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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

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 15665 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

Acoustics — Acoustic insulation for pipes, valves and flanges

1 Scope

This International Standard defines the acoustic performance of three classes (Classes A, B and C) of pipe insulation. It also specifies three types of construction that will meet these acoustic performance classes. Furthermore, this International Standard defines a standardized test method for measuring the acoustic performance of any type of construction, thereby allowing existing and new insulation constructions to be rated against the three classes.

This International Standard 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 International Standard 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 International Standard 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 International Standard.

2 Normative references

The following referenced documents are indispensable for the application 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 3741:1999, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms*

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*

3 Terms and definitions

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

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

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

NOTE Acoustic insulation typically consists of a sound-absorbing and/or resilient material ("porous layer") on the piping and an impermeable outer cover ("cladding").

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 Airflow resistivity equals the pressure drop divided by the product of the air velocity and the thickness of the sample.

NOTE 2 The unit of airflow resistivity is $N \cdot s/m^4 = Pa \cdot s/m^2$.

NOTE 3 Procedures for determining the flow resistivity are described in ISO 9053.

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

NOTE See Note to 3.5.

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

NOTE 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. For piping outdoors in field situations, the determination of sound pressure insulation D_p is a less accurate but more practical approach. 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 0,33 m in diameter, to minimize near field measurement effects. The measurement position 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.

4 Classes of acoustic insulation

This clause defines three classes of acoustic insulation, denoted Classes A, B and C, in terms of requirements for minimum insertion loss. The minimum insertion loss is specified in Table 1 and illustrated in Figures 1 to 3. Equations for the approximate calculations of the required insertion loss (within 0,5 dB) are presented in Annex A.

The insertion loss of acoustic insulation 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;

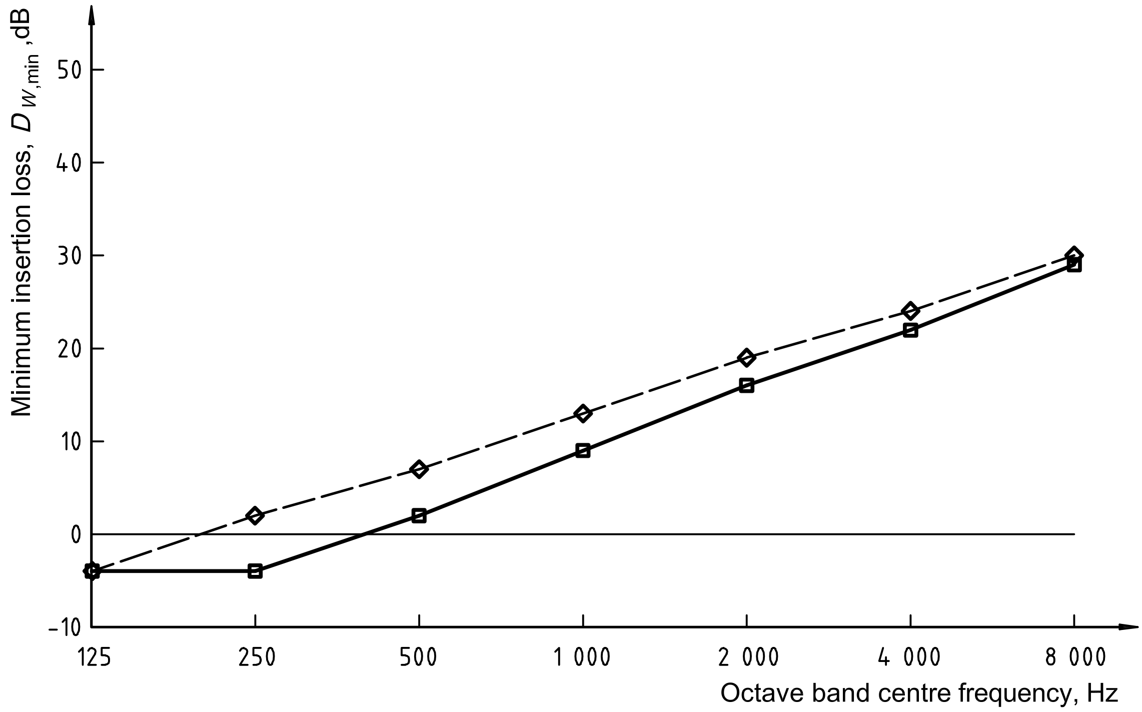
— greater than or equal to 300 mm diameter but less than 650 mm;

— 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, dB						
A1	$D < 300$	–4	–4	2	9	16	22	29
A2	$300 \leqslant D < 650$	–4	–4	2	9	16	22	29
A3	$650 \leqslant D < 1\,000$	–4	2	7	13	19	24	30
B1	$D < 300$	–9	–3	3	11	19	27	35
B2	$300 \leqslant D < 650$	–9	–3	6	15	24	33	42
B3	$650 \leqslant D < 1\,000$	–7	2	11	20	29	36	42
C1	$D < 300$	–5	–1	11	23	34	38	42
C2	$300 \leqslant D < 650$	–7	4	14	24	34	38	42
C3	$650 \leqslant D < 1\,000$	1	9	17	26	34	38	42

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 above requirement shall be designated as “unclassified”.

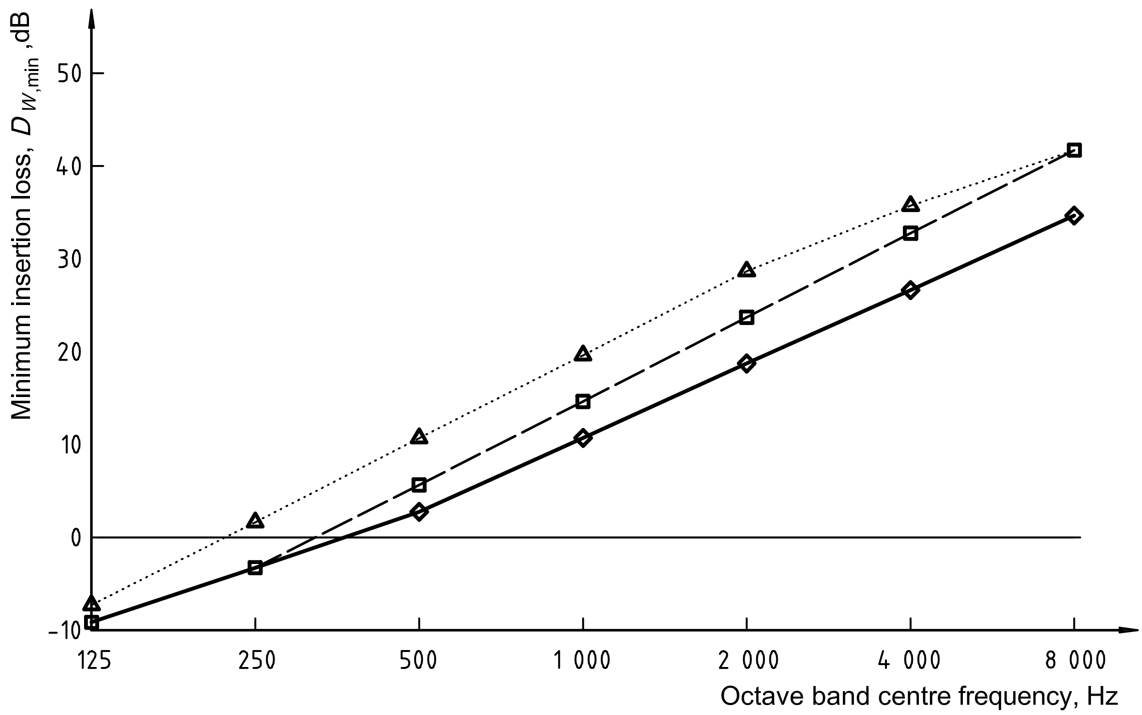


Key

Classes A1 and A2

Class A3

Figure 1 — Minimum insertion loss required for Class A



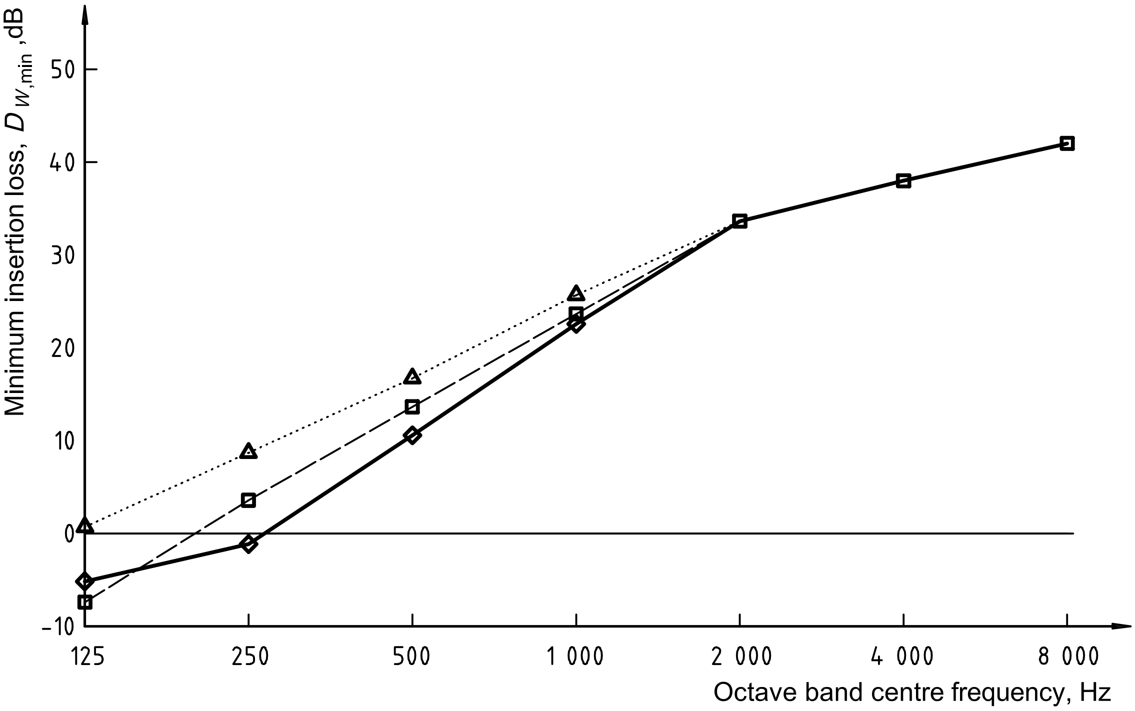
Key

Class B1

Class B2

Class B3

Figure 2 — Minimum insertion loss required for Class B



Key

Class C1
Class C2
Class C3

Figure 3 — Minimum insertion loss required for Class C

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 Acoustic insulation will reduce the noise radiated directly from the pipe but there is a counteracting effect: for radiation of any residual vibrations the insulation cladding has a larger area than the surface area of the bare pipe. Furthermore the cladding may 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 is, if the mechanical stiffness contribution of the porous material is low, approximately given by the formula:

$$f_0 = 60 / \sqrt{m''d}$$

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 1,4 f_0.

