0	0.0001	0	0.0001	0	0
6300	0.0005	0	0	0	0	0	0	0	0	0	0	0
8000	0	0	0	0	0	0	0	0	0.0038	0	0	0
10000	0	0	0	0.0053	0	0	0	0	0	0	0	0

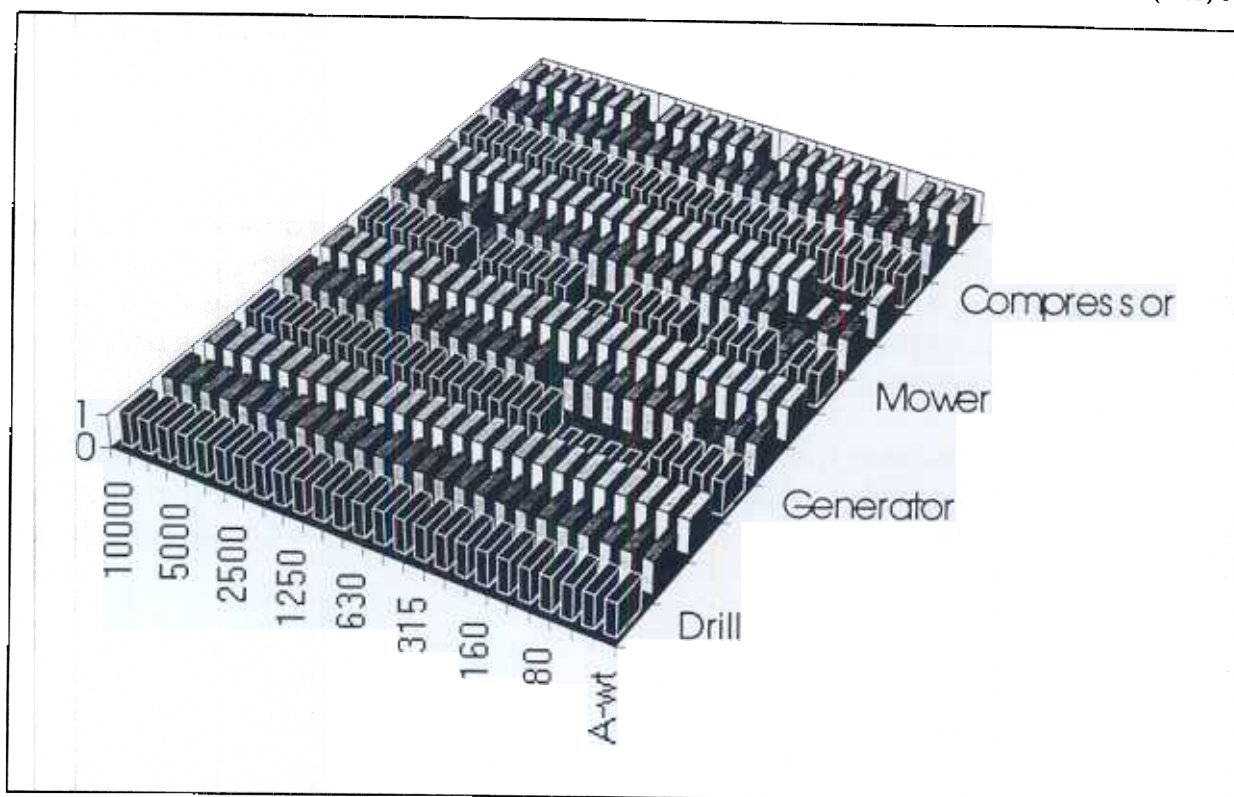


Figure 21a Statistical significance of between-laboratory differences, data divided by distance, for a hemispherical surface to ISO 3744. Based on Table 34a

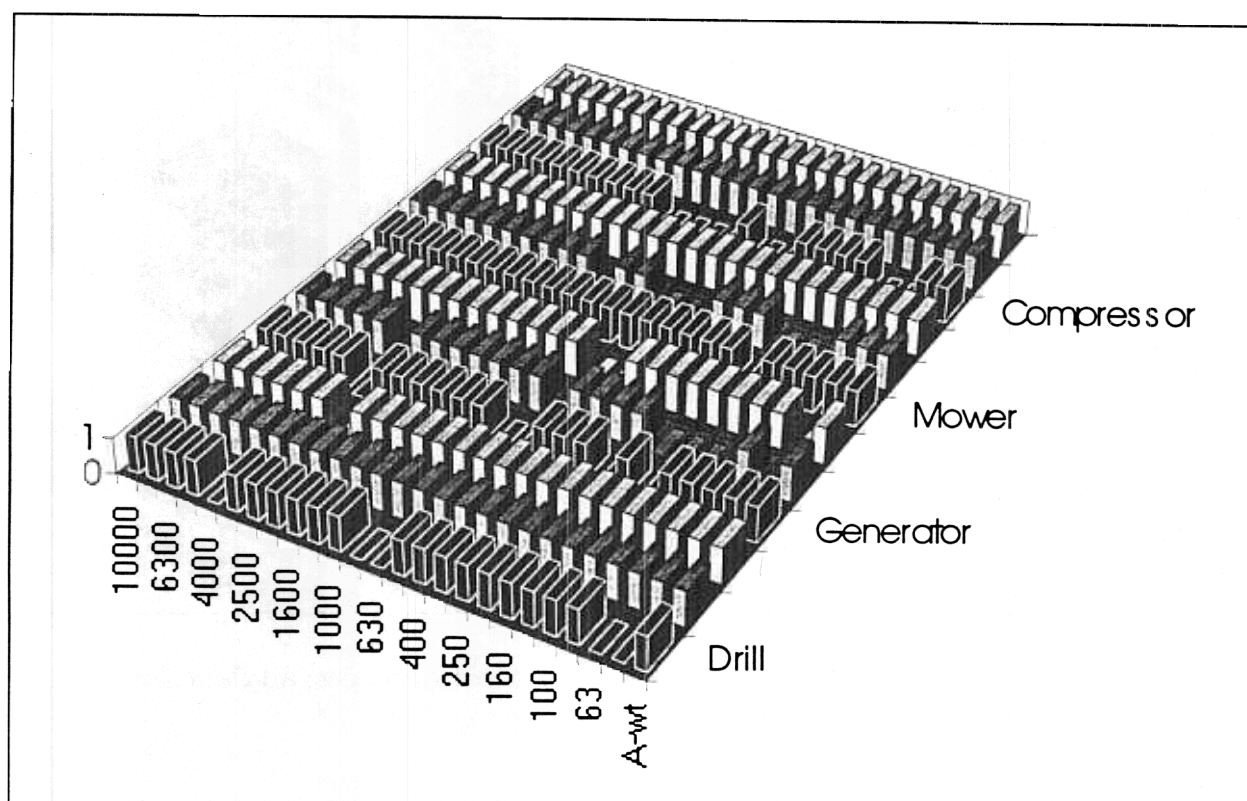


Figure 21b Statistical significance of between-laboratory differences, data divided by distance, for a parallelepiped surface to ISO 3744. Based on Table 34b.

9.1.4 ISO 3744, between-surface differences, all data.

The statistical analyses continued with an investigation into the differences between sound power estimates using hemispherical surfaces and those using parallelepiped surfaces. The magnitude of these differences for A-weighted levels was shown in Table 9. Here the statistical significance of these and the one-third octave band level differences are assessed.

In the first analysis the data from all four laboratories was pooled for each surface and the statistical significance of the differences between the two data sets calculated. The resulting values of the F-statistic are shown in Table 35, and 95% statistical significance displayed in Figure 22.

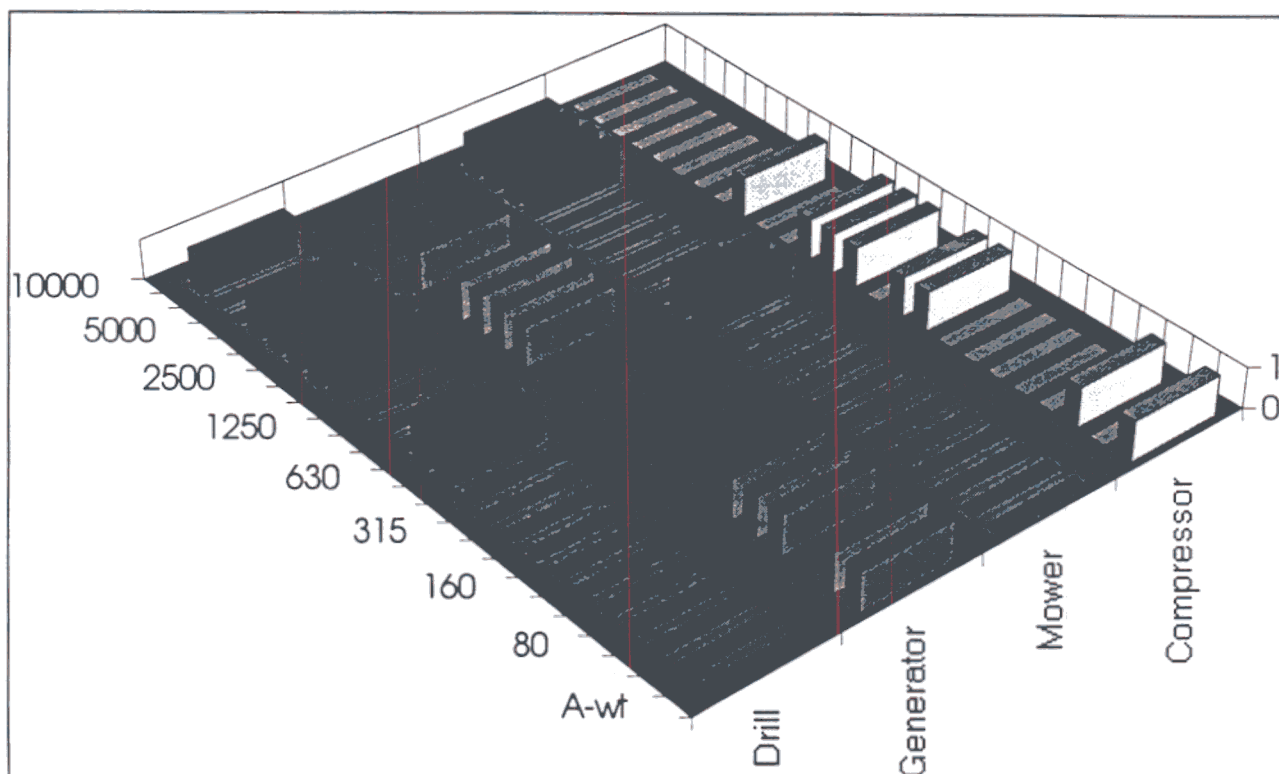


Figure 22 Statistical significance of between-surface differences, all data, for ISO 3744. Based on Table 35.

Table 35 F-statistic for between-surface differences, all data for ISO 3744

machine	1	2	3	4
freq (Hz)	F Statistic			
"A" wtg	0.0745	0	0.4721	0.0001
50	0.6336	0.005	0.906	0.1385
63	0.666	0.288	0.3358	0.0288
80	0.7747	0	0.8445	0.0779
100	0.7661	0	0.3384	0.1707
125	0.7522	0.0083	0.4962	0.2057
160	0.7573	0.3757	0.2409	0.2721
200	0.5009	0.1257	0.7373	0.4347
250	0.5763	0.512	0.8525	0.0015
315	0.4234	0.8807	0.9607	0.0261
400	0.1205	0.8548	0.2191	0.2638
500	0	0.0708	0.1214	0.0004
630	0.0014	0.2087	0.0011	0.0025
800	0.9867	0.1742	0.0087	0.0484
1000	0.2201	0.0001	0.1023	0.1788
1250	0.1215	0	0.4209	0.0564
1600	0.0052	0.0001	0.6495	0.022
2000	0.0052	0.0045	0.059	0.0786
2500	0.0005	0.1114	0.062	0.1507
3150	0.0175	0	0.1768	0.1527
4000	0.0448	0.3282	0.0176	0.3017
5000	0.5285	0.201	0.0007	0.2623
6300	0.1563	0.1173	0.0299	0.1901
8000	0.021	0.2268	0.0358	0.3843
10000	0.1694	0.3511	0.1424	0.2737

It can be seen that the values of the F-statistic are very variable. The 95% significance levels shown in Figure 22 indicate that for roughly half the one-third octave frequency bands the differences are significant. Considering A-weighted levels, only two of the four machines show a significant difference. It is therefore difficult to draw any meaningful conclusions regarding differences in data due to the surface used. In addition, an examination of the data in Table 9 shows that while the A-weighted differences were of the order 1 dB, they were positive for some laboratories and negative for others. It must be concluded, therefore, that there is not a general systematic difference in sound power determinations resulting from the type of enveloping surface used.

9.1.5 ISO 3744, between-surface differences, divided by laboratory.

The analysis in sub-section 9.1.4 was repeated to examine the possibility that any significant difference between data from hemispherical and parallelepiped surfaces is clouded by pooling results from all laboratories. In this analysis the data for each laboratory has been treated separately and calculated values of the F-statistic indicate the statistical significance of sound power level differences between the two surfaces as determined by each laboratory. This analysis necessarily provides a great deal of data and so results are shown in two Tables 36a and 36b. Statistical significance is displayed in Figure 23.

Table 36a F-statistic for between-surface differences, for machines 1 and 2, divided by laboratory for ISO 3744

machine	1				2			
lab	1	2	3	4	1	2	3	4
freq (Hz)	F Statistic							
"A" wtg	0	0.0003	0.0001	0.0047	0	0.0016	0	0.0009
50	0.1041	0.0014	0.3598	0.1015	0	0	0.0001	0.0001
63	0.1203	0.0004	0.8786	0.0279	0.3848	0.0018	0.4051	0.0006
80	0.0517	0.0001	0.5907	0.0154	0.0009	0.5278	0.0113	0.0478
100	0.0892	0.0066	0.7287	0.0091	0.0371	0.2325	0.0013	0.2367
125	0.0869	0.0026	0.4331	0.2215	0.1379	0.3501	0.043	0.0671
160	0.2481	0.004	0.1213	0.1084	0.1741	0.8714	0.543	0.8056
200	0.0239	0.0042	0.0115	0.0616	0.0254	0.2011	0.8255	0.0915
250	0.1449	0.0009	0.004	0.0417	0.01	0.0037	0.0016	0.0156
315	0	0.0009	0.0713	0.0112	0.9066	0.152	0.2132	0.0695
400	0	0.0001	0.3652	0.2494	0.0095	0.083	0.8807	0.1329
500	0	0.0142	0.0002	0.5333	0.0105	0	0.0004	0.0001
630	0.0001	0.0018	0.0012	0.3699	0.0008	0	0.0002	0.0002
800	0.234	0.0086	0.2942	0.2772	0.2525	0.5632	0.0001	0.1215
1000	0	0.0003	0.1823	0.0664	0	0.0168	0	0
1250	0	0.0008	0.001	0.0119	0	0.5489	0	0
1600	0	0	0	0.0053	0.0049	0.6571	0	0
2000	0	0.5683	0.0499	0.0164	0	0.0224	0.0002	0.0002
2500	0	0.0053	0	0.0026	0.0001	0.0009	0	0.014
3150	0.0001	0.527	0.0117	0.0231	0	0.8893	0	0.0002
4000	0.7914	0.3276	0	0.0491	0.106	0.2138	0.6903	0.0139
5000	0.2379	0.2014	0.0748	0.1109	0.0049	0.4534	0.0041	0.0006
6300	0.0232	0.0427	0.2894	0.0216	0.0025	0.2643	0.0001	0.0007
8000	0	0.374	0.0001	0.0104	0	0.5555	0.0467	0.0845
10000	0.4108	0.0659	0.339	0.0107	0.0002	0.5256	0.1339	0.1826

Table 36b F-statistic for between-surface differences, for machines 3 and 4, divided by laboratory for ISO 3744

machine	3				4			
lab	1	2	3	4	1	2	3	4
freq (Hz)	F Statistic							
"A" wtg	0.079	0	0.0181	0.0869	0.0133	0.4833	0.7638	0
50	0.818	0	0	0.772	0.7513	0.4286	0.0002	0.2454
63	0.101	0.0895	0.0296	0.0657	0.0002	0.0269	0.0061	0.079
80	0.016	0.4921	0.1594	0.3427	0.0124	0.4416	0.1016	0.2836
100	0	0	0	0.4979	0.6638	0.0131	0.0045	0.3983
125	0.051	0.1051	0.0292	0.2234	0.7614	0.7951	0.2352	0.133
160	0.12	0.0651	0.4743	0.523	0.8042	0.2088	0.4073	0.2816
200	0.848	0.0694	0.3597	0.7015	0.4869	0.0817	0.8505	0.7525
250	0.016	0.1201	0.3138	0.4966	0.0018	0.4002	0.0057	0.0302
315	0.333	0.4968	0.0607	0.5564	0.0611	0.1779	0.0292	0.0454
400	0.246	0	0.0859	0.1854	0.796	0.0767	0.1828	0.1086
500	0.516	0.003	0.0744	0.1262	0.0015	0.0003	0.0175	0.0051
630	0.007	0.0192	0.0823	0.0091	0.0004	0.4548	0.0091	0.0956
800	0.204	0	0.0386	0.0362	0.0566	0.5367	0.0086	0.2504
1000	0.106	0	0.022	0.1869	0.0409	0.0903	0.9725	0.1905
1250	0.353	0	0.0067	0.6207	0.0062	0.1969	0.6582	0.1518
1600	0.502	0	0.0004	0.8649	0.0314	0.4814	0.3793	0.1002
2000	0.385	0						
2500	0.329							
3150								
4000								
5000	3E-04	0.0001	0.8742	0.015				
6300	0	0	0.065	0.0258	0	0	0.003	0.0551
8000	0.134	0	0.0968	0.0985	0	0.0474	0.4259	0.0582
10000	0.13	0	0.1138	0.1423	0	0.0395	0.9406	0.0208

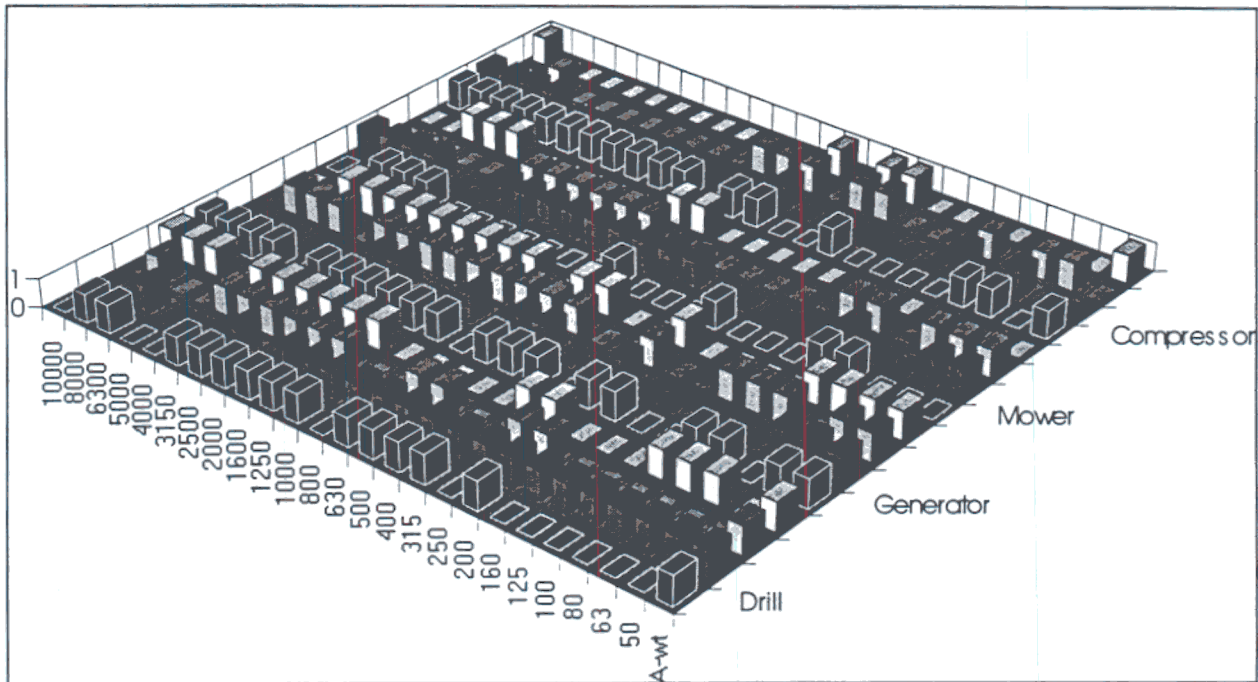


Figure 23 Statistical significance of between-surface differences, data divided by laboratory, for ISO 3744. Based on Tables 36a and 36b. Boxes run from light to dark, for laboratory 1 through to laboratory 4.

