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A guide to measuring sound power

An overview of international standards

White Paper

Choosing the correct standard for qualifying an acoustic source can be a challenge. The decision must take into account a number of factors: Type of noise source, available equipment and testing environment, regulations, etc. This white paper provides an overview of the existing standards as well as the applicable regulations and noise codes.

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Contents

Executive summary

When you think about measuring sound, what usually comes to mind is measuring sound pressure with a microphone. But is this the best way to qualify an acoustic source? When a metal plate vibrates, it moves the air particles around it. When the sound wave acts upon a particle, it is temporarily disturbed from its resting position. The excited particles transfer momentum from one particle to another. What we measure with a microphone is the disturbance of the air particles. Depending on where we hold the microphone or if we are inside or outside a building, the measured sound pressure will vary. In order to objectively qualify the source of the sound, we have to measure sound power; the acoustical energy emitted by that vibrating metal plate expressed in watts [W]. It is independent of the environment, distance or direction; sound power is the cause and sound pressure is the easily measureable effect.

An example of a similar phenomenon would be a heating system. For instance, a regular household radiator releases heat, but to measure the effect, we use thermometers, which display the temperature (in degrees Celsius or Fahrenheit). Depending on where we put the radiator, in the middle of a desert or in an igloo, the measured temperature will differ, but the radiated heat will remain unchanged.

Sound power is measured to make objective comparisons but also because legislation requires it. To release a new product, it is often compulsory to certify it according to International Organization for Standardization (ISO) standards as well as local and regional regulations. Apart from certification, sound power testing helps to develop better products in compliance with industry and ISO standards. In fact, it can enable firms to meet or even exceed expectations, thus improving their competitive advantage and supporting their branding strategy.

Sound power levels may be used for:

- Certifying noise emitted by machines or equipment
- Verifying declared values
- Comparing noise emitted coming from different machines (in type and size)
- Engineering work to reduce noise emitted by machinery
- Predicting noise levels
- Characterizing the noise source

Sound power

Is the rate at which the energy of sound is radiated per unit time. The unit of sound power (*W*) is watt [W].

$W = I \cdot A$, where I – sound intensity [W/m^2] , A – area [m^2]

Sound power level

$L_w = 10 \log_{10}\left(\frac{W}{W_0}\right)$ dB, where W_0 = 1pW

Sound pressure

Is the local pressure deviation from the ambient atmospheric pressure caused by a sound wave. The unit of sound pressure (*p*) is Pascal [Pa].

Sound pressure level

$L_p = 20 \log_{10}\left(\frac{p}{p_0}\right)$ dB, where p_0 = 20μPa

Sound intensity

Is the sound power per unit area. The unit of sound intensity (*I*) is watt per meter square [W/m^2].

$I = p \cdot \vartheta$, where p – sound pressure [Pa], v – particle velocity [m/s]

Sound intensity level

$L_I = 10 \log_{10}\left(\frac{I}{I_0}\right)$ dB, where I_0 = 1pW/m^2

Measuring sound power

Measuring sound power is not a straightforward process. Sound power can be determined either through the measurement of sound pressure [Pa] or sound intensity: the rate of energy flow through a unit area, expressed in watts per unit area [W/m^2].

Additional methods, such as acoustic holography, are also available but are not ISO compliant. The added value of quantitative array techniques is the localization information, but the results obtained with acoustic cameras cannot be used for legislative purposes.

Sound pressure-based sound power measurements can only be performed in very specific environmental conditions, usually only met in acoustic rooms (anechoic or reverberant chambers). The sound pressure-based approach is most commonly used when performing certification measurements. A set of ISO standards governs these requirements and indicates measurement procedures that are necessary to obtain quality results.

Sound intensity-based sound power can be measured in any sound field, but certain requirements with regard to the type of sound must be met. The measurements can be performed on individual machines or sound sources in the presence of other components radiating noise, because steady background noise does not contribute to the measured sound intensity. However, this approach has a limited usable frequency bandwidth, time demanding measurement procedures and limitations on the characteristics of the noise source. ISO standards govern sound intensity-based measurements and describe the procedures that are required to obtain quality results.

Selecting one of the above methods depends on the purpose of the test as well as the available equipment, desired grade of accuracy, background noise level or the test environment. Table 1 on page 5 is an overview of the sound power measurement methods described in the ISO 3740:2000, Acoustics – Determination of sound power levels of noise sources – Guidelines for the use of basic standards.

ISO distinguishes three methods of accuracy: Precision, engineering and survey with a complete description available in ISO 12001:

Precision method: This is a grade 1 method that gives the most accurate results. Measurements have to be performed in laboratory conditions with the most precise equipment available. Precision methods ensure the lowest uncertainty values but require the most effort during measurement

Engineering method: This is a grade 2 method that gives very accurate results. The influence of the acoustic environment as well as the source type is taken into account. This is the preferred grade of accuracy when performing engineering actions such as preventive or reactive sound design campaigns

Survey method: This is a grade 3 method that requires the least amount of time and equipment. The results are meant to compare sources with similar characteristics, but have limited value in evaluating noise

Table 1– List of sound power ISO standards

	Standard	Testing environment	Method accuracy[1]	Character of the noise	Sound power level obtained	ANSI/ASA equivalent	DIN equivalent
Sound pressure-based methods	ISO 3741	Reverberant room	Precision	Steady, broadband, narrow-band or discrete	A-weighted 1/1 or 1/3 octave bands	ANSI/ASA S12.51/ ISO 374	DIN EN ISO 3741:2009-11
	ISO 3743-1	Hard-walled room	Engineering	Any, but no isolated bursts	A-weighted 1/1 octave bands	ANSI/ASA S12.53 P1	DIN EN ISO 3743-1:2011-01
	ISO 3743-2	Special reverberation room	Engineering	Any, but no isolated bursts	A-weighted 1/1 octave bands	ANSI/ASA S12.53 P2	DIN EN ISO 3743-2:2009-11
	ISO 3744	Free-field over reflecting pane	Engineering	Any	A-weighted 1/1 or 1/3 octave bands	ANSI/ASA S12.54/ ISO 3744	DIN 45635-1:1984-04
	ISO 3745	Semi- or anechoic room	Precision	Any	A-weighted 1/1 or 1/3 octave bands	ANSI/ASA S12.55/ ISO 3745	DIN 45635-1:1984-04
	ISO 3746	Semi- or anechoic room	Survey	Any	A-weighted	ANSI/ASA S12.56/ ISO 3746	DIN 45635-1:1984-04
	ISO 3747	Reverberant field in situ	Engineering or survey	Steady, broadband, narrow-band or discrete	A-weighted from octave bands	ANSI/ASA S12.57/ ISO 3747	DIN EN ISO 3747
Sound intensity based methods	ISO 9614-1	Any	Precision, engineering or survey	Broadband, narrow-band or discrete if stationary	1/1 or 1/3 octave bands or band limited A-weighted 1/3 octave bands	ANSI/ASA S12.12	DIN EN ISO 9614-1
	ISO 9614-2	Any	Engineering or survey	Broadband, narrow-band or discrete if stationary	1/1 or 1/3 octave bands or band limited A-weighted 1/3 octave bands	ANSI/ASA S12.12	DIN EN ISO 9614-2
	ISO 9614-3	Any	Precision	Broadband, narrow-band or discrete if stationary	Broadband, narrow-band or discrete if stationary 1/1 octave bands or band limited A-weighted 1/3 octave bands	ANSI/ASA S12.12	DIN EN ISO 9614-3

1 Grade of accuracy definition based on ISO 12001:1996, Acoustics – Noise emitted by machinery and equipment – Rules for the drafting and presentation of a noise test code.

Sound pressure-based methods

In this approach, the sound power level is calculated based on sound pressure levels measured at multiple locations around the source, applied corrections for background noise and environmental conditions.

Depending on the available testing environment and the desired grade of accuracy, the following approaches can be considered.

