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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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 $\text{N}\cdot\text{s/m}^4 = \text{Pa}\cdot\text{s/m}^2$.

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.

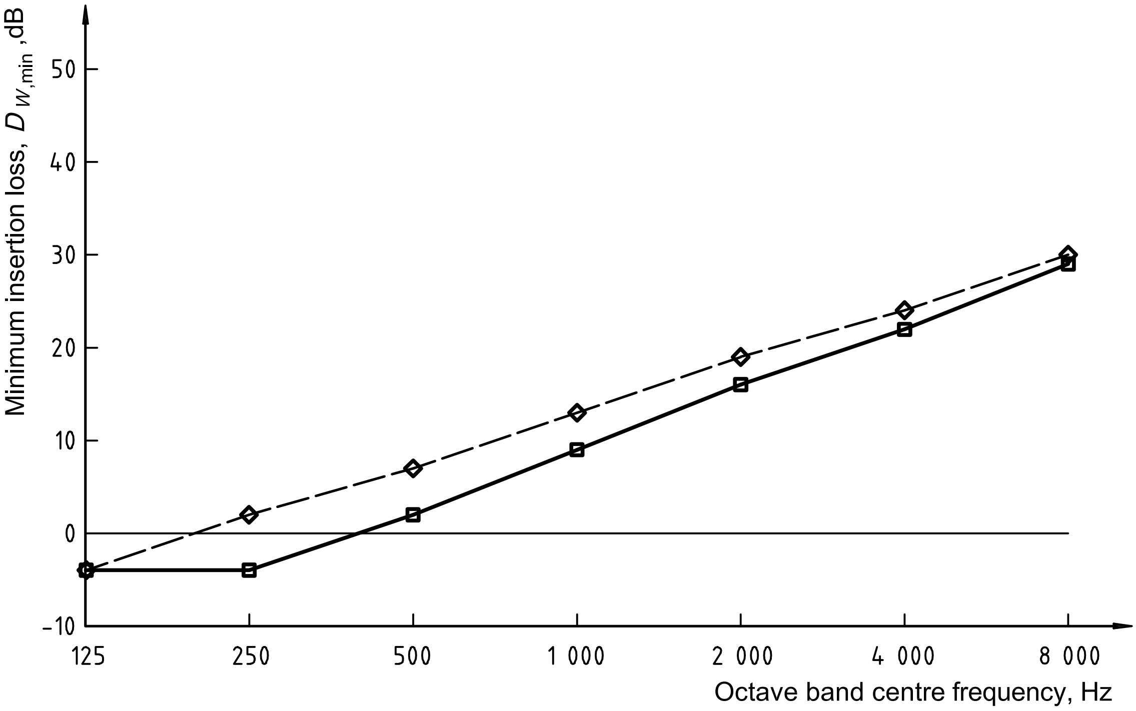
The pipe sizes used are:

- 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”.