It can be seen that the situation is still a little inconclusive, although the number of frequency bands for which the level difference is significant has increased slightly compared with the pooled data analysis. However, if only A-weighted levels are considered there is a considerable change, with now a statistically significant difference for the majority of machine-laboratory combinations. The conclusion to be drawn from these analyses is that there may be a significant difference between sound power levels determined using hemispherical surfaces and parallelepiped surfaces, but the difference does not appear to be systematic.

9.1.6 ISO 3744, between-distance differences, divided by surface

The analysis described here examines the possibility of a systematic variation in measured sound power level with distance (or radius). The analysis was initially performed using pooled data from all laboratories but with the two surfaces considered separately. Resulting F-statistics are shown in Table 37 and 95% statistical significance displayed in Figure 24.

Table 37 F-statistic for between-distance differences, divided by surface, ISO 3744

machine	1		2		3		4	
surface	1	2	1	2	1	2	1	2
freq (Hz)	F Statistic							
"A" wtg	0.8727	0.1595	0.2284	0.0094	0.4071	0.0193	0.7286	0.5033
50	0.9617	0.9356	0.7359	0.5313	0.8228	0.0881	0.3083	0.9793
63	0.9678	0.9793	0.5792	0.5877	0.0183	0.767	0.0429	0.6687
80	0.972	0.8562	0.5484	0	0.0154	0.2758	0.1099	0.4082
100	0.8237	0.7962	0.6456	0	0.446	0.0009	0.1201	0.3327
125	0.854	0.353	0.2174	0.0128	0.0082	0.2093	0.1743	0.6822
160	0.8175	0.4199	0.9339	0.0006	0.6619	0.4376	0.3618	0.599
200	0.9796	0.3811	0.8823	0.0041	0.7695	0.2162	0.4898	0.4656
250	0.9937	0.2241	0.1692	0.0214	0.0077	0.1245	0.1863	0.6443
315	0.6685	0.1597	0.4445	0.0011	0.0366	0.6108	0.0417	0.0748
400	0.921	0.3826	0.1508	0.0693	0.8367	0.3147	0.0795	0.1564
500	0.3348	0.0891	0.7909	0.1076	0.2555	0.2356	0.0083	0.5122
630	0.4355	0.0624	0.8949	0.2034	0.3501	0.0099	0.0124	0.3768
800	0.4646	0.121	0.5537	0.3993	0.7457	0.0547	0.1057	0.7304
1000	0.8394	0.0525	0.9783	0.4308	0.7025	0.0404	0.0803	0.8083
1250	0.8681	0.1063	0.9274	0.0108	0.4121	0.0161	0.0536	0.3805
1600	0.9395	0.0595	0.3729	0.1157	0.0432	0.008	0.0458	0.1961
2000	0.6885	0.1697	0.2078	0.4681	0.0062	0.3033	0.1631	0.6393
2500	0.7914	0.0441	0.9079	0.072	0.0009	0.3588	0.2578	0.6995
3150	0.4086	0.0316	0.0046	0.0941	0.0029	0.0424	0.0586	0.4834
4000	0.0347	0.0492	0.8917	0.4254	0.546	0.0223	0.151	0.9792
5000	0.3333	0.0766	0.6897	0.7388	0.9985	0.1177	0.1945	0.9739
6300	0.4728	0.2039	0.3422	0.3589	0.8495	0.2101	0.2433	0.9962
8000	0.8497	0.3805	0.9217	0.7557	0.8296	0.3573	0.5744	0.9714
10000	0.9516	0.5213	0.9393	0.4308	0.5399	0.5586	0.4494	0.983

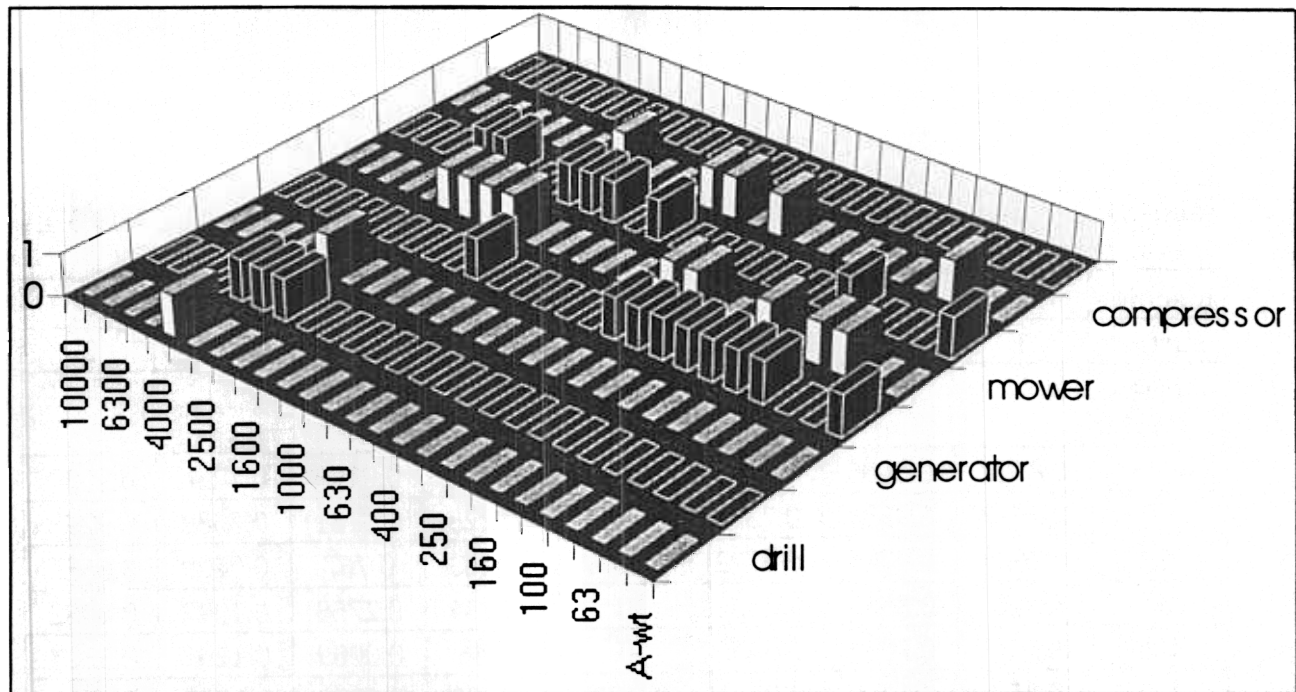


Figure 24 Statistical significance of between-distance differences, data divided by surface, for ISO 3744. Based on Table 37. Light boxes are for hemispherical surfaces, dark boxes are for parallelepiped surfaces.

It can be seen that there is little evidence of a statistically significant difference with measurement distance although differences in A-weighted levels for two machines are significant for parallelepiped surfaces.

9.1.7 ISO 3744, between-distance differences, divided by surface and laboratory.

The analysis of sub-section 9.1.6 was repeated after separating the data for individual laboratories to examine the possibility that pooling the data was masking the effects of changing the measurement distance. This analysis provides a vast amount of data and so to avoid over complication only results for A-weighted levels are reproduced in this Report. Values of F-statistic are shown in Table 38 with the 95% statistically significant values (F-statistic less than 0.05) shown in bold.

It can be seen that now both surfaces show a greater statistically significant dependence of measured level on measurement distance (radius) especially for the parallelepiped surfaces. Similar conclusions may be drawn to those for the between-surface data, that there may be a significant difference between sound power levels determined using different measurement distances (radii) but the difference is not systematic and the dependence, if it exists, is very slight.

Table 38 F-statistic for between-distance differences, divided by surface and laboratory, for A-weighted levels to ISO 3744

machine	1		2		3		4	
surface	1	2	1	2	1	2	1	2
lab	F Statistic							
1	0.1386	0.5709	0.0205	0.0153	0.0018	0.0031	0.0031	0.0422
2	0.1588	0.0003	0.0041	0.0001	0.0005	0.0008	0	0.0324
3	0.2282	0.1828	0.1668	0.0002	0.0857	0.0007	0.0075	0.025
4	0	0	0.0077	0.0013	0.1148	0	0.0708	0

STATISTICAL ANALYSIS FOR ISO 3746

This standard only requires the evaluation of A-weighted sound power levels and so in this section all the calculations of the F-statistic are able to be shown in tabular form. The analyses performed on the ISO 3744 data have been repeated for this standard. Thus we consider between-laboratory, between surface and between-distance effects, although for this standard the actual number of analyses is increased due to the use of two different acoustic environments (different K_2 factors).

ISO 3746, between-laboratory differences, all data.

The first analysis examined the significance of differences between the sound power levels measured by the four laboratories, in which all the data (i.e. surfaces, distances and environments) were pooled. This resulted in F-statistic values of zero for all four machines, consequently a table is unnecessary. All differences were highly significant.

9.2.2 ISO 3746, between-laboratory differences, divided by environment.

This second analysis involved repeating the calculations of the first analysis, but with data divided into the two environments to assess to possibility that measurements made in one environment provided more consistent data. Values of F-statistic are shown in Table 39 with values that are significant at the 95% level shown in bold.

Table 39 F-statistic for between-laboratory differences divided by environment for measurements to ISO 3746

machine	1		2		3		4	
environment	1	2	1	2	1	2	1	2
F Statistic	0.0307	0	0	0	0	0.0277	0	0.0224

It can be seen that the differences are statistically significant in all cases, indicating that measurements using one surface are not more consistent than those using the other.

9.2.3 ISO 3746, between-laboratory differences, divided by surface.

The second analysis is repeated here but this time dividing the data into the two surfaces. Results are shown in Table 40, with 95% significance levels shown in bold.

Table 40 F-statistic for between-laboratory differences divided by surface for measurements to ISO 3746

machine	1		2		3		4	
surface	1	2	1	2	1	2	1	2
F Statistic	0	0.0005	0.0002	0	0.0003	0	0.0024	0

It can be seen that all values are statistically significant indicating that the measurements conducted in one of the environments are not more consistent than those carried out in the other environment.

9.2.4 ISO 3746, between-laboratory differences, dividing by surface and distance.

This last between-laboratory analysis (equivalent to the third initial analysis for ISO 3744, sub-section 9.1.3) involved dividing the data into surface and distance (pooling data from the two environments). Values of F-statistic are shown in Table 41.

Table 41 F-statistic for between-laboratory differences divided by surface and distance for measurements to ISO 3746

surface	1			2		
distance	1	2	3	1	2	3
machine	F Statistic					
1	0	0	0	0.0002	0.0083	0.9
2	0.0254	0.0221		0	0	0
3	0	0.0031		0.0009	0	0.0001
4	0.4806	0		0	0	0

It can be seen that all but two values are significant at the 95% level (data in bold). Thus measurements carried out using either surface and any distance can be ascribed a similar consistency. Or, conversely, if an attempt to reduce the reproducibility standard deviations were made by reducing the choice of measurement configurations, there is no evidence from these analyses of variance as to how this should be done or that this would produce more consistent results.

ISO 3746, between-surface differences, all data

The next series of three analyses were designed to assess the difference between data measured using hemispherical surfaces and those measured using parallelepiped surfaces. These differences were tabulated in Table 11. Values of F-statistic calculated by pooling all data are shown in Table 42.

Table 42 F-statistic for between-surface differences, for measurements to ISO 3746

machine	1	2	3	4
F Statistic	0.0052	0.0854	0.0003	0.0015

It can be seen that for three of the machines the difference between the two sets of data is significant. This implies that A-weighted sound power levels determined using one surface are different from those using the other. This is more clear-cut than was the case for ISO 3744, where there was a significant difference for only two of the four machines.

ISO 3746, between-surface differences, divided by environment.

The analysis described in 9.2.5 uses data from two acoustic environments. To gauge the effect of this combination the analysis has been repeated using two sets of data, one for each environment. Values of F-statistic are shown in Table 43.

Table 43 F-statistic for between-surface differences divided by environment for measurements to ISO 3746

machine	1		2		3		4	
environment	1	2	1	2	1	2	1	2
F Statistic	0.0115	0.183	0.8187	0.0012	0.1662	0	0.0228	0.0308

It can be seen that at this level of disaggregation the results are more equivocal, and the conclusions drawn from the analysis in sub-section 9.2.5 should perhaps be treated with caution.

9.2.7 ISO 3746, between-surface differences, divided by laboratory.

The previous two analyses involve pooling data from all four laboratories. To examine the differences between measurements from the two surfaces for each individual laboratory the data has been divided into four sets, but with the two environments combined. Values of F-statistic are shown in Table 44.

Table 44 F-statistic for between-surface differences divided by laboratory for measurements to ISO 3746

machine	1	2	3	4
lab	F Statistic			
1	0	0.0012	0.0063	0.0864
2	0	0.0348	0.0952	0.4944
3	0	0.0384	0.5379	0.0558
4	0	0.0011	0	0

It can be seen that only for two machines are the differences consistently significant. We conclude that it is unproven whether there are, in general, significant differences between sound power levels measured using hemispherical and parallelepiped surfaces.

9.2.8 ISO 3746, between-distance differences, all data.

The final set of three analyses examine the effect of measurement distance and are equivalent to the last two analyses performed on the ISO 3744 data in sub-section 9.1. The values of F-statistic shown in Table 45 were calculated from all pooled data and indicate that there is a statistically significant dependence on distance, with the exception of results for the drill. It should be remembered that a relatively small range of measurement distances were used for the drill.

Table 45 F-statistic for between-distance differences for measurements to ISO 3746, all data

machine	1	2	3	4
F Statistic	0.3782	0.0002	0.0011	0.0012

9.2.9 ISO 3746, between-distance differences, divided by surface.

To assess the effect of surface type on the difference in sound power levels determined at different distances the data have been divided into two sets, one for each surface, and the analysis repeated. Values of F-statistic are shown in Figure 46. It can be seen that the outcome is similar to the results of the analysis in Section 9.2.8.

Table 46 F-statistic for between-distance differences divided by surface for measurements to ISO 3746

machine	1		2		3		4	
surface	1	2	1	2	1	2	1	2
F Statistic	0.8665	0.0534	0.0046	0.0135	0.0089	0.0398	0	0.1565

9.2.10 ISO 3746, between-distance differences, divided by surface and laboratory.

To complete the picture the data has been further divided to examine the significance of distance for individual laboratories. Values of F-statistic are shown in Figure 47.

Table 47 F-statistic for between-distance differences divided by surface and laboratory for measurements to ISO 3746

surface	1				2			
machine	1	2	3	4	1	2	3	4
lab	F Statistic							
1	0.1918	0.4445	0.1582		0.0000	0.0001	0.0304	0.0025
2	0.0348	0.0023	0	0.0013	0.2827	0.0173	0.6829	0
3	0.0096	0.1488	0.1341		0.3462	0.1128	0.2714	0
4	0.2413	0.0149	0.3822	0.253	0.1086	0.0001	0	0

The pattern is now less obvious, with only half the possible measurement configurations having differences that are significant to the 95% level. For no laboratory are the differences consistently significant. We conclude that although some dependence of measured sound power levels on measurement distance has been observed, it is not possible to draw definitive conclusions about whether the dependence is real.

9.3 STATISTICAL ANALYSIS FOR ISO 9614-1

The analyses carried out for this standard are somewhat less extensive since, although measurements were made in two acoustic environments, they were only made using one parallelepiped surface. Three analyses have been carried out.

9.3.1 ISO 9614-1, between-laboratory differences, all data.

The first analysis examines the differences between laboratories using all data (similar to the first analysis of sub-section 9.1). Values of the F-statistic are shown in Table 48. The majority of F-statistic values are significant at the 95% level and are shown in bold

(the inclusion of a graphical representation will only duplicate this observation). The non-significant A-weighted value for the drill is puzzling. The spectrum of the drill is dominated by energy around 1250 Hz where there is a high value of F-statistic (0.7345), and it is possible that this has a disproportionate effect on the A-weighted result.

Table 48 F-statistic for between-laboratory differences for measurements to ISO 9614-1, all data

machine	1	2	3	4
freq (Hz)	F Statistic			
"A" wtg	0.8726	0.002	0.0091	0
50	0.0009	0.0007	0.2955	0.0058
63	0.0057	0.0003	0.0015	0.0001
80	0.0077	0.0402	0.5475	0.0631
100	0.0107	0	0.8801	0.0264
125	0.0004	0.0003	0.0118	0.0002
160	0.0003	0.0035	0.1879	0.2374
200	0.0026	0	0	0.9493
250	0.0066	0	0.0077	0
315	0.0004	0.4934	0	0.0001
400	0.9669	0.4823	0.0536	0.0008
500	0	0.2385	0.0059	0.0846
630	0	0	0	0.0006
800	0	0	0.0033	0.0015
1000	0.0005	0	0.0374	0.4438
1250	0.7345	0	0.283	0
1600	0	0	0.6469	0
2000	0.0118	0.0089	0.2946	0
2500	0	0.0079	0.169	0
3150	0.0026	0.6734	0.0224	0.0001
4000	0	0.2506	0.0055	0
5000	0	0.0018	0.0072	0

9.3.2 ISO 9614-1, between-laboratory differences, divided by environment.

The analysis in 9.3.1 was repeated with the data divided into two sets, one for each environment, in order to assess whether data from one environment was less consistent between laboratories than those from the other. The F-statistic is shown in Table 49 and the 95% confidence data in Figures 25a and 25b. It can be seen that generally the differences in each environment are significant, again with the exception of A-weighted

values for the drill. It is concluded that measurements to ISO 9614 had similar levels of consistency in the two environments.

Table 49 F-statistic for between-laboratory differences divided by environment for measurements to ISO 9614-1 (for two one-third octave bands there was insufficient measured data to obtain a meaningful value of the F-statistic, these are indicated by blank cells)

environment	1				3			
machine	1	2	3	4	1	2	3	4
freq (Hz)	F Statistic							
"A" wtg	1	0.0038	0.0055	0.0003	0.6749	0.0011	0.0002	0.0044
50	0.0109	0.0002	0.0115	0.0018	0.0077	0	0.0027	0.0077
63		0	0.0853	0.0063	0.0035	0.0001	0.0313	0
80	0.0308	0.0003	0.3282	0.348		0	0.7871	0.0072
100	0.0258	0.0004	0.001	0.0019	0.0175	0.0004	0.0202	0.6565
125	0.0162	0	0.5264	0.0055	0.0018	0.0089	0.0202	0.044
160	0.0026	0.01	0.1019	0.0001	0.0021	0.0214	0.2899	0.9413
200	0.0001	0.0014	0.0019	0.0297	0.0335	0.0013	0.0012	0.2756
250	0	0.0025	0.038	0.0001	0.0033	0.0022	0.3034	0.0002
315	0.0001	0.3882	0	0.0069	0.057	0.6931	0.0001	0.0051
400	0.0226	0.7464	0.0416	0.0002	0.4093	0.4175	0.615	0.108
500	0	0.4391	0.0378	0.4692	0.0037	0.5113	0.0174	0.0407
630	0	0.0003	0.0001	0.007	0	0.0001	0.0002	0.0004
800	0.0014	0.0004	0.0031	0.0374	0.0059	0.0002	0.0001	0.0224
1000	0.0376	0	0.0099	0.5137	0.0229	0.0001	0.0001	0.257
1250	0.071	0	0.1688	0.0005	0.2043	0.0017	0.0028	0.0015
1600	0	0.0001	0.0433	0.001	0	0.0001	0.0086	0.0002
2000	0.0213	0.012	0.0109	0.0013	0.0238	0.0001	0.4506	0.0003
2500	0.0001	0.0086	0.0103	0.0003	0.0001	0	0.0183	0.0039
3150	0.0062	0.1425	0.0025	0.0102	0.0873	0.0587	0.001	0.0026
4000	0.0028	0.0034	0.0066	0.0003	0.002	0.0106	0	0.0169
5000	0	0.0001	0.0125	0.0011	0.0057	0.0029	0.0002	0.0035

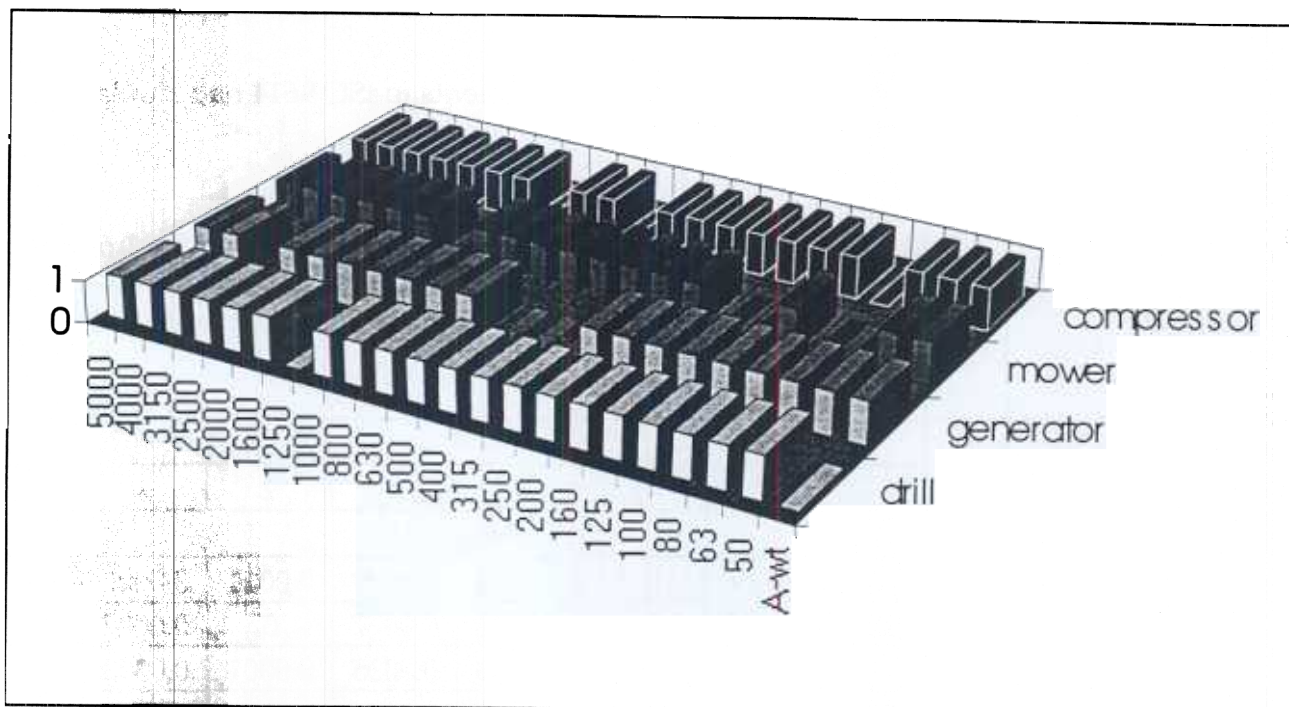


Figure 25a Statistical significance of between-laboratory differences for ISO 9614-1, in environment 1. Based on Table 49.

