TECHNICAL SPECIFICATION

ACOUSTIC INSULATION FOR PIPING

DEP 31.46.00.31-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the acoustic insulation of pipes, valves and flanges to reduce the noise emitted by these items.

Acoustic insulation of other equipment, such as large vessels and machinery, are excluded from the scope of this DEP. Also excluded are aspects common to thermal insulation, such as cladding, fastening, sealing, surface protection, safety regulations and compatibility of the porous layer materials with the environment. For these aspects reference is made to DEP 30.46.00.31-Gen. and DEP 30.46.00.32-Gen.

This DEP is a revision of the DEP of the same number dated November 1983.

Sections 3 and 4 of this DEP deal with acoustic aspects and are intended for the noise control engineer responsible for the acoustic design of the plant. Four classes of insulation are included in terms of their required acoustic performance and the choice of class will depend on the expected or measured noise radiated from the pipe and the required noise reduction. A general description is given of how this should be derived from equipment data or from measurements in operating units.

Sections 5, 6 and 7 of this DEP specify materials and installation aspects and are intended for the insulation contractor so that he can achieve the required noise reduction.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F" as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants and, where applicable, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for and on behalf of the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Pipe
Unless the context indicates otherwise, the word pipe also includes other piping components such as valves, fittings and flanges.

Acoustic insulation
Acoustic insulation consists of one or more layers of a sound-absorbing material (the 'porous layer(s)') and one or more impermeable layers (the 'cladding'). It is applied to reduce the noise radiated from the pipe.

Flow resistivity
The flow resistivity of a porous material is defined as the pressure drop per unit thickness of the material for an air flow of unit velocity through the material.

It may be expressed as:

Flow resistivity = pressure drop / (air velocity * thickness of sample)

The dimension of flow resistivity is $Ns/m^4 = Pa.s/m^2$ (also referred to as Rayl/m)

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

Insertion loss
Insertion loss (IL) is the difference in the sound pressure level at a given fixed point anywhere outside the influence range of noise sources other than the pipe, before and after the acoustic insulation has been fitted. It is not appropriate to express insertion loss as a single number such as dB(A) because it varies with frequency. It shall therefore be quoted as decibels in octave bands (minimum range 125 Hz to 8 KHz).

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (8.).

2. GENERAL

General requirements with respect to noise are given in DEP 31.10.00.31-Gen. which specifies the procedures for controlling noise and specifies maximum allowable noise levels.

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 travel inside the pipe with little attenuation. Noise radiation should be reduced by using low noise equipment. If this is not reasonably practicable, the noise radiation may be reduced by incorporating in-line silencers or by applying acoustic insulation in accordance with this DEP.

In many respects acoustic insulation is similar to thermal insulation and is frequently installed by a sub-contractor specialised in thermal insulation. However, some aspects of acoustic insulation are different and the purpose of this DEP is to draw the attention of both the installer and the noise control engineer to these aspects.

It is emphasised that the ultimate success of acoustic insulation depends on the quality of installation; small gaps or bridging effects can have a far greater effect on the acoustic properties than on the thermal properties and may completely negate the acoustic performance. Thorough inspection shall therefore be performed during installation.

3. NOISE REDUCTION ENGINEERING

3.1 REQUIRED ATTENUATION

3.1.1 Plant design phase

The following considerations may be used to estimate the required attenuation in the design phase of a plant:

Firstly, determine the sound pressure level at a distance of 1 metre from the bare pipe wall. Piping upstream and downstream of the source shall be considered separately. The method to be applied depends on the pipe noise source in question (many valve manufacturers, for example, provide calculated dB (A) levels downstream of their valves). Both the octave band sound pressure levels and the overall A-weighted level should be determined. Appendix 10 gives typical octave band spectra for the most common sources of pipe noise.

3.1.1.1 Work area noise

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 area in question can be compared directly with the area's noise limit, see DEP 31.10.00.31-Gen., and any excess noise obtained by subtraction.

If other noise sources are also present the total noise level should be determined before comparing it with the work area noise limit. The most economical means of eliminating excess noise should then be considered; either by reducing the pipe noise or by reducing the other sources.

3.1.1.2 Environmental noise or reverberant space

(i) If the pipe is in a reverberant space or is subject to environmental noise limits, its sound power level should be determined. The sound power level L_W of the pipe is derived from:

$$L_w (s) = L_p (x,r) + 10 \log (2\pi rs) \quad \text{(dB)} \quad (1)$$

in which:

	s	=	the length of the pipe (s>>r), m
	D	=	diameter of the pipe, m
	r	=	distance from the pipe axis, m (r normally = (1 + ½D), which is 1 m from pipe wall)
	$L_p(x,r)$	=	the sound pressure level at a distance r from the axis of the pipe, at a distance x from the source, counted along the pipe
	log	=	logarithm to base 10

NOTE: Preferred value for x is 1 m; where attenuation along the pipe is considered negligible, other values of x may also be used.

(ii) If the pipe is long (see below) it may be worth taking into account the attenuation along the length of the pipe, which is expressed by the formula:

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

in which:

	$L_p(x,r)$	=	see equation (1)
	$L_p(1,r)$	=	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	=	attenuation factor, (dB)

The value of β shall be 0.06 dB for pipes carrying gas or vapour and 0.017 dB for pipes carrying liquid, except that other values may be used if sufficient data is available. The length of pipe should exceed ($3D/\beta$) before attenuation should be taken into account. On the basis of equation (2) the sound power level L_w of a long pipe can be shown to be:

$$L_w(s \rightarrow \infty) = L_p(1, r) + 10 \log \frac{rD}{\beta} + 14.4 \qquad \text{(dB)} \qquad (3)$$

NOTE: The complete equation for the relation between L_w and $L_p(1)$ is:

$$L_w(s) = L_p(1, r) + 10 \log \frac{2\pi rD}{0.1\beta \ln 10} + 10 \log (1 - 10^{-0.1\beta s/D}) \qquad \text{(dB)} \qquad (4)$$

in which ln = logarithm to base e

For small values of ($\beta s/D$), equation (4) can be shown to simplify into equation (1) and into equation (3) for very long pipes. The errors involved in applying equation (1) to pipes longer than ($3D/\beta$) and in applying equation (3) to shorter pipes can be shown to be less than 3 dB.