ISO 3741: Precision method in a reverberant room

ISO 3741	
Accuracy	Precision method (grade 1)
Testing room	Reverberant room
Type of noise	Steady, broadband, narrow-band or discrete
Extra equipment	Microphone traverse, (optional) reference sound source

This standard is applicable to all types of noise (steady, unsteady, fluctuating, isolated bursts, etc.) if the volume of the source is not greater than two percent of the volume of the reverberation test room. A list of requirements has to be met for the following components/conditions:

- Reverberation room must meet requirements listed in the standard
- Background noise level cannot exceed the defined levels
- Constant relative humidity and temperature
- Instrumentation system must meet the requirements of International Electrotechnical Commission (IEC) 61672-1:2002, class 1
- Reference source (if used) must meet the ISO 6926 standard

This standard covers two methods: direct and comparison. In the direct one, an equivalent sound absorption of the reverberation test room is used, which implies a measurement of reverberation time. In the comparison method, a reference sound source with a calibrated sound power level is measured to assess the influence of the environment on the obtained results.

Depending on the room parameters and the lowest 1/3 octave mid-band frequency of interest, the location, number of microphone positions and distance between them has to be chosen depending on room parameters and the lowest 1/3 octave mid-band frequency of interest. ISO suggests the use of a moving traverse; a microphone positioning system.

The final result of ISO 3741 with the direct method is the sound power level in each 1/3 octave band, calculated by using the mean corrected 1/3 octave band time-averaged sound pressure level, equivalent absorption area, total surface and volume of the test room and meteorological conditions.

Both results can be presented either with no weighting or A-weighted.

ISO 3743-1: Engineering method in a hard-walled room

ISO 3743-1	
Accuracy	Engineering method (grade 2)
Testing room	Highly reflective walls; additional requirements in the standard
Type of noise	Any, but no isolated bursts
Extra equipment	Reference sound source

The method described in this standard is based on a comparison between the sound pressure levels of a noise source and a reference sound source in octave frequency bands.

This standard is suitable for small items or portable equipment. All noise types are supported apart from isolated bursts. The volume of the testing room must be greater than 40 meters^3 (m) with hard and strongly reflective surfaces. The standard also limits the size of the source in comparison to the test room.

A list of requirements must be met for the following components/conditions:

- Hard-walled room has to meet requirements listed in the standard
- Absorption coefficient of the room cannot exceed 0.2 at all frequencies
- Background noise level cannot exceed certain levels
- Constant relative humidity, temperature
- Instrumentation system has to meet the requirements of IEC 61672-1:2002, class 1
- Reference source has to meet the ISO 6926 standard

A minimum of three microphone positions must be used. The location, number of microphone positions and distance between them has to be chosen depending on the room dimensions and the lowest octave mid-band frequency of interest.

Different measurement procedures are described in the standard depending on the type of noise emitted by the source.

The final result of the ISO 3743-1 is the sound power level in each octave band, calculated by using the octave band sound power of the reference sound source, mean octave band time-averaged sound pressure levels of the noise source and the reference source and background noise corrections.

The result can be presented either with no weighting or A-weighted.

ISO 3743-2: Engineering method in special reverberation rooms

ISO 3743-2	
Accuracy	Engineering method (grade 2)
Testing room	Has to meet requirements on reverberation time and volume
Type of noise	Any, but no isolated bursts
Extra equipment	Optional, but not advised: reference sound source

In this method, the standard requires a specially designed room with a specified reverberation time over the frequency range of interest and a minimum volume of 70m^3. This method is applicable to small, movable machines, devices and components. The maximum size of the object as well as the lower limit of the frequency range depends on the dimensions of the room. If the 125-hertz (Hz) octave band is within the frequency range of interest, the volume should be bigger, but it should not exceed 300m^3 if 4 kilohertz (kHz) and 8 kHz octave bands are also to be measured. The reverberation time of the room, measured according to ISO 354, must meet the requirements listed in the norm and be slightly higher at low frequencies.

A reference sound source is not required, as the sound power level is determined from a single sound pressure level measurement in each microphone position. All types of noise are supported apart from isolated bursts.

A list of requirements must be met for the following components/conditions:

- Stringent requirements for the reverberation room
- Background noise level cannot exceed certain levels
- Constant relative humidity, temperature
- Instrumentation system has to meet the requirements of IEC 61672-1:2002, class 1 for the sound level meter, and IEC 61260:1995 for the octave band filters

The calculation of the approximate sound power level is based on mean-square values of sound pressure level averaged in time over all microphone positions. It is possible to use either a single microphone and move it from one position to the other, an array of fixed microphones or a continuously moving microphone. The ISO standards specify a set of rules governing the number and position of microphones. If the moving microphone setup has been selected, an averaging technique must be used. Correction of the background sound pressure level should be applied if necessary.

The final result of the ISO 3743-2 is the approximate band power levels or A-weighted sound power levels of the source, calculated using the mean octave band levels or the mean A-weighted sound pressure levels, reverberation time of the room and its volume.

This standard also allows using the comparison method with a reference sound source. Due to the stringent requirements on the special reverberation room, it is advised to use the ISO 3743-1 approach instead if the comparison approach is preferred.

ISO 3744: Engineering method in essentially free-field over a reflective plane

ISO 3744	
Accuracy	Engineering method (grade 2)
Testing room	Free-field over a reflecting pane
Type of noise	Any
Extra equipment	Optional hemisphere, optional reference sound source

The ISO 3744 closely follows the ISO 3745 method, but is less stringent with regard to the requirements for the testing environment and the measurement setup. All noise source types are supported (steady, unsteady, fluctuating, isolated bursts). There is no limitation to the size of the source, providing that the conditions for the measurement are met.

Measurements can be performed both indoors and outdoors, with one or more sound-reflecting planes present (for example, the floor). A flat outdoor area with no objects located close to the source or a semi-anechoic room is considered to be perfectly suitable for the requirements. Additional procedures are suggested to apply corrections if the environment is not ideal. The influence of the environment has to be determined either with the use of a reference sound source (preferred) or the room absorption measurements.

A list of requirements must be met for the following components/conditions:

- Background noise level cannot exceed certain levels
- Sound field in the testing environment should be free of undesirable sound reflections from nearby objects or room boundaries (other than the reflecting pane)
- Reflecting pane should be greater in size than the measurement surface by at least 0.5 meters
- Instrumentation system has to meet the requirements of IEC 61672-1:2002, class 1

The object being tested should be enclosed in any of the four measurement surfaces:

- A hemisphere, half-hemisphere or quarter-hemisphere
- A right parallelepiped
- A cylinder, half-cylinder or quarter-cylinder
- A combination of two segments, hemispherical, rectangular or cylindrical

The dimensions of these surfaces depend on the size of a reference box, a hypothetical surface defined by the smallest right parallelepiped that encloses the source being tested. The choice on the surface can be made based on the shape and dimensions of the source, keeping in mind that the distances between each microphone and the noise source should be as similar as possible.

Figure 1: Reference sound source measured with the use of a half-hemisphere microphone array.

The number and coordinates of the required microphone positions depend on the selected measurement surface and the purpose of the measurement.

The final result of the ISO 3744 is the sound-power level in frequency bands for the meteorological conditions at the time and place of the test, calculated based on surface time-averaged sound pressure level with a correction for background noise, influence of the test environment and the area of the measurement surface:

$$L_W = \overline{L'_{p(ST)}} - K_1 - K_2 + 10\log\frac{S}{S_0}\ dB$$

$\overline{L'_{p(ST)}}$ - mean, time-averaged sound pressure level, dB

K_1 – background noise correction, dB

K_2 – environmental correction, dB

S – area of the measurement surface in m^2; $S_0 = 1m^2$

The K_1 correction is calculated based on the difference in sound pressure level between the source being tested and the background noise at the same microphone position – ΔL_p. If ΔL_p >15 dB , then K_1 is equal to 0 and no correction is applied. If ΔL_p < 6 dB, then K_1 =1.3 decibel (dB) and the accuracy of the results may be reduced. For the values of ΔL_p between 6 and 15 dB, the following formula has to be applied:

$$K_1 = -10\log\left(1 - 10^{-0.1\Delta L_p}\right)\ dB$$

The environmental correction K_2 can be calculated based on either of the two methods: an absolute comparison test or a room absorption-based test.