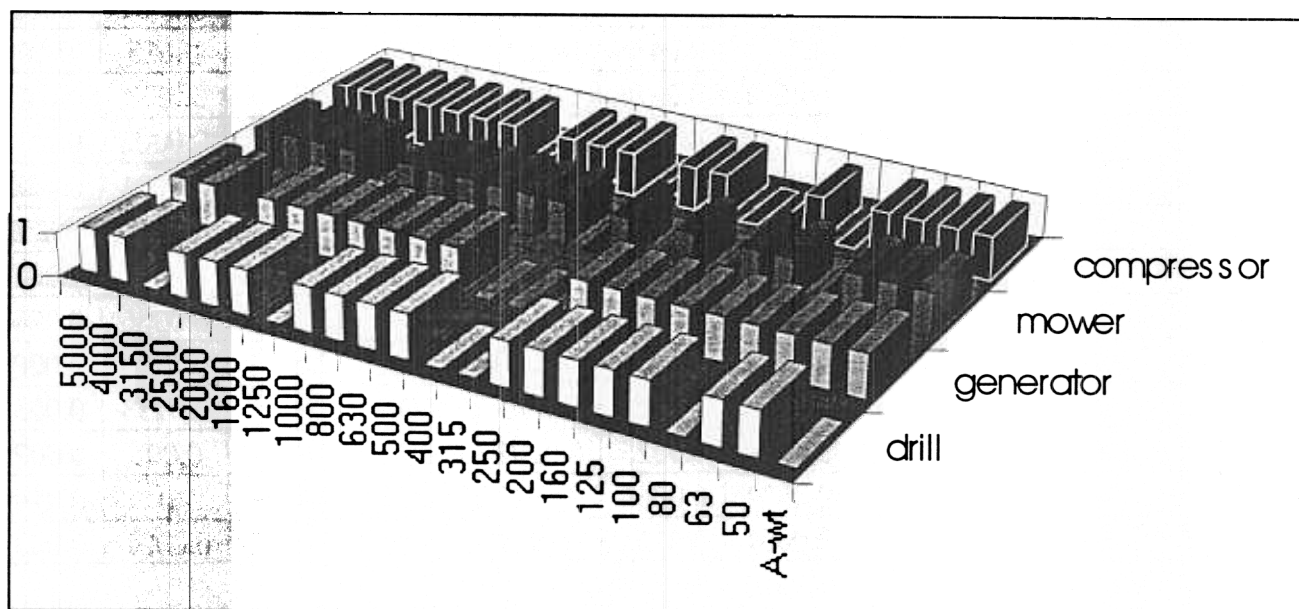


Figure 25b Statistical significance of between-laboratory differences for ISO 9614-1, in environment 3. Based on Table 49.

9.3.3 ISO 9614-1, between-environment differences.

The final analysis for this standard involved dividing the data into two sets to examine differences between the two environments. Values of F-statistic are shown in Table 50, with values that are significant at the 95% level shown in bold (it was considered unnecessary to include a graphical representation). It can be seen that the F-statistic values are generally not significant although the drill exhibits a (spurious) significant value for the A-weighted level. The A-weighted level for the generator is also significant, although in this case this results from the significant values for one-third octave values above 1000 Hz. Overall it must be concluded that there is no significant difference between the sound powers measured in the two environments.

Table 50 F-statistic for between-environment differences for measurements to ISO 9614-1

machine	1	2	3	4
freq (Hz)	F Statistic			
"A" wtg	0.0064	0.7958	0.002	0.5763
50	0.7332	0.1706	0	0.0344
63	0.927	0.6846	0.5417	0.4647
80	0.0744	0.7949	0.0302	0.1424
100	0.1905	0.6119	0.0529	0.4685
125	0.6949	0.6551	0.9083	0.5295
160	0.75	0.6483	0.3531	0.2412
200	0.3276	0.5596	0.6325	0.0464
250	0.0925	0.9859	0.6174	0.5824
315	0.1585	0.7044	0.6674	0.1946
400	0.2898	0.0057	0.1206	0.3989
500	0.5898	0.2827	0.0807	0.0127
630	0.593	0.4295	0.3503	0.0746
800	0.5189	0.7275	0.006	0.1372
1000	0.3439	0.2842	0.0007	0.1727
1250	0.074	0.6982	0	0.4717
1600	0.6758	0.596	0	0.7497
2000	0.1444	0.0935	0	0.5704
2500	0.58	0.0335	0.0001	0.7248
3150	0.1494	0.117	0.0034	0.7532
4000	0.6252	0.3012	0.0099	0.4259
5000	0.3051	0.0669	0.0055	0.303

9.4 STATISTICAL ANALYSIS FOR ISO 11201 AND 11202

Discussion of these two standards has been combined into a single section as there were very few measurements and so the analyses of variance were limited to one for each standard. The analyses examined the statistical significance of differences between sound pressure level data from the four laboratories. Values of F-statistic are shown in Tables 51 and 52 for ISO 11201 and ISO 11202 respectively. The C-weighting data are shown for completeness but are significant principally because of the difference in the detectors used (see sub-section 7.4). It can be seen from Table 51 that the differences between measurements to ISO 11201 are generally significant. This is not so, at the 95% confidence level, for ISO 11202, Table 52. Here, an important factor is that two environments of K_2 -factor 2.5 dB and 5 dB were used, but the standard limits the "local environmental correction" to 2.5 dB. Thus, even when corrected, the results obtained by the high K_2 environment were probably still too high. As a consequence, with results from the two environments combined, the intra-standard repeatability was relatively poor by comparison with the reproducibility of the measurements, and this masks the between-laboratory differences.

Table 51 F-statistic for between-laboratory differences for ISO 11201

machine	1	2	3	4
Wtg	F statistic			
"A"	0	0	0.0003	.1185
"C"	0	0	0	0

Table 52 F-statistic for between-laboratory differences for ISO 11202

machine	1	2	3	4
Wtg	F Statistic			
"A"	0.088	0.0177	0.0972	0.077
"C"	0	0	0	0

10. COMPARISON OF SOUND POWER STANDARDS

Sections 7, 8 and 9 have considered the sound power levels determined according to ISO 3744, ISO 3746 and ISO 9614-1, and associated repeatability and reproducibility uncertainties. In this Section differences between these three determinations of sound power levels are considered.

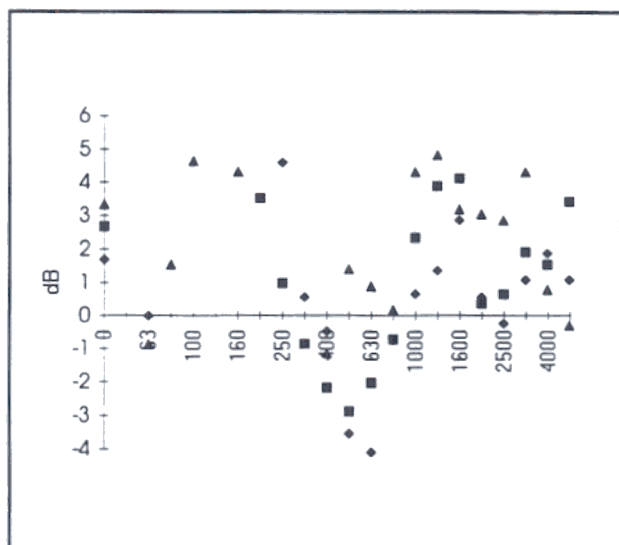
10.1 DIFFERENCES BETWEEN ISO 3744 AND ISO 9614-1 RESULTS

Differences between A-weighted sound power levels determined using ISO 3744 and those determined according to ISO 9614-1 are listed in Table 53 together with associated intra-laboratory repeatability standard deviations for each standard. In the case of ISO 3744, the data used in this comparison relate to measurements using surface 2 (parallelepiped) averaged over all measurement distances. In the case of ISO 9614-1, the data used relate to measurements made in environment 1 (K_2 -factor less than 2 dB). Thus both sets of data relate to measurements made using a parallelepiped surface in an environment of K_2 -factor less than 2 dB. The average difference between A-weighted sound power levels (ISO 3744 - ISO 9614) is 1.2 dB.

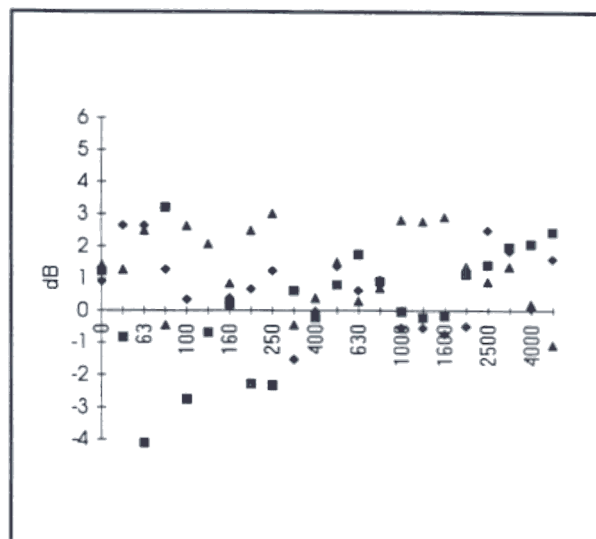
Differences that are statistically significant at the 95% confidence level are shown in bold. It can be seen that the differences for the drill are all statistically significant. However, the results for the drill are affected to some extent by background noise, which may have artificially elevated the measurements made to ISO 3744. Considering the remaining differences there is no clear indication of whether there is a significant difference between the standards. Differences for one-third octave band levels are shown in Figure 26. This Figure comprises four plots, one for each machine, with data from individual laboratories assigned a different symbol. It can be seen that there is a wide scatter of data, with the ISO 3744 data generally providing the larger sound powers. This would be consistent with the ISO 3744 data being affected by spurious reflections or extraneous noise to which ISO 9614-1 is relatively immune.

Table 53 Differences between A-weighted sound power levels (ISO 3744-ISO 9614-1)

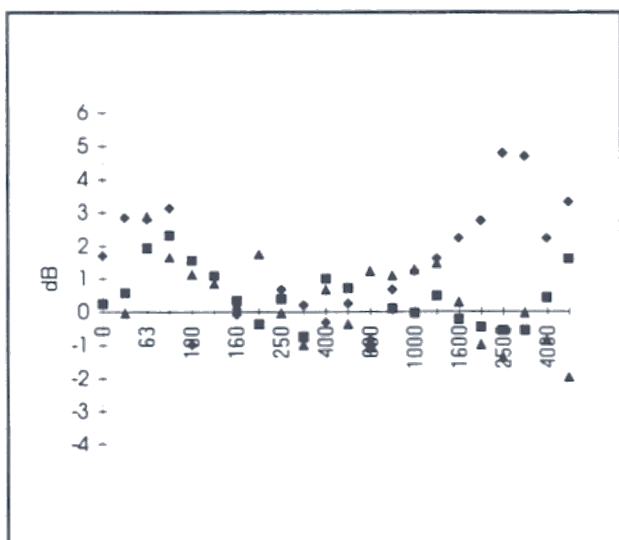
	ISO 3744			ISO 9614			ISO 3744 - ISO 9614		
lab	1	2	3	1	2	3	1	2	3
machine	standard deviation (dB)						differences (dB)		
Drill	0.28	0.65	0.3	0.15	0.38	0.15	2.66	3.34	1.7
Gen	0.33	0.23	0.34	0.01	0.21	0.15	1.21	1.4	0.9
Mower	0.37	0.21	0.63	0.37	0.47	0.06	0.24	0.26	1.69
comp	0.81	0.21	0.47	0.2	0.4	0.15	-0.34	1.88	0.05



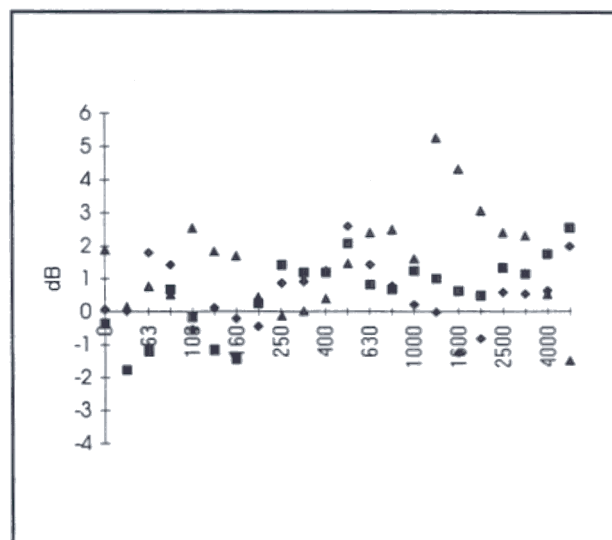
Drill



Generator



Mower



Compressor

Figure 26 Difference (ISO 3744 - ISO 9614) between measured sound power levels, for a parallelepiped measurement surface. The four laboratories are represented by different symbols.

10.2 DIFFERENCES BETWEEN ISO 3744 AND ISO 3746 RESULTS

The difference between ISO 3744 and ISO 3746 calculated from the average A-weighted sound power levels shown in Tables 20 and 22 are, - 0.96 dB, - 0.12 dB, - 0.03 dB and - 0.46 dB for machines 1, 2, 3 and 4 respectively. These differences are small compared with the reproducibility standard deviations discussed in this report. The obvious conclusion is that ISO 3746 provides sound power levels that agree with those from ISO 3744, despite differences in acoustic environment. It is worthy of note that ISO 3746 uses fewer microphone positions than ISO 3744 and is therefore much quicker and, since it can be used in semi-reverberant conditions it is potentially more useful. However, if the data are split into individual measurement configurations and laboratories and the differences re-examined, much larger differences are evident. Figures 27a and 27b show the differences for hemispherical and parallelepiped surfaces respectively with data from individual laboratories assigned a different symbol. Results are shown for each machine with data from each laboratory assigned a different symbol. It can be seen that the differences range up to ± 3 dB. Nevertheless, the differences are still consistent with the experimental reproducibility standard deviations for the two standards. Since measurements to ISO 3746 are more rapid and can be made in semi-reverberant conditions, the use of this standard should be encouraged.

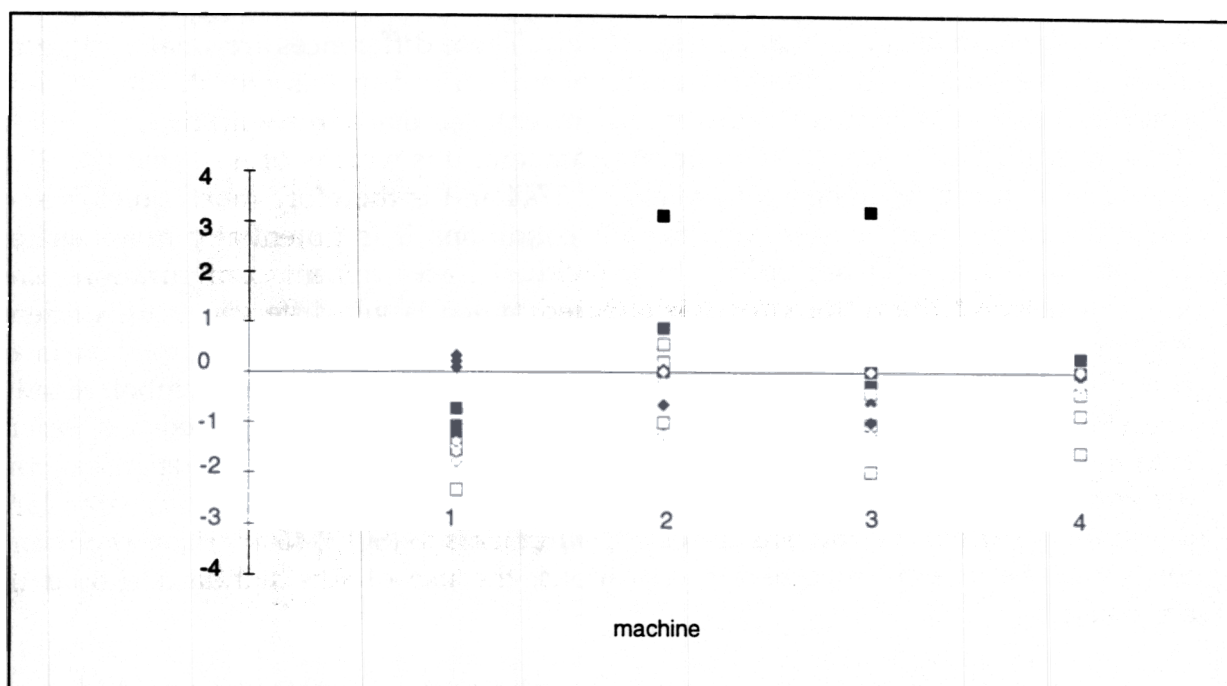


Figure 27a Difference (ISO 3746-ISO 3744) between measured A-weighted sound power levels for a hemispherical surface

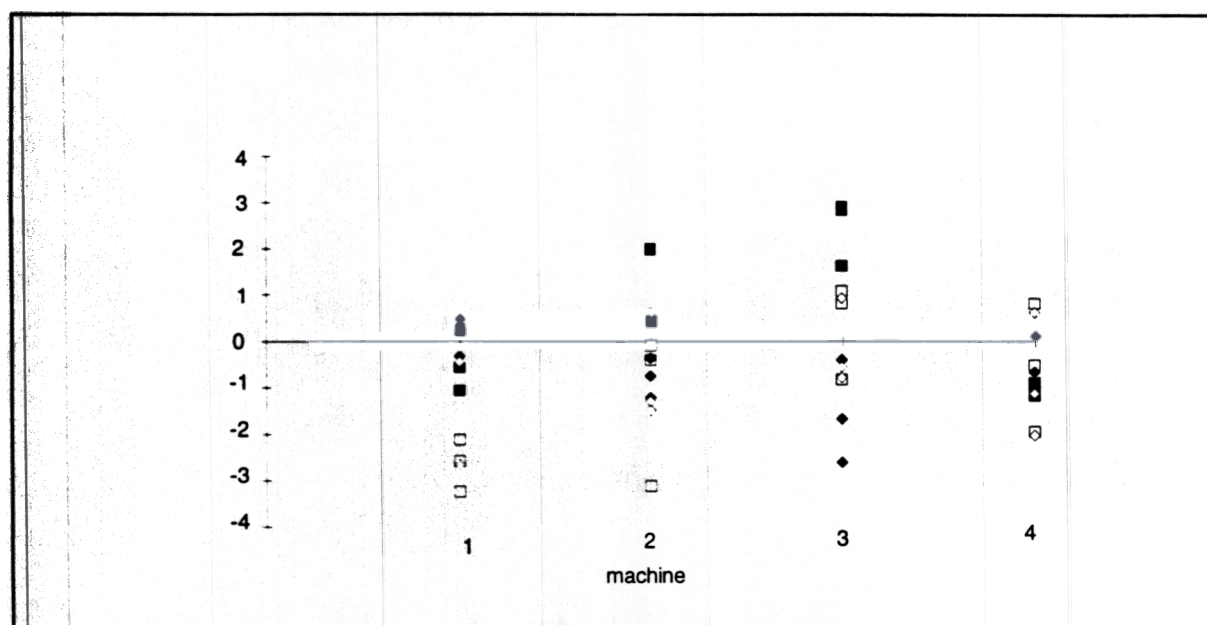


Figure 27b Difference (ISO 3746-ISO 3744) between measured A-weighted sound power levels for a parallelepiped surface

11. CONCLUSIONS

The conclusions and recommendations in this Section draw together the main findings of the Report. They are presented for each standard in turn in order of their presentation in the Report.