NOTE 3 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 3.

5 Guide 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 pipe noise.

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 may be compared directly with the work area noise limit. The sound pressure insulation 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 is derived from sound pressure levels measured in the free field (see ISO 3744):

$$L_W(s) = \overline{L}_p(x,r) + 10 \lg(2\pi rs / S_0) \text{ dB} \quad (1)$$

where

s is the length of the pipe ($s \gg r$), in metres;

S_0 = 1 m^2;

D is the outside diameter of the pipe, in metres;

r is the distance from the pipe axis, in metres, [preferably r = (1 + ½ D), 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 condition.

NOTE The preferred value for x is 1 m; where attenuation along the pipe is considered negligible, larger values of x may 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 (see reference [8]):

$$L_p(x,r) = L_p(1,r) - \beta x / D \text{ dB} \tag{2}$$

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.

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 Equation (2), the sound power level L_W of a long length of pipe can be shown to be:

$$L_W(s \to \infty) = L_p(1,r) + 10 \lg \frac{rD}{S_0 \beta'} \text{ dB} + 14{,}4 \text{ dB} \tag{3}$$

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

NOTE 1 The complete equation for the relation between $L_W(s)$ and $L_p(1,r)$ is:

$$L_W(s) = L_p(1,r) + 10 \lg\left(\frac{2\pi rD}{0{,}1\ S_0 \beta' \ln 10}\right) \text{dB} + 10 \lg\left(1 - 10^{0{,}1\beta' s/D}\right) \text{dB} \tag{4}$$

It can be shown that Equation (4) will develop into Equation (1) for small values of $(\beta' s/D)$ and into Equation (3) for very long pipes.

NOTE 2 The errors involved in applying Equation (1) for pipes longer than ($3D/\beta$) and in applying Equation (3) for shorter pipes is 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 may be based on measurements. Where the pipe noise is significantly higher than the background noise, it may 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 may be difficult to perform and require special equipment and expertise.

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 (see reference [8]):

$$L_p(x,r) = L_v + 10 \lg \sigma \text{ dB} + 10 \lg(D/2r) \text{ dB} \tag{5}$$

where

L_v is the vibratory velocity level of the pipe wall [= 10 lg (v/v_0) dB];

v_0 = 5×10^{-8} m/s;

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

For practical purposes, the value of σ can be derived from reference [8]:

$$\sigma = \frac{1}{1 + \left(\frac{c}{4Df}\right)^3} \tag{6}$$

where

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

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

NOTE This method is less preferred since estimates of radiation efficiency are inaccurate. It also requires special equipment and expertise. However, this may be the only available method for situations with high background noise levels or where space does not permit accurate acoustic 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 Equation (2).

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:

$$l = \frac{10D}{\beta_0} \times \lg\left(\frac{1-a}{R-a}\right) \qquad (7)$$

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 Equation (7) is illustrated in Figure 4, 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 Equation (7) and Figure 4 can be used for either octave band or overall sound power values.

5.4 Implications for piping design

It is important to ensure at an early stage of the design that the piping arrangement allows space for the bulk and mass of the acoustic insulation. The installation of acoustic insulation to piping as a remedial measure is usually difficult due to lack of space between adjacent pipes and the piping being at the incorrect height to allow the correct piping shoes and vibration isolation to be applied.

The noise control engineer should therefore estimate the noise levels of major piping at an early stage in the design, initially based on estimated noise data if necessary, and should mark on the piping and instrument diagrams, process engineering flow schemes or other appropriate documents, those sections of pipe which are to be acoustically insulated. At the same time, it should be considered whether the substitution of low-noise sources or the use of silencers might be more appropriate.

The design of pipe supports and hangers shall allow sufficient space for the installation of acoustic insulation.

When piping is supported by or suspended from a steel structure, resilient supports or hangers should be used. The resilient elements shall have a mechanical stop to limit the movement of the pipe, in case the resilient element fails. The method for supporting the piping shall be agreed between the parties responsible for the mechanical and the acoustic design.

NOTE Spring-loaded hangers as applied for overhead piping subject to thermal expansion will not necessarily have satisfactory acoustic performance.

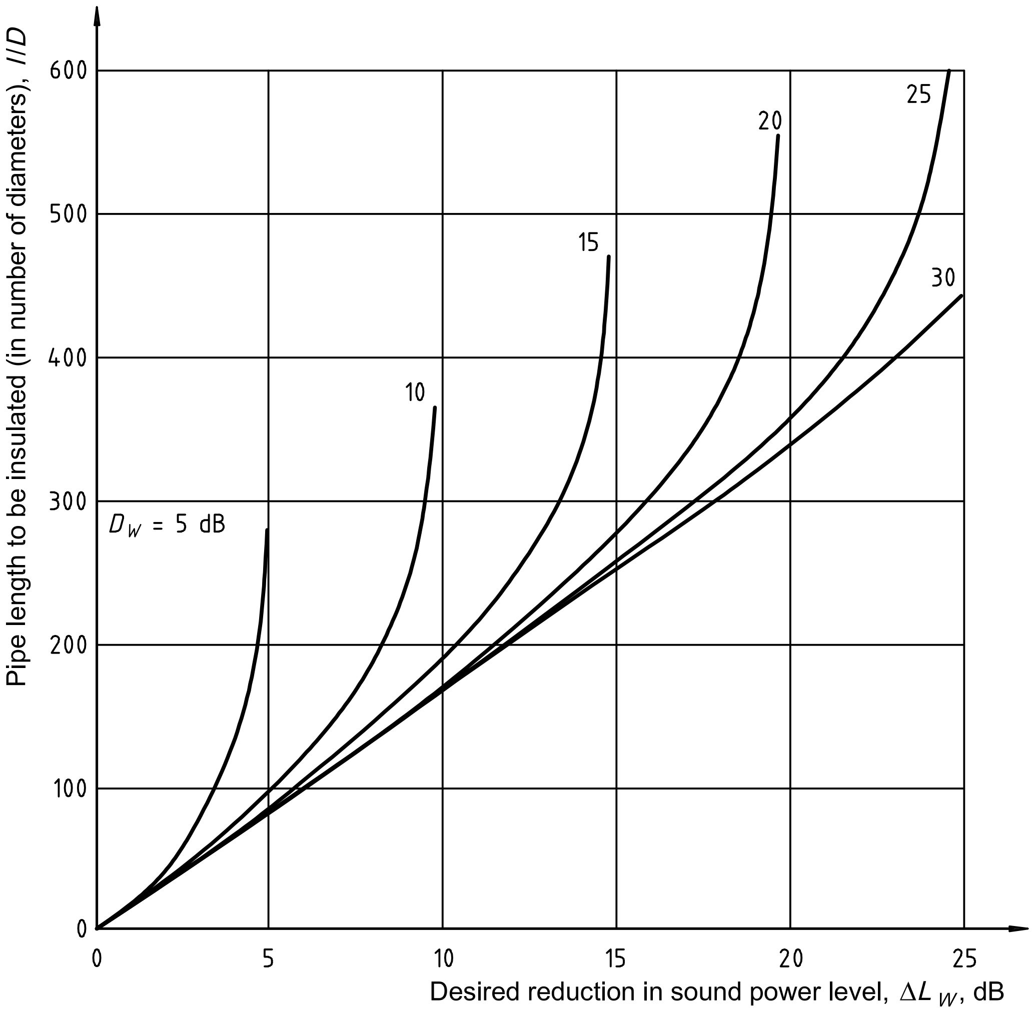


Figure 4 — Length to diameter ratio of a pipe to be insulated for a given reduction in sound power level as function of the insertion loss of the insulation (β = 0,06)

5.5 Derivation of overall noise reduction

The decision to apply acoustic insulation is usually based on a measured or calculated A-weighted sound pressure/power level in decibels of the unsilenced pipe. However, calculation of the effectiveness of acoustic insulation in terms of overall levels in decibels can only be carried out on the basis of an octave-band spectrum of the noise.

Where possible, the actual spectrum of the pipe under consideration should be obtained.

If the overall noise level in decibels is the only quantity available, the octave-band spectrum may be estimated using Table 2. This gives examples of typical spectral shapes of noise emission from pipes attached to various types of sources. The corrections in Table 2 should be subtracted from the overall A-weighted sound pressure/power level to arrive at the linear octave-band spectrum.

Table 2 — Examples of spectral shapes for noise from pipes attached to various types of sources

Source	Octave band centre frequency, Hz						
	125	250	500	1 000	2 000	4 000	8 000
	Difference between A-weighted overall and linear octave band level, dB						
Control valve[a]	20	16	17	9	6	5	7
Centrifugal compressor[b]	15	12	9	7	3	10	12
Centrifugal pump	4	2	4	5	7	9	12
Reciprocating compressor	3	4	5	6	8	8	8

a In gas service with gas reaching sonic velocity in the valve, typical nominal pipe diameters are 150 mm to 350 mm.

b Typical pipe diameter exceeding 300 mm.

The effect of the acoustic insulation is obtained by subtracting the insertion loss of the type of insulation considered, per octave band. The overall A-weighted sound pressure/power level in decibels after insulation may be obtained by applying A-weighting to the spectrum and adding these octave-band levels. The insertion loss in decibels is the difference between the levels for bare and insulated pipe respectively.

Table 3 gives an example of the calculation of the overall noise reduction of a 200 mm pipe insulated with Class A acoustic insulation and connected to a control valve. The level of 100 dB of the bare pipe is assumed for calculation purposes only.

The situation in the field and the quality of the application of the insulation can differ substantially from that in the laboratory where the insertion loss values have been determined. A correction term to take this discrepancy into account shall be estimated by the designer. The causes for this discrepancy include, but are not limited to, the following:

— noise radiated by the structure supporting the pipe;

— noise radiated by equipment and small pipes attached to the pipe;

— failure to install the acoustic insulation as it was designed.

These discrepancies are usually greater for higher classes of acoustic insulation. For example, it is expected that the difference between laboratory and field insertion losses for Class B and C insulation will be greater than those for Class A.

