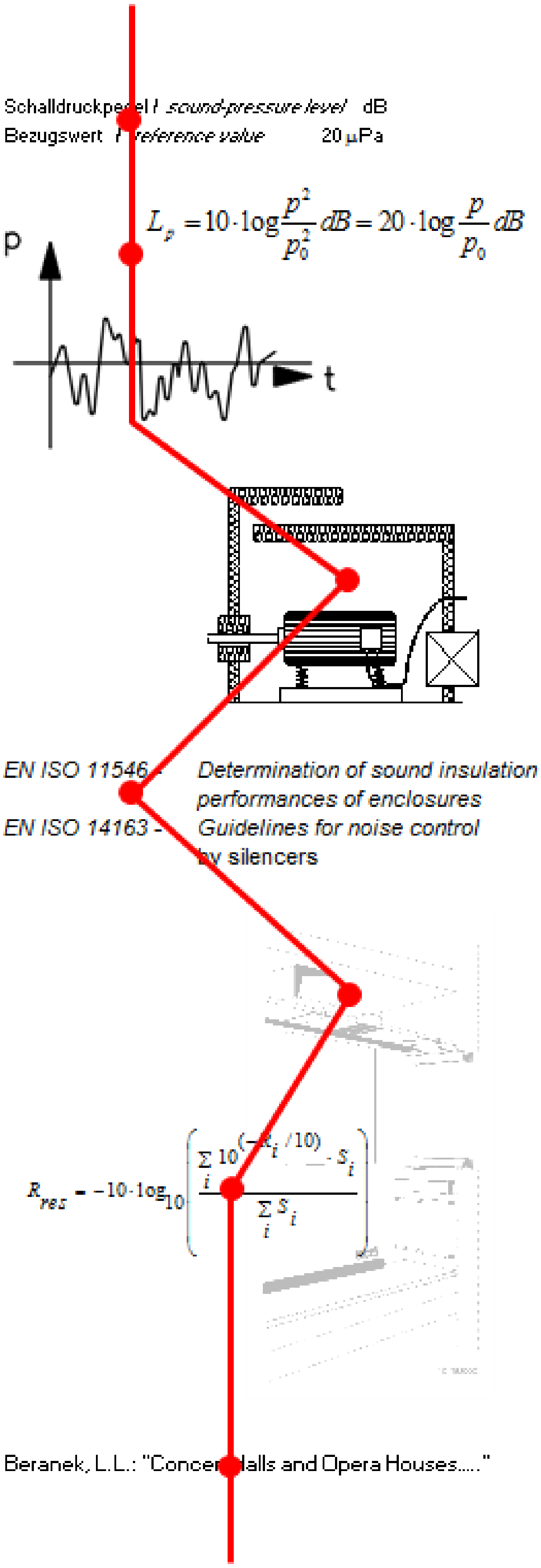
FESI Document A7

Guidance through FESI Documents A2 through A6

July 2013, 1st revised edition



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Guidance through FESI Documents A2 through A6

Contents

A7-0 Intention

The FESI Document A7 “Guidance through FESI Documents A2 through A6” is both a synopsis and a reading guide through a series of five papers on acoustical problems that present themselves to the builder and on their solutions.

The terminology used has been taken from CEN in close co-operation with the acoustical Technical Committee TC 126.

Upon completion of this document, the total series of acoustical documents does comprise the following titles:

- A2 “Basics of acoustics” – Rev.4, July 2013
- A3 “Product characteristics – Acoustic insulation, absorp tion, attenuation” – Rev.1, July 2013
- A4 “Acoustics in buildings” – Rev.1, July 2013
- A5 “Acoustics in rooms” – Rev.1, July 2013
- A6 “Industrial acoustics” – Rev. 3, July 2013
- A7 “Guidance through FESI Documents A2 through A6” - Rev.1, July 2013

The series of documents has been completed in 2008. It should be subjected to a thorough revision not later than 2012.

These acoustic documents of FESI do not intend to change or to relativize national regulations or national or international standards. Instead, frequent use is being made of these by quotation. Where documents are quoted without a date of edition, the respective most recent version of that document applies. Where documents are quoted with a date of edition, only the edition quoted applies, irrespective of possible more recent versions of that same document.

A7-1 Introduction

This synopsis and reading guide to the FESI acoustical documents mentioned above will allow for a first assessment of the content of documents A2 through A6 and the advisability or otherwise of a more detailed study of any of the issues indicated in the titles of these documents.

Additionally, chapters on noise control, acoustic comfort and the measurements and documentation of acoustic performance levels will be added.

In chapter 2 of this paper, the content of FESI documents A2 through A6 is briefly presented. The chapter gives an overview, so that the reader gets an indication about where to find what in the A2 through A6 series.

Chapter 3 of this document is then a consecutive discussion of a variety of acoustical problems that present themselves to the contractor. In that chapter, reference is being made to the individual chapters in papers A2 through A6, frequently in tabular form. Some problems are discussed under different aspects in more than one of the A2 through A6 series. Thus, chapter 3 serves as a quick reference.

Chapter 4 “Measurements and documentation” gives a complete list of all the regulations and standards that have been quoted in the entire series of documents.