11.1 ISO 3744 REPEATABILITY AND REPRODUCIBILITY

For all machines the raw mean data (means of three repeat measurements) from the four laboratories spanned about 10 dB in all one-third octave bands; for A-weighted levels the data spanned about 4 dB.

The intra-laboratory repeatability standard deviations exhibited a slight dependence on frequency, generally increasing at low and high frequencies, but were generally less than 0.5 dB with the majority less than about 0.3 dB. The average standard deviation for A-weighted levels was 0.18 dB.

The intra-standard repeatability standard deviations were generally around 1 dB with lower values of the order 0.5 dB and values approaching 2 dB not uncommon; the average value for A-weighted levels was 0.8 dB.

Generally, reproducibility standard deviations were around 2 dB but increased with frequency above about 4 kHz to approximately 4 dB at 10 kHz; the average value for A-weighted levels was 1.1 dB.

For frequencies below about 400 Hz reproducibility standard deviations were smaller than the estimates in ISO 3744, between 400 Hz and 4 kHz they were machine dependent but were generally greater than the values given in ISO 3744, and at higher frequencies they were consistently greater than the ISO estimates. These large reproducibility standard deviations may have resulted from the range of K_2 -factors that are allowed by ISO 3744. The only requirement is that measurements are made in an acoustical environment with a K_2 -factor less than or equal to 2 dB. No correction is required to measured data to take account of K_2 . **It is recommended, therefore, that corrections to allow for variations in the acoustical environment should be required by ISO 3744.**

11.2 ISO 3744 ANALYSIS OF VARIANCE SUMMARY

The differences between sound power determinations by the four laboratories were statistically significant for A-weighted levels for all machines and in all but a few frequency bands, and furthermore were significant for both hemispherical and parallelepiped measurement surfaces and for all measurement distances for both surfaces. **It is concluded that there is not a preferred measurement surface or distance, each combination used in this study providing data with essentially the**

same consistency between laboratories.

The average difference between A-weighted sound power levels determined using hemispherical and parallelepiped measurement surfaces was just over 0.5 dB, but varied between machines and laboratories. The difference was found to be statistically significant for two of the four machines when data from all laboratories was pooled. When the data was divided by laboratory, the difference remained significant at all laboratories for at least two machines. However, the actual differences were both positive and negative, and it is concluded that there is no general systematic difference between sound power determinations using hemispherical and parallelepiped surfaces to ISO 3744.

Again considering data from all laboratories, there was little evidence of a statistically significant dependence of measured sound power level on measurement distance. However, when the data was divided by laboratory the dependence became more significant, particularly for the parallelepiped measurement surface. It is concluded that although some results showed a significant dependence on measurement distance, the dependence is very weak and not fully consistent.

ISO 3746 REPEATABILITY AND REPRODUCIBILITY

For all machines the A-weighted sound power levels measured by the four laboratories spanned a range of approximately 4 dB. This is similar to the A-weighted data for ISO 3744. The intra-laboratory standard deviations were similar for all measurement surfaces and distances and both acoustical environments and averaged 0.15 dB.

The intra-standard repeatability standard deviation, averaged over all laboratories and machines, was 0.98 dB.

The reproducibility standard deviation, averaged over all machines, was 1.3 dB. This is much less than the estimated standard deviation of reproducibility of 4 dB published in ISO 3746 for noise sources of the type used in this study. The text in the standard makes it clear that standard deviations are dependent on machine type and environment and so it may be that if very large machines with time variable and/or impulsive noise attributes are considered the reproducibility standard deviations are larger.

ISO 3746 ANALYSIS OF VARIANCE SUMMARY

The differences between A-weighted sound power levels determined by the four laboratories were statistically significant for all machines for both hemispherical and parallelepiped surfaces, in both environments and at all distances. Thus, if an attempt were made to improve the reproducibility of measurements by reducing the choice of measurement configurations, there is no evidence from these analyses of variance

as to how this should be done or that this would produce more consistent results.

The mean difference between A-weighted sound power levels determined using hemispherical surfaces and parallelepiped surfaces was just over 0.6 dB, but varied between machines and laboratories. Considering all measured data the difference was statistically significant for three of the four machines. When the data were divided between the two environments a statistically significant difference only occurred for some machine-environment combinations, and when data from individual laboratories were considered separately the results were also equivocal. **We conclude that it is unproven whether there is, in general, a systematic difference between sound power levels measured using hemispherical and parallelepiped surfaces to ISO 3746. In any event the effect must be very small.**

Considering all data there was a statistically significant dependence of the measured sound power level on measurement distance for three of the four machines, and this persisted when the data were divided by surface type. However, when the data were further divided by laboratory, for no laboratory were the differences consistently significant. **We conclude that although some dependence of measured sound power levels on measurement distance has been detected, the dependence, if it exists, is marginal.**

11.5 ISO 9614-1 REPEATABILITY AND REPRODUCIBILITY

For all machines the sound power levels measured by the four laboratories spanned about 5 dB in all one-third octave bands; for A-weighted levels the span was about 3 dB. This is less than the equivalent values for ISO 3744 and ISO 3746.

The intra-laboratory repeatability standard deviations were less than 0.5 dB with the majority less than about 0.3 dB. There was a very slight increase with decreasing frequency. The average standard deviation for A-weighted levels was 0.22 dB. This was similar to the equivalent values for ISO 3744 and ISO 3746.

The intra-standard repeatability standard deviations were generally around 1 dB with lower values of the order 0.5 dB and higher values of approximately 2 dB; the average value for A-weighted levels was 0.44 dB, smaller than for ISO 3744 and ISO 3746.

Generally, reproducibility standard deviations were around 1 dB with a very slight increase towards lower frequencies; for A-weighted levels, the average value was 0.6 dB. **Almost all reproducibility standard deviations were within the estimates published in ISO 9614-1.** It should be borne in mind that these reproducibility data were based on measurements using only one measurement surface and distance. However, the results for ISO 3744 indicate that reproducibility does not necessarily deteriorate with an increase in the number of measurement configurations.

ISO 9614-1 ANALYSIS OF VARIANCE SUMMARY

The differences in sound power determinations by the four laboratories were statistically significant for all machines in both the environments used.

There was no significant difference between the results of measurements in the two environments (characterised by K_2 -factor less than 2 dB, and approximately 5 dB).

ISO 11201 REPEATABILITY AND REPRODUCIBILITY

The average intra-laboratory repeatability for measurements of A-weighted emission sound pressure levels was 0.23 dB.

Since measurements were made in only one acoustical environment, the intra-standard repeatability was essentially untested. The average reproducibility standard deviation was 0.88 dB. **The guidance given in ISO 11201 suggests that the reproducibility standard deviation should be less than 2.5 dB, so the measured value was well within this estimate.**

Laboratories interpreted differently the meaning of "C-weighted peak emission sound pressure level" as defined in ISO 11201. **This should be clarified in the standard.**

ISO 11202 REPEATABILITY AND REPRODUCIBILITY

The average intra-laboratory repeatability for measurements of A-weighted emission sound pressure levels was 0.12 dB.

The average intra-standard repeatability standard deviation was 1.36 dB.

The average reproducibility standard deviation was 1.7 dB. The guidance given in ISO 11202 suggests that, due to the limitations on K-factor corrections, the reproducibility standard deviation may be as high as 5 dB. However, this 5 dB estimate is related to the "correct" sound pressure level. A comparison of the mean sound pressure level data from ISO 11202 and ISO 11201 shows differences of 3.59 dB, 2.28 dB, 2.84 dB and 0.99 dB for machines 1, 2, 3, and 4 respectively. If it is assumed that the data from ISO 11201 are "correct" and these differences are added to the measured ISO 11202 reproducibility standard deviations, then, **the reproducibility of 5 dB quoted in the standard is still reasonable.**

It is clear that if the procedures detailed in ISO 11204 were followed and a more representative correction for K-factor applied, then the estimates of emission sound pressure level from ISO 11202 would be more accurate.

11.9 COMPARISON OF ISO 3744 AND ISO 9614-1

There was no clear indication of a statistically significant difference between sound power levels measured using these two Standards. The average difference (ISO 3744 - ISO 9614) between A-weighted sound power levels was 1.2 dB. This positive difference would be consistent with the ISO 3744 data being influenced by spurious reflections or extraneous noise to which ISO 9614-1 is relatively immune.

11.10 COMPARISON OF ISO 3744 AND ISO 3746

The average difference between A-weighted sound power levels determined by these two standards (ISO 3744 - ISO 3746) was -0.4 dB and was small compared with the reproducibility standard deviations for the two standards. We conclude that ISO 3746 provides sound power levels that agree very well with those from ISO 3744, despite differences in acoustic environment requirements. It is worthy of note that ISO 3746 uses fewer microphone positions than ISO 3744 and is therefore much quicker and, since it can be used in semi-reverberant conditions, it is potentially more useful. When the data associated with each machine and with hemispherical and parallelepiped measurement surfaces are examined separately, the differences between the two standards range up to ± 3 dB. However, these differences are still consistent with the experimental reproducibility standard deviations of the two standards. Since measurements to ISO 3746 are more rapid and can be made in semi-reverberant conditions, the use of this standard should be encouraged.

12. ACKNOWLEDGEMENTS

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APPENDIX 1: INSTRUCTIONS TO THE LABORATORY SUB-CONTRACTORS

Measurement Programme on Machinery Noise Emission

1 Measurements required

The overall aim of the programme is to evaluate and analyse the measurement uncertainties of new international standard procedures for determination of the noise emission of machinery. Three standards are of interest for the sound power level, and four further standards concern the emission sound pressure levels at specified positions.

The standards concerned are the following:

- | | |
|------------|--|
| ISO 3744 | Acoustics - Determination of sound power levels of noise sources using sound pressure - Engineering method employing an enveloping measurement surface in an essentially free field over a reflecting plane. |
| ISO 3746 | Acoustics - Determination of sound power levels of noise sources using sound pressure - Survey method employing an enveloping measurement surface over a reflecting plane. |
| ISO 9614-1 | Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 1: Measurement at discrete points. |
| ISO 11201 | Acoustics - Noise emitted by machinery and equipment - Measurement of emission sound pressure levels at the work station and at other specified positions - Engineering method. |
| ISO 11202 | Acoustics - Noise emitted by machinery and equipment - Measurement of emission sound pressure levels at the work station and at other specified positions - Survey method. |
| ISO 11203 | Acoustics - Noise emitted by machinery and equipment - Determination of emission sound pressure levels at the work station and at other specified positions from the sound power level. |
| ISO 11204 | Acoustics - Noise emitted by machinery and equipment - Measurement of emission sound pressure levels at the work station and at other specified positions - Method requiring environmental corrections. |

All the measurements necessary for the completion of the programme can be obtained by carrying out tests according to ISO 3744, ISO 3746, ISO 9614-1, ISO 11201 and ISO 11202. These tests will yield sufficient information for data to be derived also on the uncertainties of ISO 11203 and ISO 11204, and it is therefore not necessary to perform any tests for the latter two.

2 Machines to be used

Tests will be conducted on four machines to be supplied by NPL, comprising (a) an electric drill, (b) a diesel generator, (c) a two-stroke petrol-engined lawnmower, and (d) a diesel-engined air compressor. Their overall sizes are shown in Table 1.

The drill requires a 240 V mains electrical supply and will be provided with a mounting stand. The generator, lawnmower and air compressor will all be free-standing on the floor of the test area.

Table 1. Approximate machine dimensions.

Machine	Dimensions (m)		
	Side-to-side	Front-to-back	Height
(a)	0.3	0.05	0.3
(b)	0.5	0.7	0.7
(c)	0.5	0.7	0.4
(d)	1.2	1.6	1.2

3 Data acquisition

Sound pressure levels and sound intensity levels are to be measured, and sound power levels and emission sound pressure levels are to be calculated, according to the respective requirements of ISO 3744, ISO 3746, ISO 9614-1, ISO 11201 and ISO 11202, for each of the four machines in their normal operating condition. The versions of the standards to be used for the measurements are identified in the specifications which follow, and copies are included in Annex 2. The arrays of measurement positions to be selected, and the measurement radii and distances to be used, are specified below. The guidance given in the standards must then be followed to derive the co-ordinates of the individual measurement positions, conduct the measurements, apply the necessary corrections, and obtain the required results. As a guide for tendering purposes, the total numbers of measurement positions expected in the various test configurations are included in the respective specifications.

All measurements are to be repeated, to obtain three independent sets of results at each measurement radius and each measurement distance, in each acoustical environment specified for the respective standards and machines.

All the individual measurements of sound pressure levels and sound intensity levels, and the calculated sound power levels and emission sound pressure levels, are to be entered on to computer disk using SPSS Data Entry software, to be prepared and supplied by NPL. This will require use of an IBM PC/XT, PC/AT, PS/2, or compatible computer with version 2.0 or later of PC/DOS or MS/DOS. The required format for

data input will be pre-determined and the software will guide the input process.

4 Measurements according to ISO 3744

The version of the standard to be used is labelled ISO 3744:1992 in Annex 2.

The acoustic environment can be either a hemi-anechoic room or an outdoor space fulfilling the stated requirements. If convenient, the electric drill may be tested in a room and the three other machines, all of which produce exhaust gases, can be tested outdoors. The environmental correction, K_2 , is to be determined for each environment using a calibrated reference sound source, in accordance with clause A.3.1 of ISO 3744.

Sound pressure levels are to be measured with frequency weighting A and in 1/3-octave bands of mid-band frequencies from 50 Hz to 10 kHz, on three hemispherical measurement surfaces of radii listed in Table 2, and three parallelepiped measurement surfaces.

Table 2. Measurement radii, r , for the hemispherical measurement surfaces.

Machine	r_1 (m)	r_2 (m)	r_3 (m)
(a)	1.0	1.25	1.5
(b)	2.0	4.0	6.0
(c)	2.0	4.0	6.0
(d)	4.0	6.0	8.0

The number of measurement positions for each hemispherical measurement surface is 10.

The measurement distances and expected numbers of measurement positions for the parallelepiped measurement surfaces are listed in Table 3.

Table 3. Measurement distances, d , and expected numbers of measurement positions for parallelepiped measurement surfaces.

Machine	Number of measurement positions			
	$d_1 = 0.25$ m	$d_2 = 1.0$ m	$d_3 = 1.5$ m	$d_4 = 2.0$ m
(a)	14	9	9	-
(b)	37	9	-	9
(c)	21	9	-	9
(d)	61	21	-	9

5 Measurements according to ISO 3746

The version of the standard to be used is labelled ISO/DIS 3746 in Annex 2.

Each machine is to be tested in two acoustic environments, one requiring an environmental correction, K_{2A} , within the range 2.0-2.5 dB and the other requiring a correction within the range 4.5-5.5 dB. K_{2A} is to be determined using a calibrated reference sound source, in accordance with clause A.3.1 of DIS 3746.

Sound pressure levels are to be measured with frequency weighting A, on three hemispherical measurement surfaces of the same radii listed in table 2, and three parallelepiped measurement surfaces.

The number of measurement positions for each hemispherical measurement surface is 4.

The measurement distances and expected numbers of measurement positions for the parallelepiped measurement surfaces are listed in Table 4.

Table 4. Measurement distances, d , and expected numbers of measurement positions for parallelepiped measurement surfaces.

Machine	Number of measurement positions			
	$d_1 = 0.25 \text{ m}$	$d_2 = 1.0 \text{ m}$	$d_3 = 1.5 \text{ m}$	$d_4 = 2.0 \text{ m}$
(a)	8	5	5	-
(b)	20	5	-	5
(c)	12	5	-	5
(d)	33	12	-	5

6 Measurements according to ISO 9614-1

The version of the standard to be used is labelled ISO 9614-1:1993 in Annex 2; in particular, the specifications for the Engineering Grade (Grade 2) of accuracy are to be followed.

The sound intensity instrument (comprising the probe and processor) must be of Class 1 according to IEC 1043. The guidance of the manufacturer or supplier of the instrument may be sought in this respect, but documentary evidence will be required to show that the performance of the instrument has been verified in a laboratory making calibrations traceable to national standards.

Each machine is to be tested in two acoustic environments, one being the same hemi-

anechoic environment (either a room or outdoors) used for the measurements according to ISO 3744, and the other being the second environment used for the measurements according to ISO 3746 (having an environmental correction, K_{2A} , of 4.5-5.5 dB).

Sound intensity levels are to be measured in 1/3-octave bands of mid-band frequencies from 50 Hz to 5.0 kHz, on one parallelepiped measurement surface only, selected to fulfill the requirements of the standard. The number of measurement positions will vary between the different machines, but an average of 20 can be assumed as a rough guide for estimating purposes.

7 Measurements according to ISO 11201

The version of the standard to be used is labelled ISO/DIS 11201 in Annex 2.

Each machine is to be tested in the same acoustic environment used for the measurements according to ISO 3744.

Time-average sound pressure levels with frequency weighting A and peak sound pressure levels with frequency weighting C are to be measured at four positions only, in accordance with clause 11.5 of the standard.

8 Measurements according to ISO 11202

The version of the standard to be used is labelled ISO/DIS 11202 in Annex 2.

Each machine is to be tested in the same two acoustic environments used for the measurements according to ISO 3746.

Time-average sound pressure levels with frequency weighting A and peak sound pressure levels with frequency weighting C are to be measured at four positions only, in accordance with clause 11.5 of the standard.

APPENDIX 2. DATA ENTRY INSTRUCTIONS

MEASUREMENT PROGRAMME ON MACHINERY NOISE EMISSION

Data Acquisition: Data input to disk

Supporting reference manual for Data Entry

Acoustics Branch
National Physical Laboratory
Teddington
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TW11 0LW

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- Annex 2: Help Page used in input file for
standards ISO 3744, ISO 3746 and ISO 9614-1

1. General Information

This manual is to be used in conjunction with the Measurement Programme on Machinery Noise Emission. The overall aim of the programme is to evaluate and analyse the measurement uncertainties of new international standard procedures for the determination of the noise emission of machinery. All the measurements necessary for the completion of the programme can be obtained by carrying out tests according to ISO 3744, ISO 3746, ISO 9614-1 and ISO 11201 and ISO 11202.

The manual is intended to be used to help the user with the data input of machinery noise emission values. Measurement data are to be entered onto computer disk using SPSS Data Entry software. This manual describes the software, how to install the software, the layout of the input files, troubleshooting and the codes and definitions used. It is advised that you should get accustomed to using the system for a short time before you commence your data entry.

2. SPSS Data Entry Software

SPSS (Statistical and Presentation Software Systems) is a statistical analysis package. The package will be used to analyse the data when they have been returned to NPL. SPSS Data Entry II is a stand alone module of the SPSS package. It contains powerful facilities for interactive data entry, data editing, and data cleaning. The software allows for data entry into a spreadsheet or data entry form. For entering machinery noise emission values, a customised data entry form has been set up to guide the input process. The data entered into this customised system will in turn set up a spreadsheet of variables and values, which will be used for the final analysis by NPL using other modules of SPSS. It should be noted that the order of entry of the data values is constrained by the method of analysis of the results.

3. Installing Data Entry Software

The Data Entry II software must be installed on to an IBM PC/XT, PC/AT, PS/2, or closely compatible computer with version 2.0 or later of PC/DOS or MS/DOS. You will need to make a directory on your hard disk drive into to which you should copy the files on disk 1. You can use either instructions at the DOS prompts or the Windows environment to install the software. Using commands at the DOS prompts, you can install the files as follows:

- 1 Please type at the DOS prompt of root directory:

md c:\SPSSDE [ENTER] (to make directory called SPSSDE)

- 2 You will need to insert disk 1, DATA ENTRY FILE DISK into your floppy disk drive. We will assume that the floppy disk is in drive specified as a. Please use a different drive specification on the following commands if this is not appropriate.

- 3 To copy the files from disk 1 to your new directory, please type:

copy a:*.* c:\spssde [ENTER]

- 4 To check that the files have been copied, you may list the directory of files by typing:

cd spssde to move to the spss directory

dir [ENTER] to list the files.

