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Acoustics — Acoustic insulation for pipes, valves and flanges

Acoustique — Isolation acoustique des tuyaux, clapets et brides

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 15665:2003), which has been technically revised.

The main changes are as follows:

— addition of Class D2 and D3 Insertion Loss from Shell DEP 31.46.00.31 to expand the purview of this document;

— addition of new pipe sound sources to incorporate pneumatic pumps and solid pellet conveyors;

— updates to Clause 6 relating to insulation construction and system material components to incorporate newer technologies and materials;

— change of previous Clause 9: "*Acoustic insulation constructions that meet the insulation class requirements*" into Annex A to update and expand the use of various, newer material system constructions. Additional emphasis placed on the requirement for insertion loss testing, as defined in this standard, for determining acoustic performance of pipework insulation systems

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Acoustics — Acoustic insulation for pipes, valves and flanges

1 Scope

This document defines the acoustic performance of four classes (Classes A, B, C and D) of pipe insulation. It also defines a standardized test method for measuring the acoustic performance of any type of material system construction, thereby allowing existing and new insulation constructions to be rated against the four classes. Furthermore, this document presents some typical types of construction that would be expected to meet these acoustic performance classes.

This document is applicable to the acoustic insulation of cylindrical steel pipes and to their piping components. It is valid for pipes up to 1 m in diameter and a minimum wall thickness of 4,2 mm for diameters below 300 mm, and 6,3 mm for diameters from 300 mm and above. It is not applicable to the acoustic insulation of rectangular ducting and vessels or machinery.

This document covers both design and installation aspects of acoustic insulation and provides guidance to assist noise control engineers in determining the required class and extent of insulation needed for a particular application. It gives typical examples of construction methods, but the examples are for information only and not meant to be prescriptive.

This document emphasises the aspects of acoustic insulation that are different from those of thermal insulation, serving to guide both the installer and the noise control engineer. Details of thermal insulation are beyond the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 354, *Acoustics — Measurement of sound absorption in a reverberation room*

ISO 3741:2010, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Precision methods for reverberation test rooms*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
piping
cylindrical pipes and fittings such as valves, flanges, bellows and supports

Note 1 to entry: Piping is a pipe, or a system of pipes used to convey fluids (solids, liquid or gas) from one location to another. Piping fittings: Fittings are used in pipe systems to connect straight sections of pipe and adapt to different sizes or shapes.

3.2
acoustic insulation
acoustic lagging
outer cover applied with the aim of reducing the noise radiated from the pipe

Note 1 to entry: Acoustic insulation/acoustic lagging typically consists of a sound-absorbing and/or resilient material ("porous layer") on the piping and an impermeable outer cover ("cladding"). The term "insulation" used for the remainder of this standard refers to insulation and to lagging, which are both considered to be the same thing.

3.3
airflow resistivity
pressure drop per unit thickness of a porous material encountered by a steady air flow of unit velocity through the material

Note 1 to entry: Airflow resistivity equals the pressure drop divided by the product of the air velocity and the thickness of the sample.

Note 2 to entry: The unit of airflow resistivity is N s/m^4 = Pa s/m^2.

Note 3 to entry: Procedures for determining the flow resistivity are described in ISO 9053-1 and ISO 9053-2.

3.4
insertion loss
sound power insulation
D_W
difference in the sound power level radiated from a noise source before and after the application of the acoustic insulation for any octave or one-third-octave band

Note 1 to entry: Insertion loss is measured in decibels.

Note 2 to entry: See Notes to entry 2 and 4 to 3.5.

3.5
sound pressure insulation
D_p
difference in the sound pressure level, at a specified position relative to the noise source, before and after the application of the acoustic insulation for any octave or one-third-octave band

Note 1 to entry: Sound pressure insulation is measured in decibels.

Note 2 to entry: For noise sources located indoors, especially for laboratory measurements, the determination of sound power insulation, D_W, is most appropriate. D_W can be determined in a reverberation room or with sound intensity measurements. Sound intensity measurements can also be used to obtain D_W in the field. Methodology for determining sound power using sound intensity should refer to ISO 9614-1 or ISO 9614-2 as is most appropriate.