(iii) If the sound pressure level near to a source or the sound power level of a pipe section connected to that source is known and the pressure or power level has to be determined of another section under different conditions but connected to the same source, the following formula can be used to determine the difference in level due to those other conditions:

$$\Delta L = 10 \log t/t_k - 30 \log D/D_k - 10 \log P/P_k \qquad \text{(dB)} \qquad (5)$$

in which:

	ΔL	=	difference in (sound pressure or power) level, dB
	t	=	pipe wall thickness, m
	D	=	pipe diameter, m
	P	=	internal static pressure in pipe, Pa

Subscript $_k$ refers to the conditions of the known level

The contribution of the pipe to the noise in a 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 adjacent point should be calculated.

If allowable limits are exceeded by the combined effect of noise sources, the most economical method of reducing noise should be found.

3.1.2 Plants in operation

In operating units the assessment of pipe noise should be based on measurements, and where the pipe noise is significantly higher than the background noise it may be measured directly as airborne noise.

If background noise is significant, pipe noise can be determined with sound intensity measurements. These measurements require special equipment and qualified personnel.

A third, less preferred option is to assess the pipe noise by measuring the vibratory velocity level as follows:

$$L_p(x,r) = L_v + 10 \log \sigma + 10 \log (D/2r) \qquad \text{(dB)} \qquad (6)$$

in which: L_v = the vibratory velocity level in the pipe = 10 log (v/v_o)

v_o = 5×10^{-8}, m/s

10 log σ = radiation efficiency (10 log σ is negative, as $0 < \sigma < 1$)

The symbols D and r are pipe diameter and radial distance, as before. For practical purposes the value of σ can be derived from:

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

in which c = velocity of sound in air, m/s

f = octave band mid-frequency, Hz

This method also requires special equipment and qualified personnel.

3.2 CHOICE OF ACOUSTIC INSULATION CLASS

Where pipe noise is to be reduced, the various alternatives should be considered:

- equipment designed for low noise;
- silencers;
- acoustic insulation.

If the assessment concludes that acoustic insulation of a pipe is required, the necessary reduction of pipe noise should be tabulated in octave bands. Reference to (4.1, Table 1) will then indicate which class of insulation is required; see also (4.2) for the limits of application.

Pipes will usually have to be insulated from the source up 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 upstream or downstream of the source to render further insulation unnecessary.

This may be the point where the contribution of the pipe to the work area noise level is below the specified value, as according to equation (2). Alternatively, if the sound power level of a pipe is to be reduced, the length of the pipe, L, to be insulated can be derived as follows:

$$L = \frac{10D}{\beta} \log\left(\frac{1 - a}{R - a}\right) \quad \text{(m)} \qquad (8)$$

in which R = the reduction factor required for the radiated sound power level

= antilog $\{(L_{w,after} - L_{w.before}) / 10\}$

and a = the insertion loss factor of the acoustic insulation

= antilog $\{(L_{p,\ after} - L_{p,\ before}) / 10\}$

= antilog (-IL/10)

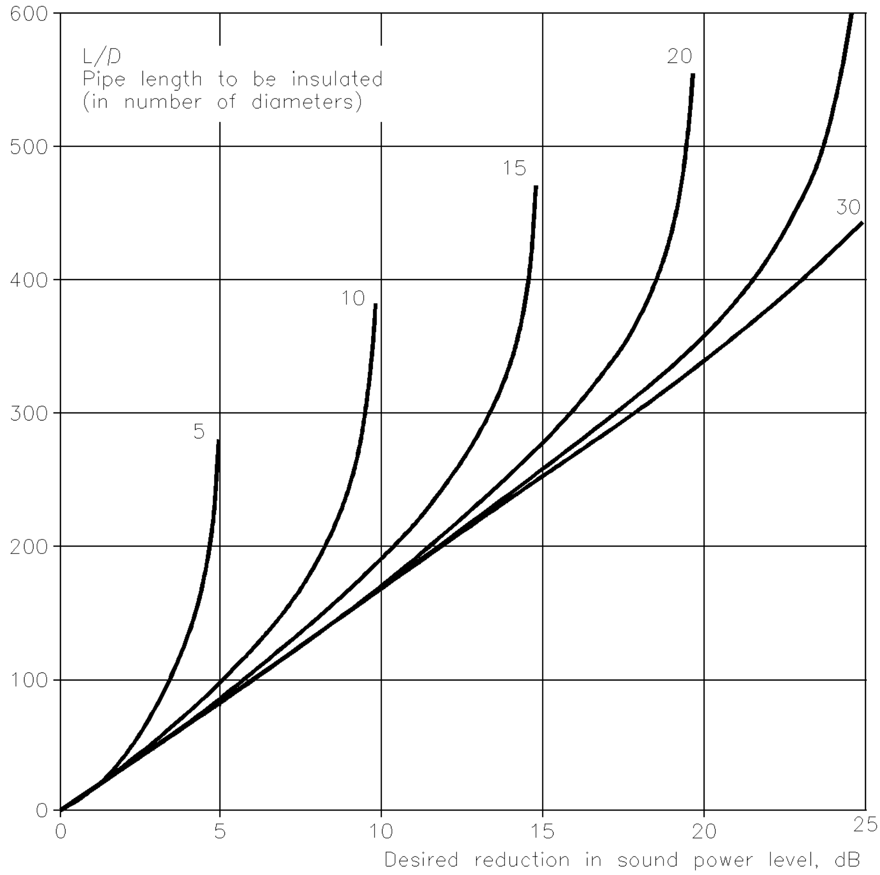
IL = the insertion loss of the insulation (see Section 8)

NOTE: antilog (x) means 'ten to the power x'

The relation between the variables in equation (8) is illustrated in Figure 1, with the attenuation factor β taken as 0.06. This figure shows 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 in some cases it may be more economical to choose a class of cladding with higher insertion loss, because the required length is (much) shorter.

NOTE: Both equation (8) and Figure 1 can be used for either octave band or overall dB(A) values.

Figure 1: Length of pipe to be insulated for a given reduction in sound power level
Parameter: Insertion loss of insulation, dB



The noise control engineer shall specify the class and extent of acoustic insulation for the piping of all relevant noise sources.

3.3 IMPLICATIONS FOR PIPING DESIGN

It is important to ensure at an early stage of the design that the piping arrangement allows for the bulk and mass of acoustic insulation. The noise control engineer should therefore estimate the noise levels of major piping and mark on the process engineering flow schemes those sections of pipe which are to be acoustically insulated. At the same time he should consider whether the substitution of low-noise sources or the use of silencers would be more appropriate.

The design of pipe supports and hangers shall allow sufficient space for the installation of acoustic insulation (see Section 5, Table 2 for the dimensions of the insulation).