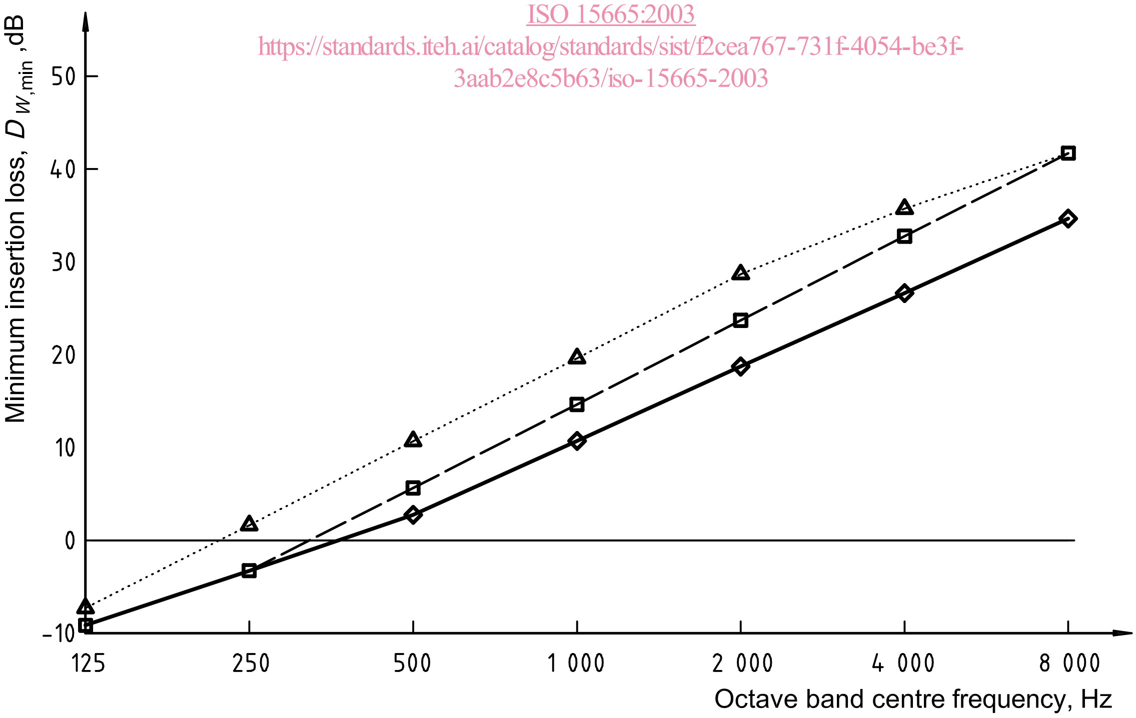


Key

—□— Classes A1 and A2

—◇— Class A3

Figure 1 — Minimum insertion loss required for Class A



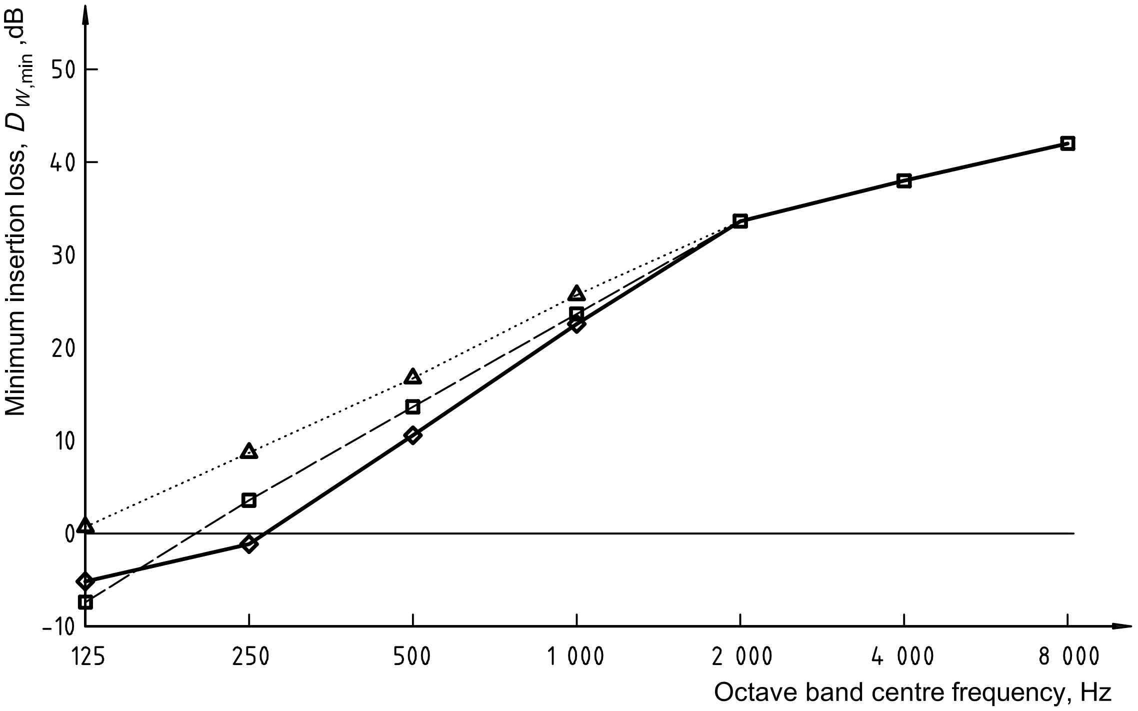
Key

—□— 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):

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

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];

$\bar{L}_p(x,r)$ 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:

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

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:

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

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.