Absolute comparison test: In this approach a reference sound source (RSS), which is compliant with ISO 6926, is used to verify the influence of environment on the measured sound power. In this method, the environment correction K_2 is calculated as:

$$K_2 = L^*_W - L_{W(RSS)}\ dB$$

In which L^*_W.is the sound power of the RSS measured according to this standard with K_2 assumed as 0 and LW(RSS) is the declared sound power level of the RSS.

Room absorption-based test: This approach requires the measurements of the equivalent sound absorption area A of the room in which the test is performed. The measurement of A can be performed by measuring reverberation time (according to ISO 3382-2), using the two-surface method, direct method with a RSS or an approximation method. The K_2 correction can be calculated from:

$$K_2 = 10\log\left[1 + 4\frac{S}{A}\right]\ dB$$

Once all corrections are known, the ISO 3744-based sound power level can be calculated. The result can be presented either with no weighting or A-weighted.

ISO 3745: Precision method in anechoic or semi-anechoic rooms

ISO 3745	
Accuracy	Precision method (grade 1)
Testing room	High quality anechoic or semi-anechoic room
Type of noise	Any
Extra equipment	Optional hemisphere, optional microphone traverse

This standard specifies precision methods to obtain sound power level in 1/1 or 1/3 octave bands with optional A-weighting, based on the measurements of sound pressure levels on a surface enveloping the noise source. Corrections to allow for differences in meteorological conditions are also included.

The method described in this standard is suitable for all noise types. The maximum size of the measured source is limited to the available enveloping hemisphere and the size of the testing room.

A list of requirements has to be met for the following components/conditions:

- A high-quality anechoic or semi-anechoic room meeting stringent requirements
- Background noise level cannot exceed certain levels
- Air temperature in the room has to be between 15 Celsius (°C) and 30°C Instrumentation system has to meet the requirements of IEC 61672-1:2002, class 1
- The test object should be enclosed by either a spherical (anechoic room) or hemispherical (semi-anechoic room) measurement surface. The radius depends both on the size of the source and the lower frequency of interest

To obtain the spherical or hemispherical measurement setup, either one of the arrangements can be used:

- Fixed positions of at least 20 microphones
- Single microphone or microphone sets moved along at least 10 circular paths (360° turn) or the source placed on a rotating disc
- A single microphone moved along at least eight meridional arcs
- A single microphone moved along at least five circular paths, creating a spiral

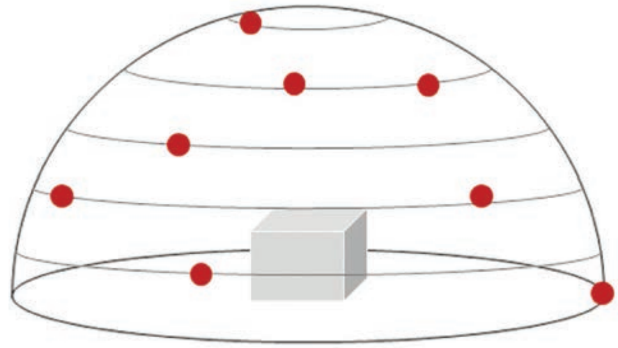

Figure 2: Fixed positions of microphones on a hemisphere.

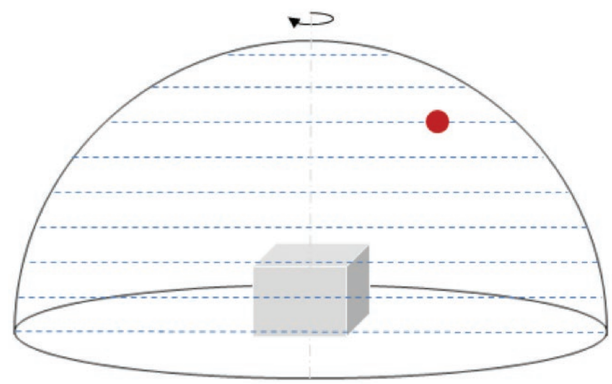

Figure 3: Coaxial circular paths for a moving microphone or source.

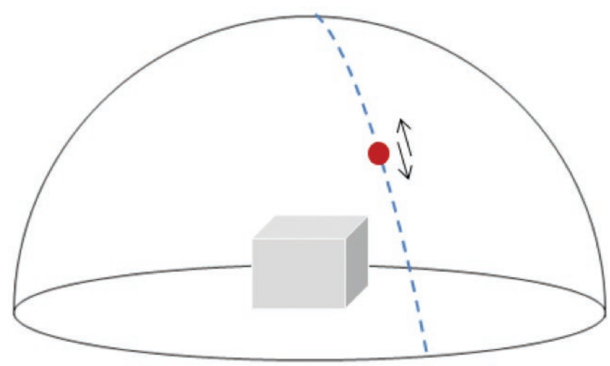

Figure 4: Meridional path for a moving microphone.

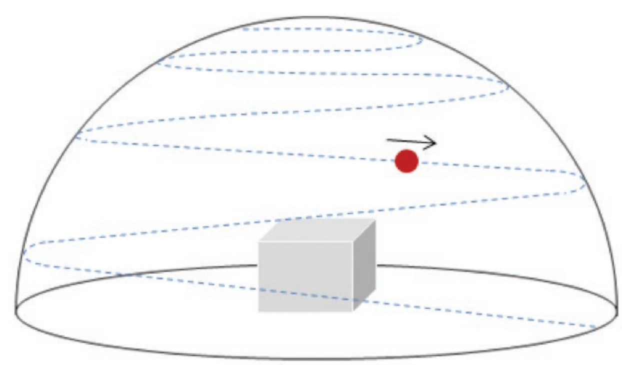

Figure 5: Spiral path for the moving microphone.

The standard requires at least 20 microphone positions for the fixed arrays, providing that the level difference between the highest and lowest sound pressure level (SPL) measured in all frequency bands is less than half the number of microphone positions. If that requirement is not met, the number can be extended to 40. If other setups are used, the number of required microphone positions will vary.

The final result of the ISO 3745 is the sound power level in each frequency band of interest, calculated based on the surface time-averaged sound pressure level, under reference meteorological conditions and with a correction for the measurement surface.

The result can be presented either with no weighting or A-weighted.

ISO 3746: Survey method with no special test environment

ISO 3746	
Accuracy	Survey method (grade 3)
Testing room	No special room required, but with limitations on the background noise
Type of noise	Any
Extra equipment	Optional hemisphere

The following standard gives results with grade 3 accuracy (survey method) and provides methods to calculate the A-weighted sound pressure level from the mean square sound pressure measured over a hypothetical measurement surface, with the noise source preferably mounted on a sound-reflecting pane in a large open space. Corrections are defined to account for reflections from nearby objects. All noise source types are supported (steady, unsteady, fluctuating, isolated bursts). There is no limitation as to the size of the source if the requirements of the standard for the measurement are met.

A room or flat outdoor area can be used for the measurements if there is no significant background noise. ISO specifies procedures to verify the adequacy of room. A list of requirements has to be met for the following components/conditions:

- Averaged background noise level has to be at least 3 dB below the mean sound pressure level of the source
- Instrumentation system has to meet the requirements of IEC 61672-1:2002, class 2
- Environmental correction for the test room should not exceed 7 dB

The object being tested should be enclosed in either of the measurement surfaces (but for better accuracy, other surfaces listed in the ISO 3744 can be used):

- A hemisphere, half-hemisphere or quarter-hemisphere
- A right parallelepiped

Depending on the chosen measurement surface, the number of required microphone positions will vary. For the measurements on similar noise sources (for example, equipment of the same type), the same shape of the measurement surface should be used.