Note 3 to entry: For piping outdoors in field situations, the determination of sound pressure insulation, D_p, is less accurate but can be a more practical approach provided extraneous noise sources do not significantly impinge upon the measurements. The sound pressure measurement positions should be selected in relation to the design goal of the acoustic insulation, which will in general be in a circle around the piping. It is preferable to use a measurement distance of 1 m from the pipe surface, or 2,5 times the pipe diameter for pipes less than or equal to 0,33 m in diameter, to minimize near field measurement effects.

Note 4 to entry: The measurement positions and plant operational conditions for determination of D_W or D_p should be the same with and without the acoustic insulation. If the radiation patterns of both the untreated and acoustical insulated piping are "cylindrical omni-directional", the two measures (D_W and D_p) yield the same result.

3.6
anechoic termination
non-reflecting acoustic assembly located at the end of a pipe or duct, which transforms a pipe or duct of finite length into an acoustically infinite long pipe/duct, specifically for in-pipe/duct aero-acoustic measurements

4 Classes of acoustic insulation

This clause defines four classes of acoustic insulation or acoustic lagging, denoted Classes A, B, C and D, in terms of requirements for minimum insertion loss. The minimum insertion loss is specified in Table 1 and illustrated in Figures 1 to 4. Formulae for the approximate calculations of the required insertion loss (within 0,5 dB) are presented in Annex B.

The insertion loss of acoustic insulation or acoustic lagging is related to the diameter of the pipe on which it is applied. The pipe diameters are divided into three pipe size groups and the insulation class will consist of a letter/number combination indicating the diameter on which the insulation is applied.

The pipe sizes used are:

— less than 300 mm outside diameter;

— greater than or equal to 300 mm but less than 650 mm;

— greater than or equal to 650 mm diameter but less than 1 000 mm.

Table 1 — Minimum insertion loss required for each class

Class	Range of nominal diameter D mm	Octave band centre frequency, Hz 125	250	500	1 000	2 000	4 000	8 000
		Minimum insertion loss D_W, dB						
A1	$D < 300$	-4	-4	2	9	16	22	29
A2	$300 \leq D < 650$	-4	-4	2	9	16	22	29
A3	$650 \leq D < 1\,000$	-4	2	7	13	19	24	30
B1	$D < 300$	-9	-3	3	11	19	27	35
B2	$300 \leq D < 650$	-9	-3	6	15	24	33	42
B3	$650 \leq D < 1\,000$	-7	2	11	20	29	36	42
C1	$D < 300$	-5	-1	11	23	34	38	42
C2	$300 \leq D < 650$	-7	4	14	24	34	38	42
C3	$650 \leq D < 1\,000$	1	9	17	26	34	38	42
D2	$300 \leq D < 650$	-3	4	15	36	45	45	45
D3	$650 \leq D < 1\,000$	3	9	26	36	45	40	40

In order to conform to a given class, the insertion loss of all seven octave bands shall exceed or be equal to the levels specified. An acoustic insulation that does not fully satisfy the above requirement shall be designated as “unclassified”.

Acoustic insulation will reduce the noise radiated directly from the pipe but there is a counteracting effect: for radiation of any residual vibrations as the insulation cladding has a larger radiating area than the surface area of the bare pipe. Furthermore, the cladding can have a higher radiation efficiency than the pipe, at low frequencies. These effects are relatively more important on small diameter pipes and pose a limit to the applicability of the various classes of insulation.

Acoustic insulation will also exhibit a resonance at low frequency due to the mass of the cladding and the spring action of the trapped air and the porous layer. The resonance frequency in hertz, if the mechanical stiffness contribution of the porous material is low, is approximately given by Formula (1):