Table 3 — Example of calculation

Noise level in decibels

Parameter	Octave-band-centre frequency, Hz							Total
	125	250	500	1 000	2 000	4 000	8 000	A-weighted
Noise level from bare pipe connected to control valve								100
Source correction for valve noise (Table 2)	20	16	17	9	6	5	7	
Estimate of octave-band spectrum of noise from bare pipe	80	84	83	91	94	95	93	
Insertion loss Class A1 and A2 (Table 1)	–4	–4	2	9	16	22	29	
Octave-band spectrum of insulated pipe	84	88	81	82	78	73	64	
A-weighted spectrum of insulated pipe	68	79	78	82	79	74	63	86
Noise level reduction								14

5.6 Typical noise reduction values

Typical noise reduction values may be calculated for different types of sources and various types of insulation.

On the basis of the octave band spectra of Table 2 and using minimum insertion loss values of Table 1, the following approximate A-weighted noise level reductions in decibels are obtained with the various classes of insulation for different types of source. The noise control engineer should make his own assessment based on the actual data available.

Table 4 — Typical noise level reduction values for insulation of piping connected to different types of noise sources

Class	Diameter D mm	Expected reduction of the overall A-weighted sound pressure/power level dB[a]			
		Centrifugal pumps	Centrifugal compressors	Control valves	Reciprocating compressors
A1 and A2	$D < 650$	4	10	14	5
A3	$D \geqslant 650$	9	15	18	9
B1	$D < 300$	5	11	16	5
B2	$300 \leqslant D < 650$	6	14	18	6
B3	$D \geqslant 650$	10	18	22	10
C1	$D < 300$	9	18	22	9
C2	$300 \leqslant D < 650$	11	20	24	10
C3	$D \geqslant 650$	17	25	29	17

[a] The shaded areas indicate that the particular type of insulation may not be (cost-)effective for that application or represents an unusual application.

6 Construction of typical acoustic insulation systems

6.1 General

This clause lists materials suitable for acoustic insulation and the particular properties necessary for acoustic purposes. They shall be suitable for the maximum operating temperatures and for the chemical nature of the environment. The examples of materials given do not exclude the use of any other suitable materials; also different intermediate layers may be used. Great care needs to be exercised in substituting materials because many thermal standard insulating materials are not suitable for acoustic insulation, particularly rigid insulation materials.

Annex B shows the general construction of acoustic insulation. Annex C gives some examples of typical construction details.

6.2 Cladding

6.2.1 General

The cladding, also known as jacketing, serves the following purposes.

— It is a barrier to the noise radiated by the pipe. The layer may be provided with an added mass and/or damping layer.

— It protects the porous layer from mechanical damage and provides a weather protection for the porous layer and the pipe surface underneath. It shall therefore have sufficient strength and durability.

In order for the cladding to be effective, especially for high insulation classes, acoustic leaks shall be avoided, for example by means of adequate overlaps and sealing. Openings shall be sealed with mastic. Precautions shall be taken that vibrations do not loosen the fasteners.

6.2.2 Materials for the outer layer

The following are examples of materials that are suitable for the outer layer or cladding:

— steel, galvanized or aluminized;

— stainless steel;

— aluminium;

— lead (this should be avoided if possible as it is toxic);

— plastic or rubber.

Galvanized steel shall not be used over austenitic stainless steel or austenitic nickel steel/alloy piping and equipment.

6.2.3 Materials for an additional layer

An additional layer can provide extra mass to the cladding to increase the insertion loss of a specific thickness of insulation. This can help where there is limited space available for acoustic insulation.

A damping layer may be applied to the cladding to provide mechanical damping (increasing the loss factor) and hence lower noise radiation. Any damping layer shall be in direct contact with the cladding.

The damping layer will reduce the deteriorating effects of localized structural contacts between piping and cladding.

Examples of materials include the following:

- high mass-per-unit-area limp rubber or plastic sheets;
- bitumen-based free damping layers;
- visco-elastic polymer damping compounds (sheets, spray-ons);
- constrained layer (sandwich) thin steel or aluminium sheets;
- double-skin thin-sheet metal cladding (friction and air-pumping losses).

6.2.4 Vibro-acoustic seals

Localized contact between the cladding material and the (vibrating) pipe wall shall be avoided, for example with flanges. For this purpose, a sealing material shall be applied to close the gap and to prevent acoustic short circuit (see Figures C.1 and C.2).

The following materials are suitable for use in vibro-acoustic seals:

- synthetic and natural rubber;
- non-flammable felt.

Where these materials are incompatible with the operating temperature, such seals shall be made of a compressed layer of porous material (see 6.3).

6.3 Porous layer

The porous layer serves the following purposes:

- it is a resilient vibration-isolating support for the cladding;
- it converts acoustic and vibratory energy into heat and should therefore have an optimum airflow resistivity for the oscillatory flows which occur in sound fields.

The porous layer is normally in the form of blankets or preformed pipe sections.

In order to avoid transmission of structure-borne sound to the cladding, a layer of porous material with a mechanical stiffness less than $10^5/t$ N/m^3 should be selected, where t (in metres) is the thickness of the porous layer.

Low effective stiffness may also be ensured by choosing a porous layer of smaller thickness than the distance between pipe surface and cladding, creating an air gap. In that case, spring supports should be chosen as described in 6.4

The following materials are suitable for use as porous layer:

- mineral fibre (glass, rock, ceramic);
- open-cell flexible plastic foam.

Fibres of insulation systems that are perpendicular to the pipe wall can increase the stiffness and thereby reduce the acoustic performance of the system.

Materials with a rigid structure (e.g. PUF/PIR, cellular glass and calcium silicate) will not provide the acoustic function, but may be required for other reasons. These layers should be used in addition to, not as a replacement for, the porous layer.

6.4 Support of the cladding

Where the porous layer is composed of semi-rigid sections and the pipe is horizontal, it will not normally be necessary to support the cladding. Where soft blankets are used or an air-gap is applied, it may be necessary to support the cladding separately.

Rigid spacers, as used in distance rings for thermal insulation, shall not be used in acoustic insulation. Spacers may contain resilient elements. The resilient elements shall have a built-in mechanical stop, in the direction normal to the pipe axis, in order to limit its maximum deflection (see Figure C.3).

Support rings (see Figure C.4) which carry the weight of vertical stretches of acoustic insulation shall contain resilient elements. Spring stiffness in lateral directions should be in the range as given for distance rings, where possible. Resilient elements for support rings have both axial and lateral mechanical stops, to limit movements of the insulation, in the event that the resilient element fails.

Where the operating temperatures prohibit the use of natural or synthetic rubber as resilient material, other materials should be used instead, for example steel springs in the form of a folded band or knitted metal.

7 Installation

7.1 General

An essential feature of acoustic insulation is that the cladding shall not be in direct or indirect metal-to-metal contact with the pipe. Any such contact would allow transmission of vibrations to the cladding, which would reduce or nullify the noise reduction of the insulation. It could even enhance the noise radiation because of the greater surface area of the cladding.

Resilient elements shall not be pre-stressed or pre-tensioned to the extent that their operational range of deflections is exceeded.

The pipe on which the acoustic insulation is to be mounted is not necessarily hot. Attention shall be paid to corrosion prevention by suitable coatings and the prevention of both ingress of rainwater and condensation of water vapour within and upon the insulation. Preventing condensation of vapour is particularly important on pipes in “cold” services. All seams shall be carefully sealed to prevent leaks.

Although materials used for thermal insulation may also be suitable for acoustic insulation, there are some additional application requirements. Special attention shall be paid to the prevention of noise leakage through gaps and to isolation of vibrations in order to prevent their transmission to the cladding or supporting structures.

NOTE Figures C.1 to C.6 show the general principles required for acoustic insulation but the actual installation may vary in detail according to local circumstances.

7.2 Extent of insulation

The length of each pipe to be insulated and the class of insulation shall be as specified by the noise control engineer responsible for the acoustic design of the installation.

7.3 End caps

At any place where the acoustic insulation has to be terminated, end caps shall be used, see Figures C.1 and C.2. For flanges, the end cap shall be located as close to the flange as possible but still allow bolt removal. Rigid end caps shall be isolated from the pipe by means of a vibro-acoustic seal (see 6.2.4).

7.4 Acoustic enclosures

When the noise radiated from a valve body is to be reduced, the equipment shall be surrounded by an acoustic enclosure. Flanges may also be surrounded by an acoustic enclosure or by removable insulation covers. Acoustic enclosures shall be easily demountable to provide access to the flange or valve.

The acoustic enclosure should have an outer surface with a mass per unit area at least equal to that of the cladding of adjacent pipes. The porous layer should be similar in material and thickness to that used on the piping, and shall be fixed adequately to ensure acoustic performance when replaced after removal. Joints should be sealed to prevent noise leakage. Examples are given in Figures C.7 to C.9.

Demountable parts of acoustic enclosures shall have lifting lugs, if their mass exceeds 25 kg.

Flexible joints (bellows) may also be surrounded by an acoustic enclosure or by removable insulation. However, the construction shall take into account the potential range of thermal expansions.

In some cases, ventilation of the flexible joints is required because of possible emission of hazardous gases and/or heat transfer (a closed acoustic insulation may lead to the temperature limits of certain types of bellows being exceeded). Vented joints will often limit the maximal achievable sound insulation. Figure C.10 shows a practical solution.

Where acoustic enclosures are installed around flanged joints, they shall be of sufficient length to overlap the ends of the pipe cladding. For non-vented enclosures, the overlap should at least be equal to the insulation thickness, (see Figure C.7), and for vented joints at least 100 mm for Class A, 200 mm for Classes B and 300 mm for Class C (see Figure C.10).

Acoustic blankets may be used that can be repeatedly re-installed and consist of a porous layer and cladding. Test reports should be obtained to verify that these blankets have sufficient insertion loss when installed.

7.5 Prevention of mechanical damage

Where acoustic insulation may be liable to mechanical damage, special provision shall be made to protect it. For example, where it may be stepped on, separately supported steps should be provided. Where mechanical load cannot be avoided, the cladding should be re-inforced by using stiffer plate and additional distance rings.

8 Combined thermal and acoustic insulation

8.1 General

Thermal requirements for insulation are beyond the scope of this International Standard. However, it should be noted that thermal needs can be inconsistent with acoustical needs. Some pipes may need thermal insulation but no acoustical insulation, and *vice versa*. All suitable resilient or porous insulation materials will have thermal insulating properties, but rigid thermal insulation (e.g. calcium silicate) has very low acoustical insulating properties.