4. Getting Started

1. In order to run the SPSS Data Entry II software, you must start each session in the SPSSDE directory. At the DOS prompt, from the root directory, please type

cd SPSSDE [ENTER]

You should now be given the following prompt to confirm that you are in the correct directory:

c:\spssde

2. To start the SPSS Data Entry programme, type:

SPSS/DE [ENTER]

3. The screen will display a Main Menu and a Control Menu. At the top, the current file is displayed. This should read <none>. For these particular screen commands, the ↑ signifies the [SHIFT] key, the ^ signifies the [CTRL] key.

4. In order to load the relevant file, please type

[SHIFT] F2

F2

[ENTER] to select the spss/pc file

5. You must now select the correct disk relevant to your data. Each disk is labelled with a standard, laboratory code and machine code. The name of the SPSS/PC file is given on each disk. An explanation of the codes is given in Annex 1. Insert the relevant disk into floppy disk drive. We will assume from now on that this is drive a. If in fact you are using a different drive, please use a different drive specification where "a" appears.

You must now type in the name of your input file:

a:\s*l*m*.sys [ENTER]

4. The screen now displays details about the file. To continue press:

[SPACE]

5. The screen will display three menu sets. You are only to be concerned with ↑F5 Data command. PLEASE IGNORE ALL OTHER PROMPTS. Therefore, please press:

↑F5

6. The screen display will now display a different background behind the three menus. Press

[SPACE]

to remove the menus.

You are now ready to input data values. Please note that at anytime you hit [ESC] too many times, you may be moved to the menu in (3). The current file header will now display the file that is currently active. To return to the data input screen of 6, you must type **↑F5** again.

NOTE 1

If you find that your computer is too slow at accessing and processing the files on the floppy disk (which may only be for input file for ISO 3744), it may be necessary to copy the active file onto the hard disk drive (c:) for inputting the data, and saving it back onto the floppy disk after use. If you should require assistance with this, please consult section 9.

NOTE 2

It is necessary to leave the disk in the floppy disk drive throughout the input of data. Removing the disk may result in the loss of data.

5. General Layout of each input file.

Title Page

For each file, the first page displayed is the title page. This gives the name of standard method for measurement or calculation of machinery noise emission values, the laboratory performing the measurements and the machine being measured. Please check that all the details are correct before proceeding to the next page. If the file has been selected incorrectly, please press [ESC] and return to stage 3 of "Getting started".

Acoustic Environment

The second page of each file is concerned with the acoustic environment used in each measurement. Information is given about test environment, the suitability of the test environment and limitation for background noise as set out in each standard and the instructions given in the original contractual information. Depending on the standard, you may be asked to give information on the K values or to code the environment as indoor or outdoor. Please read each section carefully.

In addition to providing the information on this page, you may have to provide a separate written report detailing the individual calculations of the K factors and the details of the test environment with a sketch as described in the section of the standards dealing with "Information to be Recorded".

Weather Conditions

The third page of each file relates to the weather conditions during the measurements. This page should be viewed effectively as a daily log of the measurements. The page asks for information on the date and time, details of the measurements taken (e.g positions used, number of trial, problems and any other relevant weather information as requested in the "Information to be Reported" section of each standard. You will then be asked to input temperature, pressure, humidity and wind data for each measurement set. Please note that the right hand side displays some code data. These are for use by NPL and it is therefore not necessary for you to use this section.

The top half of the page displays some notes about the entry of weather data. In the top left hand corner, the screen displays a case number. Although the data entry procedure has been prepared so as to follow a set pattern for data input, the data values are effectively being entered into a spreadsheet. Each line of the spreadsheet is in fact a different case number.

The weather data can be entered over a number of days if necessary. In order to enter weather data for a different day, please follow the notes in b given on the screen. This will bring you to another the case number/page of weather data. You may wish to try this before you start.

Please refer to section 6, getting around the file for more information on the use of the [UP] and [DOWN] arrow keys.

General

The fourth page of the data files for Standards ISO 3744, 3746 and 9614-1 is a general information page explaining the procedure for the input of sound power values. It points out that the subsequent data entry is only concerned with calculated sound power values. Details of the sound pressure and intensity data must be stored in an alternative format of your choice which must be returned to NPL with details of how to access these data.

The page explains the selection of input parameters relevant to each sound power value. The input parameter definitions and codes are given in Annex 1 of this document. The input parameters eg. laboratory, machine, environment type, third octave band etc have been pre-entered into each file and must not be overwritten by the user. Each combination of input parameters effectively is represented by a different line on the resulting spreadsheet to be used by NPL. You must follow the instructions on the screen to locate the correct combination of input parameters relevant to your sound power value.

Help Page

Page 5 of the data files for Standards ISO 3744/3746 and 9614-1 is a help page. This is reproduced in Annex 2. This page gives details of how to enter values, edit values, move around the sound power input page and warnings. More details are given in section 6.

Sound Power Data Input

Page 6 of the data files for Standards ISO 3744/3746 and 9614-1 is the page for entering all of your calculated sound power data values. You will be asked to select the relevant input parameters as described on the help page. You must type in the data value and reselect the next input parameters. Please follow the instructions on this page and the help page.

It is important to note that you must not overwrite any data on this page except for sound power values. Again, each combination of input parameters is represented by a different case number, thus assigning a separate line in the resulting spreadsheet for each sound power value.

Select Input Parameters

For the methods of Standards ISO 11201 and 11202, the layout of the input file differs from above since there is a greater amount of information to enter for each combination of input parameters. Page 4 asks the user to select the input parameters including test environment, microphone position, trial number etc. See Annex 1 for definition and coding used.

Emission Sound Pressure Levels

For the methods of Standards ISO 11201 and 11202, page 6 is used to enter the emission sound pressure data values. The top half of the page repeats the input parameters selected from the last page. This also gives some supplementary notes and warnings about the data input.

It is very important to note that use of the [UP]/[DOWN] (↑,↓) cursor arrow keys is forbidden on this page since this will move the user to another combination of input parameters and will place the data in the wrong place ! If you wish to move around the screen, please use the [RIGHT] (→) and [LEFT] (←) arrow keys (see section 6). If you use the [UP/DOWN] arrow keys by mistake, the case number will change and the input parameter displayed in the top half of the screen will also change. This is because you will have effectively moved to another line of the resulting spreadsheet. You must re-select the correct combination by reusing the [UP/DOWN] arrow keys.

Continue/Exit/Help Prompt Page

The final page of each file gives a choice of:

- (1) Continuing to enter more sound power data
- (2) Entering additional weather data
- (3) Exiting input file.

Please follow the prompts given on the screen

NOTE

The data input files ask that details of calculations, descriptions of test environments etc are included in separate reports. Please make sure that these and any other relevant details about the measurements and results as set out in the sections of each standard "Information to be recorded/reported" are provided including the details of the instrumentation used.

6. Getting around input file

When entering data into an input file, you should follow the prompts and instructions given on the screen. After entering a value, you must hit

[ENTER]

This will automatically move you to the next prompt. You should proceed using this method.

2. If you should make a mistake before you hit [ENTER], please use the [RIGHT/LEFT] (→ ←) arrow keys and retype the value and hit [ENTER].
3. If you should make a mistake and you have hit [ENTER], again use the [RIGHT/LEFT] (→ ←) arrow keys and retype the value and hit [ENTER].
4. For any reason, you wish to skip to other prompts, you must use the [RIGHT/LEFT] (→ ←) arrow keys and not the [UP]/[DOWN] (↑,↓) cursor arrow keys.
5. For any reason, you wish to go to another page, you can use [PAGE UP]/[PAGE DOWN] keys.
6. For selection of correct input parameters, you must use the [UP]/[DOWN] (↑,↓) cursor arrow keys as has already been described. Note that holding these keys down will allow you to scroll through. For the ISO 3744 and ISO 9614-1 input files, in order to locate the relevant combination of input parameters quickly, details are given about particular case numbers which can be accessed using [SHIFT [F5]], F7.

NOTE

In order to carry out operations 3 to 6, you may have to press [ESC] once if the cursor is flashing. The system will "beep" to warn you that this is required.

7. Saving files and exiting SPSS

- 1 When you have completed your data input, you must save your file before exiting SPSS using the following instructions:

[ESC] if cursor is flashing
[SHIFT [F2]]
[F3] to save file
[ENTER] for spss/pc
[ENTER] to save the current active file (a:\s*l*m*.sys)
[ENTER] for compressed or non-compressed mode
[SPACE] to return to screen with three menus

2. To exit SPSS, use

[SHIFT [F10]] to exit and return to DOS prompt.

3. To back up your file after exiting SPSS, use the following at the DOS prompt c:\spssde:

a: [ENTER] to move to floppy drive a:
copy s*l*m*.sys c: [ENTER] to copy files to c drive and typing the command (using appropriate values for *).
c: [ENTER] to move back to c drive

You may check that you have copied files by reading your directory by typing **dir [ENTER]** to list the files.

Please return to section 4 "Getting started" to input data for further measurements.

8. Things to avoid/troubleshooting

Hitting [ESC] twice	This will move you to the screen described in section 4.3. You will not lose any of the data you have entered. Use !F5 to re-access your data input.
Incorrect use of [UP]/[DOWN] (↑,↓)	This will move you to another case number and page of data, may be with incorrect combination of input parameters. You must re-use keys to return to correct place.
Exiting SPSS without saving file	Using !F10 will move you out of SPSS. A prompt will be displayed informing you that you have some unsaved changes. Please follow instruction in section 7 to save your file from the [SHIFT [F2]] instruction.
Saving file on incorrect drive	When prompted to enter filename when saving your file, the name should be preceded with drive specification i.e a:\s*!m*.sys. If no drive specification is given, the file may be saved in the spssde directory and will have to be copied onto floppy disk.
Do not hit [SHIFT [F3]]	This will move you into a different area of SPSS which may change your data file. In this event, hit [SHIFT [F5]] to return to data input.
Losing your place !	If you become unsure of where you are in entering the data e.g. by using the [UP]/[DOWN] (↑,↓) arrows, or moving out/in of the main system by mistake, press [ESC] if cursor is flashing, the [UP] (↑) arrow key until you reach case number 1, and the [PAGE UP] until you return to page 1. You will be at the beginning of the file and may proceed.
Not backing up each file	After entering data into a particular file, you should back it up onto hard disk after exiting SPSS. To do this you should follow instructions in section 7.

9. Getting assistance

If you experience problems using the data input software, then please contact:

Nicole Porter ☎ 081 943 6705, E-mail: ndp@newton.npl.co.uk

If you experience problems with the measurement procedures, then please contact

Richard Payne ☎ 081 943 6209

Alternatively, by fax on **081 943 6161**

ANNEX 1: Definitions and codings

Standard	This refers to the measurement standard in use for a set of measurements. 1 = ISO 3744 2 = ISO 3746 3 = ISO 9614-1 4 = ISO 11201 5 = ISO 11202								
Machine	This refers to the machine under test 1 = Electric drill 2 = Generator 3 = Lawnmower 4 = Compressor								
Laboratory	This refers to the laboratory carrying out the tests. Your test laboratory will be assigned a number at the start of the work.								
Filename S*L*M*.SYS	The filename refers to the file to be used for inputting the data. Each disk is labelled with a filename. The filename is made up so as to include the standard, laboratory and machine used. The * denote the relevant number of each. For example, measurements for standard ISO 9614-1, laboratory 2, and the lawnmower should be stored in file S3L2M3.SYS.								
K values	In the various standards, correction values must be calculated for the suitability of the test environment, limitations of background noise and local environment. These are referred to as K values. Please see appropriate standards for details.								
Trial number	It is required that each set of measurements is to be repeated to obtain three independent sets of results. Each repeat is referred to as a trial number for the present. Trial number is therefore coded as 1, 2 or 3.								
Measurement position	In the methods of ISO 11201/2, sound emission values must be measured for four measurement positions. These are coded as 1,2,3 and 4.								
Test environment	The Measurement Programme imposes certain requirements on the test environment in terms various K₂ values (please refer to standards). The test environment codes use for entering the data in standards ISO 3746 and ISO 11202 are: <table><tr><td>Test environment</td><td>=</td><td>1</td><td>for $2 < K_{2A} < 2.5$ dB</td></tr><tr><td></td><td>=</td><td>2</td><td>for $4.5 < K_{2A} < 5.5$ dB</td></tr></table>	Test environment	=	1	for $2 < K_{2A} < 2.5$ dB		=	2	for $4.5 < K_{2A} < 5.5$ dB
Test environment	=	1	for $2 < K_{2A} < 2.5$ dB						
	=	2	for $4.5 < K_{2A} < 5.5$ dB						

and for ISO 9614-1:

Test environment	=	1	for measurements in environment specified in ISO 3744
		2	for $4.5 < K_{2A} < 5.5$ dB

Surface

In standards ISO 3744 and 3746, two types of measurement surfaces are to be used. Please assign code 1 to hemispherical surface and code 2 to parallelepiped surface.

Distance/radius (suffix)

For some of the standards, measurements are to be performed at different distances away from the source for parallelepiped surfaces and different radii for hemispherical surfaces. The details provided by NPL in the Model agreement NPL 1993/3, Annex 1, page 3/4 gives the details of these required distances and radii. The suffix in table 2 are the codes used for the hemispherical surfaces. In the case of the distances used in the parallelepiped measurements, please assign the values 1,2 or 3. For the d_4 distances, use code 3.

Band

This refers to the centre frequency of the third octave band relevant to the sound power data value. Note that band 0 actually refer to the A-weighted value.

Combination

Each data value must be input for a given standard, machine, lab, trial number, measurement position, distance, shape etc. The terminology used here refers to the combination of these input parameters.

ANNEX 2: Help Page used in input file for standards ISO 3744/3746/9614-1

**** HELP PAGE ****

- NOTE 1: The left hand corner of this page displays a case number. This is set by the combination of input parameters selected.
- NOTE 2: To select the correct combination of input parameters (surface, distance, bandwidth, trial number etc.), please press [ESC] once if cursor is flashing, and the [UP/DOWN] arrow keys.
- NOTE 3: WARNING !! do NOT use the [UP/DOWN] arrow keys once you have selected the relevant parameter combination ! If you do this by mistake, you must return by reusing the [UP/DOWN] keys to find the relevant case number and combination. You may wish to try this before the start of data input.
- NOTE 4: To input values, type in numeric and press [ENTER], then reselect next input combination as described in note 2. To exit data input, press [ESC] if cursor is flashing followed by [PAGE DOWN].
- NOTE 5: If you hear a 'beep' or cursor is flashing, press [ESC] once.
- NOTE 6: If you wish to change a value, type over and press [ENTER].

Press [ENTER] to continue

APPENDIX 3. TABLES OF MEASURED DATA

APPENDIX 3.1 DATA FOR ISO 3744

The tables in this section of Appendix 3 list the means of the three repeat sound power determinations carried out, according to ISO 3744, by each laboratory together with the associated standard deviations both expressed in dB. Each table lists data for one machine, one type of measurement surface and one measurement distance (24 tables in total). The data have been output from the SPSS spreadsheet and contain some coded descriptions, which are as follows:

machine,	1	drill
	2	generator
	3	mower
	4	compressor
distance,	1	smallest radius or measurement distance
	2	middle radius or measurement distance
	3	largest radius or measurement distance
surface,	1	hemispherical enveloping surface
	2	parallelepiped enveloping surface

The tables are arranged with those for machine 1, distance 1 first and machine 4, distance 3 last, with both surfaces on each page.

machine:	1							
distance	1							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	90.11	0.35	93.13	0.06	89.93	0.06	89.75	0.02
50	39.89	0.79	79.9	1.81	69.3	1.13	77.46	0.07
63	38.39	0.7	79.17	1.86	69.07	0.75	68.74	0.21
80	39.22	0.7	78.47	1.46	68.4	2.25	69.4	0.15
100	42.45	0.64	76.63	2.12	63.37	0.76	61.37	0.33
125	43.51	0.27	75.23	3.18	60.2	0.89	61.79	0.11
160	46.64	0.36	73.97	3.19	59.87	0.06	61.35	0.32
200	50.22	0.14	72.83	3.61	61.87	0.81	58.23	0.37
250	52.71	0.3	70.7	3.03	60.37	0.38	57.57	0.05
315	56.91	0.14	68.87	2.97	60.57	0.38	58.6	0.09
400	62.69	0.12	68.23	2.22	62.87	0.21	63.82	0.12
500	68.34	0.28	70.63	1.01	68	0.36	67.78	0.27
630	73.07	0.02	74.4	0.4	71.5	0.1	74.15	0.12
800	78.87	0.28	80.07	0.15	77.83	0.21	80.24	0.24
1000	83.57	0.34	86.97	0.15	82.33	0.06	81.45	0.12
1250	80.94	0.63	85.9	0.1	79.37	0.25	78.48	0.12
1600	78.19	0.39	83.47	0.12	78.37	0.12	77.62	0.04
2000	77.86	0.46	83.3	0.1	80.1	0.2	77.75	0.13
2500	75.92	0.33	81.87	0.55	77.03	0.49	75.7	0.08
3150	77.2	0.52	78.87	0.15	76.9	0.2	75.75	0.05
4000	76.95	0.28	75.3	0.1	75.07	0.35	76.11	0.23
5000	78.11	0.47	75	0.17	77.5	0.1	77.33	0.35
6300	77.6	0.61	74.3	0.17	77.7	0.2	76.23	0.18
8000	77.15	0.18	73.47	0.25	79	0.26	78.17	0.12
10000	78.37	0.23	71.77	0.15	80.93	0.06	78.17	0.04

machine:	1							
distance	1							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	91.58	0.49	92.93	0.06	90.73	0.21	90.37	0.01
50	62.66	8.69	67.27	1.17	66.73	1.3	74.72	1.44
63	58.36	9.5	69.63	1.33	65.1	1.35	69.89	1.3
80	54.18	9.01	66.83	1.25	63.53	1.5	68.58	0.37
100	52.58	4.33	64.33	0.65	57.37	0.75	64.51	1.79
125	47.64	3.56	63.37	0.91	54.07	0.72	60.36	3.6
160	48.29	1.52	64.2	0.7	54.53	1	61.78	1.03
200	50.49	0.56	59.57	0.86	60.87	0.35	60.09	1.37
250	52.64	0.84	58.5	0.35	59.1	0.53	58.44	0.1
315	56.13	0.12	60.13	0.4	56.03	0.25	60.6	0.56
400	61.72	0.25	62.6	0.17	64.4	2	65.06	1.14
500	67.03	0.36	69.17	0.57	67.43	0.55	67.09	0.82
630	72.84	0.11	72.9	0.1	71.57	0.06	71.85	1.39
800	79.57	0.16	79.57	0.12	79	0.26	78.95	1.2
1000	85.28	0.62	86.97	0.06	83.1	0.52	81.88	0.93
1250	82.95	0.94	86.17	0.15	80.17	0.25	79.85	0.8
1600	80.39	0.61	82.6	0	79.73	0.45	79.15	2.12
2000	79.6	0.46	81.73	0.35	81.03	0.85	79.05	1.27
2500	79.64	0.33	80.77	0.06	79.43	0.15	78.04	1.31
3150	78.14	0.53	80.27	0.12	77.03	0.25	77.25	1.87
4000	76.82	0.27	76.83	0.15	76.13	0.06	75.99	1
5000	77.69	0.36	75.43	0.06	76.67	0.42	76.67	0.97
6300	78.21	0.6	74.87	0.12	77.4	0.1	77.11	0.95
8000	78.76	0.17	74.47	0.21	79.9	0.1	79	0.63
10000	79.12	0.28	72.57	0.21	81.13	0.21	79.33	0.4

machine:	1							
distance	2							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	90.6	0.31	93.27	0.84	89.8	0.1	89.85	0.04
50	41.25	2.32	73.63	1.15	67.83	1.36	80.07	0.74
63	40.19	0.64	77.23	2.75	69.83	1.4	72.26	0.68
80	40.23	0.46	74.77	2.97	68.1	1.23	69.2	0.71
100	44	2.2	68.8	3.68	61.57	0.57	60.71	0.84
125	44.17	0.41	67.97	3.27	61.57	0.45	62.28	0.68
160	47.51	0.33	66.4	2.55	63.33	0.06	59.02	0.75
200	50.81	0.48	64.67	2.68	67.43	0.23	59.6	1.01
250	52.81	0.4	64.27	2.7	62.57	0.31	60.69	0.74
315	57.02	0.07	63.9	1.04	59.23	0.12	59.54	0.36
400	62.44	0.22	65.03	0.61	66.03	0.35	64.03	0.08
500	68.45	0.47	68.9	0.66	70.17	0.21	69.3	0.08
630	73.23	0.02	73.73	0.85	71.77	0.15	75.13	0.12
800	78.69	0.23	79.47	0.57	78.07	0.23	81.01	0.1
1000	83.98	0.29	87.4	0.61	81.93	0.21	83.2	0.09
1250	81.75	0.64	86.33	0.25	79.57	0.12	78.99	0.18
1600	78.87	0.47	83.63	1.42	78.3	0.1	76.48	0.33
2000	78.26	0.33	81.97	0.91	79.23	0.32	76.8	0.39
2500	76.13	0.35	80.07	1.89	77.17	0.31	75.3	0.14
3150	77.82	0.42	80.9	1.76	77.1	0	75.51	0.25
4000	77.26	0.1	77.37	1.18	75.43	0.21	76.52	0.14
5000	78.79	0.42	75.03	1.69	77.7	0	77.78	0.19
6300	78.53	0.53	74.9	1.74	77.17	0.21	77.04	0.11
8000	77.43	0.15	73.47	1.37	79.13	0.31	77.95	0.17
10000	78.54	0.58	72.03	1.08	80.73	0.21	78.84	0.09