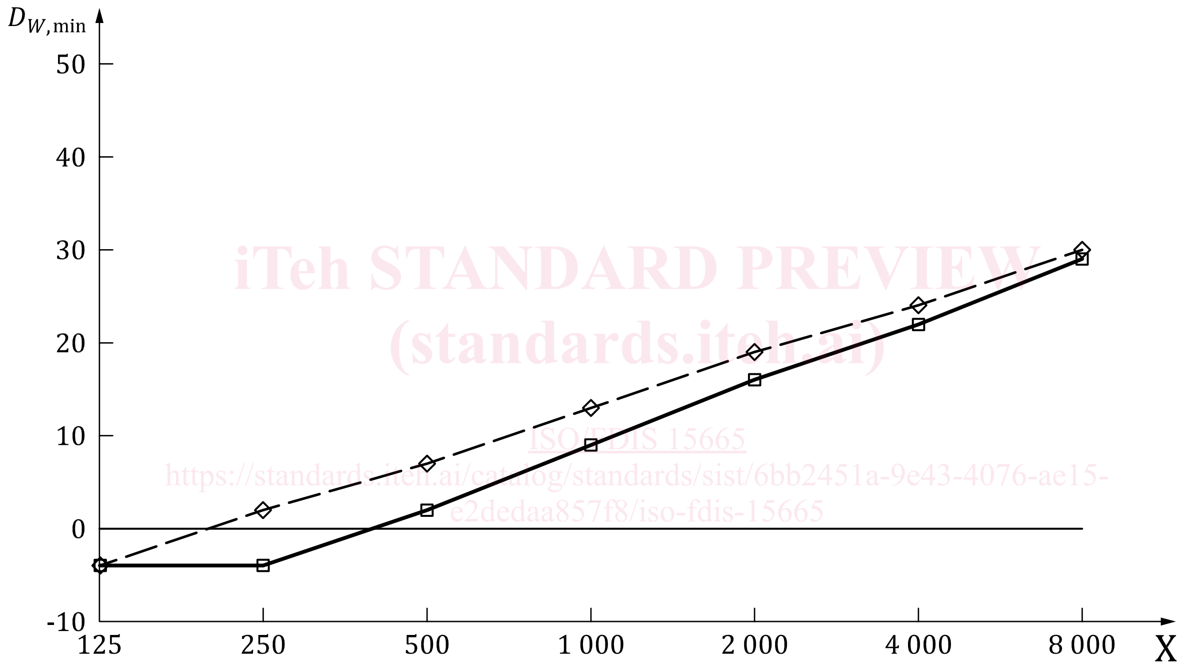
$$f_0 = \frac{60}{\sqrt{m'' d}} \tag{1}$$

where

m'' is the numerical value of the mass per unit area of the cladding, expressed in kilograms per square metre,

d is the numerical value of the distance between the tube wall and the cladding, expressed in metres.

The insertion loss of the acoustic insulation is expected to be negative for frequencies below $1{,}4f_0$.