8.2 Hot services

When insulation is required for thermal as well as for acoustic reasons, the same material may be used for both purposes, provided that the provisions of 6.3 are fulfilled. The thickness of the porous layer shall be determined by the more stringent of the two requirements.

8.3 Cold services

Cold thermal insulation is often made of hard non-absorbent material that has no intentional acoustic properties. It often only serves to increase the effective diameter of the pipe that requires acoustic insulation.

Where cold insulation and acoustic insulation are required, the cold insulation system shall be applied first to the pipe and the acoustic insulation shall be applied on top. To prevent condensation at the interface between the two layers, a second vapour seal shall be applied outside the porous layer of the acoustic insulation. Care should be taken to avoid damage when applying the cladding directly over the vapour seal; rivets or self-tapping screws shall not be used.

9 Acoustic insulation constructions that meet the insulation class requirements

9.1 General

There are many forms of acoustic insulation that may be applied. The acoustic performance of an insulation construction can be tested to demonstrate conformance to a specific insulation class (see Clause 10).

The constructions summarized in Table 5 will provide, without verification, acoustic insertion loss of the appropriate class, provided that the acoustic insulation is installed correctly, with full attention to detail. The related material requirements are discussed in the following subclauses.

Table 5 — Insulation constructions meeting classes of acoustic insulation

Class	Description	Value
A	min. thickness of porous layer	50 mm
	max. stiffness of porous layer	2,0 x 10^6 N/m^3
	min. mass per unit area of metal cladding	4,5 kg/m^2 (e.g. 0,6 mm steel plate)
B	min. thickness of porous layer	100 mm
	max. stiffness of porous layer	10^6 N/m^3
	min. mass per unit area of metal cladding	6,0 kg/m^2 (e.g. 0,8 mm steel plate)
C	min. thickness of porous layer	100 mm
	max. stiffness of porous layer	10^6 N/m^3
	min. mass per unit area of metal cladding	
	for nominal pipe diameters < 300 mm	7,8 kg/m^2 (e.g. 1,0 mm steel plate)
	for nominal pipe diameters ⩾ 300 mm	10,0 kg/m^2 (e.g. 1,3 mm steel plate)

NOTE 1 Where a high mass per unit area is required for the cladding, this may be composed of two layers. An example of an acceptable construction is to combine an outer layer of steel or aluminium and an inner layer of barium oxide/sulfate loaded vinyl film to provide the additional mass.

NOTE 2 The performance of an acoustic insulation system is related to the wall thickness of the pipe. The insulation systems of Table 5 are based on standard pipe wall thickness, see also 10.3.3. Thinner pipe walls may adversely affect the performance of the insulation system, but an increase in wall thickness will not influence the performance significantly.

Unless otherwise specified, pipe fittings shall be insulated to the same class as the straight sections of the pipe.

Where a steel structure is used to support the pipe, there shall be vibration isolation between steel structure and pipe.

Class A: For acoustic purposes flanges and valves need not be insulated.

Classes B and C: Distance and support rings should be avoided if possible. Where used, they shall conform to 6.4. All flanges and valves shall be insulated to the same class as the pipe (see 7.4), except where insulation of these items is not allowed for safety reasons (e.g. in hydrogen service, see Figure C.10). Pipe supports, when necessary, shall be insulated up to the concrete or steel base (see Figure C.5) or alternatively to the vibration isolator.

9.2 Materials

9.2.1 General

This subclause lists requirements for materials that are suitable for the acoustic insulation specified in Clause 9. The requirements are additions to those presented in Clause 6.

9.2.2 Cladding

The minimum mass per unit area of the cladding shall be in accordance with Table 5, for the class of insulation considered.

9.2.3 Porous layer

The porous layer shall be in the form of blankets, preformed pipe sections or similar. For fittings, such as elbows or tees, preformed sections of pipe insulation may be available. If not, then blocks of porous material should be cut from either preformed pipe sections or flat material and fitted to the pipe wall. These shall be tapered and cut to fit. Gaps between blocks shall be minimized.

Suitable materials for the porous layer are given in 6.3. The flow resistivity of the porous layer shall be in the range 25 000 Ns/m^4 to 75 000 Ns/m^4. This is normally obtained by materials with a density of 80 kg/m^3 to 120 kg/m^3.

9.2.4 Vibro-acoustic seals

Vibro-acoustic seals shall be applied at positions where metal-to-metal contact would normally occur (see 6.2.4, Annex B and Figure C.1). They shall have a minimum thickness of 3 mm and a minimum width of 50 mm.

The edges of the cladding or end cap (see 7.3) shall be folded where they rest on the vibro-acoustic seal. If the seal is of porous insulation material, the outer edge shall be weatherproofed with a flexible mastic compound.

9.3 Vibration isolation material at pipe supports

Vibration isolation material shall be fitted at pipe supports where the piping rests in steelwork.

The aim of the material is to prevent the acoustic range of vibration that may exist in the pipe wall from being transmitted into supporting steelwork and re-radiated as noise.

This material is not required where piping rests on the ground, or on a concrete structure or foundation, even if there is a metal plate set into the structure where the pipe support makes contact.

The material shall be suitable for the environment in which it will be installed.

10 Testing of acoustic insulation systems

10.1 General

This clause describes a method for the determination of the insertion loss of acoustic insulation systems on pipes with a nominal diameter of 100 mm to 1 000 mm. The test method under laboratory conditions is described in principle. For specific information about measuring equipment, test facilities, etc., relevant standards should be consulted. The determination of insertion loss is basically a determination of difference in sound power levels. The procedure described below is based on ISO 3741 (precision methods for reverberation rooms) and is basically in accordance with ASTM E1222 (see Bibliography).

NOTE Engineering methods for the determination of sound power levels of small movable sources are described in ISO 3743-1 and ISO 3743-2. As these state restrictions to the maximum physical dimensions of the noise source, they are less suitable for the purpose of the tests as described in this clause.

The insertion loss of the acoustic insulation system depends on the insulation materials, the method of installation, the dimensions of the pipe (wall thickness, diameter) and the excitation mechanisms causing noise radiation from the pipe (loudspeaker in the laboratory and flow, valve and machinery noise in the field). For these reasons the results obtained under laboratory conditions can differ from those obtained in similar situations in practice. The results are very useful for design purposes and for comparing different insulation systems.

10.2 Measurement method: Reverberation room

A steel pipe is installed in a reverberation room. Noise is introduced in this pipe using a loudspeaker or acoustic driver at one end. The sound pressure levels within the reverberation room are measured in the situation with the bare pipe and with the pipe covered with insulation. The insertion loss of the insulation system is the difference between the sound pressure levels for noise radiating from the bare pipe and the levels for noise radiating from the insulated pipe, with an adjustment for changes in sound absorption in the test room due to the cladding system.

NOTE If the cladding is a sound-reflecting material, such as steel or aluminium, the sound absorption in the reverberation room is virtually unchanged by addition of pipe insulation on the bare pipe. In that case a corresponding correction for changes in sound absorption is not required.

The results shall be obtained in one-third-octave bands from 100 Hz to 10 000 Hz, or octave bands from 125 Hz to 8 000 Hz. The accuracy in the lower frequency range depends strongly on the size of the reverberation room.

10.3 Test facility

10.3.1 Test room

The requirements regarding the volume of the test room depend on the desired accuracy, the frequency range of interest and the dimensions of the test specimen.

The test room shall comply with the requirements for the acoustic environment as specified in ISO 3741. This concerns the volume, shape and absorption of the test room, the background noise level, temperature and humidity.

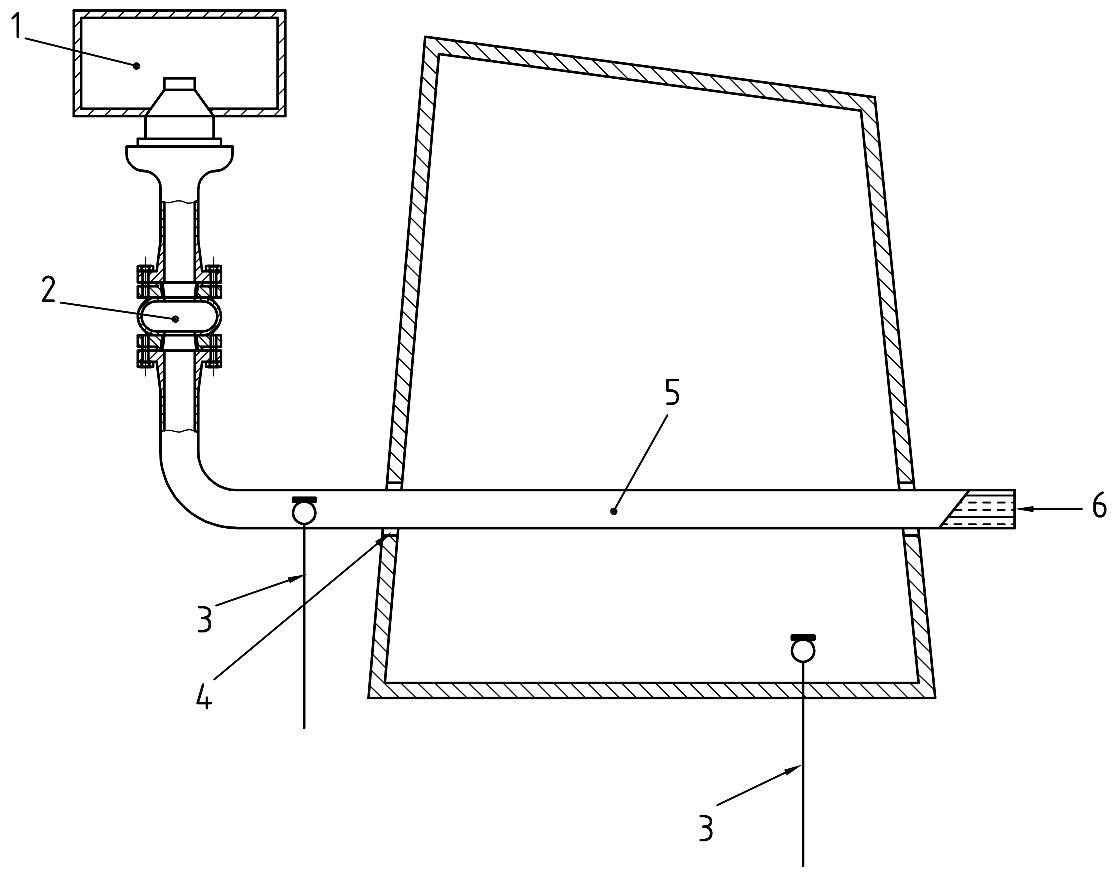
The minimum volume of the test room is specified in Table 3 of ISO 3741:1999. For reverberation rooms with volumes less than the values shown in this table for the frequency range of interest, or with a volume exceeding 300 m^3, the adequacy of the room for broadband measurements shall be demonstrated using the procedure of Annex D of ISO 3741:1999. The volume of the test specimen, including the acoustic insulation, is preferably not greater than 2 % of the volume of the reverberation room used for the test.