machine:	1							
distance	2							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	91.4	0.13	91.83	0.32	90.33	0.29	94.18	0.09
50	38.24	0.81	69.47	1.85	71.57	2.9	90.91	4.72
63	37.34	0.4	71.37	1.86	70.93	2.41	84.14	3.2
80	39.28	0.41	69.6	1.56	69.33	1.19	80.48	2.17
100	42.95	0.67	66.83	1.8	66	1.57	74.05	0.98
125	43.98	0.75	65.73	1.4	62.23	2.48	71.31	1.29
160	46.96	0.26	64.77	1.37	60.93	0.99	73.69	7.26
200	50.84	0.19	61.03	2.08	61.8	1.05	70.69	0.9
250	52.59	0.1	60.13	2.39	58.87	1.19	73.48	4.06
315	55.52	0.13	61.2	0.87	58.67	0.4	69.39	2.02
400	60.68	0.15	62.27	0.71	61.33	0.23	72.51	1.85
500	65.28	0.09	67.77	0.25	63.8	0.44	72.85	1.81
630	71.45	0.04	72.03	0.25	68.5	0.26	77.76	0.8
800	78.14	0.14	78.33	0.35	77.27	0.21	86.84	1.74
1000	84.77	0.17	85.37	0.38	82.73	0.46	90.51	1.79
1250	82.84	0.23	83.87	0.47	80.17	0.32	88.94	1.57
1600	80.98	0.1	81.83	0.23	79.43	0.06	87.56	1.92
2000	78.97	0.08	82.7	0.1	79.4	0.44	86.16	1.86
2500	78.55	0.17	79.03	0.32	79.43	0.47	86.58	2
3150	78.58	0.17	80.07	0.74	77.63	0.29	84.45	1.35
4000	77.16	0.21	76	0.1	76.77	0.06	86.14	1.68
5000	78.41	0.35	75.07	0.38	77.1	0.44	86.83	1.16
6300	78.95	0.17	73.73	0.32	77.07	0.23	86.79	1.69
8000	79.22	0.09	73.43	0.31	79.5	0.26	88.39	2.36
10000	78.72	0.3	71.6	0.4	81.33	0.38	88.9	2.14

machine:	1							
distance	3							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	90.14	0.15	93.97	0.06	89.97	0.15	90.21	0
50	41.4	0.7	75.9	2.55	72.17	0.9	80.68	0.34
63	40.83	0.12	74.6	1.64	73.17	1.27	73.08	0.53
80	40.76	0.04	73.87	1.22	71.43	1.21	71.92	0.13
100	43.07	0.5	70.43	0.61	67.67	1.76	64.83	0.55
125	45.46	0.13	69.53	0.84	64.8	0.61	65.76	0.6
160	48.29	0.43	67.97	0.64	64.23	0.57	64.7	0.67
200	50.08	0.1	64	0.8	64.7	0.53	62.04	0.53
250	53.04	0.16	63.8	1.47	63.17	0.6	60.81	0.54
315	56.8	0.03	63.83	0.76	61.8	1.06	60.69	0.61
400	62.65	0.13	65.9	0.62	63.3	0.35	64.66	0.27
500	68.72	0.2	68.9	0.46	67.97	0.21	69.37	0.41
630	73.27	0.03	72.7	0.17	71.5	0.1	73.97	0.16
800	79.19	0.11	79.27	0.15	77.8	0.1	79.14	0.27
1000	83.49	0.2	87.83	0.15	82.13	0.12	82.07	0.24
1250	80.85	0.29	87.33	0.06	79.33	0.21	79.8	0.19
1600	78.28	0.18	84.33	0.06	78.17	0.06	78	0.15
2000	78.03	0.16	81.27	0.23	79.53	0.21	78.51	0.12
2500	75.26	0.13	82.73	0.15	77.37	0.15	76.17	0.14
3150	77.15	0.17	81.47	0.23	77.2	0.17	76.92	0.32
4000	76.92	0.03	78.83	0.31	75.4	0.2	76.79	0.34
5000	78	0.14	76.3	0.26	77.8	0.26	79.12	0.3
6300	78.01	0.16	75.47	0.23	77.67	0.15	77.43	0.18
8000	77.37	0.09	74.03	0.25	79.33	0.12	78.95	0.11
10000	78.97	0.1	71.7	0.3	81.77	0.35	78.68	0.07

machine:	1							
distance	3							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	91.31	0.04	91.57	0.06	90.33	0.29	91.06	0.06
50	42.77	3.24	74.4	1.92	75.4	1.39	86.15	1.67
63	41.55	2.35	74.13	0.4	75.23	1.6	76.53	2.15
80	43.69	0.09	72.07	0.93	72.53	0.93	76.56	1.25
100	43.62	0.04	69.5	1.31	67.27	0.78	64.71	3.57
125	46.39	1.34	67.53	0.78	65.63	1.4	65.4	3.09
160	48.95	0.81	65.47	0.21	64.17	0.72	62.23	2.11
200	51.47	0.22	63.43	0.06	63.4	0.75	60.42	1.6
250	52.51	0.27	62.03	0.35	61.47	0.86	63.79	4.9
315	55.77	0.31	62.4	0.3	61.6	0.62	61.8	2.29
400	60.68	0.12	63.37	0.84	64.13	1.8	61.12	1.08
500	65.28	0.07	67.9	0.1	65.57	0.23	63.85	0.08
630	71.11	0.1	72.23	0.15	67.63	0.12	70.4	0.25
800	78.07	0.06	78.63	0.15	75.97	0.29	79.22	0.12
1000	84.7	0.18	84.77	0.21	81.67	0.4	82.8	0.16
1250	83.05	0.27	82.9	0.1	79.67	0.4	81.01	0.22
1600	81.01	0.07	81.7	0.26	80	0	79.59	0.28
2000	79.23	0.07	82.77	0.12	80.57	0.49	78.45	0.06
2500	78.52	0.56	79.2	0.1	78.4	0.46	78.24	0.18
3150	78.57	0.04	79.9	0.36	78.1	0.26	76.56	0.05
4000	77.05	0.34	76.93	0.06	76.57	0.15	77.6	0.38
5000	78.01	0.12	74.2	0.26	77.9	0.52	78.81	0.55
6300	78.86	0.1	73.3	0.3	77.6	0.26	78.63	0.37
8000	79.23	0.07	73.9	0.26	79.87	0.15	80.78	0.34
10000	78.49	0.09	73.17	0.06	81.57	0.29	80.79	0.45

	2							
	1							
	1							
lab :	1	2	3	4				
	94.11	0.6	0.2	92.13	0.21	93.85		
80	96.49	0.16	97.9	1.57	97.23	0.23	95.54	
100	88.21	0.38	90	2.26	87.73	0.31	87.8	0.57
125	98.32	0.12	97.83	1.19	97.27	0.06	97.15	1.64
160	94.44	0.07	95.4	0.36	94.27	0.31	94	1.99
200	93.51	0.06	94.73	0.25	94.57	0.21	92.9	3.86
250	91.52	0.17	91.7	0.2	91.4	0.36	92.53	2.32
315	89.97	0.18	89.5	0.4	87.6	0.2	89.29	1.6
400	87.91	0.13	89	0.26	88.6	0.2	90.44	0.64
500	89.95	0.23	91.8	0.17	90.17	0.25	88.48	0.8
630	96.54	0.18	98.43	0.06	94.9	0.17	95.21	0.14
800	95.55	0.09	96.3	0.26	93.97	0.15	95.74	1.4
1000	91.9	0.2	94.63	0.4	90.87	0.06	92.6	1.04
1250	89.57	0.28	93.43	0.25	89.47	0.31	90.69	0.64
1600	93.08	0.13	95.47	0.29	92	0.3	92.57	0.49
2000	94.15	0.07	96.33	0.38	93	0.17	94.41	0.68
2500	91.44	0.3	93.1	0.46	92.33	0.12	92.16	0.7
3150	92.67	0.1	93.97	0.4	92.67	0.15	91.96	0.3
4000	92.31	0.14	91.73	0.31	90.87	0.25	91.21	0.94
5000	89.4	0.43	86	0.46	88.27	0.06	89.58	0.81
6300	88.88	0.21	85.03	0.42	88	0.1	87.82	0.93
8000	86.9	0.17	81.97	0.67	87.37	0.15	88.63	1.73
10000	83.46	0.21	78.17	0.8	83.57	0.06	85.16	1.53

machine:	2							
distance	1							
	2							
	1	2	3	4				

1.31

94.47

0.06
0.55
0.4
0.4

(EXT)

machine:	2							
distance	2							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	103.8	0.04	104.5	0.21	102.9	0.2	103.9	0.03
50	105.9	0.09	107.6	0.25	106.3	0.1	106.2	0.42
63	93.2	1.12	94.07	0.93	92.37	0.29	94.6	1.08
80	96.39	0.28	96.3	0.2	97	0.3	96.2	0.08
100	86.91	0.94	88.67	0.21	86.77	0.15	89.58	0.13
125	97.89	0.43	97.2	0.17	96.77	0.21	98.13	0.6
160	94.37	0.17	93.37	0.38	93.73	0.06	96	0.33
200	93.35	0.17	92.73	0.23	92.9	0.26	95.94	1.3
250	91.02	0.54	88.13	0.72	90.17	0.4	93.23	1.42
315	88.74	0.4	86.5	0.62	89.2	0.1	89.41	2.05
400	87.31	0.28	88	0.61	87.1	0.17	89.6	1.82
500	89.73	0.64	92.9	0	89.23	0.4	88.83	1.35
630	96.59	0.33	97.57	0.4	95.17	0.35	95.77	0.6
800	95.31	0.15	95.27	0.21	93.33	0.21	95.79	0.83
1000	91.4	0.24	94.9	0.3	91.13	0.29	93	0.12
1250	89.72	0.58	92.5	0.1	88.97	0.06	91.04	0.37
1600	92.72	0.16	94.1	0.26	91.53	0.32	91.95	0.4
2000	94.07	0.2	94.97	0.47	92.87	0.15	93.72	0.27
2500	91.36	0.2	92.37	0.91	92.23	0.42	92.6	0.86
3150	91.74	0.08	92.7	0.1	92.57	0.06	91.79	0.61
4000	92.17	0.16	90.73	0.12	90.57	0.06	92.11	0.64
5000	89.63	0.37	86.33	0.15	88.83	0.23	89.8	0.67
6300	88.36	0.16	84.37	0.21	86.47	0.06	88.14	0.51
8000	86.77	0.45	80.57	0.21	86.67	0.4	89.33	0.62
10000	83.17	0.19	76.77	0.12	84.27	0.12	85.61	0.72

machine:	2							
distance	2							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	104.4	0.23	104.2	0.06	103.9	0.06	104.2	0.07
50	106.7	0.07	106.7	0.06	107.4	0	107	1.1
63	94.07	0.33	93.5	0.2	92.83	0.64	95.32	0.59
80	96.57	0.12	96.63	0.15	97.4	0.4	96.91	1.94
100	88.09	0.77	89.77	0.35	88.87	0.32	88.51	0.9
125	98.29	0.16	98.4	0.1	97.4	0.1	98.03	1.47
160	93.79	0.05	94.47	0.06	93.3	0	94.5	1.33
200	91.42	0.19	95.3	0.26	93.07	0.15	90.86	1.32
250	89.35	0.89	92.63	0.21	91.07	0.64	89.8	0.03
315	88.47	0.43	89.6	0.2	88.57	0.21	86.69	1.71
400	87.7	0.82	89.4	0.26	87.8	0.46	88.71	0.75
500	90.97	0.23	90.63	0.32	91.4	0.66	91.09	0.64
630	97.17	0.2	96.73	0.12	95.47	0.06	96.93	1.18
800	95.14	0.22	95.5	0.1	94.43	0.21	96.15	0.24
1000	94.19	0.67	93.13	0.21	92.63	0.25	94.04	0.4
1250	91	0.63	92.73	0.25	91.13	0.23	91.65	0.63
1600	93.44	0.42	94.7	0.1	93.33	0.23	93.69	0.61
2000	94.62	0.16	94.87	0.12	93.33	0.06	95.03	0.96
2500	91.89	0.33	90.07	0.15	93.17	0.15	92.8	0.85
3150	92.93	0.26	92.77	0.15	93.67	0.15	92.47	0.83
4000	91.93	0.43	90.77	0.06	90.37	0.35	92.21	0.97
5000	89.71	0.28	85.5	0.1	89.33	0.15	90.59	1.15
6300	88.78	0.25	84.4	0.2	88.33	0.29	88.57	0.95
8000	87.72	0.14	82.27	0.06	87.2	0.36	89.2	1.17
10000	83.72	0.35	76.97	0.06	84.67	0.15	84.92	0.64

	2							
	3							
	1							
	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	103.7	0.16	104.8	0.21	103.1	0.06	103.8	0.27
50	106	0.09	107.9	0.12	106.8	0.15	106.3	0.12
63	93.29	0.99	94.4	0.26	93.43	0.06	94.49	0.28
80	95.82	0.29	96.43	0.15	97.03	0.06	96.79	0.24
100	86.79	1.53	88.43	1.05	86.43	0.31	89.98	0.77
125	98.41	0.45	99.63	0.23	96.7	0.17	97.91	0.63
160	93.91	0.33	93.87	0.32	93.8	0.17	96.13	0.66
200	93.63	0.1	92.67	0.6	94.2	0.44	95.69	1.26
250	91.29	0.34	90.13	0.67	88.83	0.15	92.68	0.53
315	89.31	0.59	87.77	0.59	88.83	0.49	89.74	0.43
400	87.1	0.16	87.03	0.55	88.43	0.15	90.3	0.73
500	89.82	0.15	93.17	0.35	89.67	0.58	89.42	0.48
630	96.38	0.1	98.73	0.31	95.33	0.25	95.52	0.4
800	95.23	0.18	95.9	0.26	93.77	0.38	96.06	0.81
1000	91.66	0.42	94.63	0.78	91.47	0.15	92.7	0.26
1250	90.21	0.4	92.7	0.26	89.63	0.15	90.18	0.44
1600	93.35	0.48	95.2	0.46	92.2	0.26	91.9	0.27
2000	93.72	0.05	94.97	0.29	92.7	0.26	93.63	0.47
2500	90.51	0.45	93.53	0.32	92.07	0.12	92.31	0.19
3150	91.25	0.09	91.57	0.12	92.77	0.06	91.97	0.09
4000	92.4	0.11	89.7	0.3	91.2	0.1	92.16	0.33
5000	89.59	0.2	84.97	0.12	88.17	0.21	89.51	0.29
6300	88.04	0.1	83.47	0.29	86.73	0.15	87.37	0.21
8000	86.1	0.32	80.97	0.35	86.43	0.31	89.41	0.2
10000	82.9	0.12	76.17	0.21	84.27	0.31	85.12	0.33

machine:	2							
distance	3							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	105.1	0.1	104.1	0.06	103.8	0.12	105.3	0.35
50	106.8	0.33	106.7	0.15	107.4	0.4	107.4	0.51
63	93.35	0.97	93.3	0.1	91.8	0.1	96.3	1.34
80	97.76	0.56	95.7	0.1	97.37	0.15	96.47	1.39
100	87.52	0.24	89.63	0.25	87.73	1.12	89.25	0.92
125	98.2	0.26	98.6	0.1	96.7	0.1	98.94	0.83
160	94.57	0.4	93.97	0.06	93.63	0.6	95.7	0.94
200	91.98	0.11	93.13	0.06	93.6	0.17	93.1	0.85
250	90.45	0.63	92.1	0.17	91.93	0.38	89.71	0.52
315	88.77	0.61	89.2	0.17	88.53	0.59	86.84	1.21
400	88.24	0.41	88.33	0.06	87.53	0.78	88.85	0.43
500	90.76	0.38	90.4	0.1	90.7	0.72	91.3	0.32
630	97.95	0.23	96.5	0.1	96.1	0.17	97.33	0.44
800	95.82	0.2	95.2	0.17	94.17	0.06	96.45	0.49
1000	94.21	0.69	93.93	0.15	92	0.1	94.87	0.48
1250	91.95	0.54	91.6	0.1	90.63	0.23	92.67	0.63
1600	94.47	0.66	94.4	0.1	92.77	0.29	94.33	0.18
2000	95.36	0.39	95	0.1	93.47	0.15	95.6	0.42
2500	92.12	0.16	92.37	0.15	93.1	0.1	93.21	0.34
3150	93.4	0.2	92.37	0.06	93.47	0.06	93.37	0.39
4000	92.95	0.2	89.83	0.12	90.9	0.1	93.27	0.41
5000	90.21	0.25	84.5	0.1	88.5	0.26	91.51	0.77
6300	89	0.19	82	0.1	88.17	0.12	89.7	0.6
8000	88.9	0.32	79.9	0.1	86.87	0.4	90.3	0.81
10000	84.51	0.5	75.97	0.46	83.47	0.06	86.28	0.4

machine:	3							
distance:	1							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	104.1	0.09	103.9	0.1	102.8	0.61	103.4	0.28
50	93.08	0.21	94.83	0.42	94.43	0.84	93.94	0.13
63	82.16	2.21	83.1	0.26	84	0.62	82.07	1.58
80	87.56	1.42	93.37	1.37	89.37	0.35	88.07	2.02
100	99.79	0.12	102.7	0.35	98.43	0.29	101.2	2.14
125	86.85	0.83	92.67	2.05	87.07	0.31	86.68	1.4
160	91.64	0.27	91.23	0.21	90.67	0.23	90.8	1.77
200	99.64	0.27	97.7	0.44	99.4	0.56	96.9	0.48
250	94.45	1.09	96.87	1.27	94.57	0.23	93.7	0.33
315	98.51	0.68	95.9	0.46	95.67	0.35	96.7	0.08
400	94.21	0.7	95.53	0.38	94.2	0.56	93.4	0.69
500	95.4	0.8	95.73	0.15	94.87	0.15	95.4	0.85
630	94.89	0.25	95.07	0.15	93.67	0.38	94.91	1.24
800	94.43	0.24	94.97	0.06	92.97	0.72	93.84	1.1
1000	93.47	0.23	93.9	0.2	91.93	0.68	92.77	0.75
1250	92.56	0.25	94.3	0.17	90.43	0.93	91.82	0.63
1600	91.68	0.3	93.87	0.31	90.2	0.95	91.02	0.45
2000	90.55	0.34	92.1	0.3	89.03	1.02	90.55	0.75
2500	90.06	0.48	89.53	0.25	90.2	0.95	90	0.95
3150	90.91	0.74	87.63	0.31	90.17	0.81	90.59	1.04
4000	91.38	0.23	87.63	0.15	90.17	0.64	91.31	1.28
5000	91.87	0.36	87.93	0.32	90.7	0.26	92.09	1.57
6300	88.53	0.51	83.3	0.44	87.03	0.4	89.12	1.48
8000	85.01	0.75	78.77	0.47	83.47	0.64	84.62	1.39
10000	83.15	1.47	75.13	0.65	80.87	1	81.66	1.34