A7-2 General characteristics of FESI Documents A2 through A6

First, some general characteristics of these documents are exposed, analysing later the most prominent characteristics of each of them:

- The documents have been written by consensus among professionals of the acoustic sector of countries represented in the Acoustic Commission of FESI. The diversity in the specialisation of the members of this commission is remarkable, which renders the approach to the problems addressed in these documents almost universal.
- A realistic approach to the acoustic information is given: practical topics, accompanied or justified with technical rationale.
- The a. m. information is complete, since it includes – exposing some limitations – all the aspects that can be considered important in usual acoustical applications.
- In addition, it is trustworthy, since the methodologies of calculation or design presented are internationally accepted.
- The information is related to standards, which are frequently quoted. This will assist harmonisation in the acoustic practice.
- The documents heed national legislation and have been written so that they do not present confrontation with legal differences between different countries, and they are mentioning the legislation (mainly directives) wherever possible.

Because of these reasons, the documents can give great service not only to the installer, but to any acoustic professional (e. g. teachers) who needs to consolidate or to extend his knowledge.

These documents, in their current format, can be slightly “dense”, since a lot of information is transmitted in little space. For this reason, they are especially useful as complementary to other information, or to acquire knowledge of a particular topic. Nevertheless and though they are conceived of complete and autonomous form, to use them as exclusive didactic material will demand a meticulous study, which is recommended to be completed by some additional reading.

A7-2.1 How to use these documents: Useful recommendations

Below, some particularly useful aspects of the documents are provided, primarily for those with some professional or practical knowledge of acoustics.

A7.2.1.1 FESI Document A2 “Basics of acoustics” (2001)

General explanations on acoustics and on the areas in which this topic is divided (A2-2), physical and technical bases of acoustics (A2-3), the relationship between acoustics and human response – time and frequency weighting – (A2-4), managing of levels and dB arithmetic (A2-5), standards and literature (A2-7), and introduction to the following documents (A3 – A6).

This document is not intended as a didactic workbook in the usual sense, but as a kind of “dictionary” that allows for an expeditious answer to any questions that may arise when reading the other FESI documents, or any acoustic documentation or books.

A7-2.1.2 FESI Document A3 “Product characteristics – Acoustic insulation, absorption, attenuation” (2002)

This document gives information on insulation (airborne noise and structure-borne noise), acoustic absorption and structure-borne sound damping. The text is presented with references to regulations, which are very useful as a complement to it. It can also be used as a “bridge” between traditional texts on these issues and “modern” requirements. The document is divided in:

- A3-2 “Terms and definitions” (acoustic insulation, attenuation)
- A3-3 “Airborne sound insulation”
- A3-4 “Structure-borne sound insulation”
- A3-5 “Airborne sound absorption”
- A3-6 “Structure-borne sound attenuation”.

In this chapter, some unusual items are studied, from which it is possible to emphasise:

- Explanations of some useful isolation parameters like R, R_W, etc.
- Practical information to apply the law of mass (both simple and double walls).
- Pipe isolations.
- Absorption: different values depending on the configuration of components (thickness of layers, gaps, etc.).
- Resonator absorber.
- Structure-borne noise damping.

A7-2.1.3 FESI Document A4 “Acoustics in buildings” (2007)

This document is of maximum interest and current importance, since it introduces information about the new approach to the calculation of insulation in buildings that is realised in Europe according to ISO 12354.

Chapter A4-2 deals with airborne sound insulation between rooms. It is a very interesting and clear information about parameters depending on the frequency, single-number parameters and their relationship. It also contains interesting information related to lateral transmissions (A4-2.4) and, especially, to parasitic transmission (A4-2.5).

In chapter A4-3, the acoustic insulation against outside noise is studied, putting extra emphasis on parasitic transmission in case of facades (A4-3.4).

Later, chapter A4-4 deals with the transmission of noise generated in a room to the outside, including information which can help to calculate the radiated acoustic power of buildings (A4-4.4).

In chapter A4-5, the impact sound insulation is analysed, describing how to reach a prediction of the impact sound pressure level (A4-5.4).

Finally, the building equipment noise is treated in chapter A4-6, including some basic precautions to take to limit noise emissions (A4-6.4).

A7-2.1.4 FESI Document A5 “Acoustics in rooms” (2007)

This document deals with the acoustic properties and characteristics of rooms (auditoria and electronic systems are not included). The document is divided in two general chapters. In the first one, acoustic performance in different rooms (A5-2), the main theoretical parameters used to study and characterise the acoustic answer of a room are introduced: reverberation (A5-2.2, an extensive and useful chapter), speech intelligibility (A5-2.3), sound propagation in rooms (A5-2.4), background noise in rooms (A5-2.5) and other parameters more complicated (A5-2.6).

The second chapter (A5-3) deals with how to obtain an acoustically satisfactory room (referring to its acoustical properties), in close relation with the information given in the first part (A5-2). In chapter A7-3.2 "Acoustic comfort" a table from acoustic document A5 has been copied which gives an overview of the information to be obtained from that document.

A table in A5-3.1 gives the key parameters for the acoustic performance of different rooms that are treated in A5.

For each room, after a short introduction, requirements, calculations and recommendations are explained.

A7-2.1.5 FESI Document A6 “Industrial acoustics” (2006)

In this document, we can distinguish two general chapters: noise propagation (A6-2) and noise control (A6-3). Beside exposing questions habitually treated in other texts, it is important to emphasise certain aspects of its content that should be of maximum interest, or that are not easily found anywhere else.