10.3.2 Installation

The test pipe shall be installed in such a way that sound contribution due to other sound transmission paths may be neglected compared with the sound transmission through the test specimen (see Figure 5). This is especially important regarding flanking sound transmission, which shall be at least 10 dB lower than the sound transmission through the test specimen. For that reason the test pipe has to be resiliently mounted outside the reverberation room at both ends. The test pipe shall penetrate through walls of the reverberation room without rigid connections. These penetrations shall be sealed adequately.

NOTE Appendix X1 of ASTM E1222:1990 describes a procedure to quantify flanking transmission in order to determine the maximum insertion loss that can be measured.

ISO 3741 states requirements for background noise. If the background levels appear to be too high, it may be necessary to insulate the pipe section outside the reverberation room.



Key

1 loudspeaker cabinet

2 flexible joint, reduction of structure-borne noise transmission

3 microphone

4 elastic seal

5 pipe with insulation under test

6 anechoic termination

Figure 5 — Sketch of test configuration for measuring insertion loss of pipe insulation

The pipe is terminated by means of a closed anechoic termination, which shall be located outside of the reverberation room. The termination shall have a reflection coefficient (power) of less than 10 % in the frequency range as defined in 10.5.

10.3.3 Pipe dimensions

The steel pipe shall have a length of at least 4 m and a diameter from 100 mm to 1 000 mm. For standard tests on pipes with outside diameters in the range of 100 mm to 300 mm, a minimum wall thickness of 4,2 mm is required; for pipes with a diameter in the range of 300 mm to 1 000 mm a minimum wall thickness of 6,3 mm is required.

For practical reasons, larger wall thickness are not recommended because they can cause measuring problems. Experience has proved that the measured insertion loss will also be valid for a larger wall thickness than that used during the test.

10.3.4 Sound source

Outside the reverberation room the test pipe is connected to a sound source with sufficient output in relation to the insertion loss to be measured. The test signal in each one-third-octave or octave band shall be white noise. Measurements may be performed simultaneously within one or more frequency bands.

A microphone shall be used inside the pipe to control the consistency of the noise source before and after insulation is applied to the pipe.

The sound source is attached flexibly to the test pipe wall in order to prevent transmission of structure-borne sound to the pipe. There shall be an arrangement (e.g. a bend) between the source and the test section in order to excite the higher order pipe modes sufficiently.

The change in sound absorption in the reverberation room due to the cladding system may be determined using a reference sound source in the reverberation room (different from the source connected to the pipe) which complies with ISO 354.

10.4 Test specimen

The acoustic insulation system shall be installed according to the manufacturer's standard instructions.

The gap at the penetrations of the (bare or insulated) pipe through the walls of the reverberation room shall be resiliently sealed in order to prevent that significant sound contributions radiate from the walls.

10.5 Measurements

The following measurements shall be carried out sequentially.

a) Measurements without insulation:

- excite the steel pipe with either broadband noise or sequential one-third-octave band noise at centre frequencies from 100 Hz to 10 kHz using the sound source connected to the pipe outside the test room;
- determine the average sound pressure level (L_b) in the test room according to ISO 3741;
- determine the average sound pressure level (L_{br}) using the reference sound source in the test room, with the sound source outside the test room turned-off.

b) Measurements with insulation:

- repeat the excitation of the pipe;
- determine the average sound pressure level transmitted by the test specimen including the cladding system due to the external source (L_c);
- determine the average sound pressure level due to the reference sound source in the test room (L_{cr}).

It is essential that the following conditions are not changed during the test:

- the setting of the test signal in the steel pipe;
- the setting of the reference source in the test room;
- the location of the source in the test room;
- the microphone positions or microphone path.

Examination and, if it appears necessary, interruption of structure-borne noise contacts between test specimen and the adjacent wall are essential. Cleaning of the test room after each modification of the test specimen is necessary to prevent changes in sound absorption in the test room. The sequence of the measurements (without and with insulation) may be altered if desired.

10.6 Results

In each frequency band of interest, the insertion loss is calculated according to the formula:

$$D_W = L_b - L_c - (L_{br} - L_{cr})$$

where

D_W is the insertion loss, in decibels;

L_b, L_c are the average reverberant sound pressure levels from the bare (L_b) pipe and the insulated (L_c) pipe, in decibels;

L_{br}, L_{cr} are the average reverberant sound pressure levels in the test room from the reference source with the bare pipe (L_{br}) and the insulated (L_{cr}) pipe, in decibels.

NOTE Regarding the term ($L_{br} - L_{cr}$), which takes into account the changes in sound absorption in the test room due to the cladding system, see the Note in 10.2.

Octave-band insertion loss data may be calculated from one-third-octave-band data as follows:

$$D_{W,\text{oct}} = -10 \lg \left(\frac{1}{3} \sum_{i=1}^{3} 10^{-D_{Wi}/10} \right) \text{dB}$$

where D_{Wi} is the insertion loss in each one-third-octave band of the related octave band.

10.7 Information to be reported

The information listed below shall be compiled and reported for all measurements made in accordance with this International Standard.

a) Test specimen under test:

— description of the pipe and the acoustic insulation system (dimensions and materials);

— special features for installing the insulation in the reverberation room, especially if deviating from normal installation procedures;

— location of test specimen in test room;

— location of sound source in test room.

b) Acoustical environment:

— description of test room, including dimensions, in metres, surface treatment of the walls, ceiling and floor; sketch showing the location of source and room contents;

— air temperature in degrees Celsius, relative humidity in percent, and barometric pressure in pascals;

— frequency range qualifications according to ISO 3741.

c) Instrumentation equipment used for the measurements, including name, type, serial number and manufacturer:

   — date, place, and methods for the calibration of the equipment used for the measurements;

   — copy of calibration certificate.

d) Acoustical data:

   — the location and orientation of the microphone path or array (a sketch should be included if necessary);

   — any corrections applied in each frequency band to account for background noise, in decibels;

   — insertion loss in octave bands in tabular form, insertion loss in one-third octave-bands in graphic form, in decibels to the nearest 0,5 dB;

   — the date and time when measurements were performed;

   — full details of person/organization that performed the test.

The report shall state whether or not the reported sound power levels have been obtained in full conformity with the requirements of this International Standard. If not, then each deviation shall be reported and the possible consequences shall be evaluated.

If the volume of the test pipe in relation to the volume of the reverberation room causes the uncertainty of the measured values in specified frequency bands to exceed the values as given in Table 2 of ISO 3741:1999, this shall be mentioned explicitly (see 10.3.1).

Annex A
(informative)

Equations for the calculation of the minimum required insertion loss $D_{W,\min}$ of the insulation classes

The required insertion loss of the insulation classes $D_{W,\min}$ for the octave centre frequencies from 125 Hz to 8 000 Hz can be approximately calculated (within 0,5 dB) by the empirical equations given in Table A.1.

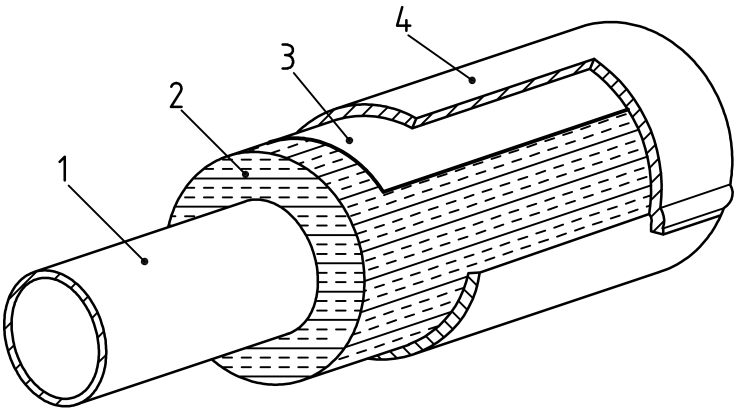
Table A.1 — Calculation of minimum required insertion loss

Insulation class	Frequency band Hz	Required insertion loss $D_{W,\min}$ dB
Class A1 and A2	$125 \leqslant f \leqslant 250$	–4
	$250 < f \leqslant 8\,000$	$22 \lg f/f_0 - 57$
Class A3	$125 \leqslant f \leqslant 8\,000$	$19 \lg f/f_0 - 44$
Class B1	$125 < f \leqslant 500$	$20 \lg f/f_0 - 51$
	$500 < f \leqslant 8\,000$	$27 \lg f/f_0 - 70$
Class B2	$125 < f \leqslant 250$	$20 \lg f/f_0 - 51$
	$250 < f \leqslant 8\,000$	$30 \lg f/f_0 - 75$
Class B3	$125 < f \leqslant 2\,000$	$30 \lg f/f_0 - 70$
	$2\,000 < f \leqslant 8\,000$	$22 \lg f/f_0 - 43{,}5$
Class C1	$125 \leqslant f \leqslant 250$	$13 \lg f/f_0 - 32$
	$250 < f \leqslant 2\,000$	$39 \lg f/f_0 - 94{,}5$
	$2\,000 < f \leqslant 8\,000$	$13{,}5 \lg f/f_0 - 10{,}5$
Class C2	$125 < f \leqslant 2\,000$	$34 \lg f/f_0 - 78$
	$2\,000 < f \leqslant 8\,000$	$13{,}5 \lg f/f_0 - 10{,}5$
Class C3	$125 \leqslant f \leqslant 2\,000$	$27 \lg f - 55{,}5$
	$2\,000 < f \leqslant 8\,000$	$13{,}5 \lg f/f_0 - 10{,}5$
f_0 = 1 Hz		

Annex B
(informative)

General construction of acoustic insulation

The examples shown in Figures B.1 and B.2 are intended to be typical construction methods and are not mandatory.



Key

1 pipe

2 porous layer

3 added mass or damping layer

4 cladding

NOTE Cladding may be fixed in position with

— rivets,
— self-tapping screws, or
— stainless-steel retaining bands.