Key

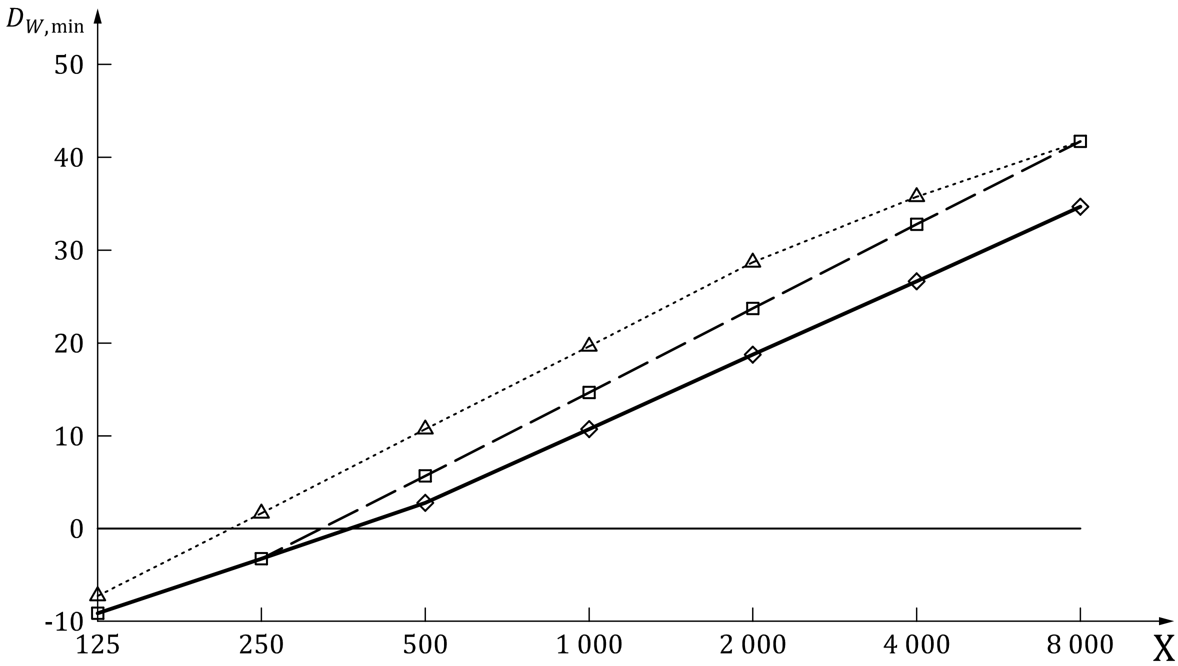
X octave band centre frequency in Hz

$D_{W,\text{min}}$ minimum insertion loss in dB

—□— Classes A1 and A2

–◇– Class A3

Figure 1 — Minimum insertion loss required for Class A



Key

X octave band centre frequency in Hz

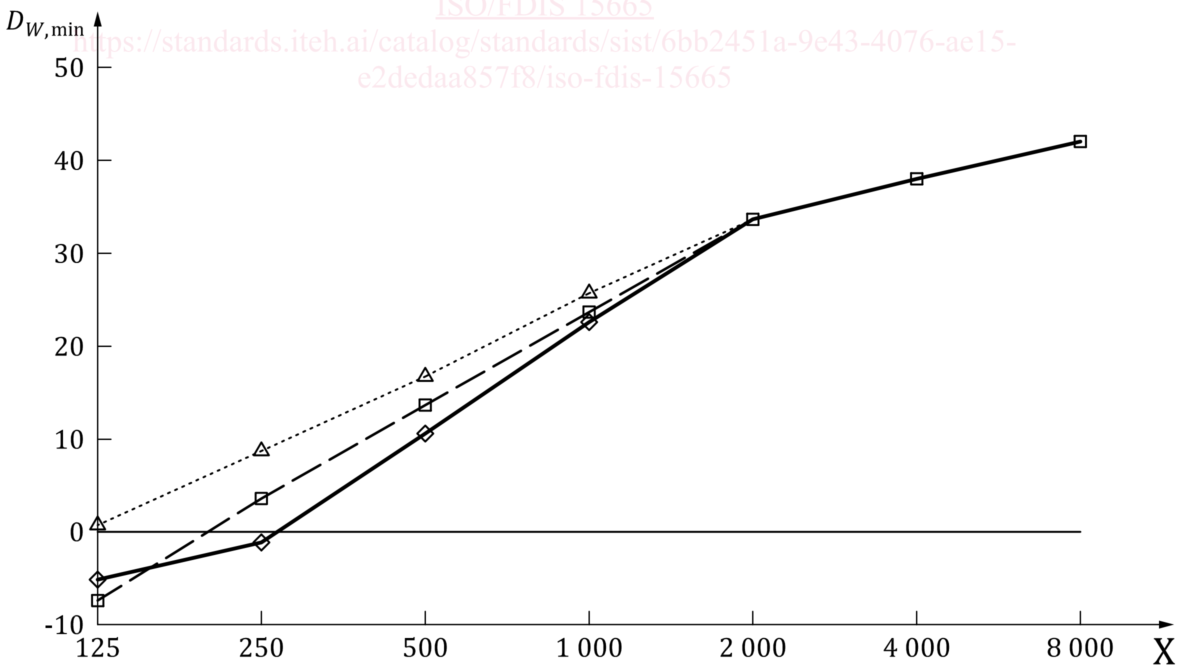
$D_{W,\min}$ minimum insertion loss in dB