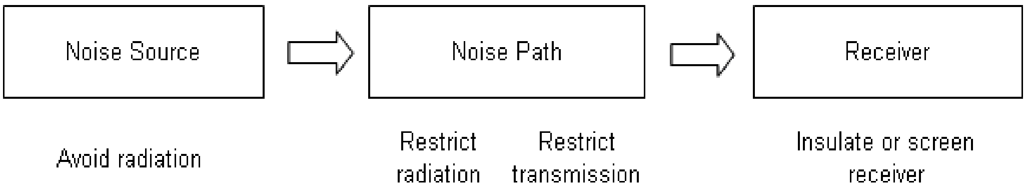
As for propagation, very interesting information is provided in the sub-chapters: A6-2.2 “Indoor sound propagation”, A6-2.2.1 “Diffuse field conditions” and A6-2.3 “Sound propagation in ducts, pipes and ventilation systems”.

Regarding noise control, very good and useful information is provided through a complete chapter, dealing with machinery noise and its reduction, and the absorption means applied to control noise. Practical advice for the installation of acoustic enclosures, screens and silencers is also given. The information is divided into three sub-chapters: A6-3.2 “Noise control at source”, A6-3.3 “Noise control on the propagation path” (including enclosures and silencers), and A6-3.3 “Noise control at the receiver”.

A7-3 Application of FESI documents

A7-3.1 Noise control

A general noise control methodology, the “source-path-receiver model” is dealt with in FESI Document A6 “Industrial acoustics”, described in chapter A6-3.1, Figure 28, page 25. This methodology is "general", i. e. it also applies to noise control in buildings and in the open.



The basic concept is that the further to the “left” the above model is attacked, the more effective noise abatement is obtained.

Consequently, noise control at the source has the highest priority while the poorest solution is to supply the human “receiver” with hearing protectors or encapsulate / enclose him in a small cabin. Control of noise along the transmission path is useful when the source cannot be sufficiently controlled.

A7-3.1.1 Noise control at source

Inside the source, too, a hierarchy is given:

1. Avoid noise generation – substitute with a more silent process and/or equipment.
2. Control the noise generation – choose low-noise process parameters.
3. Prevent the noise to be transmitted to an “amplifier-loudspeaker system”.
4. Decrease the noise radiation from the source. Among the tools are closely fitting enclosures, partial screening and absorption as well as closing openings with silencers or by tightening.

Tools for Noise control at source	Reference to FESI Documents	International standards
Source-Path-Receiver model	A6-3.1 Figure 28, p. 25	ISO/EN 11690
Low noise design	A6-3.2.2; A6-3.2.5: A6-3.2.6	ISO/EN 11688
Information on noise emission	A6-3.2.3	EN ISO 11689 ISO 1996 ISO 3741: ISO 3745: EN ISO 5135
Low noise process or machinery	A6-3.2.4	EN ISO 11688
Structureborne sound insulation	A3-4	
Enclosures	A6-3.3.2	ISO/DIS 15667:2000 ISO 11957
Insulation (covering of plane surfaces and pipes)	A6-3.3.2.1 – A3-3.3.2.2	EN ISO 15665
Silencers	A6-3.3.4	EN ISO 14163:1998 ISO/DIS 7235:2001
Vibration insulation	A3-4.1	
Vibration damping	A3-6	

A7-3.1.2 Noise control at the noise transmission path

When the generated noise has left the source, it can be controlled by classical methods. These are distance, absorbing materials for control of reflections, as well as screens and barriers which constitute obstacles for the direct travel of sound waves. Partitions are useful for separation of noisy activities from e. g. silent workplaces. Vibration insulators prevent vibrations and structure-borne noise to be spread over larger distances.

Tools for Noise control at the transmission path	Reference to FESI Documents	International standards
Outdoor sound propagation	A6	ISO 9613, part 1 + 2 ISO 1996
Room acoustics	A5 Acoustics in rooms	ISO/EN 11690 ISO/DIS 17624:2001 ISO 3382-2: EN 12354-6
Airborne sound insulation between rooms	A4-2	EN 12354-2
Acoustic insulation against outside noise	A4-3	EN 12354-3
Indoor sound propagation – diffuse field	A6-2.2.1	ISO/EN 11690 ISO 3382-2
Indoor sound propagation – flat rooms	A6-2.2.2	ISO/EN 11690 ISO 3382-2
Indoor sound propagation – complex situations	A6-2.2.3	ISO/EN 11690 ISO 3382-2
Sound propagation in ducts, pipes and ventilation systems	A6-2.3	EN ISO 15665
Absorption treatment	A6-3.3.1	EN 12354-6
Airborne sound absorption	A3-5	ISO 354: EN 29053
Sound absorbing materials	A3-5.4	EN 29053
Plane single walls – The mass law	A3-3.3.1.1	EN 12354
Double walls	A3-3.3.2	EN 12354
Enclosures	A6-3.3.2	ISO/DIS 15667
Screens	A6-3.3.3	ISO/DIS 17624
Silencers	A6-3.3.4	EN ISO 14163:1998 ISO/DIS 7235:2001
Pipes		ISO 15665
Vibration insulation	A6-3.3.5	
Structure-borne sound attenuation	A3-6	

A7-3.1.3 Noise control at the receiver
Receiver is a technical expression for a position where human beings could be exposed to noise. The receiver positions for measurements are regulated by national authorities.