The final result of the ISO 3746 is the A-weighted sound power level is valid for the meteorological conditions at the time and place of the test, calculated based on the surface time-averaged sound pressure level, background noise and test environment corrections and the area of the measurement surface.

ISO 3747: Engineering or survey method in situ in a reverberant environment

ISO 3747	
Accuracy	Engineering method (grade 2) or survey method (grade 3)
Testing room	In-situ method if certain requirements are met
Type of noise	Any
Extra equipment	Reference sound source

This method is based on a comparison of the sound pressure levels of a noise source mounted in situ in a reverberant environment with those of a calibrated reference sound source. The solution is meant for objects that cannot be easily moved. All noise source types are supported (steady, unsteady, fluctuating, isolated bursts). However, sources that emit narrow-band noise or discrete tones may not give reproducible results.

The testing environment that meets the requirements of this standard is a room where the sound pressure levels at the microphone positions depend mainly on reflections from the room surfaces. The background noise in the room has to be low in comparison with both the machine being tested and the reference sound source. Depending on the extent to which the requirements concerning the room are met, the results are obtained with either engineering (grade 2) or survey (grade 3) accuracy.

A list of requirements must be met for the following components/conditions:

- The instrumentation system has to meet the requirements of IEC 61672-1:2002, class 1
- The reference source has to meet the ISO 6926
- The background noise level cannot exceed certain levels

In total, three or four microphone positions must be used and distributed as evenly as possible around the noise source. The same positions and microphone orientations should also be used for background noise and reference source measurements. The method description provides rules for choosing microphone positions, and locating the reference sound source. Depending on the room in which the noise source is located, it is possible that more than one reference sound source location is required.

Figure 6: The reference sound source is being measured with the use of a hemisphere and mobile acquisition system.

The final result of the ISO 3747 is the sound power level in each octave band, for the meteorological conditions at the time and place of the test, calculated based on the sound power level of the calibrated reference source and the mean corrected time-averaged sound pressure levels of both the noise and reference sound source.

The result can be presented either with no weighting or A-weighted.

Sound intensity-based methods

In this approach, the sound power level is calculated based on the measurement of the flow of sound energy emitted by the source. When performing sound pressure-based measurements, as explained previously, it is often required to invest in costly facilities for high precision of the measurement (such as anechoic or reverberant rooms). In the ISO 9614 methods, the sound power level can be determined using far less restrictive test conditions than imposed by the ISO 3740 family. Limitation of the intensity-based approach is the usable frequency bandwidth of the intensity probes and the time required to perform the measurements.

Based on the desirable grade of accuracy and measurement method, we can distinguish the following three approaches.

Figure 7: Sound intensity-based measurement.

ISO 9614-1: Precision, engineering or survey discrete measurement points method

ISO 9614-1	
Accuracy	Depends on field indicators
Testing room	No special room required, but with limitations on the background noise
Type of noise	Any, if stationary
Extra equipment	Optional measurement grid

This method allows you to calculate the 1/1 and 1/3 octave or band-limited weighted sound power level based on the component of sound intensity normal to the measurement surface by measuring in points around the test object. This standard is applicable for noise sources that are broadband, narrowband or tonal, as long as they are stationary in time. There are no restrictions on the size of the noise source.

Measurements can be performed either in situ or in special-purpose test environments. The recommendation is to avoid testing in the presence of variable external noise sources or in variable conditions. Measuring in high wind speed or in variable temperature should be avoided. A list of requirements must be met for the following components/ conditions:

- Continuous testing environment
- Sound intensity measurement instrument and probe that meet the IEC 61043, class 1 (class 2 for survey)
- Calibration of the pressure microphones inside the probe has to be performed with a calibrator that meets the requirements of IEC 60942:2003

The test must be performed on an accurate measurement surface. On average, the distance between the measurement surface and the source should be greater than 0.5 m. The chosen surface can include nonabsorbent areas, such as floors or walls. The sound intensity measurement has to be performed in at least 10 uniformly distributed points with at least 1 position/m^2. If over 50 positions are required or there is no significant external noise source present, it is possible to limit the amount of measured points to 1position/2 m^2.

Parallelepiped, hemisphere, cylinder or hemi-cylinder measurement surfaces are suggested by the ISO standard. If it is possible to turn off the source, it is advised to do so in order to verify the importance of external sources for the overall measurement.

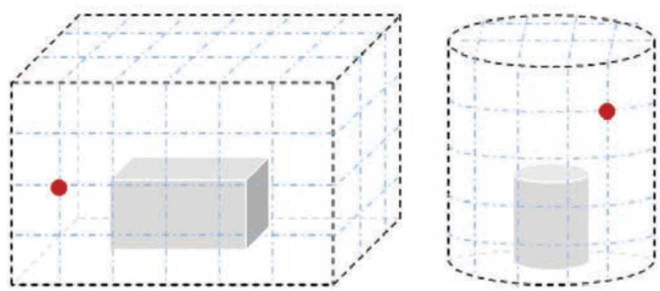

Figure 8: Measurement surfaces with measurement points indicated by grid lines.

Field indicators have to be calculated to assess the test environment and the choice of the measurement matrix. Following indicators are mentioned in the standard:

- F_1 – Temporal-variability indicator of the sound field
- F_2 – Surface pressure-intensity indicator
- F_3 – Negative partial-power indicator
- F_4 – Field nonuniformity indicator

The grade of accuracy of the test can be established based on the results of the calculation of these parameters.

The final result of the ISO 9614-1 is the A-weighted sound power level of the noise source in 1/1 or 1/3 octave bands, calculated based on signed magnitude of the normal sound intensity component measured at each segment of the surface and the area of that segment.

ISO 9614-2: Engineering or survey scanning measurement method

ISO 9614-2	
Accuracy	Engineering method (grade 2) or survey method (grade 3)
Testing room	No special room required, but with limitations on the background noise
Type of noise	Any, if stationary
Extra equipment	Optional mechanical moving system – robot arm

This method allows you to calculate the 1/1 and 1/3 octave or band-limited weighted sound power level based on the measurement of the component of sound intensity normal to the measurement surface. Contrary to the previous standard, in this method the intensity probe has to be moved continuously along one or more specified paths surrounding the noise source (the measurement surface enveloping the test object must be divided into segments). The intensity probe then has to be scanned over each segment.

This standard is applicable for noise sources that are broadband, narrowband or tonal as long as they are stationary in time. There are no restrictions on the size of the noise source. Measurements can be performed either in situ or in special-purpose test environments. It is recommended to avoid testing in the presence of variable external noise sources or in variable conditions. Measuring in high wind speed or in variable temperature should be avoided. A list of requirements has to be met for the following components/ conditions:

- Continuous testing environment
- Sound intensity measurement instrument and probe have to meet the IEC 61043, class 1 for the engineering grade and class 2 for the survey method
- Calibration of the pressure microphones inside the probe has to be performed with a calibrator meeting the requirements of IEC 60942:2003

Choose an accurate measurement surface to perform the test. On average, the distance between the measurement surface and the source should be bigger than 0.5 m. The chosen surface can include nonabsorbent areas, such as floors or walls. During the measurement procedure, scanning can be performed either manually or with the use of a mechanical moving system (robot arm).

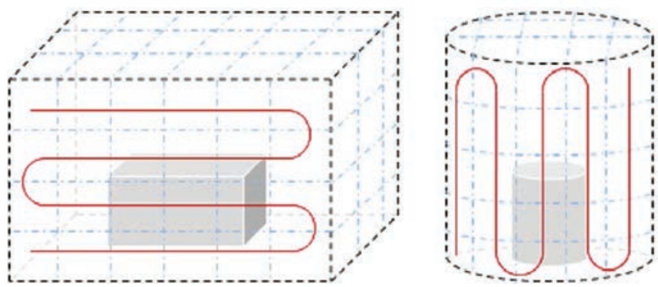

Figure 9: Measurement surfaces with scanning paths.