Figure B.1 — General construction of acoustic insulation

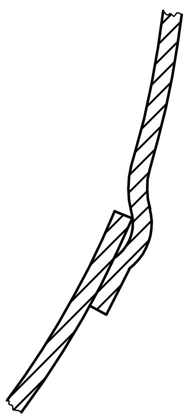
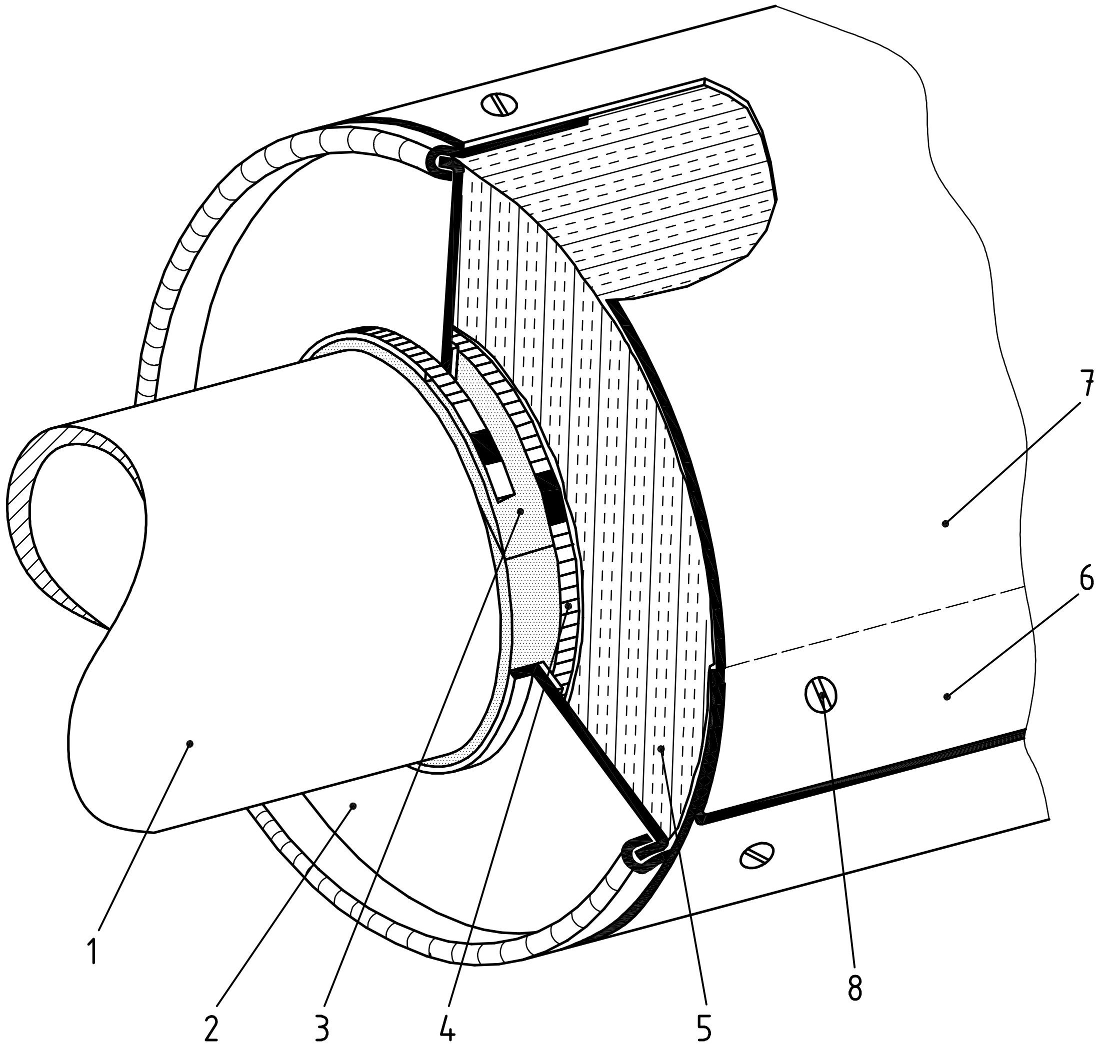


Figure B.2 — Overlap (such that ingress of rain water is prevented)

Annex C
(informative)

Examples of typical construction details

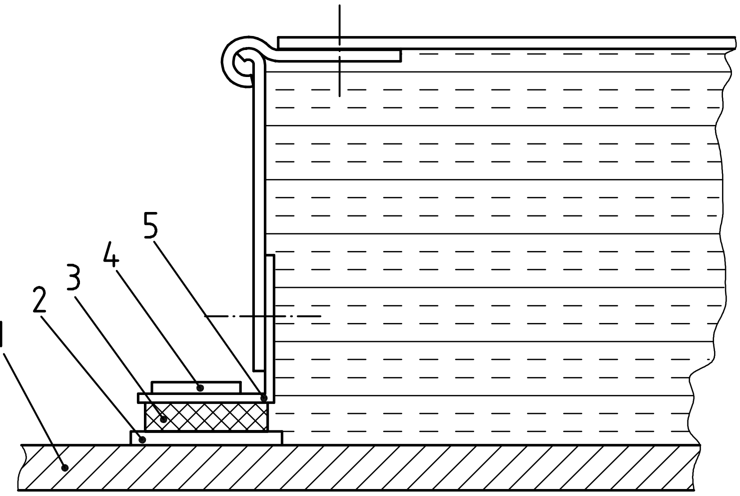
The examples shown in Figures C.1 to C.10 are intended to be typical construction methods and are not mandatory.



Key

1 pipe
2 end cap, may consist of two overlapping halves with overlap in the horizontal plane
3 vibro-acoustic seal [see Figure C.2 a)]
4 retaining banding
5 porous layer
6 overlap (longitudinal seams shall be located in the 4 to 5 o'clock position to prevent moisture intrusion)
7 cladding
8 fixing system of the cladding: rivets, screws (these shall not be used when cladding is directly over a vapour barrier) or stainless-steel straps

Figure C.1 — Typical arrangement of acoustic insulation showing cladding and end cap



Key

1 pipe

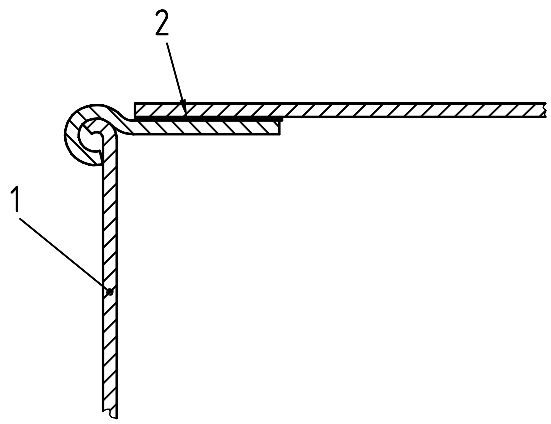
2 adhesive/sealing layer

3 vibro-acoustic seal

4 retaining band

5 shaped profile collar

a) Vibro-acoustic seal



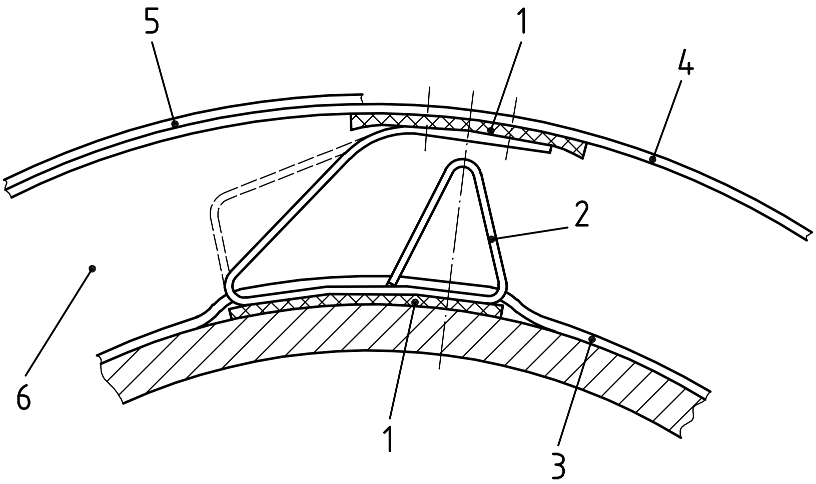
Key

1 end cap

2 mastic seal

b) End cap to cladding seal

Figure C.2 — End cap of pipe insulation



Key

1 resilient pad

2 spring + stop

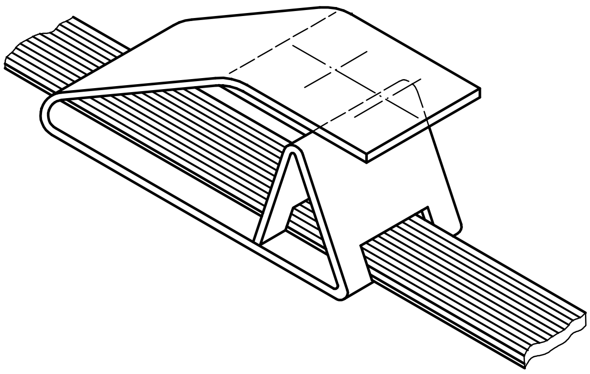
3 retaining band

4 cladding support ring

5 cladding

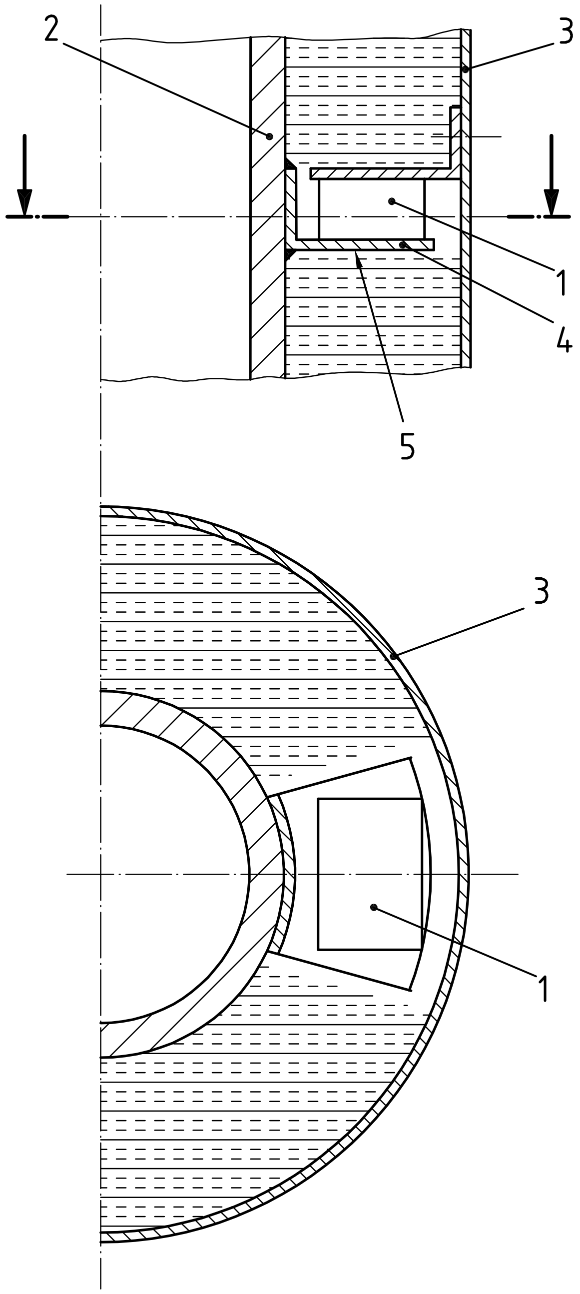
6 air-gap (may be provided with porous layer)

a)



b)