Environmental noise limits are protecting people against noise exposure from neighbouring industries or traffic. Environmental noise control at the receiver also comprises sound insulation of building elements like facades, windows and doors.

Occupational noise limits are protecting employees against hearing damage as well as ensuring good communication and acoustic comfort (Annex B). Noise control at the receiver includes hearing protectors, cabins and the like.

Most noise limits given by authorities are based on the equivalent noise level over a period.

Tools for Noise control at the receiver (under construction)	Reference to FESI Documents Interactive	International standards
Environmental noise limits		Directive 2002/49/EC
Occupational noise limits		Directive 2003/10/EC
Equivalent noise level	A2 should be …	
Limiting exposure	A6-3.5.1	ISO 9612
Cabins / personnel enclosures	A6-3.5.2	ISO 15667:2000 ISO 11957 EN 12354-6
Individual protection	A6-3.5.3	
Acoustic insulation against outside noise	A4-3	EN 12354-3

A7-3.2 Acoustic comfort

Regrettably, no European regulation deals with this subject and there are only very few legislative demands existing in EU countries. Equally, standardisation on this subject is scarce. Therefore it is required to consult very specialised books to obtain any information about acoustic comfort. It is because of these facts that aspects of acoustic comfort play a major part in the series of FESI acoustic documents.

The most important information on acoustic comfort given in FESI documents is in A5 "Acoustics in rooms". The information given in other documents is shown in the table below.

Subject	**Information**	**Reference to FESI documents**	**International standards**
Sound absorption	Basic information	A3-2	
	Materials and absorption coefficient α	A3-5	
Building equipment	Basic information on noise levels	A4-6	
	Information on equipment noise	A4-6.3	
Reception areas	Basic information on maximum sound pressure levels	A4-6.1	
Industrial noise	Detailed information on indoor sound propagation	A6-2.2	
	Basic information on comfort and security aspects	A6-4	
Acoustic performance in rooms	Detailed information on reverberation	A5-2.2	
	Detailed information on speech intelligibility	A5-2.3	
	Detailed information on sound propagation	A5-2.4	
	Background noise and noise criteria curves	A5-2.5	
	Special parameters (clarity, spaciousness, harmony criteria)	A5-2.6	
Recommendations for different rooms	In all cases: general information, requirements and recommendations		
	Offices (reverberation time and intelligibility)	A5-3.2	
	Classrooms / Kindergarten (reverberation time and intelligibility)	A5-3.3	
	Workshops	A5-3.4	
	Meeting rooms (reverberation time and intelligibility)	A5-3.5	
	Sport rooms	A5-3.6	
	Large offices, open spaces (many parameters)	A5-3.7.1	
	Restaurants	A5-3.7.2	
	Large auditorium, concert halls	A5-3.8	
	Multi-purpose rooms	A5-3.9	
	TV / Music recording studios	A5-3.10	
	Cinemas	A5-3.11	
	Rooms with hygienic requirements	A5-3.12	
	Improvement of acoustical characteristics of exiting rooms	A5-4	

Where to look for the most important aspects constituting acoustic comfort:

- reverberation time,
- speech of intelligibility,

- noise level requirement

is shown in the table next hereunder.

Chapter	Type of room	Reverberation time	Speech intelligibility	Noise level requirement	Special treatment	Difficulty to study
A5-3.2	Office	X		X		
A5-3.3	Classroom / Kindergarten	X	X	X		
A5-3.4	Workshop	X	(X)	X	X	
A5-3.5	Meeting room	X	(X)	X		
A5-3.6	Sport room / gym	X	(X)	(X)	X	
A5-3.7.1	Large office		(X)	X	X	
A5-3.7.2	Restaurant		(X)		(X)	
A5-3.8	Large auditorium	X	X	X	X	XX
A5-3.9	Multi-purpose room	X	X	X	X	X
A5-3.10	TV / recording studio	X		X	XX	X
A5-3.11	Cinemas	X			XX	X
A5-3.12.1	Reverberant	X			XX	X
A5-3.12.2	Anechoic				XX	XX
A5-3.13	Clean room				X	

X applicable (X) applicable in special cases XX extremely important

For each room, after a short introduction, requirements, calculations and recommendations are explained.

A7-4 Measurements and documentation

The main values used to characterise airborne sound are

- sound pressure level and its time relation,
- sound power of a source and its time relation.

These values describe both the noise being originated by sound sources – engines, musical instruments, speech – and the perception of sound by the human ear. They describe, as well, the danger of hearing damage due to high noise levels.

Sound pressure and noise frequency describe, too, the danger of hearing damage due to high noise levels.

Regarding the “structure-borne” sound, as it only reaches the human ear once the “vibration” of the structure which “bears” the sound has caused an airborne sound at the surface of that structure, the same values can be used for the purposes contained in these documents.

The above values, too, are involved in the parameters used to describe noise control (sound insulation and attenuation) in the evaluation and improvement of room acoustics, and in the protection of human hearing against unacceptable noise at workplaces, leisure and living areas.