They shall also be such that the insulation can be fitted completely around the pipe. Where pipes are attached to steel structures special consideration should be given to the isolation of vibrations between the pipe and the structure, see Appendix 7. Vibration isolation pads shall be selected suitable for the applied (static) loads.

If 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, even if 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 used for overhead piping subject to thermal expansion do not necessarily have a satisfactory acoustic performance.

4. CLASSES OF ACOUSTIC INSULATION

4.1 DEFINITION OF CLASSES

Table 1 defines four classes of acoustic insulation (A, B, C and D) in terms of requirements for minimum insertion loss.

Table 1 Required insertion loss

		Octave band centre frequency (Hz)						
		125	250	500	1000	2000	4000	8000
Class	Nominal Diameter range (DN)	**Minimum insertion loss (dB)**						
A		-10	-10	1	9	20	30	35
B		-8	-3	9	21	30	35	40
C	< 300	-5	-1	12	26	45	45	45
	300 < 650	-3	4	15	25	35	40	40
	≥ 650	3	9	18	25	33	40	40
D	300 < 650	-3	4	15	36	45	45	45
	≥ 650	3	9	26	36	45	40	40

NOTE: The reduction in overall sound pressure level in dB(A) will depend on the frequency spectrum of the source. Some typical examples are given in Appendix 10.

4.2 RESTRICTION IN APPLICATION

Acoustic insulation will reduce the noise radiated directly from the pipe but there is a counteracting effect: for any residual vibrations of the cladding a larger radiating area is available 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 greater with small diameter pipes and they limit the applicability of the various classes of insulation. The performance of the various classes at high frequencies generally does not depend on pipe size.

The values of insertion loss given in Table 1 should be attained by an insulation system which has been designed and installed in accordance with this DEP, but the noise control engineer may apply a factor to allow for possible expected deficiencies in installation and maintenance.

5. DIMENSIONS OF ACOUSTIC INSULATION

The dimensions of the acoustic insulation for the four classes shall be as indicated in Table 2. If properly installed, the acoustic performance obtained with the various classes will be as given in (4.1).

NOTE: If the contractor or supplier wishes to propose alternative constructions for the classes he shall indicate which class he proposes to modify. He shall also give evidence that the proposed construction has the required acoustic performance.

Table 2 Classes of acoustic insulation

Class A	thickness of porous layer (mm)		50	
	minimum mass per unit area of cladding (kg/m^2)		4.5	(e.g. 0.6 mm steel plate)
Class B	thickness of porous layer (mm)		100	
	minimum mass per unit area of cladding (kg/m^2)		6.0	(e.g. 0.8 mm steel plate)
Class C	thickness of porous layer (mm)		100	
	minimum mass per unit area of cladding (kg/m^2)	pipe diameter < DN 300	7.8	(e.g. 1.0 mm steel plate)
		pipe diameter ≥ DN 300	10.0	(e.g. 1.3 mm steel plate)
Class D	**Only specified for nominal pipe diameters ≥ DN 300**			
	thickness of first porous layer (mm)		50	
	minimum mass per unit area of cladding (kg/m^2)		6.0	(e.g. 0.8 mm steel plate)
	thickness of second porous layer (mm)		50	
	minimum mass per unit area of cladding (kg/m^2)	pipe diameter < DN 650	7.8	(e.g. 1.0 mm steel plate)
		pipe diameter ≥ DN 650	10.0	(e.g. 1.3 mm steel plate)

NOTES:

1. Where the above requirements for thickness of the cladding and the requirements of DEP 30.46.00.31-Gen. are not the same, the thicker of the sheet materials specified shall be used.

2. 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 an outer layer of steel or aluminium (for mechanical protection) satisfying the requirements of DEP 30.46.00.31-Gen., see Note 1, and an inner layer of lead or PVC foil weighted with barium oxide to provide the additional mass.

Pipe fittings shall be insulated to the same class as the straight sections of the pipe (see Appendices 4 to 7).

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

Class A:
Flanges and valves need not be insulated for acoustic purposes.

Classes B, C and D:
Distance and support rings should be avoided as far as possible; but if used they shall comply with (6.4.).

All flanges and valves shall be insulated to the same class as the pipe (7.5), except where insulation of these items is not allowed for other reasons (e.g. flanges in hydrogen service). Pipe supports shall be insulated up to the concrete or steel base, see Appendix 7.

6. COMPONENTS AND MATERIALS

This section lists materials suitable for acoustic insulation and the particular properties necessary for acoustic purposes. All materials shall comply with DEP 30.46.00.31-Gen. or DEP 30.46.00.32-Gen., as applicable. They shall be suitable for the maximum operating temperatures and for the chemical nature of the environment.

6.1 POROUS LAYER

The porous layer serves the following purposes:

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

The porous layer shall be in the form of blankets or pre-formed pipe sections.

The flow resistivity of the porous layer shall be in the range 25 000 - 75 000 Ns/m^4. The following materials are suitable for acoustic purposes:

(a) mineral wool;
(b) glass wool.

Materials with a closed cell structure, e.g. PUF/PIR and cellular glass, shall not be used.

6.2 CLADDING

The cladding serves the following purposes:

- it is a barrier to the noise radiated by the pipe;
- 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.

The following materials are suitable for acoustic purposes:

(a) aluminised steel;
(b) stainless steel;
(c) aluminium;
(d) lead (not as an outer layer);
(e) mineral-loaded plastic (not as an outer layer).

The minimum mass per unit area of the cladding shall be in accordance with Section 5, Table 2.

6.3 ANTI-VIBRATION SEALS

The following materials are suitable for use in anti-vibration seals:

(a) synthetic and natural rubber;
(b) non-flammable felt.

Where these materials are unsuitable for the operating temperature, the seals shall be made of compressed porous layer material (6.1).

6.4 SUPPORT OF THE CLADDING

Where the porous layer is composed of pre-formed pipe sections and the pipe is horizontal, it will not normally be necessary to support the cladding, but where blankets are used it may be necessary to support the cladding separately.

Best results have been obtained with glass fibre pads mounted between two positioner rings or guided by one positioner ring. These pads have an elastomeric coating and are flexible along one axis but rigid along other axes. The pads shall be installed with their flexible axis radial to the pipe. The pads shall be fitted at a circumferential spacing of about 0.25 m and an axial spacing of between 1 m and 1.5 m.

Short semi-rigid sections of porous layer at intervals are less suitable, but if used it shall first be confirmed that they are suitable for the operating temperature and the chemical environment.