Class B1

Class B2

Class B3

Figure 2 — Minimum insertion loss required for Class B



Key

X octave band centre frequency in Hz

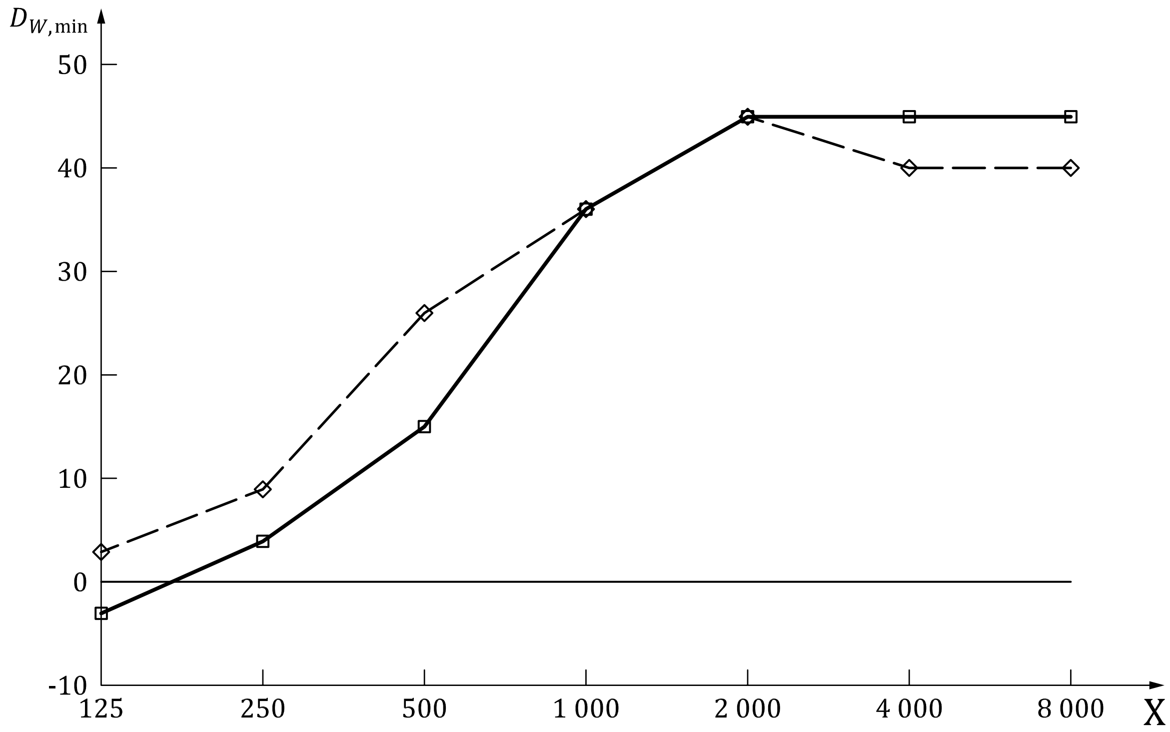
$D_{W,\min}$ minimum insertion loss in dB

Class C1

Class C2

Class C3

Figure 3 — Minimum insertion loss required for Class C



Key

X octave band centre frequency in Hz — Class D2

$D_{W,\min}$ minimum insertion loss in dB — Class D3

Figure 4 — Minimum insertion loss required for Class D

NOTE 1 The reduction in overall A-weighted sound pressure level will depend on the frequency spectrum of the source. Some typical examples are given in 5.5 and 5.6.

NOTE 2 The values of the minimum required insertion loss given in Table 1 were derived from laboratory measurement results of about 60 different (standard) acoustic pipe insulation systems and obtained by statistical evaluation of the test data for each insulation class. For each octave band and each insulation class, the minimum required insertion loss was calculated as the arithmetic mean value of the respective test data minus their standard deviation (standard deviations were typically 3 dB in the octave bands 125 Hz to 1 000 Hz, and 9 dB from 2 000 Hz to 8 000 Hz). Slight simplifications led to the straight-line approximations displayed in Figures 1 to 4.

5 Guidance to the reduction of noise from pipes

5.1 Required insertion loss: design phase steps

5.1.1 Determination of sound pressure levels

Determine the sound pressure level, $L_p(1,r)$, at a distance of 1 m from the bare pipe wall. Where this is not known, information can be obtained from the supplier of the upstream equipment, or from references in the Bibliography. Piping upstream and downstream of the source shall both be considered, separately.