machine:	3							
distance:	1							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	103.4	0.23	102.5	0.1	102.6	0.1	103.1	0.16
50	94.67	0.38	93.27	0.49	95.03	0.12	95.36	
63	83.93	0.23	83.23	0.46	84.23	0.75	82.51	0.71
80	89.77	0.64	86.5	0.82	88.23	1.01	89.87	0.79
100	102.3	0.04	99.03	0.25	101.6	0.1	103.7	1.13
125	87.66	0.63	86.3	0.95	86.4	0.52	87.46	0.28
160	91.1	0.46	91.73	0.59	89.4	0.44	91.4	0.37
200	98.95	0.26	99.03	0.15	97.8	0.17	99.98	0.82
250	95.15	0.84	92.47	0.21	92.87	0.57	94.59	0.99
315	98.81	0.64	99.03	0.38	97.83	0.15	97.31	
400	94.85	0.34	94.27	0.21	94.57	0.12	93.12	0.48
500	96.02	0.55	93.37	0.25	94.73	0.12	95.34	0.2
630	95.05	0.36	95.13	0.21	93.87	0.32	94.49	0.76
800	93.97	0.1	93.13	0.15	93.03	0.15	94.65	0.87
1000	92.88	0.32	93.63	0.12	91.97	0.15	93.68	0.57
1250	92.01	0.58	93.1	0.17	90.6	0.1	92.92	0.33
1600	91.1	0.54	91.33	0.06	90.4	0.2	92.1	0.24
2000	89.42	0.56	87.1	0.1	88.8	0.2	90.67	0.2
2500	88.44	0.45	84.63	0.12	89.73	0.21	90.03	0.19
3150	88.66	0.32	87.13	0.06	89	0.26	88.96	0.29
4000	89.96	0.26	86.2	0.1	87.97	0.06	89.71	0.26
5000	90.25	0.25	85.57	0.15	89.33	0.12	90.17	0.26
6300	86.85	0.38	83.03	0.38	86.8	0.26	87.39	0.68
8000	82.74	0.27	75	0.1	82.77	0.23	83.57	0.54
10000	79.73	0.29	70.47	0.06	80.13	0.29	80.29	0.43

machine:	3							
distance	2							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	103.2	0.18	104.5	0.06	102	0.21	103	0.05
50	93.62	0.22	96.47	0.67	93.7	0.62	92.58	0.48
63	83.27	0.21	83.57	1.75	83.77	0.81	81.82	0.49
80	87.65	0.52	86.6	0.4	87.47	0.57	87.74	0.96
100	99.24	0.07	102.2	0.12	96.87	0.15	99.93	1.25
125	86.54	0.91	87.27	0.12	84.47	0.47	85.41	0.7
160	91.15	0.43	94.17	0.38	89.57	0.06	88.42	0.57
200	98.18	0.79	99.27	0.21	100.6	0.55	96.86	0.1
250	94.49	0.1	94.17	0.38	92.63	0.32	92.94	0.36
315	99.07	0.45	101.5	0.1	96.8	0.2	96.09	1.14
400	94.46	0.15	96.2	0.1	93.5	0.2	91.92	1.24
500	96.14	0.05	95.7	0.17	93.27	0.12	93.74	1.24
630	94.74	0.37	95.63	0.21	93.17	0.29	94.3	1.41
800	93.56	0.2	95.4	0.1	92.1	0	94.35	1.04
1000	92.53	0.32	95.17	0.15	91.4	0.17	92.06	1.01
1250	90.97	0.3	94.57	0.06	89.67	0.25	90.34	0.94
1600	89.95	0.31	92.8	0.2	88.5	0.26	89.11	1.5
2000	88.45	0.29	90.87	0.06	87.5	0.36	88.93	1.29
2500	87.67	0.25	89.73	0.06	88.9	0.35	88.15	1.26
3150	88.08	0.27	87.67	0.25	89.3	0.36	87.54	1.38
4000	90.41	0.08	88.33	0.06	89.33	0.32	89.69	1.15
5000	91.51	0.1	90.43	0.12	90.53	0.35	89.99	1.09
6300	87.94	0.22	84.33	0.23	87.13	0.45	87.18	0.82
8000	83.18	0.18	80.47	0.15	83.4	0.4	83.01	0.86
10000	79.93	0.17	75.07	0.12	80.9	0.46	79.97	0.97

machine:	3							
distance	2							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	102.8	0.12	103	0.06	104	0.25	105	0.1
50	94.15	0.08	93.27	0.21	96.77	0.15	94.79	0.75
63	83.99	0.57	85.93	2.1	85.23	0.47	82.14	1.15
80	88.9	0.45	89.63	0.68	89.37	0.86	88.13	0.39
100	100.8	0.09	101	0.12	100.8	0.2	100.6	0.59
125	86.9	0.14	86.63	0.32	87.2	0.4	86.43	0.59
160	91.44	0.43	90.03	0.23	91.77	0.31	90.47	1.07
200	98.53	0.38	98.7	0.17	101.2	0.29	99.37	2.03
250	94.71	0.2	95.5	0.1	94.57	0.12	94.48	0.38
315	99.15	0.43	98.6	0.1	97.17	0.12	97.8	1.47
400	93.87	0.51	94.83	0.59	93.67	0.25	93.14	1.43
500	95.26	0.22	94.63	0.23	94.6	0.46	94.69	0.44
630	93.21	0.02	94.73	0.12	92.93	0.29	92.9	0.51
800	93.09	0.22	94.37	0.06	93.63	0.12	93.2	0.68
1000	92.22	0.29	93.17	0.06	93.37	0.23	92.42	1.06
1250	90.94	0.07	92.9	0	92.43	0.21	91.82	1.19
1600	89.93	0.13	91.3	0.17	92.13	0.21	91.31	1.16
2000	88.1	0.24	88.33	0.06	91.1	0.26	90.1	1.39
2500	87.29	0.22	87.5	0.26	92.2	0.36	89.29	1.29
3150	88.11	0.19	88.37	0.15	92.27	0.35	88.92	1.65
4000	89.92	0.06	88.57	0.21	91.33	0.45	90.09	0.92
5000	91.1	0.05	87.6	0.1	91.53	0.4	90.35	0.95
6300	87.26	0.04	82.27	0.35	88.67	0.32	87.72	0.94
8000	83.16	0.05	75.43	0.21	86.23	0.38	84.08	1.13
10000	79.99	0.16	72.2	0.17	83.9	0.35	81.25	1.35

machine:	3							
distance	3							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	103.5	0.2	104	0.1	102.7	0.12	103.6	0.43
50	95.72	3.28	95.43	0.21	93.4	0.1	93.09	0.37
63	83.92	1.82	85.9	0.2	83.4	0.17	84.18	0.96
80	88.57	2.44	88.37	0.45	86.87	0.57	88.98	0.7
100	99.54	0.07	101.8	0.12	97.8	0.1	101.7	0.04
125	86.35	0.25	86.9	0.4	84.6	0.46	87.13	0.32
160	91.4	0.3	93.8	0.44	91.13	0.76	89.5	0.22
200	98.96	0.28	98.9	0.44	100.5	0.12	96.87	0.87
250	94.26	0.56	94.4	0.1	92.4	0.2	93.47	0.33
315	98.95	0.21	101.6	0.21	98.43	0.72	95.86	0.85
400	94.48	0.23	95.67	0.4	93.5	0.17	93.09	0.04
500	95.47	0.22	94.37	0.23	94.37	0.12	95.46	0.44
630	95.16	0.15	95.5	0.17	93.7	0.1	95.68	0.38
800	94.04	0.11	94.9	0.1	92.87	0.15	94.97	0.28
1000	92.9	0.16	94.8	0.17	92.07	0.25	93.05	0.38
1250	91.96	0.23	93.87	0.06	90.87	0.45	91.09	0.28
1600	90.84	0.26	92.23	0.12	89.6	0.46	90.31	0.38
2000	89	0.42	90.2	0.17	88.27	0.51	89.83	0.48
2500	87.69	0.51	88.97	0.15	89.5	0.56	89.15	0.57
3150	88.54	0.57	88.37	0.12	89.7	0.56	88.79	0.56
4000	91.3	0.19	87.1	0	89.87	0.25	90.97	0.34
5000	91.82	0.21	88.9	0.1	90.2	0.26	91.62	0.22
6300	88.2	0.26	84.4	0.1	87.23	0.31	88.44	0.33
8000	82.76	0.33	79.37	0.21	83.53	0.4	84.39	0.28
10000	80.12	0.31	75.1	0.26	81.4	0.72	80.45	0.9

machine:	3							
distance	3							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	103.5	0.1	102.7	0.06	103.1	0.26	103.7	0.06
50	94.09	0.42	94.13	0.67	95.73	0.31	88.45	0.25
63	84.37	0.61	89.87	1.8	84	0.53	77.83	1.04
80	89.49	0.35	89.63	1.78	88.3	0.17	83.84	0.38
100	100.5	0.28	100.1	0.2	99.73	0.06	95.96	0.15
125	87.18	0.99	88.33	1.33	86.07	0.55	81.62	0.06
160	90.55	0.52	93.37	0.31	91.27	0.97	84.52	0.38
200	99.13	0.67	100.1	0.21	99.83	0.32	92.72	0.29
250	96.25	0.69	94.23	0.06	93.63	1	89.06	0.49
315	99.33	0.68	99.4	0.26	99.4	1.25	91.59	1.25
400	95.51	0.38	94.23	0.21	94.17	0.4	88.52	0.15
500	96.25	0.28	94.47	0.4	94.67	0.42	90.22	0.57
630	93.79	0.05	95.27	0.15	92.1	0.26	87.82	0.51
800	94.1	0.28	93.77	0.12	92.8	0.2	89.29	0.2
1000	92.78	0.1	93.43	0.06	92.17	0.12	87.82	0.75
1250	91.65	0.19	91.93	0.21	91.37	0.15	87.02	0.72
1600	90.76	0.27	90.1	0	91.13	0.12	86.52	1.08
2000	89.38	0.29	89	0.1	89.87	0.15	85.26	1.19
2500	88.28	0.3	87.6	0.17	90.8	0	84.19	0.98
3150	88.92	0.41	86.43	0.21	90.27	0.06	83.49	1.13
4000	90.6	0.1	87.53	0.25	89.13	0.29	84.89	0.61
5000	91.24	0.2	86.53	0.12	90.4	0.17	85.09	0.44
6300	87.19	0.34	81.77	0.21	87.73	0.15	82.09	0.62
8000	83.23	0.27	75.63	0.06	84.2	0.17	78.76	0.76
10000	80.62	0.27	71.1	0.26	82.13	0.06	76.42	1.07

machine:	4							
distance	1							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	93.06	0.25	96.63	0.15	93.3	0.26	94.19	0.59
50	109.5	0.12	109.1	0.06	106.6	0.15	110.3	1.48
63	104.1	0.2	107.1	0.06	101.8	0.5	104	0.24
80	95.04	0.29	99.07	0.5	95.67	0.47	96.03	0.97
100	99.37	0.05	100.5	0.1	96.67	0.4	99.98	0.64
125	96.46	0.14	99.47	0.15	95.3	0.26	97.5	1.17
160	93.56	0.12	97.13	0.23	92.8	0.26	96.27	1.18
200	87.53	0.23	90.6	0.2	88.6	0.2	91.35	0.43
250	86.19	0.38	90.73	0.06	86.97	0.21	86.79	0.63
315	87.6	0.42	92.03	0.12	88.33	0.15	87.59	0.42
400	87.45	0.4	89.7	0	87.4	0.1	88.11	0.49
500	85.78	0.46	89.37	0.12	86.6	0.26	86.21	0.86
630	84.34	0.47	88.13	0.21	84.2	0.1	84.71	0.72
800	83.52	0.26	86.93	0.15	82.97	0.25	84.96	0.29
1000	81.41	0.42	85.6	0.17	82.53	0.47	82.78	0.61
1250	78.57	0.41	83.9	0.2	79.23	0.46	79.98	0.46
1600	78.82	0.4	85.17	0.06	79.43	0.57	80.26	0.69
2000	76.12	0.38	80.97	0.31	76.6	0.95	77.89	0.72
2500	76.27	0.13	80.9	0.36	79	0.56	79.03	0.79
3150	76.32	0.39	79.93	0.45	79.2	0.5	77.93	0.87
4000	73.36	0.12	73.93	0.15	74.97	0.5	76.16	0.47
5000	73.5	0.03	72.23	0.15	75.37	0.35	75.05	1.07
6300	72.18	0.09	69.7	0.3	73.37	0.4	73.35	0.83
8000	71.43	0.08	68.6	0.3	73.1	0.2	72.52	1.14
10000	72.25	0.04	70.2	0.4	75.53	0.23	73.77	1

machine:	4							
distance	1							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	95.78	0.32	95.77	0.15	94.4	0.26	99.3	0.08
50	109.1	0.12	109.5	0.36	110.2	0.75	112.2	0.8
63	105	0.2	106.2	0.49	106.4	0.26	106.4	1.2
80	98.12	0.1	97.07	0.21	97.6	1.18	98.28	0.62
100	99.86	0.58	100.8	0.29	99.63	0.42	101.6	1.2
125	97.5	0.23	98.1	0.17	98.17	0.47	99.79	0.65
160	95.94	0.41	96.13	0.21	95.47	0.55	97.49	0.65
200	90.27	0.76	90.23	0.4	90.3	0.44	92.63	1.12
250	89.52	0.29	89.87	0.25	89.43	0.32	90.63	1.26
315	89.76	0.16	90.1	0.17	90.57	0.15	91.97	1.94
400	89	0.22	87.83	0.21	90.17	0.06	90.82	1.99
500	89.5	0.44	87.97	0.12	90.2	0.44	90.57	2.51
630	87.45	0.25	87	0.1	87.27	0.46	88.52	2.18
800	86.2	0.28	86.97	0.25	85.67	0.38	87.25	1.96
1000	84.77	0.3	84.83	0.21	83.6	0.26	85.25	1.15
1250	82.14	0.2	84.5	0.4	80.2	0.53	83.14	1.28
1600	83.24	0.75	84.47	0.25	81.13	0.49	83.83	1.71
2000	79.33	0.54	78.47	0.15	78.1	0.61	80.92	1.63
2500	80.05	0.33	79.13	0.31	78.83	0.23	82.17	1.97
3150	80.16	0.25	80.1	0.36	78.5	0.26	81.14	1.75
4000	76.87	0.55	72.87	0.32	75.57	0.38	79.13	1.58
5000	76.64	0.45	70.63	0.31	75.93	0.42	79.52	2.32
6300	74.94	0.39	68.2	0.17	74.3	0.1	77.68	1.95
8000	73.93	0.4	65.2	0.17	73.1	0.17	76.68	2.56
10000	76.01	0.52	66.73	0.06	76	0.46	78.82	2.42

machine:	4							
distance	2							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	94.72	0.5	95.03	0.15	93.9	0.2	93.39	0.04
50	108.7	0.24	108.5	0.21	107.6	0.42	116.4	0.8
63	104.3	0.14	104.8	0	105.5	0.35	109.5	0.75
80	96.38	1.25	95.83	0.4	97.6	0.2	102.9	0.85
100	100.3	1.37	99.2	0.17	97.53	0.51	105.4	1.11
125	97.11	0.39	96.37	0.21	97.47	0.15	102.7	0.5
160	95.91	0.92	93.13	0.35	94.83	0.85	100.6	0.28
200	89.56	0.79	87.47	0.06	89.2	0.35	96.25	0.65
250	88.01	0.59	88.7	0.3	87.1	0.26	92.51	0.62
315	89.02	0.4	89.57	0.21	88	0.1	93.82	0.71
400	88.76	0.61	88.5	0.1	87.03	0.06	92.34	0.71
500	87.8	0.56	88.97	0.32	87.33	0.15	91.34	0.65
630	85.63	0.68	87.33	0.23	85.27	0.06	90.88	0.82
800	85.29	0.53	85.63	0.29	83.63	0.4	91.35	1.01
1000	84.15	1.32	84.17	0.12	82.33	0.06	89.21	0.81
1250	80.91	0.5	82.83	0.12	80.17	0.4	86.6	0.95
1600	82.47	1.34	83.33	0.06	80.53	0.61	86.57	0.88
2000	78.23	0.8	78.57	0.06	76.8	0.35	84.49	0.8
2500	77.65	0.7	78.43	0.06	78.8	0.3	85.4	0.98
3150	77.7	0.28	79.5	0.1	78.83	0.15	84.87	0.93
4000	75.35	0.85	72.93	0.23	75.33	0.23	82.94	0.85
5000	75.51	0.29	71.27	0.15	75.17	0.15	82.18	0.79
6300	72.91	0.24	68.87	0.15	73.07	0.15	80.42	0.88
8000	71.29	0.23	64.97	0.38	73	0.1	79.19	0.89
10000	72.64	0.42	66.9	0.26	76.03	0.32	80.67	1.01

machine:	4							
distance	2							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	94.32	0.81	95.6	0.1	93.67	0.38	98	0.1
50	108.6	0.22	109	0.06	109.2	0.78	113.6	1.25
63	104.7	0.31	104.1	0.12	105.4	0.45	107.6	0.53
80	96.94	0.91	96.43	0.06	97.23	0.61	99.91	0.71
100	98.09	1.28	100.1	0.1	98.07	0.81	101.9	0.63
125	95.8	0.53	98.47	0.15	96.6	0.92	100.1	0.42
160	92.94	1.12	97.23	0.51	93.9	0.7	97.65	1.09
200	88.01	1.39	90.07	0.29	89.07	0.38	92.39	0.27
250	88.38	0.6	89.63	0.21	89.7	0.26	90.97	0.93
315	88.66	0.61	89.43	0.35	90	0.2	92.5	0.2
400	87.23	0.83	88.33	0.15	88.9	0	90.9	0.53
500	88.29	0.95	88.3	0.44	89.9	0.66	91.12	0.76
630	86.06	0.74	87.5	0.26	86.63	0.55	88.51	0.35
800	84.71	1.11	86.5	0.1	84.93	0.42	88.16	0.15
1000	83.17	0.44	84.77	0.15	82.73	0.25	86.54	0.48
1250	80.91	0.83	83.17	0.06	79.83	0.71	83.39	0.42
1600	81.74	1.48	83.5	0	80.5	0.79	83.77	0.26
2000	77.73	1.04	80.23	0.38	77.23	0.61	81.39	0.28
2500	78.59	0.9	79.2	0.26	77.87	0.4	82.38	0.44
3150	78.39	0.61	79.37	0.06	77.7	0.1	81.49	0.63
4000	75.21	1.15	74.47	0.15	74.77	0.47	79.94	0.58
5000	75.58	0.69	70.57	0.06	75.8	0.3	80.11	0.17
6300	74.18	0.71	67.77	0.15	74.2	0.17	78.43	0.23
8000	73.18	0.54	64.33	0.06	72.83	0.49	77.49	0.12
10000	75.21	0.67	65.03	0.15	75.9	0.87	79.93	0.55

machine:	4							
distance	3							
surface:	1							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	94.47	0.32	95.6	0.1	94.23	0.23	93.97	0.08
50	108.2	0.1	111.2	0.12	106.1	0.45	109.8	0.34
63	104.5	0.08	106.9	0.17	100.5	0.68	103.1	0.24
80	97.04	0.82	97.43	0.12	96.9	0.36	96.14	0.22
100	99.56	1.14	99.93	0.06	96.73	0.38	99	0.38
125	97.13	0.22	98.23	0.06	95.9	0.26	97.13	0.4
160	94.67	0.52	95.97	0.31	94.17	0.15	95.84	0.51
200	89.69	0.49	89.5	0.35	89.63	0.25	90.78	0.51
250	88.18	0.3	90.2	0.26	87.23	0.5	87.3	1.1
315	87.98	0.57	89.4	0	88.23	0.57	86.86	0.14
400	88.32	0.14	87.67	0.15	88.03	0.25	87.73	0.85
500	87.78	0.51	88.37	0.12	87.73	0.51	86.35	0.88
630	85.57	0.25	86.47	0.12	84.8	0.17	83.86	0.79
800	85.31	0.55	87	0.1	84.63	0.32	84.41	0.79
1000	83.14	0.36	85.7	0.1	83.87	0.12	82.54	0.51
1250	81.18	0.51	83.33	0.15	80.97	0.35	79.71	0.97
1600	81.98	0.95	83.17	0.06	81.6	0.26	79.59	1.19
2000	77.95	0.7	78.87	0.32	78.23	0.58	77.55	0.69
2500	77.3	0.76	79.3	0.3	80.23	0.31	77.68	0.97
3150	77.58	0.27	79.4	0.35	79.87	0.21	77.36	1.11
4000	75.89	0.71	73.3	0	76.57	0.47	75.61	1.02
5000	75.37	0.53	71.2	0.2	76.4	0.17	74.74	1.21
6300	73.05	0.35	68.83	0.06	73.1	0.44	72.84	1.01
8000	72.13	0.45	65.07	0.21	72.73	0.42	72.01	0.69
10000	73.55	0.46	66.07	0.4	75.23	0.68	73.21	1.21

machine:	4							
distance	3							
surface:	2							
lab :	1		2		3		4	
freq (Hz)	mean	sd	mean	sd	mean	sd	mean	sd
"A" wtg	95.39	0.4	95.37	0.15	93.57	0.21	98.86	0.14
50	108.9	0.12	109.4	0.1	107.7	0.38	114.9	0.67
63	104.9	0.31	105	0.1	104	0.26	108.7	0.45
80	97.52	1.12	97.6	0.66	97.33	0.4	101	0.89
100	100.5	1.34	100.6	0.06	97.4	0.56	103.8	0.2
125	97.11	0.05	97.87	0.06	95.8	0.4	102.3	0.9
160	94.79	0.41	95.47	0.32	93.67	0.83	100.9	1.14
200	89.76	0.5	89.97	0.64	87.83	0.06	94.28	0.6
250	89.02	0.46	89.27	0.38	86.8	0.36	92.22	0.51
315	88.31	0.31	89.57	0.4	87.5	0.2	91.46	0.86
400	87.99	0.57	87.93	0.21	86.03	0.06	90.76	0.55
500	88.69	0.37	87.77	0.23	86.57	0.29	92.08	1
630	87.16	0.84	86.8	0.26	84.5	0.2	88.75	0.6
800	85.99	0.49	86.57	0.15	83.97	0.15	89.74	0.62
1000	84.3	0.09	84.43	0.25	82.43	0.23	87.58	0.4
1250	82.77	0.72	83.5	0.36	79.9	0.2	85.27	0.1
1600	83.67	0.58	84.5	0.44	81	0.26	85.13	0.71
2000	79.36	0.63	80.17	0.35	76.93	0.32	82.72	0.38
2500	78.89	0.45	78.13	0.74	79.9	0.26	83.54	0.72
3150	78.85	0.07	77.93	0.31	79.97	0.31	82.57	0.8
4000	77.08	0.65	72.4	0.26	75.2	0.26	80.5	0.39
5000	76.89	0.65	70.43	0.4	75.67	0.25	80.42	0.64
6300	75.01	0.42	67.9	0.7	73.23	0.23	78.6	0.59
8000	73.98	0.5	65.1	0.2	73.3	0.44	77.32	0.49
10000	75.74	0.55	66.67	0.55	74.97	0.25	79.05	0.55