Rigid spacers, as used in distance rings for thermal insulation, shall not be used in acoustic insulation. Spacers shall 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 their maximum deflection, see Appendix 8.

Support rings (see Appendix 9) which carry the weight of vertical stretches of acoustic insulation shall contain resilient elements.

Commercially available anti-vibration mountings should be used wherever possible. 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. Products shall be chosen suitable for the load applied.

6.5 COMBINED THERMAL AND ACOUSTIC INSULATION

6.5.1 Hot services

If insulation is required for thermal as well as for acoustic reasons the same material may be used for both purposes. The thickness of the porous layer shall be determined by the more stringent of the two requirements.

Hot insulation systems are specified in DEP 30.46.00.31-Gen.

6.5.2 Cold services

The cold insulation system specified in DEP 30.46.00.32-Gen. shall be applied to the pipe first and the acoustic insulation shall then be applied on top. The density of the porous layer should be about 150 kg/m^3 for this application. To prevent condensation at the interface between the two layers a second vapour barrier shall be applied outside the porous layer. The vapour barrier shall conform to DEP 30.46.00.32-Gen. Care should be taken to avoid damage when applying the cladding directly over the vapour barrier; rivets or self-tapping screws shall not be used.

7. INSTALLATION

7.1 GENERAL

DEP 30.46.00.31-Gen. and DEP 30.46.00.32-Gen. shall apply except where otherwise specified by this DEP.

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 the isolation of vibrations in order to prevent their transmission to the cladding or adjacent structures, such as supports.

NOTE: The illustrations in the appendices show the general principles required for acoustic insulation but the actual installation may vary in detail according to local circumstances.

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 will allow a transmission of vibrations to the cladding which will reduce or nullify the noise reduction of the insulation; it may even increase the noise radiation due to 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.

As the pipe on which the acoustic insulation is to be mounted may not always be hot, corrosion shall be prevented by painting in accordance with DEP 30.48.00.31-Gen., and by preventing the ingress of rain water and the condensation of water vapour in and on the insulation.

7.2 EXTENT OF INSULATION

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

The insulation of pipe supports, flanges and valves shall be in accordance with the requirements of the class, see Section 5.

7.3 ANTI-VIBRATION SEALS

At positions where metal-to-metal contact would normally occur, anti-vibration seals shall be fitted, see Appendices 2 and 3. They shall have a minimum thickness of 3 mm and a minimum width of 50 mm.

The edges of the cladding or end cap (7.4) shall be folded where they rest on the anti-vibration seal (6.3). If the seal is of porous insulation material, the outer edge shall be weather-proofed with a flexible mastic compound.

7.4 END CAPS

At all exposed flanges the acoustic insulation shall be terminated with an end cap, see Appendix 2, and this shall be located at a distance of bolt length plus 30 mm. The end cap shall be isolated from the pipe by means of an anti-vibration seal (7.3).

7.5 ACOUSTIC ENCLOSURES

If the noise radiated from a valve has to be reduced, the valve shall be surrounded by an acoustic enclosure. Flanges shall be surrounded by an acoustic enclosure or by removable insulation. Acoustic enclosures shall be easily dismountable to provide access to the flange or valve. Joints shall be sealed to prevent noise leakage.

The mass of dismountable parts of acoustic enclosures shall not exceed 25 kg; if this is not possible, they shall be provided with lifting lugs.

The acoustic enclosure shall have an outer surface of metal sheet with a mass per unit area at least equal to that of the cladding of the adjacent pipes. The porous layer shall be similar in material and thickness to that used on the adjacent pipes and shall be retained by an inner surface layer with an open area of about 30% (e.g. perforated metal sheet). It shall be at least 10 mm away from the flange or valve.

Where acoustic enclosures are installed around flanged joints they shall be of sufficient length to overlap the ends of the pipe cladding by at least 100 mm for class A and 200 mm for classes B, C and D (see Appendix 5).

7.6 PREVENTION OF MECHANICAL DAMAGE

Special provisions shall be made to protect the acoustic insulation at locations where it could be susceptible to mechanical damage. For example, separately supported steps should be provided where the insulation may be stepped on. Where mechanical load cannot be avoided, the cladding should be reinforced by using stiffer plate and additional distance rings.

8. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Thermal insulation of hot services	DEP 30.46.00.31-Gen.
Thermal insulation for cold service	DEP 30.46.00.32-Gen.
Painting and coating of new construction projects	DEP 30.48.00.31-Gen.
Noise control	DEP 31.10.00.31-Gen.

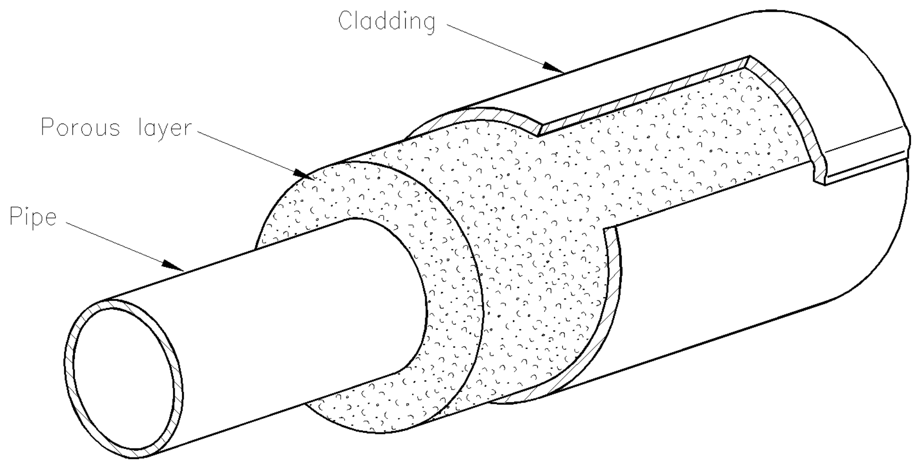
INTERNATIONAL STANDARD

Acoustics; materials for acoustical applications; determination of airflow resistance	ISO 9053

Issued by:
Central Secretariat of ISO
1, Rue de Varembé
1211 Geneva 20
Switzerland.