Figure C.3 — Typical arrangement for cladding supports



Key

1 vibration-isolating pad

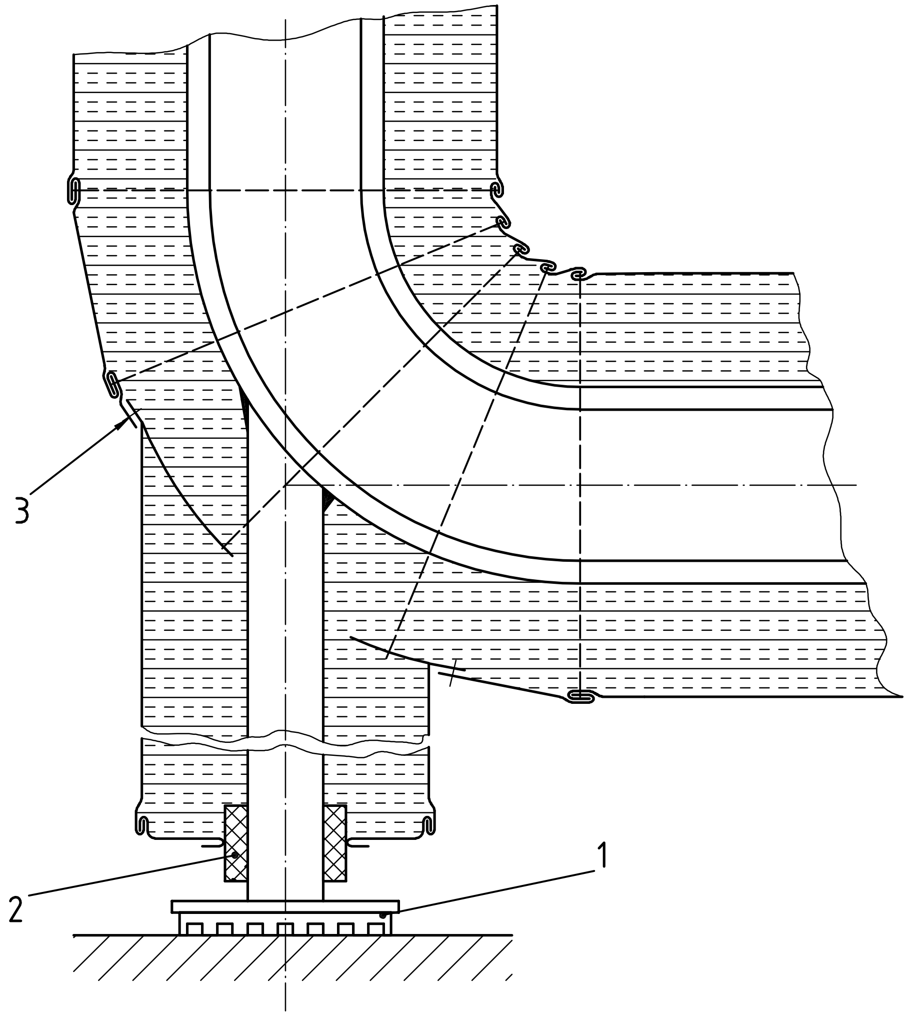
2 pipe wall

3 cladding

4 vulcanized layer

5 support on strapping band (or welded)

Figure C.4 — Typical arrangement for vibration-isolated cladding and insulation supports in vertical pipes



Key

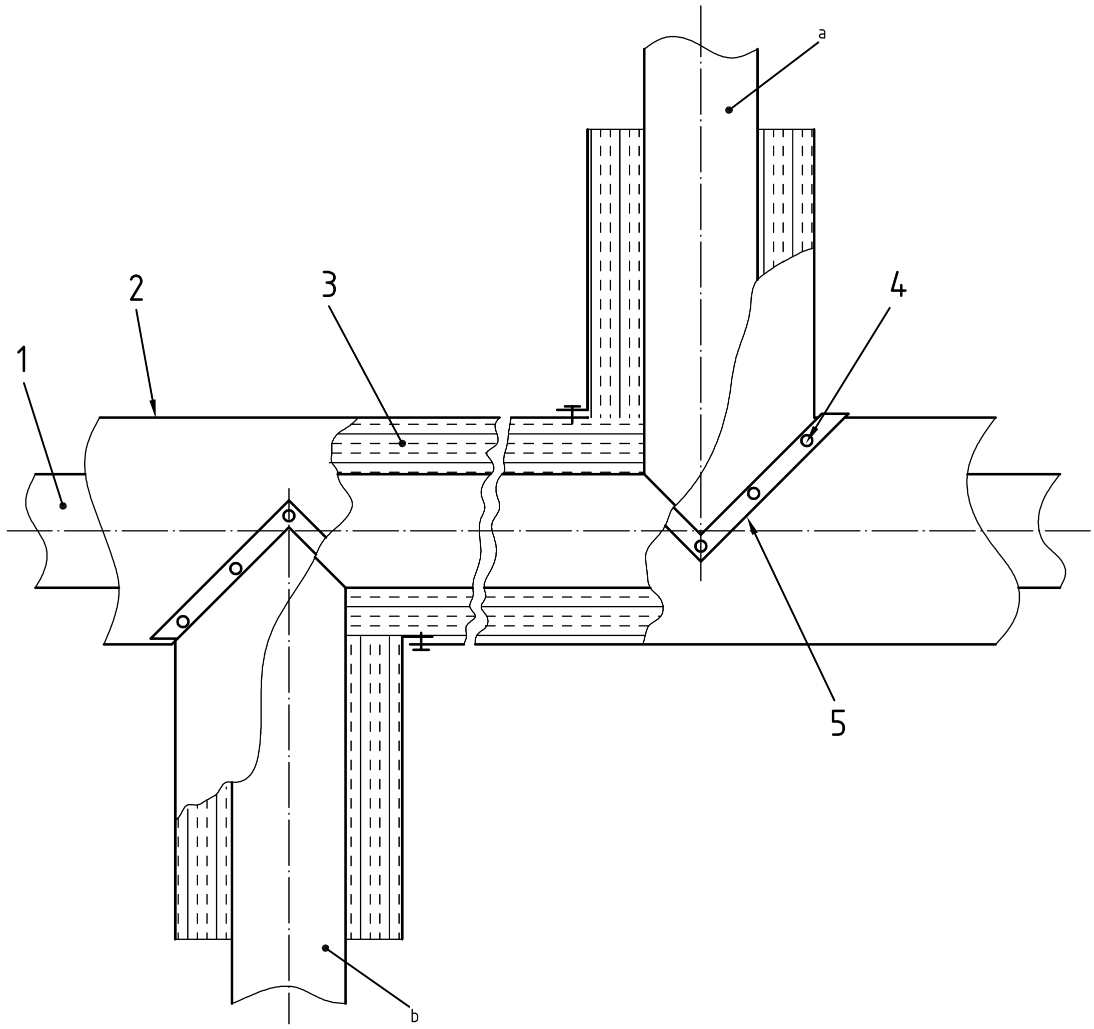
1 vibration-isolating pad

2 vibro-acoustic seal

3 mastic seal

NOTE For Class A insulation, a T-shaped construction (similar to Figure C.6) is allowed for lines up to DN 100; for Classes B and C insulation, a T-shaped construction is allowed for lines up to DN 150.

Figure C.5 — Support for vertical pipe

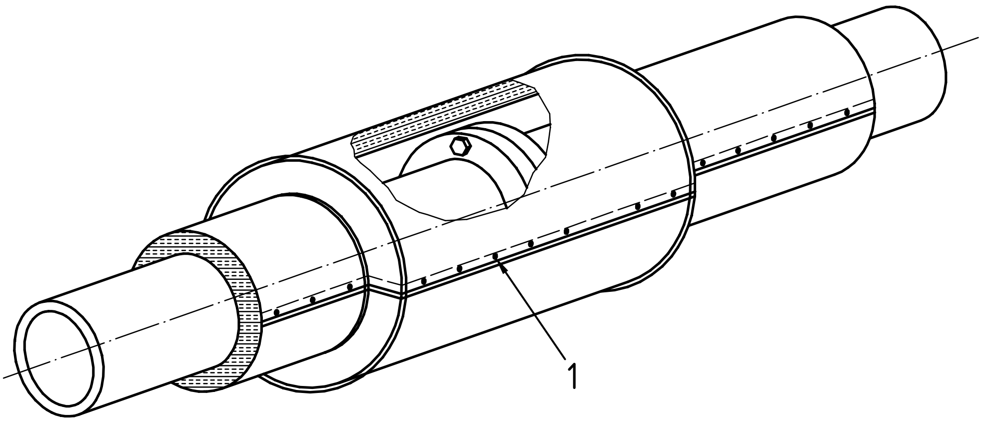


Key

1 pipe
2 cladding
3 porous layer
4 screws or rivets
5 mastic seal

[a] Upper connection.
[b] Lower connection.