A7-4.1 Sound pressure / sound pressure level

Sound pressure usually characterised by the sound pressure level, is the value which can be measured most easily. An appropriate sound receiver, the human ear or the microphone of a sound level meter, registers a pressure fluctuation being influenced by

- the radiated signal of the sound source (an engine);
- the distance to the sound source;
- background noise (ambient noise) and
- the environment in the area of the receiver (reverberant workplace or free field).

Due to these influences, the sound pressure level is not a solely “source-specific” value, i. e. not a quantity to describe e. g. engine emissions.

Sound pressure levels and their measurements are the bases of:

- an evaluation of noise at the workplace;
- an evaluation of noise in the neighbourhood;
- the generally applied determination of sound power of engines, e. g. with the objective to reduce noise and to dimension noise protection measures as well as
- sound attenuation measurements between rooms and in test facilities.

Measured quantities (sound pressure level, time weighting, frequency weighting, etc.) and hence the measuring equipment and measuring methods have to be chosen according to task and requirement.

Methods and requirements are stipulated in many standards and regulations. Below we will give the most useful of these, depending on the type of measurement. Even as these documents are of general application, each country has additional specific regulations which might need to be consulted. In FESI acoustic documents, there are references to some of these standards

Environmental noise

- Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise
- ISO 1996 -1: 2003. Acoustics – Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures.
- ISO 1996 - 2: 2007. Acoustics - – Description, measurement and assessment of environmental noise – Part 2:
- Determination of environmental noise levels

Occupational noise

- Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)
- ISO 1999:1990: Acoustics – Determination of occupational noise exposure and estimation of noise-induced hearing impairment
- ISO 9612:1997: Acoustics – Guidelines for the measurement and assessment of exposure to noise in a working environment

Determination of the sound power of engines

See chapter 47-4.2

Sound insulation measurements between rooms and in test facilities

The airborne sound insulation of building components like walls, ceilings, doors, windows and facades, both in a test facility and between rooms in buildings, will also be determined by a sound pressure level measurement considering room properties (reverberation times).

First of all, the measurements being performed in test facilities with suppressed flanking transmissions serve the determination of properties or the classification of constructions and building components. Measurements in buildings aim at determining the airborne sound insulation and the noise protection of occupants.

- EN ISO 1401-11: Acoustics – Measurement of sound insulation in buildings and of building elements (Some of these standards are intended for laboratory measurements, another for field measurements)

To calculate the insulation parameters, reverberation time too, is frequently required. Chapter A7-4.4 deals with its measurement.

Measuring equipment

The following standards, which characterise response and capabilities of measurement equipments, can be interesting to understand their functioning.

- CEI 61672-1 Electro acoustics – Sound level meter – Part 1: Specifications
- CEI 61672-2: Electro acoustics – Sound level meter – Part 2: Pattern evaluation

Rules and legislation also refer to other equipment standards (sound calibrators, octave band filters, etc.), but they are very specialised, and required only for manufacturers.

A7-4.2 Sound power / sound power level

The sound power or the sound power level is a source-specific value which is independent of the surrounding field and external influence. For instance, the sound power of an engine in constant normal operation, i. e. a direct comparison between a low-noise and a “loud” product is possible (see information according to Directive 98/37/EU).

Sound power is a useful parameter to predict the effect of a sound source on the surroundings. Also, it is possible to calculate the sound pressure level originated, taking into account the features of the environment and some rules of acoustic radiation. For this, another specific parameter of the sound source is needed, which has a close relation with the sound power: the directivity – the different sound radiations, depending on the direction.

Examples:

- Highly situated stack opening with short distance to the immission point of spherical wave propagation.
- Stack opening at long distance to the immission point of hemispherical propagation.
- Pipe at large height linear source.
- Sound source in reverberant room / room.

To determine the sound power of engines, normally sound pressure levels will be measured on a defined enveloping surface. With corrections for background and room influences, a source specific value is established (engine-specific).

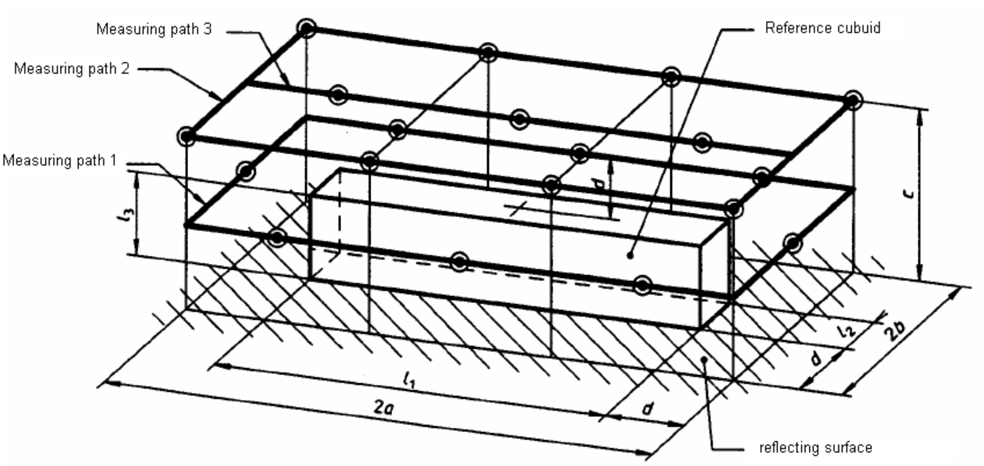


Figure with rectangular enveloping surfaces according to standards.