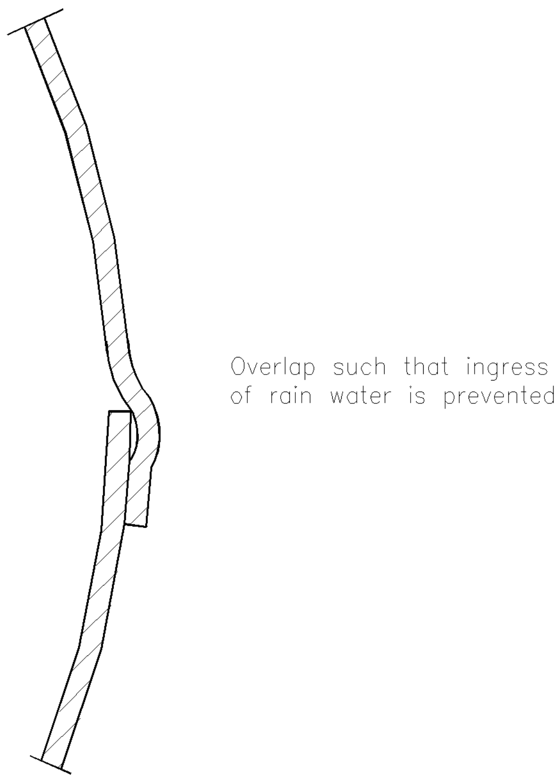
Copies can also be obtained from National Standards Organizations.

APPENDIX 1 GENERAL COMPOSITION OF ACOUSTIC INSULATION

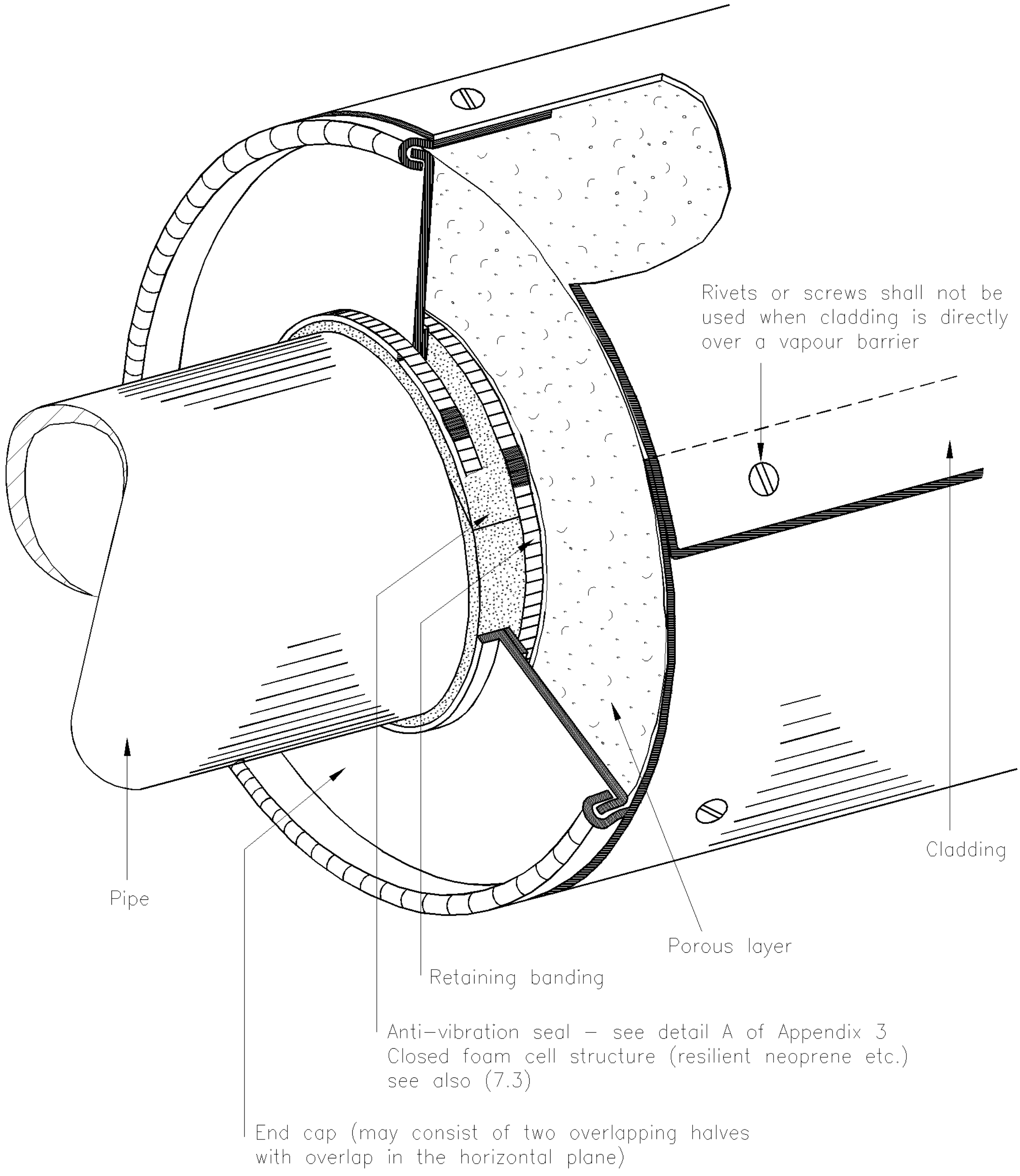


Cladding may be fixed in position with:

- rivets or
- self-tapping screws or
- stainless steel retaining bands

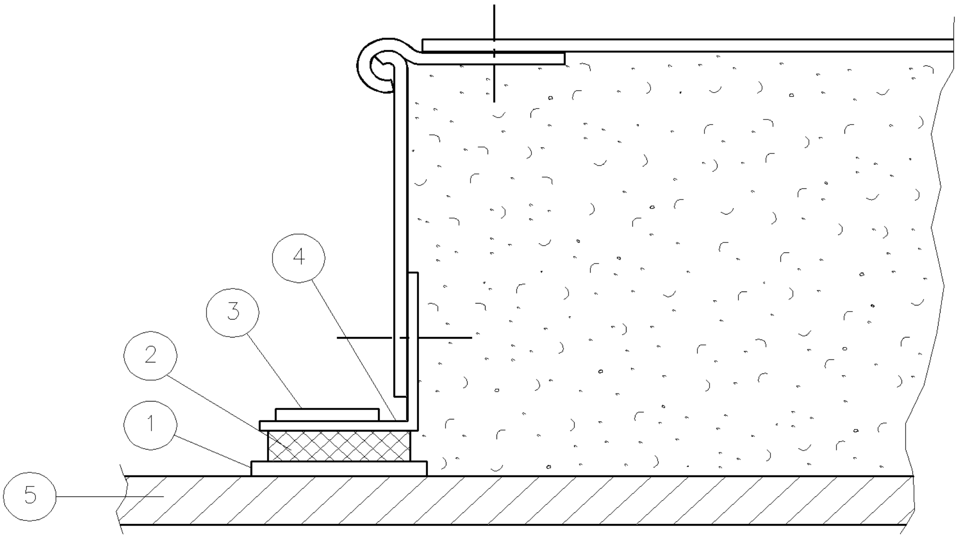


APPENDIX 2 TYPICAL ARRANGEMENT OF ACOUSTIC INSULATION SHOWING CLADDING AND END CAP



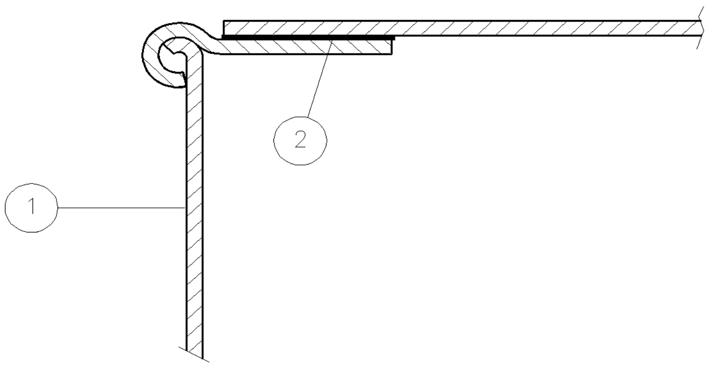
APPENDIX 3 CONSTRUCTION DETAILS - END CAPS

Detail A — Anti-vibration seal



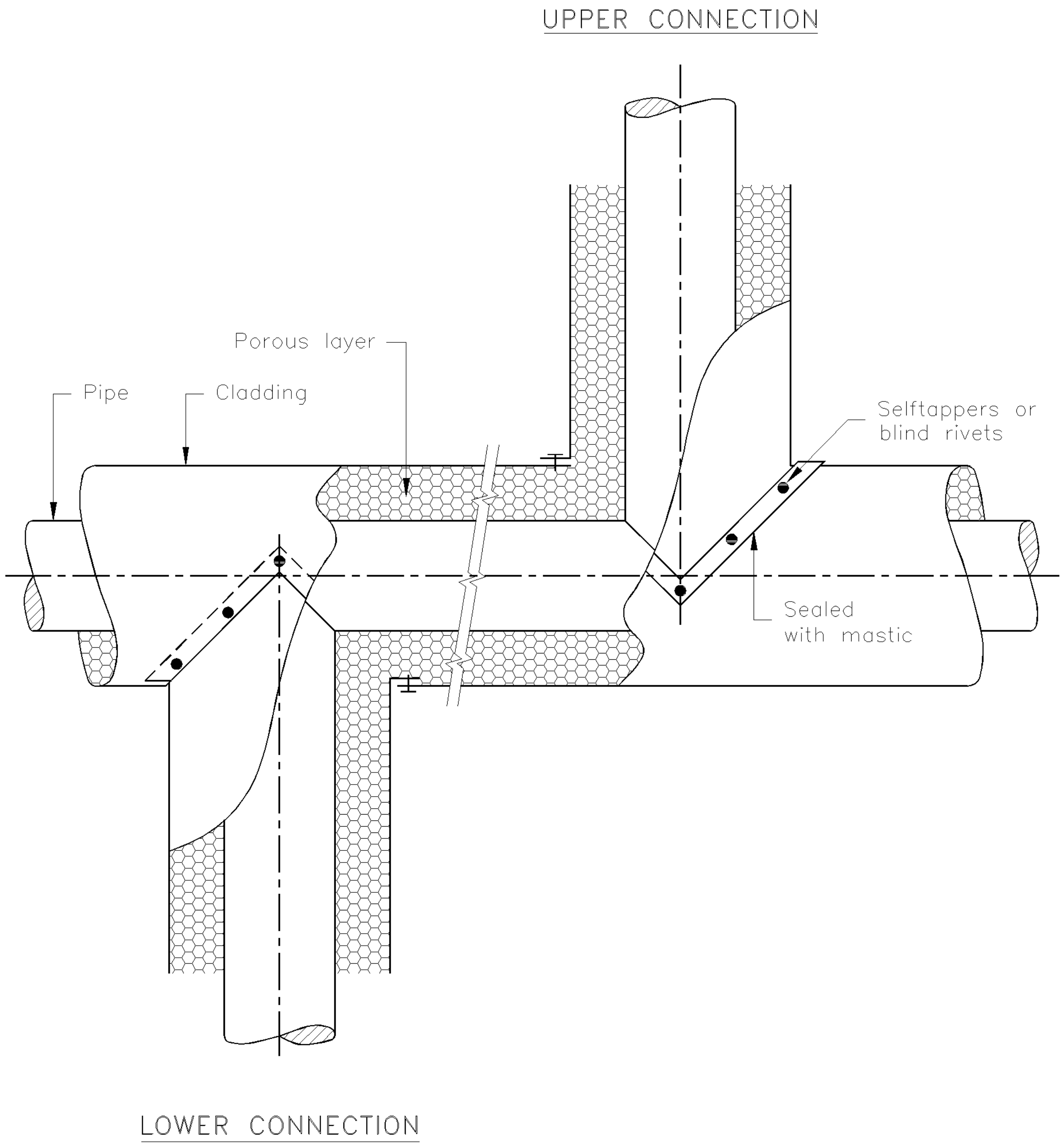
1. Adhesive/sealing layer
2. Closed cell foam resilient strip, see (7.3)
3. Retaining band
4 Shaped profile collar
5. Pipe