APPENDIX 3.2 DATA FOR ISO 3746

The tables in this section of Appendix 3 list the means of the three repeat sound power determinations carried out, according to ISO 3746, by each laboratory together with the associated standard deviations both expressed in dB. Measurements were performed in two acoustic environments one with a K_2 -factor of approximately 2.5 dB the other approximately 5 dB. Each table lists data for one machine, one environment, both measurement surfaces and all measurement distances (8 tables in total). The data have been output from the SPSS spreadsheet and contain some coded descriptions. Those not detailed in Appendix 3.1 are as follows:

environment,	2	K_2 -factor approximately 2.5 dB
	3	K_2 -factor approximately 5 dB

machine	1											
environ	2											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	89.37	0.15	89.33	0.06	89.07	0.06	91.03	0.12	91.63	0.06	90.27	0.06
2	91.7	0.26	91.7	0.17	91.63	0.12	89.7	0.17	89.27	0.23	89.47	0.06
3	90.13	0.06	89.9	0	90.3	0.14	90.4	0.17	90.8	0	90.67	0.12
4	87.95	0.02	88.47	0.13	88.6	0.05	90.26	0.19	91.53	0.03	90.64	0.09

machine	2											
environ	2											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	104.87	0.06	106.9	0.1	.	.	105.3	0.1	106.43	0.06	107.03	0.12
2	104.4	0	104.67	0.06	105.4	0	101.43	0.12	103.77	0.06	104	0
3	103.23	0.06	102.23	0.06	.	.	103.3	0.1	103.17	0.12	103.4	0
4	103.15	0.1	103.7	0.05	.	.	103.73	0.01	104.83	0.15	104	0

machine	3											
environ	2											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	103.77	0.29	106.43	0.15	.	.	105.07	0.15	105.63	0.12	106.43	0.32
2	101.93	0.06	103.43	0.12	103.57	0.06	101.67	0.12	103.77	0.32	103.8	0.1
3	102.2	0.17	101.03	0.06	.	.	102.2	0.1	102.3	0.1	100.5	0
4	102.18	0.07	102.3	0.06	.	.	102.59	0.09	104.2	0.1	104.6	0.17

machine	4											
environ	2											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	93.33	0.12	.	.	.	.	94.73	0.06	93.43	0.06	94.2	0.26
2	95.03	0.25	94.2	.	95.2	0.17	93.83	0.31	95.1	0.1	96.2	0.17
3	93.23	0.06	.	.	.	.	94.5	0.17	93	0.2	92.63	0.12
4	93.94	0.09	93.46	0.13	.	.	97.27	0.07	96.87	0.06	99.48	0.06

machine	1											
environ	3											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	90.07	0.21	89.47	0.12	89.73	0.12			91.4	0.17	90.8	0.17
2	91.33	0.38	91.2	0.17	92.47	0.23	89.73	0.15	90.77	0.21	91.53	0.25
3	89.73	0.15	89.7	0.1	90.13	0.15	90.83	0.15	90.3	0.2	90.18	0.1
4	89.16	0.04	89.8	0.11	88.9	0.04	89.36	0.13	89.87	0.57	89.93	0.04

machine	2											
environ	3											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	103.57	0.06	103	0.2	.	.	105.5	0.17	105.9	0.2	106.17	0.15
2	102.7	0.2	103.57	0.21	104.97	0.12	103.7	0.17	104.57	0.31	.	.
3	102.83	0.06	103.13	0.12	.	.	102.6	0.1	103.17	0.21	103.17	0.15
4	103.65	0.11	104	0.26	.	.	103.39	0.07	104.75	0.04	104.9	0.2

machine	3											
environ	3											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	102.77	0.12	102.73	0.21	.	.	104.07	0.15	105.17	0.12	104.87	0.57
2	101.67	0.15	101.9	0.1	104.67	0.06	104.77	0.15	103.63	0.32	.	.
3	102.53	0.25	102.53	0.23	.	.	102.13	0.06	103.23	0.06	103.27	0.06
4	102.56	0.06	102.26	0.08	.	.	102.51	0.05	104.75	0.07	103.97	0.06

machine	4											
environ	3											
surface	1						2					
distance	1		2		3		1		2		3	
lab	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	94.5	0.1	.	.	.	.	94.9	0.1	94.17	0.06	95.4	0.26
2	93.37	0.21	93.9	0.1	95.7	0	94.07	0.06	.	.	.	.
3	95.13	0.21	.	.	.	.	93.93	0.25	93.6	0	93.03	0.15
4	93.16	0.11	93.17	0.12	.	.	95.49	0.09	97.1	0.1	99.35	0.08

APPENDIX 3.3 DATA FOR ISO 9614-1

The tables in this section of Appendix 3 list the means of the three repeat sound power determinations carried out, according to ISO 9614-1, by each laboratory together with the associated standard deviations both expressed in dB. Measurements were carried out using only one measurement surface but in two acoustic environments. Each table lists data for one machine, for both acoustic environments (4 tables in total). The data have been output from the SPSS spreadsheet and contain some coded descriptions. Those not detailed in Appendix 3.1 are as follows:

environment,	1	K_2 -factor less than 2 dB
	3	K_2 -factor approximately 5 dB

machine	1											
lab	1				2				3			
environment	1		3		1		3		1		3	
freq (Hz)	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.
"A" wtg	88.77	0.15	89.07	0.13	88.77	0.38	89	0.35	88.77	0.15	89.17	0.12
50	.	.	.	.	77.07	2.91	82.03	0.21	64.2	1.27	48.75	9.83
63	.	.	.	.	72.57	3.72	79.1	0.35	.	.	61.3	3.96
80	.	.	.	.	67.97	2.51	75.07	0.95	51.8	.	.	.
100	.	.	.	.	62.23	1.65	70.5	1.8	50.6	.	55	.
125	.	.	.	.	59.03	0.81	64.9	1.65	51.8	.	44.63	4.45
160	.	.	.	.	60.47	1.96	62.37	0.38	52.5	0.62	43.85	3.46
200	47.4	0.52	51.1	3.93	53.37	1.44	58.13	0.99	55.53	0.57	52.53	1.82
250	51.6	0.3	52.73	1.75	53.37	0.15	58.1	0.56	55.2	0.44	54.7	0.69
315	56.67	0.06	58	1.11	54.47	0.74	56.3	0.72	58.2	0.1	57.97	0.12
400	63.2	0	64.47	0.72	63.9	0.4	63.57	1.14	63.77	0.06	63.8	0.26
500	68.73	0.15	69.3	0.1	66.87	0.06	67.47	0.64	69.17	0.32	68.77	0.25
630	73.83	0.06	73.83	0.12	71.53	0.25	72.07	0.25	73.33	0.12	73.53	0.06
800	79.33	0.15	79.2	0.17	78.67	0.32	78.23	0.35	78.17	0.06	78.23	0.23
1000	82.6	0.17	82.97	0.15	81.4	0.72	81.5	0.78	81.87	0.06	82.37	0.12
1250	79.03	0.12	79.53	0.12	79.47	0.55	79.13	0.47	78.67	0.15	79.57	0.12
1600	76.67	0.15	76.8	0.17	78.83	0.15	79.2	0.17	76.87	0.31	77.03	0.21
2000	78.9	0.26	79.17	0.31	79.37	0.35	80.37	0.42	79.77	0.15	79.67	0.42
2500	78.26	0.15	79	0.26	76.8	0.46	76.7	0.4	79.33	0.12	79.7	0.26
3150	76.5	0.17	76.77	0.12	75.77	0.31	76.07	0.31	76.53	0.06	77.07	0.72
4000	75.47	0.21	75.23	0.25	75.8	0.17	76.23	0.12	74.63	0.32	74.87	0.38
5000	74.63	0.12	75.01	0.46	75.2	0.17	75.43	0.51	76.17	0.15	76.7	0.17

machine	2											
lab	1				2				3			
environment	1		3		1		3		1		3	
freq (Hz)	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.
"A" wtg	103.56	0.01	104.1	0.1	102.87	0.21	103.47	0.21	103.17	0.15	102.27	0.49
50	107.62	0.03	107.3	0.17	105.37	0.25	107.87	0.38	104.83	0.57	105.23	0.21
63	98	0.19	93.2	0.72	90.93	0.35	94.33	0.6	89.77	0.42	89.3	0
80	94.5	0.2	97.33	0.5	97.03	0.15	97.7	0.4	96.67	0.57	93.77	0.15
100	91.48	0.15	91.13	0.12	87	0.61	87.13	0.97	88.97	0.91	90.63	0.42
125	99.22	0.08	98.33	0.25	96.57	0.35	97.83	0.06	98.2	0.1	98.37	0.06
160	94.45	0.32	94.67	0.23	93.4	0.36	94.17	0.25	93.8	0	93.23	0.7
200	94.78	0.14	94.33	0.21	91.53	0.91	90.87	0.81	93.33	0.38	93.13	0.65
250	92.61	0.23	92.67	0.32	88.97	1.19	88.97	1.16	90.8	0.3	90.7	0.3
315	88.65	0.08	89.7	0.26	89.7	2.67	89	1.55	90.57	0.6	89.5	0.72
400	88.34	0.31	88.87	0.59	88.33	0.51	89.33	0.65	88.13	0.21	88.7	0.44
500	89.72	0.34	89.73	0.4	89.2	0.66	89.5	0.5	89.53	0.35	89.9	0.26
630	95.55	0.09	95.8	0.5	96.33	0.23	97.53	0.23	95.17	0.12	94.8	0.1
800	94.6	0.05	94.3	0.17	94.97	0.38	95.47	0.31	93.4	0.1	93.6	0.2
1000	93.91	0.11	92.9	0	91.13	0.12	91.67	0.12	93.1	0.2	92.07	0.21
1250	91.93	0.18	92.07	0.21	89.87	0.06	90.57	0.42	91.67	0.15	91.3	0.1
1600	94.05	0.23	94.83	0.15	91.87	0.38	92.53	0.35	94.07	0.12	93.43	0.12
2000	93.95	0.18	95.47	0.15	93.27	0.4	93.8	0.3	94.23	0.15	93.9	0.1
2500	90.81	0.06	92.1	0.1	90.4	0.2	90.67	0.06	91	0.17	91.1	0.17
3150	91.29	0.03	91.97	0.25	91.3	0.46	91.67	0.12	91.8	0.26	91.5	0.17
4000	90.56	0.07	91	0.1	90.1	0.26	90.77	0.15	90.9	0.1	90.33	0.25
5000	87.67	0.09	88.53	0.38	86.57	0.21	87.43	0.12	87.47	0.06	87.33	0.25

machine	3											
lab	1				2				3			
environment	1		3		1		3		1		3	
freq (Hz)	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.
"A" wtg	103.01	0.37	104	0.1	102.47	0.47	103.6	0	101.53	0.06	102.77	0.25
50	93.71	0.16	96.93	0.15	93.6	0.3	97.1	0.1	93	0.1	94.97	0.81
63	82.16	0.93	82.1	0.61	83.47	0.86	82.97	0.06	81.7	0.61	81.43	0.67
80	87.08	1.32	85.43	0.42	86.93	1.6	84.67	0.06	85.5	0.89	85.1	2.27
100	99.66	0.2	99.43	0.29	98.9	0.79	99.6	0.17	101.7	0.17	97.6	1.13
125	86.15	1.2	86.17	0.32	86.23	0.59	86.83	0.06	85.53	0.25	84.77	1.07
160	90.71	0.24	91.13	0.83	91.53	0.25	90.9	0.1	90.9	0.61	90.37	0.45
200	99.26	0.43	99.77	0.91	97.53	0.64	97.13	0.06	100	0.3	100.93	0.72
250	95	0.83	94.2	0.6	94.1	0.72	93.83	0.06	93.03	0.51	93.5	0.62
315	99.85	0.18	99.63	0.55	100	0.17	100.17	0.21	97.93	0.23	97.23	0.25
400	93.75	0.41	94.27	0.23	93.77	0.31	94.17	0.06	94.47	0.06	94.33	0.25
500	95.13	0.39	96.1	0.26	94.53	0.06	95.37	0.15	94.43	0.25	94.4	0.82
630	95.12	0.22	95.73	0.29	93.8	0.17	94.83	0.06	93.8	0.1	93.37	0.4
800	93.61	0.12	95.07	0.35	92.67	0.42	93.83	0.12	92.47	0.06	93.13	0.06
1000	92.68	0.2	93.47	0.06	92.13	0.61	94	0.1	91.27	0.06	92.57	0.23
1250	91.05	1.04	92.67	0.12	91.17	0.9	93.13	0.06	89.87	0.15	92.2	0.3
1600	90.81	0.92	92.33	0.12	90.6	0.87	92.17	0.12	88.97	0.21	92.67	0.15
2000	89.44	0.81	90.9	0.1	89.13	0.78	90.87	0.06	87.17	0.21	90.73	0.25
2500	88.54	0.83	90.07	0.21	87.97	0.75	89.67	0.12	86.13	0.25	89.43	0.23
3150	89.11	0.68	90.03	0.25	87.37	0.87	88.97	0.06	85.8	0.26	88.93	0.25
4000	89.71	0.83	90.43	0.15	88.27	0.61	89.53	0.06	87.23	0.12	89.13	0.15
5000	89.26	0.88	90.4	0.3	88.53	0.55	89.73	0.06	87.1	0.1	88.87	0.12

machine	4											
lab	1				2				3			
environment	1		3		1		3		1		3	
freq (Hz)	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.	mean	S.d.
"A" wtg	95.5	0.2	95.52	0.46	93.7	0.4	93.9	0.3	93.83	0.15	94.3	0.35
50	110.63	0.29	110.16	1.29	109.13	0.21	107.53	1.32	109	0.46	105.57	0.71
63	106.04	0.21	108.39	0.25	104.33	0.55	102.63	0.6	103.47	0.9	104.93	0.38
80	96.86	0.52	98.88	1.71	96.5	1.01	94.9	0.95	95.97	0.35	99.33	0.67
100	99.66	0.14	99.51	1.47	97.97	0.35	98.77	0.15	98.93	0.4	99.17	0.74
125	97.95	0.07	98.47	1.18	96.3	0.4	96.3	0.1	96.73	0.55	97.13	0.75
160	96.02	0.13	95.86	2.13	94.6	0.26	95.47	0.25	94.57	0.06	95.6	1.14
200	89.09	0.07	90.19	0.34	89.67	0.31	89.67	0.6	89.53	0.15	89.63	0.25
250	87.54	0.19	87.59	0.29	89.7	0.3	89.67	0.25	87.77	0.23	88.53	0.23
315	87.7	0.71	88.14	0.12	89.67	0.4	90.07	0.75	88.47	0.15	89.43	0.15
400	86.9	0.04	86.97	0.28	87.63	0.15	87.73	0.58	87.13	0.06	87.47	0.06
500	86.75	0.51	87.98	0.44	86.53	0.47	86.93	0.58	86.3	0.2	86.87	0.31
630	86.06	0.3	86.82	0.11	84.7	0.56	84.8	0.36	84.73	0.15	86.13	0.32
800	84.95	0.22	85.56	0.44	84.2	0.46	84.37	0.31	84.1	0.26	84.6	0.44
1000	82.84	0.38	83.4	0.22	83.07	0.45	82.97	0.51	82.73	0.06	82.97	0.15
1250	80.93	0.35	81.11	0.1	78.47	0.29	78.8	0.36	80	0.44	80.67	0.67
1600	82.27	0.57	82.62	0.16	79.83	0.45	80.13	0.21	82.13	0.32	82.03	0.49
2000	78.33	0.41	78.81	0.23	76.57	0.15	77	0.26	78.23	0.4	78.03	0.23
2500	77.84	0.15	78.34	0.31	76.4	0.26	76.7	0.26	78.3	0.36	77.93	0.49
3150	78.01	0.05	78.41	0.15	76.83	0.49	77.13	0.32	78.2	0.46	77.8	0.26
4000	74.63	0.28	75.15	0.48	72.7	0.2	73.5	0.53	74.57	0.38	74.3	0.44
5000	73.82	0.25	74.7	0.48	72.03	0.4	72.8	0.46	73.8	0.36	73.53	0.23

APPENDIX 3.4 DATA FOR ISO 11201

The table in this section of Appendix 3 lists the means of the three repeat emission sound pressure determinations carried out, according to ISO 11201, by each laboratory together with the associated standard deviations both expressed in dB. Measurements were made using A- and C-weighting in one acoustical environment with a K-factor of less than 2 dB. The table lists data for all four machines. The data have been output from the SPSS spreadsheet and contain some coded descriptions which are described in Appendix 3.1.

machine		1		2		3		4	
	Wtg	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Lab 1	"A"	75	0.23	89.74	0.11	88.73	0.05	80	.84
	"C"	74.3	0.17	93.97	0.07	93.03	0.04	94.17	.13
Lab 2	"A"	78.29	0.08	89.68	0.1	88.93	0.24	79.23	.24
	"C"	79.38	0.1	95.95	0.05	95.26	0.18	96.21	.37
Lab 3	"A"	78.2	0.28	89.24	0.06	89.52	0.11	79.17	.02
	"C"	92.62	0.31	106.49	0.53	105.96	0.12	105.4	.19
Lab 4	"A"	76.49	0.1	90.45	0.13	86.84	0.8	79.13	.07
	"C"	92.06	0.67	105.35	0.26	105.23	0.05	104.61	.14

APPENDIX 3.5 DATA FOR ISO 11202

The tables in this section of Appendix 3 list the means of the three repeat emission sound pressure determinations carried out, according to ISO 11202, by each laboratory together with the associated standard deviations both expressed in dB. Measurements were made in two acoustical environments with K-factors of approximately 2.5 dB and 5 dB using A-weighting. There is a table for each machine, for A- and C-weighting. Each table contains data for both environments. The data have been output from the SPSS spreadsheet and contain some coded descriptions which are described in Appendix 3.2.

A Weighting

machine	1			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	79.76	0.07	80.71	0
2	79.99	0.07	85.03	0.06
3	78.05	0.11	80.98	0.09
4	77.85	0.08	82.37	0.04

machine	2			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	92.74	0.1	94.08	0.08
2	90.85	0.28	91.42	0.1
3	89.82	0.08	93.27	0.21
4	91.13	0.03	93.19	0.06

machine	3			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	91.83	0.36	93.05	0.1
2	90.17	0.06	91.28	0.05
3	89.46	0.24	93.11	0.53
4	90.14	0.03	91.76	0.06

machine	4			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	79.55	0.05	83.92	0.28
2	79.22	0.23	81.32	0.06
3	78.72	0.08	82.16	0.24
4	78.51	0.04	79.56	0.23

C-weighting

machine	1			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	80.18	0.03	80.98	0.13
2	81.37	0.51	86.07	0.06
3	95.89	2.7	94.91	0.16
4	91.51	0.04	95.49	0.18

machine	2			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	96.9	0.08	97.76	0.24
2	97.63	0.17	98.49	0.09
3	107.7	1.42	109.85	0.91
4	107	0.14	108.63	0.15

machine	3			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	95.84	0.18	97.59	0.24
2	96.08	0.03	96.72	0.05
3	106.63	0.2	111.21	0.45
4	106.45	0.16	108.08	0.14

machine	4			
environment	2		3	
lab	Mean	s.d.	Mean	s.d.
1	94.96	0.12	97.42	0.18
2	97.58	0.06	98.53	0.11
3	104.39	0.36	108.03	0.47
4	104.14	0.16	104.55	0.21