The following body of rules describes different methods to determine and weigh the sound radiation of engines and equipment:

ISO 3471:1999, Acoustics – Determination of sound power levels of noise sources using sound pressure – Precision methods for reverberation rooms	EN ISO 3741:1999
ISO 3743-1:1994, Acoustics – Determination of sound power levels of noise sources – Engineering methods for small, movable sources in reverberant fields – Part 1: Comparison method for hard-walled test rooms	EN ISO 3743-1:1995
ISO 3743-2:1994, Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering methods for small, movable sources in reverberant fields – Part 2: Methods for special reverberation test rooms	EN ISO 3743-2:1996
ISO 3744:1994, Acoustics – Determination of sound power levels of noise sources using sound pressure – Engineering method in an essentially free field over a reflecting plane	EN ISO 3744:1995
ISO 3746:1995, Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane	EN ISO 3746:1995
ISO 3747:2000, Acoustics – Determination of sound power levels of noise sources using sound pressure – Comparison method for use in situ	EN ISO 3747:2000
ISO 12001:1996, Acoustics – Noise emitted by machinery and equipment – Rules for the drafting and presentation of a noise test code	EN ISO 12001:1996

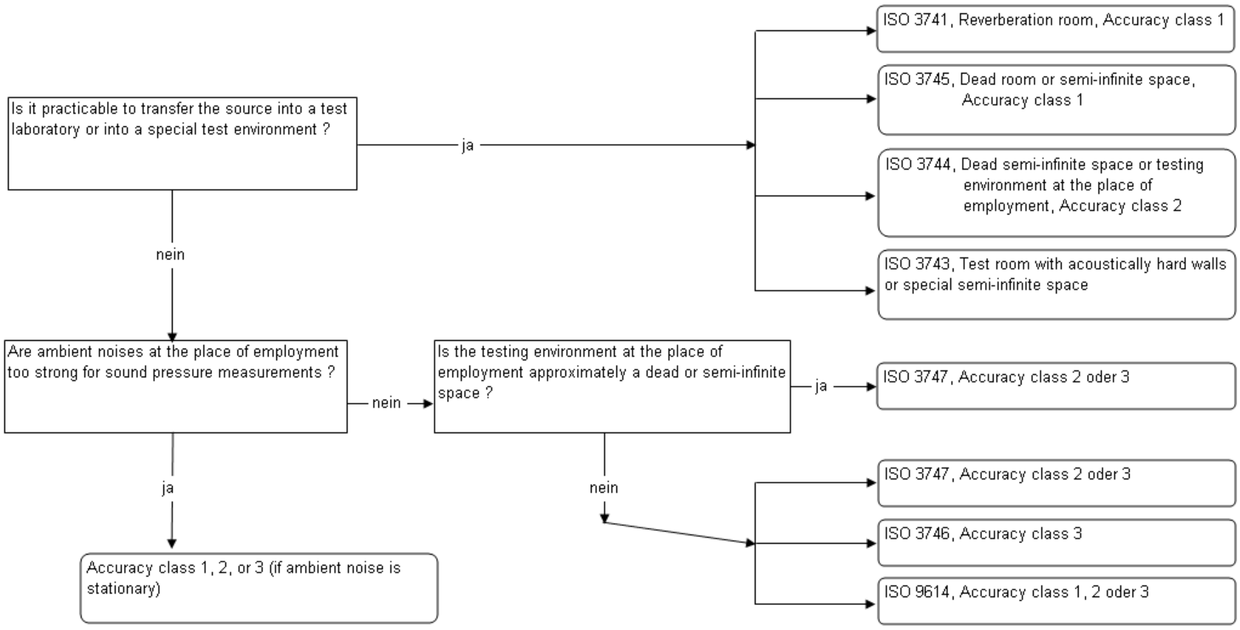
ISO 4871:1984, Acoustics – Noise labelling of machinery and equipment

ISO 6926:1990, Acoustics – Determination of sound power levels of noise sources – Requirements for the performance and calibration of reference sound sources

ISO 7574-1:1985, Acoustics – Statistical methods for determining and verifying stated noise emission values of machinery and equipment – Part 1: General considerations and definitions

ISO 7574-4:1985, Acoustics – Statistical methods for determining and verifying stated noise emission values of machinery and equipment – Part 4: Methods for stated values for batches of machines

Flow chart as guidance for the selection of suitable international standard(s) for the determination of the sound power levels of equipment and machinery.



a) The emission sound pressure level at the workplace or st other defined locations (see ISO 11200 series of documents) may be measured in the same testing environmaent.
b) ISO 9614 may be used in most testing environments which apply to then ISO 3740 and subsequent documents.

A method more complex, also valid to obtain the sound power of a source, is based on intensity measurements, and will not be considered here.

ISO 9614-1:1993, Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurements at discrete points	EN ISO 9614-1:1995
ISO 9614-2:1996, Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 2: Measurement of scanning	EN ISO 9614-2:1996

A7-4.3 Frequency / frequency components of noise A2-3.1.3

Sound pressure level and sound power level are quantitative values. Where qualitative information is required, it is necessary to use frequency analysis (spectrum analysis). Dependent upon the requirement, the bandwidth octave, third-octave or narrow band may be used.