Detail B — End cap to cladding seal

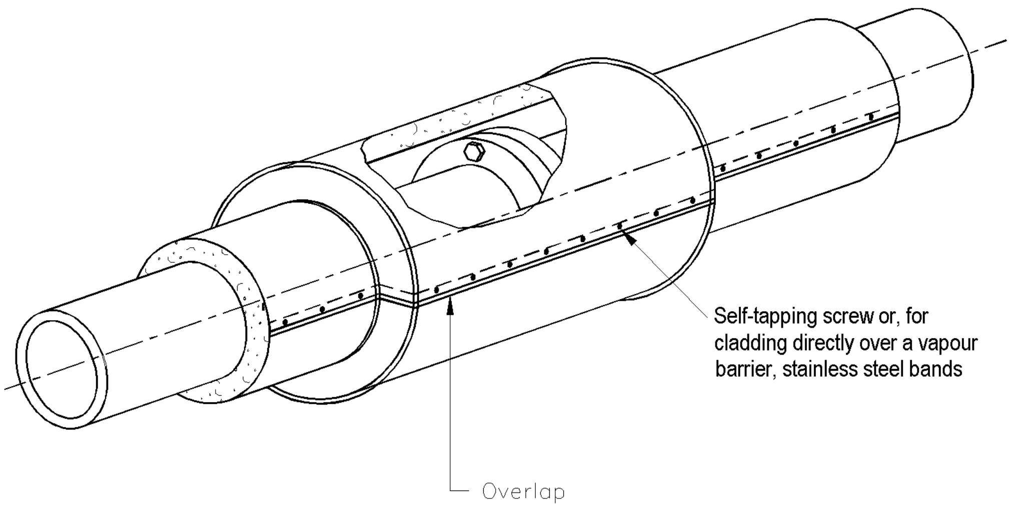


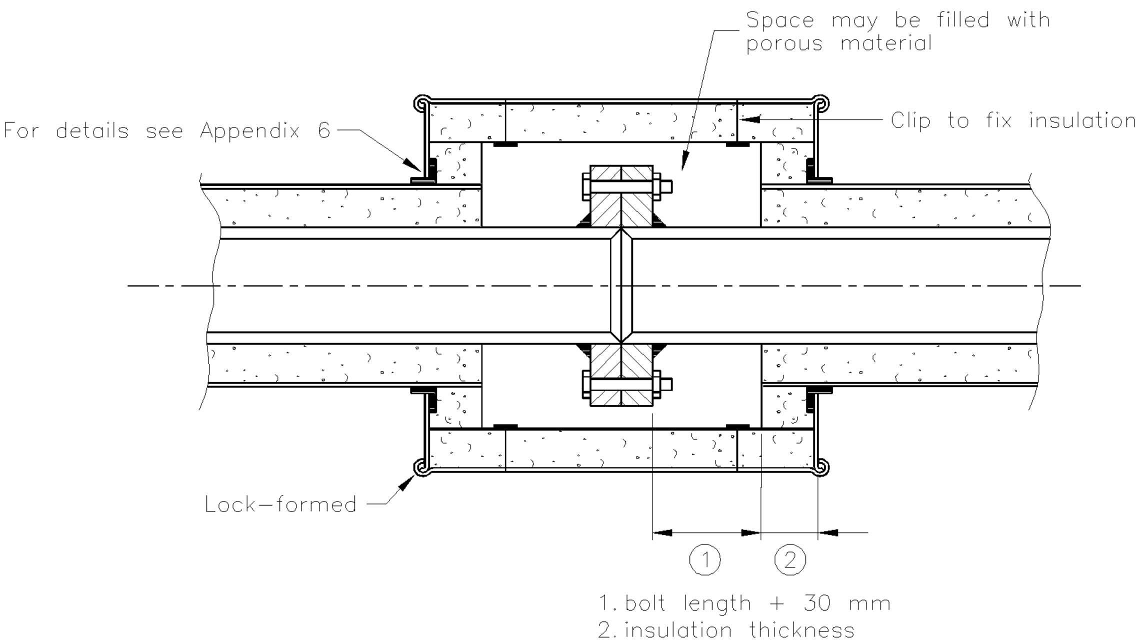
1. End cap
2. Mastic seal

APPENDIX 4 TYPICAL ARRANGEMENT FOR BRANCHES AND TEES



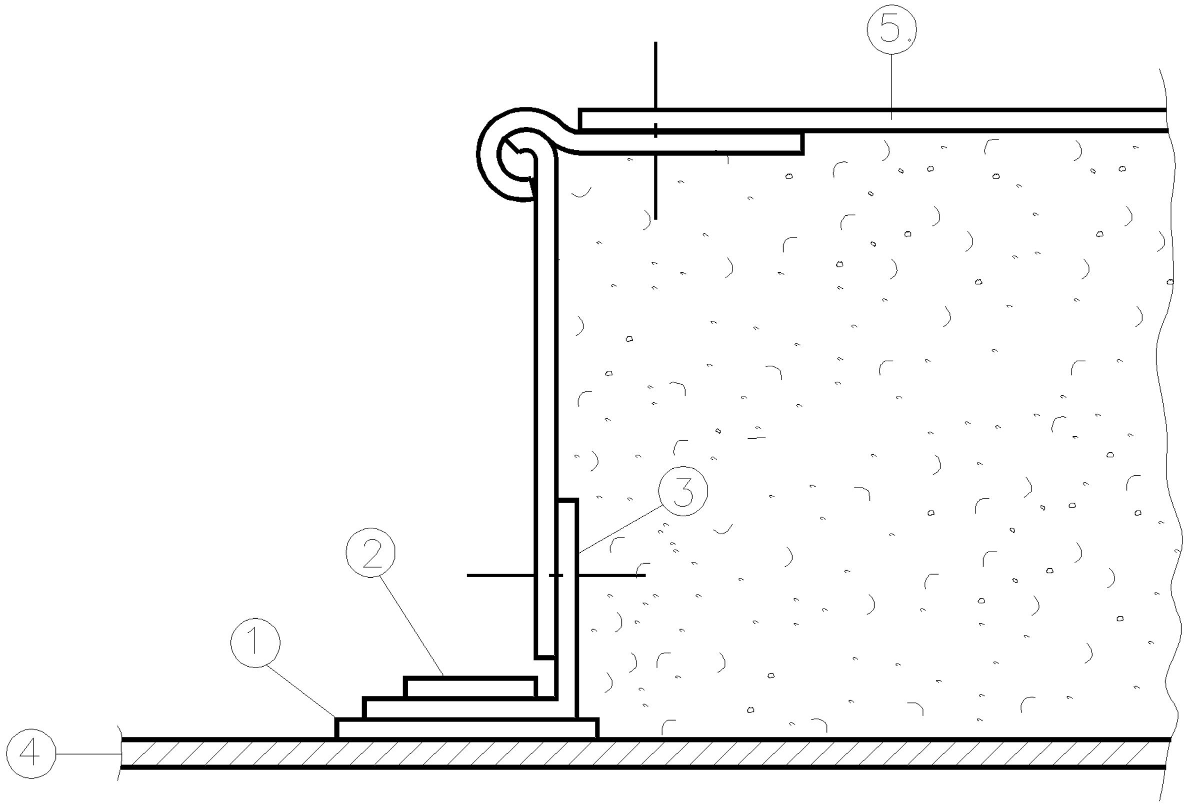
APPENDIX 5 ARRANGEMENT FOR THE ACOUSTIC INSULATION OF FLANGED JOINTS





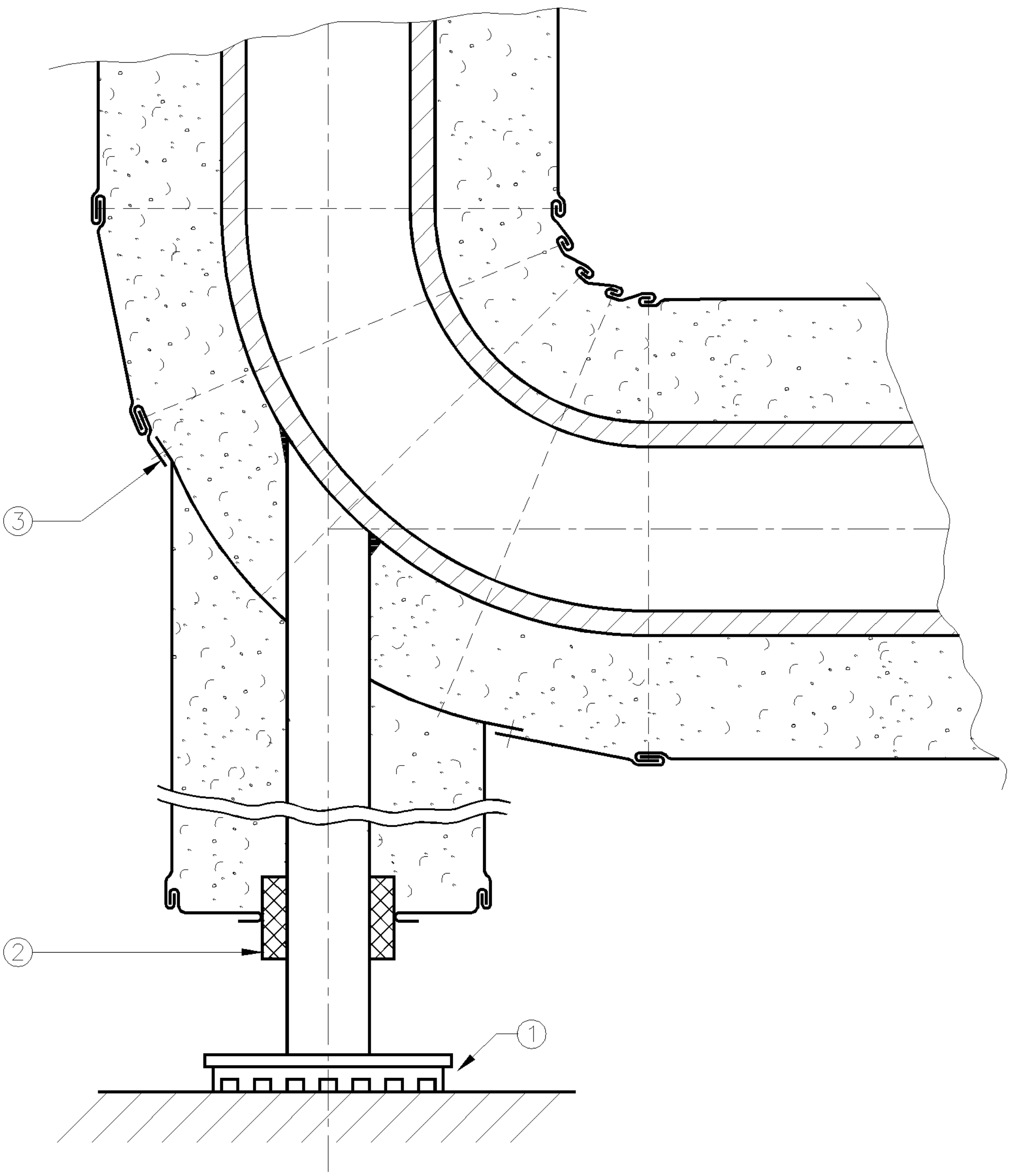
NOTE: Insulation to be fixed to box parts for easy removal and replacement

APPENDIX 6 CONSTRUCTION DETAILS - END CAPS OF BOXES



1. Adhesive sealing mastic layer