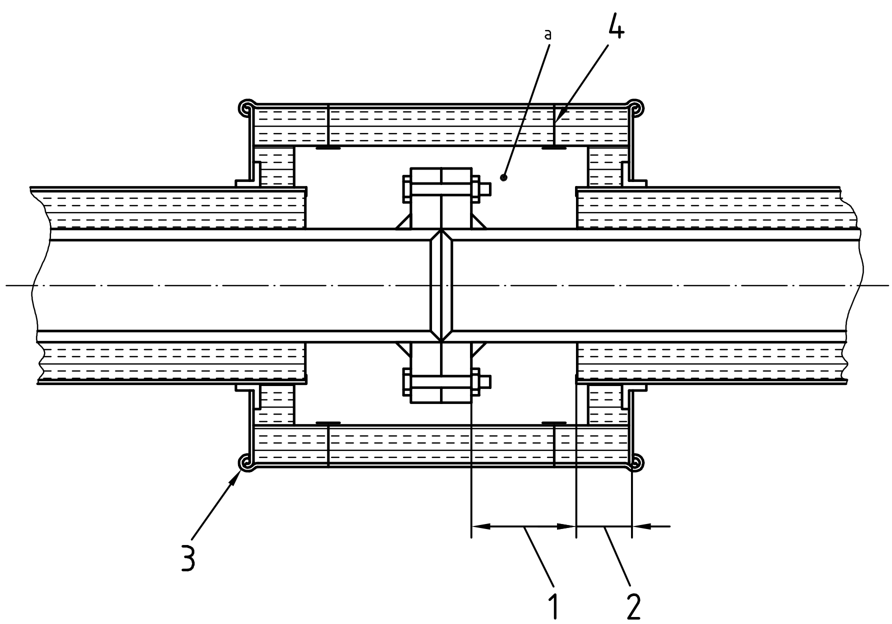
Figure C.6 — Typical arrangement for branches and tees



Key

1 fixing system of the cladding: rivets, screws (these shall not be used when cladding is directly over a vapour barrier) or stainless-steel straps

a)



Key

1 bolt length + 30 mm

2 overlap = insulation thickness

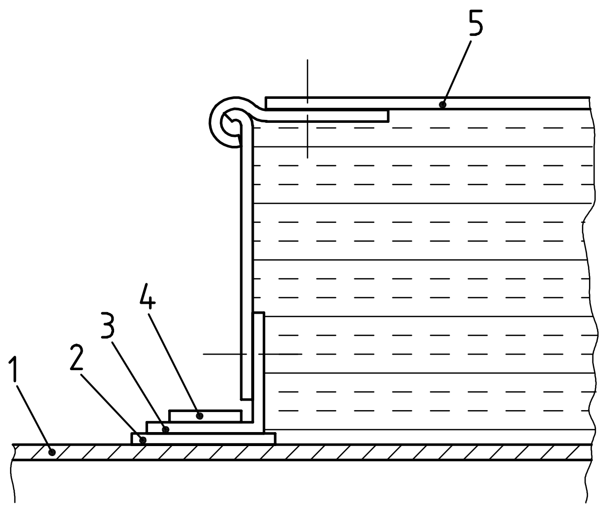
3 lock formed

4 clip to fix porous layer

[a] Space may be filled with porous material.

b)

Figure C.7 — Arrangement for the acoustic insulation of flanged joints



Key

1 pipe insulation cladding

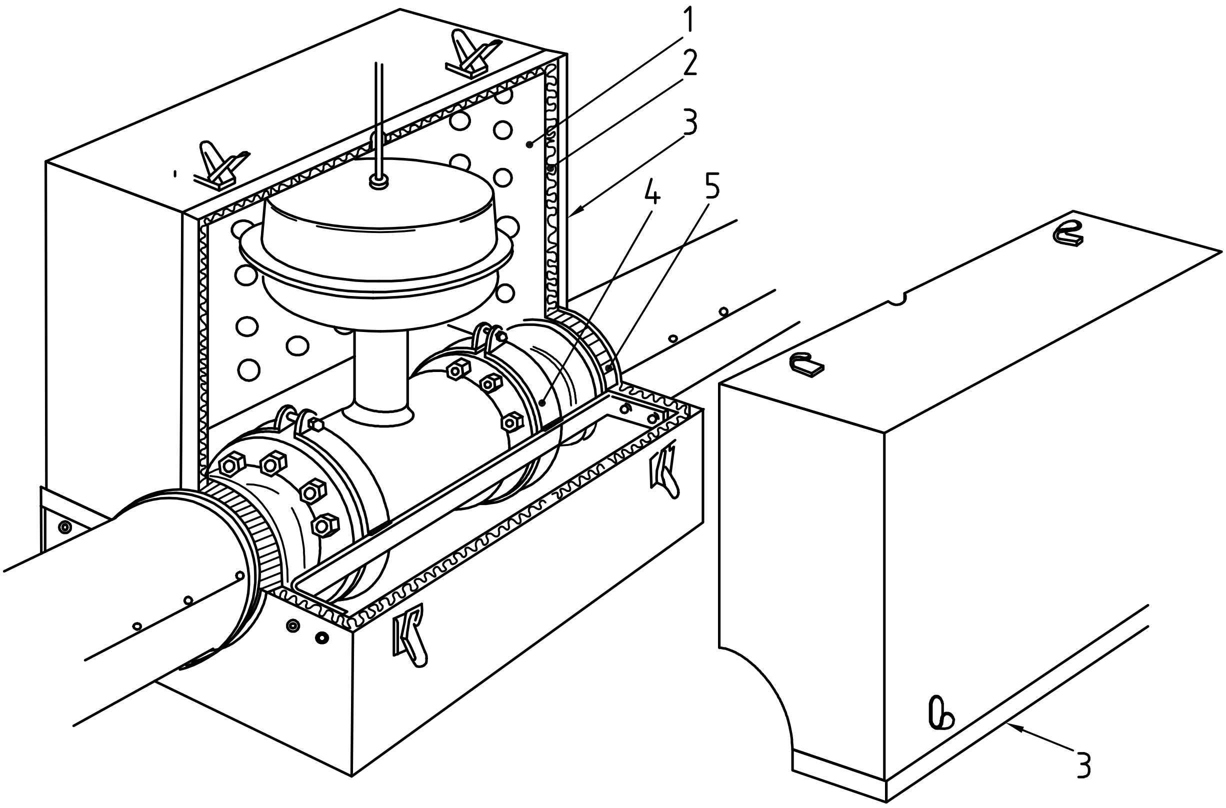
2 adhesive sealing mastic layer

3 shaped profile

4 retaining band (stainless)

5 cladding (box)

Figure C.8 — Construction details: End cap of enclosure



Key

1 perforated sheet

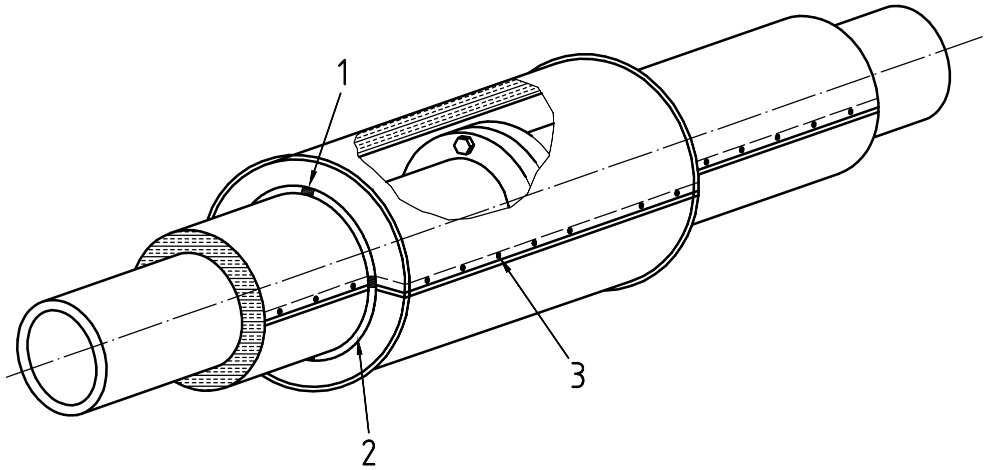
2 porous layer

3 locating edge to help locate upper portions

4 supporting framework clamped to flanges (over vibration isolation pad)

5 vibro-acoustic seal

Figure C.9 — Example of an acoustic enclosure for a valve



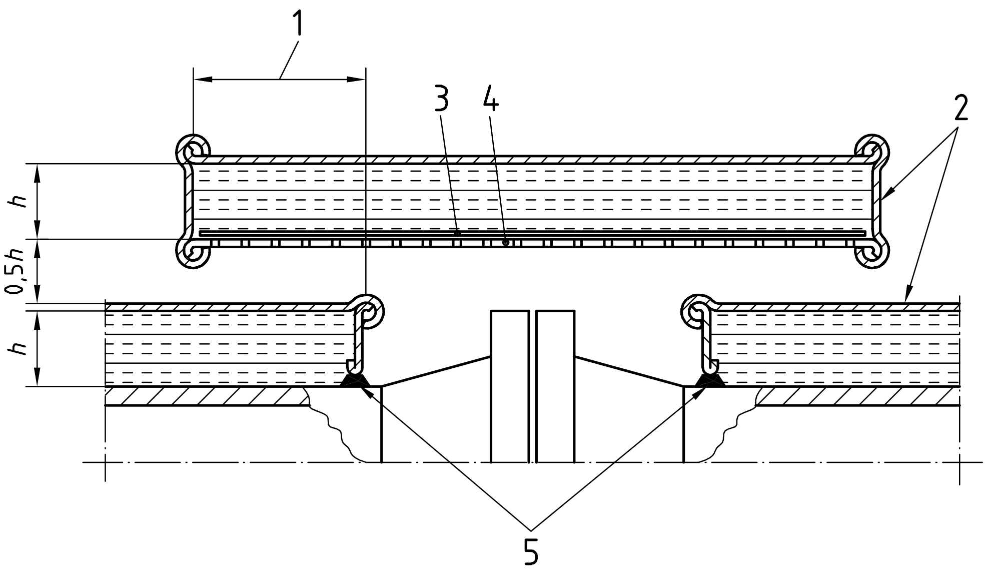
Key

1 support

2 venting aperture

3 fixing system of the cladding: rivets, screws (these shall not be used when cladding is directly over a vapour barrier) or stainless-steel straps

a)



Key

1 overlap 100 mm (or 200 mm or 300 mm)

2 cladding

3 glass cloth

4 perforated sheet

5 anti-vibration seal (if end cap is required)

b)

Figure C.10 — Vented acoustic insulation of flanged joints and bellows

Bibliography

[1] ISO 3743-1, *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*

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