Both the octave-band sound pressure levels and the overall A-weighted sound pressure level should be determined.

The method to be applied depends on the source of pipe noise under concern.

NOTE 1 Table 2 gives typical shapes of octave-band spectra for the most common sources of noise from pipes.

NOTE 2 Data or methods to predict pipeline noise from rotating equipment attached to the line are often difficult to obtain. When reliable data are not available, it is suggested that measurements be made on pipelines of similar size and wall thickness that are attached to similar equipment.

5.1.2 Evaluation of sound pressure levels against limits

If the pipe is the only source of noise in the area and is radiating under free-field conditions, the sound pressure level determined for the relevant place can be compared directly with the work area noise limit. The sound pressure insertion loss needed is obtained by subtraction.

Where other noise sources are also present, the total noise level should be determined, before comparing with the work area noise limit. See also 5.1.4.

5.1.3 Determination of sound power levels

The sound power level, L_W, radiated from the entire pipe can be derived from sound pressure levels measured in the free field as given by Formula (2) (see ISO 3744):

$$L_W(s) = \overline{L_p}(x,r) + 10 lg\left(\frac{2\pi rs}{S_0}\right) \text{dB} \quad (2)$$

where

s is the length of the pipe in metres;

S_0 equals 1 m^2;

r is the distance from the pipe axis, in metres, [preferably $r = \left(1 + \frac{1}{2}D\right)$, which is 1 m from pipe wall];

$\overline{L_p}(x,r)$ surface sound pressure level, in decibels, obtained by averaging over a specified measurement surface at a distance r from the axis of the pipe, at a distance x from the noise source, measured along the pipe in free-field conditions.

NOTE The preferred value for x is 1 m; where attenuation along the pipe is considered negligible, larger values of x can also be used

If the pipe is long and cannot be measured over its entire length, it may be worth estimating the sound pressure level by measuring the sound pressure level near the source and taking the noise attenuation along the pipe into account.

This is expressed by the following Formula (3) (see Reference [8]):

$$L_p(x,r) = L_p(1,r) - \beta x / D \ \text{dB} \quad (3)$$

where

$L_p(1,r)$ is the sound pressure level at a distance of 1 m away from the noise source, at the same distance r from pipe axis as in $L_p(x,r)$;

β is the attenuation factor, in decibels;

D is the diameter of the pipe in metres.

The value of β can be 0,06 dB for pipes carrying gas or vapour (attenuation of 3 dB for every 50 pipe diameters) and 0,017 for liquid (attenuation of 3 dB for every 175 pipe diameters), based on practical experience. If, for a particular application, evidence is available that the value for β is different, this value shall be used. The length of pipe should exceed ($3D/\beta$) before attenuation is taken into account.

On the basis of Formula (3), the sound power level L_W of a long length of pipe can be shown by Formula (4) to be:

$$L_W\left(s \to \infty\right) = L_p\left(1,r\right) + 10\lg\left(\frac{rD}{S_0\beta'}\right)\text{dB} + 14{,}4\,\text{dB} \tag{4}$$

where β' is the numerical value of the attenuation factor.

NOTE 1 The complete Formula for the relation between $L_W\left(s\right)$ and $L_p\left(1,r\right)$ is:

$$L_W\left(s\right) = L_p\left(1,r\right) + 10\lg\left(\frac{2\pi rD}{0{,}1 S_0\beta'\ln 10}\right)\text{dB} + 10\lg\left(1 - 10^{0{,}1\beta' s/D}\right)\text{dB} \tag{5}$$

It can be shown that Formula (5) will develop into Formula (2) for small values of $\left(\beta' s / D\right)$ and into Formula (4) for very long pipes.

NOTE 2 The errors involved in applying Formula (2) for pipes longer that $\left(3D/\theta\right)$ and in applying Formula (4) for shorter pipes are less than 3 dB.

NOTE 3 Noise from piping can be transmitted by the fluid or by the pipe wall or both. The acoustic insulation systems are effective for both. The propagation of noise by the pipe wall is difficult to predict.