The scan path and the axis of the probe have to be maintained as much as possible. This can be a great challenge, especially when performing the measurements manually. Simple shapes of the measuring surface allow for more accurate results. A set of rules governs the movement and distributions of the scanning paths, such as the speed of scanning or the distance between the scan lines.

The grade of accuracy of the measurements depends on the evaluation of field indicators:

- F_{pI} – Surface pressure-intensity indicator
- $F_{+/-}$ – Negative partial-power indicator

To qualify which grade of accuracy can be stated for the measurement, three criteria have to be verified:

- Adequacy of the measurement equipment, based on F_{pI}
- Limitation on the negative partial power based on $F_{+/-}$
- Partial power repeatability check

If all criteria are met, the measurement can be reported as grade 2 (engineering). If only criterion 1 and 3 are met, the measurement can be reported as grade 3 (survey). ISO standards specify a set of actions to be taken if the criteria are not met.

The final result of the ISO 9614-2 is the A-weighted sound power level of the noise source in 1/1 or 1/3 octave bands, calculated based on the mean segment-average normal sound intensity component measured on each segment of the surface and the area of that segment.

ISO 9614-3: Precision scanning measurement method

ISO 9614-3	
Accuracy	Precision method (grade 1)
Testing room	No special room required, but with limitations on the background noise
Type of noise	Any, if stationary
Extra equipment	Optional mechanical moving system – robot arm

This standard specifies a similar approach to the ISO 9614-2, but allows you to obtain precision grade results. In this method, the intensity probe must be moved continuously along one or more specified paths surrounding the noise source: the measurement surface enveloping the object being tested must be divided into segments. The intensity probe has to be scanned over each segment. A set of complementary procedures is described to help indicate the quality of the test and the grade of accuracy.

This standard is applicable for noise sources that are broadband, narrowband or tonal, as long as they are stationary in time. There are no restrictions on the size of the noise source as long as all the precision grade criteria are met. Measurements can be performed either in situ or in special purpose test environments. It is recommended to avoid testing in the presence of variable external noise sources or in variable conditions. Measuring in the presence of wind (speed > 1m/s) or in variable temperature should be avoided. A list of requirements must be met for the following components/conditions:

- Continuous testing environment
- Class 1 sound intensity measurement instrument and probe have to meet the requirements of IEC 61043:1993
- Calibration of the pressure microphones inside the probe has to be performed with a calibrator meeting the requirements of IEC 60942:2003

The sound intensity measurement tool should be able to capture both the time series of sound intensity and the squared sound pressure data continuously.

In this part of the ISO 9614 method, the measurement surface must consist of partial surfaces that can be divided into rectangular segments. The segments have to satisfy the following ratio: $0.83 \leq \Delta x/\Delta y \leq 1.2$. Compared to ISO 9614-2, the scanning paths must be orthogonal and the freedom to select them is limited.

To ensure the precision grade of the test, the measurement procedure consists of a number of criteria that must be met. For a chosen scanning path, the measurement should be performed twice. Two normal intensity levels averaged over the scanning partial surface are compared and if the difference is within tolerance, criteria 1 is met. The rest of the criteria are based on the values of calculated field indicators:

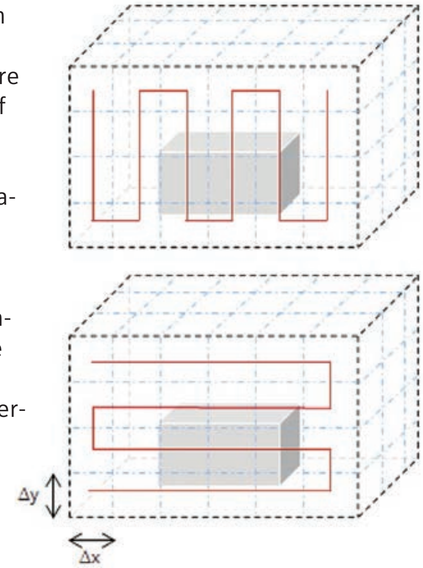

Figure 10: Orthogonal scanning paths on a rectangular partial surface.

- F_T – Temporal-variability indicator
- $F_{p|In|}$ – Unsigned pressure-intensity indicator
- F_{pIn} – Signed pressure-intensity indicator
- F_S – Field nonuniformity indicator

To qualify which grade of accuracy can be stated for the measurement, the remaining criteria have to be checked:

- Adequacy of the measurement equipment, based on F_{pIn}
- Presence of strong external noises, based on F_{pIn} and $F_{p|In|}$
- Field nonuniformity, based on F_S
- Adequacy of scan-line density, based on F_S

If all five criteria are met, the obtained intensity levels can be used to determine the sound power level of the source with grade 1 accuracy. ISO specifies a set of actions to be taken to increase the grade of accuracy if the criteria are not met. If the criteria cannot be satisfied, an ISO 9614-2-based method should be used.

The final result of the ISO 9614-3 is the octave band or 1/3 octave band-limited A-weighted sound power level, calculated based on the signed magnitude of the partial surface average normal sound intensity and area of that corresponding partial surface.

Measurement uncertainties

Measurement uncertainties characterize the dispersion of measured value due to different factors such as environmental conditions, test equipment accuracy, etc. All measurements are subject to uncertainty and a measurement result is not complete without an assessment of uncertainty.

Uncertainties in pressure-based methods

Sound power level calculations based on the ISO 3740 standards group require the uncertainties evaluation to be conducted in accordance with the ISO/IEC Guide 98-3. The uncertainties of measured sound power levels are estimated by the total standard deviation σ_{tot} and presented as the expanded measurement uncertainty U.

Total standard deviation

$$\sigma_{tot} = \sqrt{\sigma_{R0}^2 + \sigma_{omc}^2}$$

σ_{R0} - Standard deviation of reproducibility of the method

σ_{omc} - Standard deviation of the uncertainty due to instability of the operating and mounting conditions

Expanded measurement uncertainty

$$U = k \cdot \sigma_{tot}$$

k – Coverage factor, value of k depends on the desired level of confidence. For a normal distribution of measured values, $k = 2$. In that case, there is a 95 percent confidence that the measured values lie within the range of $(L_W - 2 \cdot \sigma_{tot})$ to $(L_W + 2 \cdot \sigma_{tot})$

The standard deviation σ_{omc} can be determined from repeated measurements in the same conditions (location, testing equipment, source, testing engineer, etc.). Most of the standards from the ISO 3740 group advise you to calculate the proper value of σ_{omc} and provide typical values. ISO 3743-1 and 3747 do not account for σ_{omc} when estimating the measurement uncertainty.

Table 2 – Typical values of σ_{omc}

σ_{omc} from operating and mounting conditions [dB]		
Stable	Unstable	Very unstable
0.5	2	4

The standard deviation σ_{R0} includes uncertainties due to all conditions and situations allowed by the ISO (environmental conditions, test equipment, type of source) apart from the uncertainties covered by σ_{omc} . The procedure for estimating σ_{R0} is well described in the standards, but in addition to that ISO provides typical upper-bound values of σ_{R0} for each ISO standard and each accuracy grade.