The spectral sound pressure and sound power level in connection with the frequency distribution form the basis of the assessment of noise and the dimensioning of noise protection measures by insulation or attenuation / absorption. As a general idea, the insulation and the attenuation of low-frequency noise require e. g. large masses / weights per unit area and large absorption thicknesses, while high-frequency noise can be insulated or attenuated with small weights per unit area and lower absorption thicknesses. A more detailed discussion is in FESI document A3 “Acoustics in buildings”.

A7-4.4 Reverberation time A5-2.2.3

The sound development in a room – the room response to noise – depends on the propagation characteristics of the source (directivity) and the room’s geometry and surfaces, i. e. whether the room has a reverberant or absorbing characteristic. The “reverberation time” T is the value most widely used to characterise the response of a room.

The measurement of the reverberation time is comprehensively described in document A5, chapter A5-2.2.4 so that it will not be considered in this document.

Further notes regarding requirements, measuring methods and measuring instruments are described in the following documents:

EN ISO 3382:2000, Part 1, Acoustics – Measurement of the reverberation time of rooms with reference to other acoustical parameters.

ISO 3382:2000, Part 2 Acoustics – Measurement of room acoustic parameters – Reverberation time in ordinary rooms.

A7-4.5 Weighted levels

An evaluation of noise immission levels with regard to the perception by human beings (annoyance, loudness), hearing impairment, power of concentration, etc. will be made on the basis of the sound pressure level.

The annoyance / irritation caused by a noise is described mainly by:

- time weighting (Fast, Slow, L_{eq}, L_{max}, $L_{x\%}$, L_{den}, etc.) ➔ A2-4.1, 5.3 – 5.5);
- frequency weightings “A”, “C”, “noise rating” ➔ A2-4.2;
- tonal component.

The non-continuous noise is measured with a sonometer, selecting the time response (time weighting) “fast”, “slow” or “impulse”. Depending on the annoyance caused by the noise, “maximum instantaneous levels” (“peaks”) are only used in hearing loss prevention. Normally, regulations or standards give advice to choose the correct weighting.

The frequency-dependent evaluations “A” or “C” – noise rating curves, etc. consider that low-frequency noise components with relatively high sound levels will be perceived as less irritating than high-frequency noise components with the same sound level. A more detailed discussion is found in FESI document A2 “Basics of Acoustics”.

Narrow-band “maximum instantaneous levels” (A2-3.3), i. e. tonal components like “low-frequency humming noises” or “high-frequency singing tones” mean an additional interference.

DIN 45681 Acoustics – Determination of the tonality of noises and evaluation of sound-additions for the assessment of noise immissions.
DIN 45681 Amendment 2

Standards on impulses:

ISO 10843:1997 Acoustics – Method for the description and physical measurement of single impulses or series of impulses

A7-4.6 Special acoustic measurements

A7.4.6.1 Building acoustic measurements (airborne sound insulation, impact sound level) / Omni-directional sound sources

The complete measurement system includes a spectrum analyser with two or more channels and a sound source, assisted by a PC software to record and calculate the results.

There are several types of omni power sound sources using a cluster of 12 loudspeakers in a dodecahedral configuration (see figure below), that radiate sound evenly with a spherical distribution and fulfil the relevant standards, e. g. DIN 52210, ISO 140 and ISO 3382.

The system measures the parameters needed and calculates the weighted sound reduction index according to national and international standards.

For room acoustic qualification, it can measure reverberation time and several other parameters. More details are given in FESI document A5 “Acoustics in rooms”, chapter 2.6.

The system measures the parameters needed and calculates the weighted sound reduction index according to national and international standards.

The impact sound measurements shall be conducted using a normalised tapping machine (A4-5.3).

Generally, the measurement of impact noise levels (vertical but also horizontal) is executed with a standardized hammer - mechanism. The electrically powered “ hammer “ , placed on the floor of a room, produces defined “beats”. In the room below, but also in rooms at the same level, air-borne sound levels result, which are dependent upon the “reception room correction” according to the building design.(e,g. standard impact noise level Ln) – see A4-5.3

A7-4.6.2 Sound intensity measurements

Nowadays, there has been an increasing interest in measuring the sound intensity, mostly for the investigation and localisation of noise sources. Sound intensity describes the flow of acoustic energy produced by a sound source, or sound power per unit area. Intensity = energy/(time *area) or intensity = power/area. Intensity is direction dependent., the basic units are W/m².

Many sound intensity measurements are made relative to a standard threshold of hearing intensity Io : 10^{-12} W/m²

Unlike simple microphones and sound level meters, sound intensity measurements accurately capture only the sound produced by the source under test, eliminating interference from other sounds. This is not always easy to achieve. The dominating method of measuring sound intensity is based on a combination of two pressure microphones

A7 – 4.6.3 Acoustic Holography

Acoustic holography is an acoustic measurement technique used to determine the spatial propagation of acoustical waves, or for detecting acoustical sources or objects. It is based on spatial fourier transformations of the time signal and on its interaction with the surrounding surfaces.

The object of acoustic holography is to solve the inverse acoustical problem: to determine the location of a source.

But this is not the purpose of this text, and this technology is reserved to specialists.