5.1.4 Contribution to noise in reverberant spaces or environmental noise

The contribution of the pipe to the noise in the reverberant space is calculated from its sound power level and should be added to the contributions from other sources. For environmental noise, the contribution of the pipe to the total sound power level of the plant, or to the sound pressure level at the neighbourhood point, should be calculated.

5.2 Required insertion loss: operating plants

In operating plants, the assessment of pipe noise can be based on measurements. Where the pipe noise is significantly higher than the background noise, it can be measured directly as sound pressure levels. Again, piping upstream and downstream of the source shall be considered separately.

If background noise is significant, pipe noise can often be determined with sound intensity measurements. However, *in-situ* sound intensity measurements of pipe noise can be difficult to perform and require special equipment and expertise (see References [5] and [6]).

A third option is to assess the pipe noise by measuring the vibratory velocity level of the pipe surface and using the concept of radiation efficiency is given by Formula (6) (see Reference [9]):

$$L_p\left(x,r\right) = L_v + 10\,\lg\sigma\,\text{dB} + 10\lg\left(D/2r\right)\text{dB} \tag{6}$$

where

L_v is the vibratory velocity level of the pipe wall $\left[= 10\lg\left(v/v_0\right)\text{dB}\right]$;

v_0 $= 5\cdot 10^{-8}\,\text{m/s}$;

$10\,\lg\sigma$ is the radiation efficiency ($10\,\lg\sigma$ is negative, as $0 < \sigma < 1$).

For practical purposes, the value of σ can be derived from Reference [9] and Formula (7):

$$\sigma = \frac{1}{1 + \left(\frac{c}{4Df}\right)^3} \tag{7}$$

where

c is the velocity of sound in air, in metres per second;

f is the octave-band centre frequency, in hertz.

When undertaking measurements in the field it is necessary to understand the operating conditions of the plant. Evaluation of the requirements and performance of acoustic insulation systems should always consider equivalent operating conditions.

NOTE This method is less preferred since estimates of radiation efficiency are inaccurate as no allowance is made for the stiffness(flexibility) or thickness of the pipe. It also requires special equipment and expertise. However, this can be the only available method for situations with high background noise levels or where space does not permit accurate sound intensity measurements.

5.3 Length of acoustic insulation

The noise radiated by the wall of a pipe is usually generated by equipment connected to the pipe, such as compressors, pumps, valves or ejectors. These noise sources may cause long sections of pipe to radiate noise because noise will propagate in the pipe with little attenuation.

If the assessment of various aspects of noise control indicates that acoustic insulation of a pipe is required, the necessary reduction of pipe noise should be tabulated in octave bands. Reference to Clause 4 will then indicate which class of insulation is required.

Pipes will usually have to be insulated from the noise source to (and sometimes including) the next silencer, vessel, heat exchanger, filter, etc., unless it can be shown that attenuation along the pipe has reduced the noise sufficiently at some point downstream *and* upstream of the source to render further insulation unnecessary. This may be the point where the contribution of the pipe to the noise level is below a target value, as according to Formula (3) or where the noise radiated from the bare pipe is more than 10 dB lower than the insulated pipe closest to the source.

If the sound power level of a pipe is to be reduced, the length of the pipe, l, in metres, that has to be insulated can be derived as follows by Formula (8):

$$l = \frac{10D}{\beta} \cdot \lg\left(\frac{1-a}{R-a}\right) \tag{8}$$

where

D is the diameter of the pipe, in metres;

R $= 10^{\Delta L_W /10}$;

ΔL_W $= L_{W,\text{with}} - L_{W,\text{without}}$ (desired reduction in sound power level), in decibels;

a $= 10^{-D_W /10}$;

D_W is the insertion loss of the insulation (see Clause 4), in decibels.

The relation between the variables in Formula (8) is illustrated in Figure 5, with the attenuation factor β taken as 0,06. This graph illustrates that reductions in sound power are limited by the performance (insertion loss) of the acoustic insulation, i.e. R shall be larger than a. It also illustrates that, with respect to radiated sound power, it may be more economical to choose a class of insulation with higher insertion loss, because the required length is less.

NOTE Both Formula (8) and Figure 5 can be used for either octave band or overall sound power values.