Table 3 – Typical upper bound values of σ_{R0}

Standard	Accuracy grade	A-weighted uncertainty σ_{R0} [dB]
ISO 3741	Precision	0.5
ISO 3743-1	Engineering	1.5
ISO 3743-2	Engineering	2
ISO 3744	Engineering	1.5
ISO 3745	Precision	0.5
ISO 3746	Survey[2]	3
ISO 3746	Survey[3]	4
ISO 3747	Engineering	1.5
ISO 3747	Survey	4

Based on the presented values, the total standard deviation and expanded measurement uncertainty for standards from the ISO 3740 group for a source operating and mounted in stable conditions are presented below:

Table 4 – σ_{omc} and U values of different ISO3740 standards

Standard	Accuracy grade	σ_{tot} [dB]	U [dB]
ISO 3741	Precision	0.5	1.4
ISO 3743-1	Engineering	1.5	3.2
ISO 3743-2	Engineering	2[4]	3.9
ISO 3744	Engineering	1.5	3.2
ISO 3745	Precision	0.5	1.2
ISO 3746	Survey[2]	3	6
ISO 3746	Survey[3]	4	8
ISO 3747	Engineering	1.5[4]	3
ISO 3747	Survey	4[4]	7.8

2 Noise sources that emit sound without significant tones
3 Noise sources that emit significant tonal components
4 Not accounting for σ_{omc}

Uncertainties in intensity-based methods

The uncertainties of sound power level determined with the ISO 9614 standards group are related to the nature of the sound field and absorption of the source, the external noise sources and the applied measurement procedure. They do not account for changes in operating or mounting conditions of the source. The final grade of accuracy is chosen based on the field indicators values, as well as the applied procedures to increase the accuracy of the measurements.

Because of the method's limitations, 1/1 octave bands from 63 Hz to 4 kHz or 1/3 octave bands from 50 Hz to 6.3 kHz are considered. Values of octave bands or 1/3 octave bands below 50 Hz or above 6.3 kHz can be omitted if their level is at least 6 dB below the computed A-weighted level.

ISO 9613-1 standard covers the intensity-based discrete measurement points method with three possible grades of accuracy: Precision, engineering and survey. The applicable grade depends on the calculated field indicators.

ISO 9613-3 standard covers intensity-based scanning method with one possible grade of accuracy: precision. If the requirements of this method cannot be met, ISO 9613-2 should be applied.

ISO 9613-2 standard covers the intensity-based scanning method with two possible grades of accuracy: Engineering and survey. The applicable grade depends on the calculated field indicators.

Table 5 – Standard deviation σ for different ISO 9613 parts

1/1 octave band center frequencies [Hz]	1/3 octave band center frequencies [Hz]	Standard deviation σ [dB]		
		Precision grade 1	Engineering grade 2	Survey grade 3
63 to 125	50 to 160	2	3	
250 to 500	200 to 630	1.5	2	
1,000 to 4,000	800 to 5,000	1	1.5	
	6,300	2	2.5	
A-weighted		1[5]	1.5[6]	4

Table 6 – Table 6 – Expected measurement uncertainty U for different ISO 9613 parts $U=\pm 2\sigma$ for a 95 percent certainty value

1/1 octave band center frequencies [Hz]	1/3 octave band center frequencies [Hz]	Expanded measurement uncertainty U [dB]		
		Precision grade 1	Engineering grade 2	Survey grade 3
63 to 125	50 to 160	4	6	
250 to 500	200 to 630	3	4	
1,000 to 4,000	800 to 5,000	2	3	
	6,300	4	5	
A-weighted		2[5]	3[6]	8

5 Only applicable for ISO 9614-3
6 Only applicable for ISO 9614-2

Who should measure sound power?

The standards presented in the previous sections explain how to measure sound power but do not impose any limits on the levels generated by the noise sources. These are called B-standards (from basic). Different standards and directives govern the limits for specific equipment. Within the European Union (EU), there are explicit limits on how much noise outdoor machinery can produce, putting pressure on manufacturers and end users. Anyone who wants to sell certain equipment on the European market has to measure its emitted sound power level and stay below the specified target set by national legislations. Other types of equipment do not need to meet specific targets, but the standards and directives require manufacturers to label their products with noise declarations; their guaranteed sound power levels. Standards that specify measurement procedures for a particular type of machinery or equipment are called the noise test codes, or C-standards. Following these standards ensures reliable and repeatable results.

EC/2000/14 directive on noise emission by equipment for outdoor use

The following directive provides a set of guidelines and requirements for manufacturers of outdoor equipment that is sold and operated within the EU.

It applies to a wide range of products enlisted in table 2. The directive places sound power level limits on 22 types of equipment. The directive also lists equipment that has to be marked with its guaranteed sound power level. For each of the listed types of equipment, requirements on the test methodology are provided (if applicable):

- Basic noise-emission standard (one of the previously explained b-standards)
- General supplements to the basic noise emission standards
- The test area
- The shape of the measurement surface
- Operating conditions during the test
- Mounting equipment
- Test under load/test and free of load
- Period of observation
- A method to calculate the resulting sound-power levels in the event that several tests with different operating conditions are used

In order to enable consumers and users to make a conscious choice, marking the equipment with its guaranteed sound power level is essential. The indicated values should be guaranteed by the manufacturer.

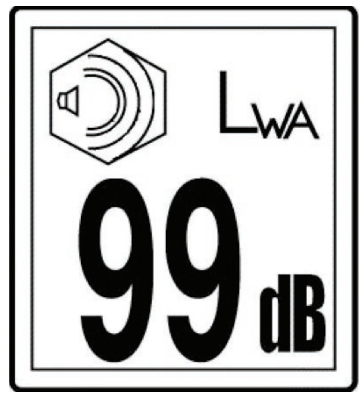

Figure 11: Indication of guaranteed sound-pressure level in accordance with directive 2000/14/EU.

The CE marking certifies that the equipment is in conformity with the provisions of this directive and any other relevant directives.

Figure 12: The CE marking is the manufacturer's declaration that the product meets the requirements of the applicable European Commission (EC) directives.

Table 6 – List of equipment covered by the 2000/14/EC directive

Builders’ hoists for the transport of goods	Equipment subject to noise marking
Compaction machines (only vibrating and nonvibrating rollers, vibratory plates and vibratory rammers)	Aerial access platforms with combustion engine brush cutters
Compressors (< 350 kW)	Builders' hoists for the transport of goods (with electric motor)
Concrete breakers and picks (hand-held construction winches, combustion-engine driven)	Building site band saw machines
Dozers (< 500 kW)	Building site circular saw benches
Dumpers (< 500 kW)	Chain saws (portable)
Excavators (hydraulic or rope-operated, < 500 kW)	Combined high-pressure flushers and suction vehicles
Excavator loaders (< 500 kW)	Compaction machines (explosion rammers only)
Graders (< 500 kW)	Concrete or mortar mixers
Hydraulic power packs	Construction winches (with electric motor)
Landfill compactors (loader-type with bucket, < 500 kW)	Conveying and spraying machines for concrete and mortar
Lawnmowers (excluding agricultural and forestry equipment, and multi-purpose devices, the main motorized component with an installed power of more than 20 kW)	Conveyor belts
Lawn trimmers/lawn hedge trimmers	Cooling equipment on vehicles
Lift trucks (combustion-engine driven, counterbalanced loaders, < 500 kW)	Drill rigs
Mobile cranes	Equipment for loading and unloading silos or tanks on trucks
Motor hoes (< 3 kW)	Glass recycling containers
Paver finishers (excluding paver finishers equipped with a high compaction screed)	Grass trimmers/grass hedge trimmers
Power generators (< 400 kW)	High-pressure flushers
Tower cranes	High-pressure water jet machines
Welding generators	Hydraulic hammers
	Joint cutters
	Leaf blowers
	Leaf collectors
	Lift trucks (combustion-engine driven, counterbalanced)
	Mobile waste containers
	Paver finishers (equipped with a high-compaction screed)
	Piling equipment
	Pipe layers
	Piste caterpillars
	Power generators (≥ 400 kW)
	Power sweepers
	Refuse collection vehicles
	Road milling machines
	Scarifiers
	Shredders/chippers
	Snow-removing machines with rotating tools (self-propelled, excluding attachments)
	Suction vehicles
	Trenchers
	Truck mixers
	Water pump units (not for use under water)

ISO 15744: Hand-held nonelectric power tools

The noise test code presented by this international standard allows you to determine and declare sound power and sound pressure level of hand-held nonelectric power tools.