A7 – 4.6.4 Measurements of room acoustic parameters other than reverberation time

We discussed the measurement of reverberation time as the most frequently used acoustic parameter for the description of the acoustic quality of a room.

For accurate measurements of other room acoustic parameters (see A5-2), special measurement equipment and specially developed software packages are being used.

PC software is used for measuring a wide range of room acoustic parameters, based on the measurement and analysis of impulse responses. This is again an activity for specialists, respectively acoustic consultants.

A7 - 4.6.4.1 Speech intelligibility – Measurements of the Speech Transmission Index (STI) or Room Acoustic Speech Transmission Index (RASTI)

Technically, STI is calculated as the weighted sum of Modulation Transfer Indices (MTI), taking into account auditory effects (according to IEC 60628.16).

RASTI is a simplified version of STI, intended to emulate STI under typical room acoustical conditions. To obtain correct RASTI values, the sound characteristics required are the same as those which must be met for the STI method.

RASTI is calculated as the weighted sum of MTIs over 500 Hz and 2000 Hz octave bands.

The expected speech intelligibility value is easy to calculate from the STI measuring data according to A5-2.3.2.

A7-4.6.4.2 Other room acoustic parameters

There are several room acoustic parameters which are important for qualifying the halls acoustically. Generally, the following parameters are the most important, and they give a good correlation with the subjective impression of the public (A5-2.6):

- Early Decay Time (EDT)
- Clarity (C_{80})

The measuring data of the interaural cross-correlation coefficient, the Binaural Quality Index (BQI), correlates very well with the subjective ratings of acoustic quality in concert halls.

For the measurements, a two-microphones receiver is being used, e. g. the microphones taped at the entrances to the ear canals of human beings.

There are several kinds of dummy head systems available that can be used for measurements of IACCs (see figure below).

A7-5 Standards and bibliography

EN ISO 3740 Acoustics - Determination of sound power levels of noise sources
- Guidelines for the use of basic standards

EN ISO 3741 Acoustics - Determination of sound power levels of noise sources using sound pressure
- Precision methods for reverberation rooms

EN ISO 3743 Acoustics - Determination of sound power levels of noise sources
- Engineering methods for small, movable sources in reverberant fields –
Part 1: Comparison method for hard-walled test rooms
Part 2: Methods for special reverberation test rooms

EN ISO 3744 Acoustics - Determination of sound power levels of noise sources using sound pressure
- Engineering method in an essentially free field over a reflecting plane

EN ISO 3746 Acoustics - Determination of sound power levels of noise sources using sound pressure
- Survey method using an enveloping measurement surface over a reflecting plane

EN ISO 3747 Acoustics - Determination of sound power levels of noise sources using sound pressure
- Comparison method for use in situ

EN ISO 11688 Acoustics - Recommended practice for the design of low-noise machinery and equipment"
- Part 1: "Planning" (ISO TR / 11688-1:1995)
- Part 2: "Introduction to low noise design" (ISO / TR 11688-2:1998)

EN ISO 11690 Acoustics - Recommended practice for the design of low-noise workplaces containing machinery"
- Part 1: "Noise control strategies"
- Part 2: "Noise control measures"
- Part 3: "Sound propagation and noise prediction in workrooms"

EN ISO 11689	Acoustics - Procedure for the comparison of noise-emission data for machinery and equipment"
EN ISO 14163	Acoustics - Guidelines for the sound protection by silencers"
EN ISO 15665	Acoustics - Acoustic insulation for pipes, valves and flanges"
EN ISO 16032	Acoustics - Measurement of sound pressure level from service equipement in buildings - Engineering method
EN 29035	Acoustics – Materials for acoustic applications; Determination of flow resistance.
ISO 12001	Acoustics - Noise emitted by machinery and equipment - Rules for the drafting and presentation of a noise test code
ISO 4871	Acoustics - Noise labelling of machinery and equipment
ISO 6926	Acoustics - Determination of sound power levels of noise sources - Requirements for the performance and calibration of reference sound sources
ISO 7574-1	Acoustics - Statistical methods for determining and verifying stated noise emission values of machinery and equipment - Part 1: General considerations and definitions - Part 4: Methods for stated values for batches of machines
EN 12354	Building acoustics - Estimation of acoustic performance of buildings from the performance of elements : Part 1: Airborne sound insulation between rooms Part 2: Impact sound insulation between rooms Part 3: Airborne sound insulation against outdoor sound Part 4: Transmission of indoor sound to the outside Part 5: Installation Noise Part 6: Sound absorption in enclosed spaces
ISO/DIS 7235	Acoustics - Laboratory measurement procedures for ducted silencers and air-terminal units - Insertion loss, flow noise and total pressure loss
ISO/DIS 15667	Acoustics - Guidelines for noise control by enclosures and cabins
ISO/DIS 17624	Acoustics - Guidelines for noise control in offices and workrooms by means of acoustical screens
ISO 354:2003	Measurement of sound absorption in a reverberation room
ISO 1996	Description and measurement of environmental noise
ISO 11957	Determination of sound insulation performance of cabins – Laboratory and in situ measurements
ISO 3382-2	Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms
ISO 3745	Sound power level: Precision methods for anechoic and semi-anechoic rooms

A list of additional acoustic standards that might be of interest will be provided shortly on the web-site of the FESI Acoustic Commission.

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