This international standard is applicable to typical hand-held nonelectric power tools such as:

- Drills, tappers, grinders, belt sanders, polishers, rotary files, rotary sanders, die grinders and circular saws
- Orbital and random orbital sanders
- Jig saws, nibblers, oscillating saws, reciprocating saws, reciprocating files and shears
- Reciprocating saws, files and knives
- Oscillating saws and knives
- Hammers and riveting hammers, rammers, tampers, scaling hammers and needle scalers
- Drifters, plug-hole drills, rotary hammers, rock drills and stoppers
- Non-ratchet screwdrivers and nut-runners
- Screwdrivers and wrenches with ratchet clutches and pawl-type ratchet wrenches
- Impact wrenches and screwdrivers, air-hydraulic impulse wrenches and screwdrivers

Figure 13: Hand-held nonelectric power drill.

The use of this standard can be extended to other equipment that does not have a dedicated noise test code if the principles of their operation are similar to the operation of pneumatic and hydraulic equipment.

The measurement of sound power level should be performed according to ISO 3744 in a free-field testing environment over a reflecting plane. The standard specifies the requirements for:

- Power tool installation and mounting during noise tests
- Operating conditions (speed, device load and feed force)
- Measurement setup (number of microphones, measurement surface, number of runs)

The result of the ISO 15744 is the A-weighted sound power is determined directly from measured A-weighted sound pressure levels.

ISO 7779/ECMA-74: Information technology and telecommunications equipment

The noise test code presented by this international standard allows you to determine and declare the noise emission values of information technology (IT) and telecommunication equipment. Compared to the previously discussed standards, additional measurement positions are introduced in this approach: the operator and bystander positions (based on ISO 11201). Sound power level determination can be performed using the ISO 3741, ISO 3744 or ISO 3745.

The method is applicable to equipment that radiates broadband noise, narrowband noise, noise that contains discrete frequency components, or impulsive noise.

We can identify the equipment-type groups that follow the ISO 7779:

- Typewriters
- Character and line printers (not keyboard operated)
- Teleprinters (online or keyboard operated, standalone)
- Keyboards
- Copiers
- Card readers – card punches
- Magnetic tape units
- Disk units and storage subsystems (hard drives)
- Visual display units (screens monitors)
- Electronic units (processors, controllers, circuits, power supplies)
- Microform readers
- Facsimile machines (telecopiers) and page scanners (online or keyboard operated copy machines)
- Check processors
- Personal computers and workstations
- Page printers (personal printers)
- Self-service automatic teller machines (ATMs)
- Enclosures or rack systems

Figure 14: Copy machine.

Based on the type of equipment and mode of operation, different requirements for the measurement setup must be met:

- Mounting of the test equipment (table-top operated, floor-standing, wall-mounted, rack-mounted, hand-held)
- Operation mode
- Additional equipment (paper for printers or copiers, robot for pressing keys, etc.)
- Measurement duration
- Equipment specific parameters (for example, speed of disc rotation in the hard disc drive)
- If the operator or bystander position should be measured

The result of ISO7779 is the sound power level, but the type of the results depends on the type of equipment and noise in the frequency domain.

ISO 9296/ECMA-109: Declared noise emission values of computer and business equipment

The ISO 9296 Acoustics – Declared noise emission values of computer and business equipment is the standard used for declaration of acoustic noise emissions of IT equipment. The content of ISO 9296 is based on the first version of the European Computer Manufacturers Association (ECMA)-109 standard. Both standards are aligned. With the approach explained in ISO 9296, sound power levels are presented as A-weighted, statistically maximum values with the reporting of the measurements done according to ISO 7779. ISO 9296 is the only standard that must be declared when labeling IT noise emissions. In order to easily distinguish between sound power level and emission sound pressure level (which historically has been used by IT manufacturers), both standards suggest using the bel [B] scale, not the decibel [dB]; 1 bel is equal to 10 dB.

IEC 60704: Household electrical appliances

IEC 60704-1:2010 covers electric appliances (including their accessories or components) for household and similar use, supplied from mains or batteries. The first part of this standard describes the generic measurement setup. Depending on the appliance of interest, different parts of the standard have to be selected. The acoustic measuring methods are based on those described in ISO 3743-1, ISO 3743-2 and ISO 3744, or with the use of intensity methods as described in ISO 9614-1 and ISO 9614-2. The choice can be made depending on the available test environment. This standard allows you to obtain results with objective methods of engineering accuracy (engineering method, grade 2). The results of these measurements should be used for noise declaration, but they also allow the user to compare noise of appliances from the same family.

In other cases, the results can be taken as a basis for engineering action in the development of new products or in deciding on means for sound insulation. For all purposes, the standard specifies procedures with known accuracy. Product family-specific parts determine the conditions in which the measurements should be performed (such as the amount of dishes in the dishwasher).

IEC 60704 has the following parts:

- BS EN 60704-2-1:2015 vacuum cleaners
- BS EN 60704-2-2:2010 fan heaters
- BS EN 60704-2-3:2002, IEC 60704-2-3 dishwashers
- BS EN 60704-2-4:2012 washing machines and spin extractors
- BS EN 60704-2-5:2005+A1:201 electric thermal storage room heaters
- BS EN 60704-2-6:2012 tumble dryers
- BS EN 60704-2-7:1998 fans
- BS EN 60704-2-8:1997, IEC 60704-2-8:1997 electric shavers

- BS EN 60704-2-9:2003 electric haircare appliance
- BS EN 60704-2-10:2011 electric cooking ranges, ovens, grills, microwave ovens and any combination of them
- BS EN 60704-2-11:1999, IEC 60704-2-11:1998 electrically-operated food preparation appliances
- BS EN 60704-2-13:2011 range hoods
- BS EN 60704-2-14:2013 refrigerators, frozen-food storage cabinets and food freezers
- DD IEC/PAS 60704-2-15:2008 household food waste disposers

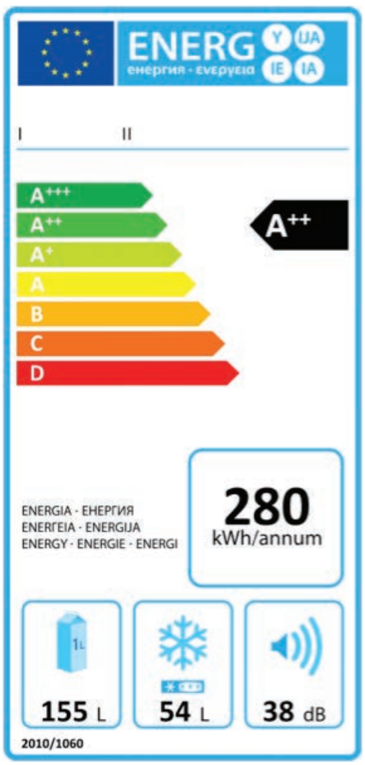

Figure 15: Energy label of a fridge with a noise-level declaration.

DIN 45635 standards

DIN 45635 is a group of German standards with the first three parts written in-line with previously explained B-standards. The parts with numbers above 3 are the noise test code documents, covering a broad range of equipment, such as chimneys, internal combustion engines, air-cooled heat exchangers, etc. There are currently over 70 parts (with nonconsecutive numbering). In time some of these standards became obsolete or were amended by the DIN ISO versions listed in Table 1.

ISO 6393: Earth-moving machinery measured in stationary test conditions

ISO 6393 is a noise test code for earth-moving machinery measured in stationary conditions. Specific procedures are given to obtain repeatable sound power measurements. In this approach, the measurement is performed in stationary conditions with the engine operating at the rated speed under no-load conditions and all attachments (buckets, dozers, etc.) connected as in the production version.

This standard covers the following machinery:

- Dozers (crawler or wheeled)
- Loaders (crawler, wheeled, skid steer and backhoe)
- Wheeled excavator (crawler, wheeled and walking)
- Dumpers (crawler, wheeled rigid-frame and articulated-framer)
- Scrapers (crawler, with one or two engines)
- Graders
- Pipe layers
- Trenchers (wheeled, crawler, walk-behind, disk)
- Landfill compactors (with loading or dozing equipment)
- Rollers (one or two drums)
- The testing environment should meet the requirements of ISO 3744, with three types of planes that can be used during the test:
- Hard-reflecting plane (concrete or nonporous asphalt)
- Combination of hard-reflecting plane and sand
- All-sand plane

The hard-reflecting plane should be used for the stationary measurement of all machines. The combination of hard-reflecting plane and sand may be used for rollers with raised pads and landfill compactors. The combination of hard-reflecting plane and sand or the all-sand plane may be used for crawler-type machines, except crawler-type excavators.

The measurement surface has to be a hemisphere. The sound power level measurement should be carried our according to ISO 3744. The measurements should be repeated at least three times. If two out of three resulting A-weighted sound power levels do not differ by more than 1 dB, the result can be accepted. A separate ISO standard, ISO 6394, covers the measurements at the operator position.

ISO 6395: Earth-moving machinery measured in dynamic test conditions

ISO 6395 is a noise test code for earth-moving machinery measured in dynamic conditions. The machine should be moving within the measurement surface with the attachments (buckets, dozers, etc.) connected as in normal operating mode. Actual work cycle tests are complex and the repeatability can become an issue.

The testing environment should meet the requirements of ISO 3744, with three types of planes that can be used during the test:

- Hard-reflecting plane (concrete or nonporous asphalt)
- Combination of hard-reflecting plane and sand
- All-sand plane

ISO 6395 covers the same types of machinery as the previously explained ISO 6393. Depending on the type of machine, measurements are made in:

- Travel mode (with the machine moving along the diameter of the measurement surface)
- Stationary work cycle mode
- A combination of the two,

This applies to when the machine is traveling both forward and reverse. ISO specified the operating conditions in which the test should be performed, including enabling backup alarms, level of fluid systems or warming up of the engine, machine velocity, etc.

The measurement surface has to be a hemisphere. The sound power level measurement should be carried out according to ISO 3744. The measurements should be repeated at least three times. If two out of three resulting A-weighted sound-power levels do not differ by more than 1 dB, the result can be accepted. A separate ISO standard, ISO 6396, covers the measurements at the operator position.

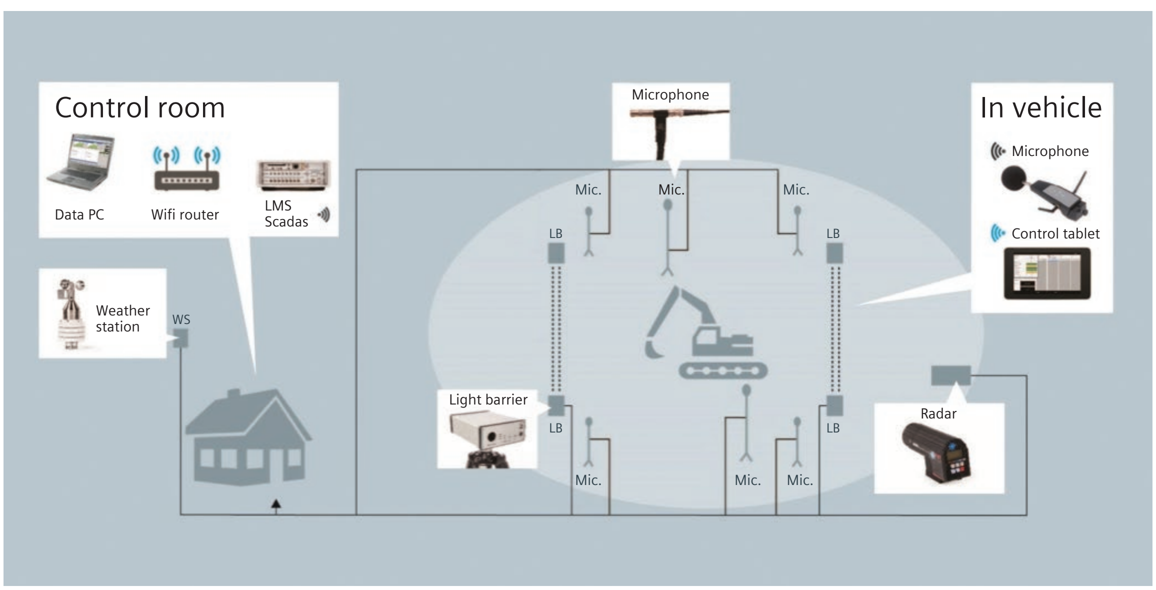

Figure 16: Test setup for ground-moving vehicle sound power measurement with operator position.

Equipment used to determine sound power

To obtain results that comply with the ISO standards and can be used for noise marking and noise limiting, good quality measuring equipment should be used. Each of the standards from the ISO 3740 and ISO 9614 families specify requirements on the equipment used to determine the sound-power levels based on the chosen method and desired grade of accuracy.

Table 7 lists the different kind of elements from the measurement setup. When a class 2 type of equipment is listed, it is often advised to use the class 1 version, if available. The grade of accuracy of the obtained results does not only depend on the equipment being used. Each of the standards accounts for different factors contributing to the precision of the final results.

Table 7 – List of standards governing the equipment used for sound power determination

	Grade of accuracy	Microphones	Intensity probe	Cables	Filters	Calibrator	Reference sound source
ISO 3741	Precision	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 61183, class 1	ISO 6926
ISO 3743-1	Engineering	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 60942, class 1	ISO 6926
ISO 3743-2	Engineering	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 60942, class 1	ISO 6926
ISO 3744	Engineering	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 60942, class 1	ISO 6926
ISO 3745	Precision	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 60942, class 1	–
ISO 3746	Survey	IEC 61672-1, class 2	–	IEC 61672-1, class 2	IEC 61260, class 1	IEC 60942, class 1	–
ISO 3747	Engineering	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 60942, class 1	ISO 6926
	Survey	IEC 61672-1, class 1	–	IEC 61672-1, class 1	IEC 61260, class 1	IEC 60942, class 1	ISO 6926
ISO 9614-1	Precision	–	IEC 61043, class 1	IEC 61043, class 1	IEC 61260, class 1	IEC 60942, class 1	–
	Engineering	–	IEC 61043, class 1	IEC 61043, class 1	IEC 61260, class 1	IEC 60942, class 1	–
	Survey	–	IEC 61043, class 2	IEC 61043, class 2	IEC 61260, class 1	IEC 60942, class 1	–
ISO 9614-2	Engineering	–	IEC 61043, class 1	IEC 61043, class 1	IEC 61260, class 1	IEC 60942, class 1	–
	Survey	–	IEC 61043, class 2	IEC 61043, class 2	IEC 61260, class 1	IEC 60942, class 1	–
ISO 9614-3	Precision	–	IEC 61043, class 1	IEC 61043, class 1	IEC 61260, class 1	IEC 60942, class 1	–

Conclusion

Choosing the correct standard to follow can be a challenge. The decision must take into account a number of factors: Type of noise source, available equipment and testing environment, regulations, etc. This white paper provides an overview of the existing standards as well as the applicable regulations and noise codes, but the decision to execute which tests and measurements ultimately rests with the product manufacturer.

To learn more about the different means of measuring sound power according to ISO standards, visit the webpages below and get in touch with our experts:

Sound pressure-based sound power testing
http://www.plm.automation.siemens.com/en_us/products/lms/testing/test-lab/acoustic/sound-power-testing.shtml

http://www.plm.automation.siemens.com/en_us/products/lms/testing/test-xpress/iso-sound-power.shtml

Sound intensity-based sound power testing
http://www.plm.automation.siemens.com/en_us/products/lms/testing/test-lab/acoustic/sound-intensity-testing-analysis.shtml

http://www.plm.automation.siemens.com/en_us/products/lms/testing/test-xpress/iso-sound-intensity.shtml

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