2. Retaining band (stainless)
3. Shaped profile
4. Pipe insulation cladding
5. Cladding (box)

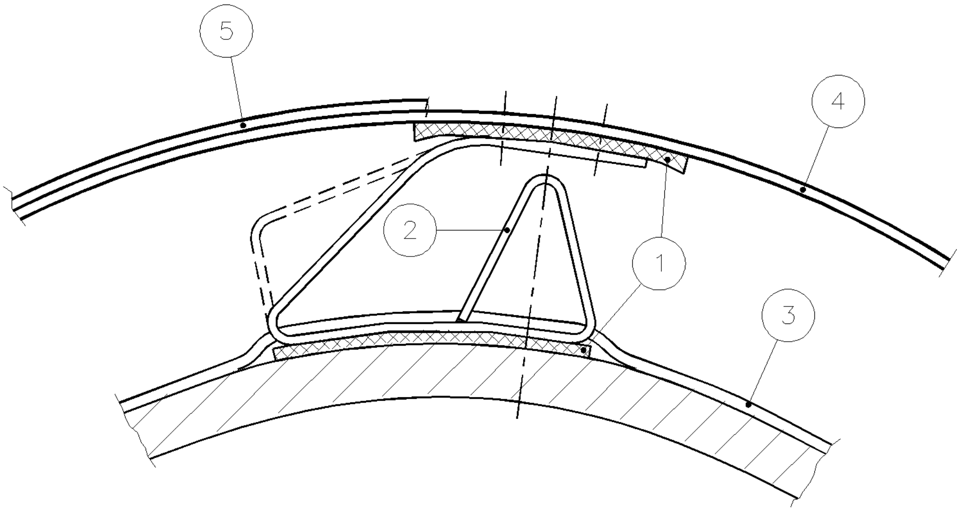
APPENDIX 7 SUPPORT FOR VERTICAL PIPE



1. Vibration isolating pad
2. Closed cell foam resilient strip (7.3)
3. Mastic seal

Note: for A type insulation up to 4" lines a T–construction is allowed
for B,C and D type insulation up to 6"lines a T is allowed

APPENDIX 8 TYPICAL ARRANGEMENT FOR CLADDING SUPPORTS



1. Resilient pad
2. Spring + stop
3. Retaining band
4. Cladding support ring
5. Cladding

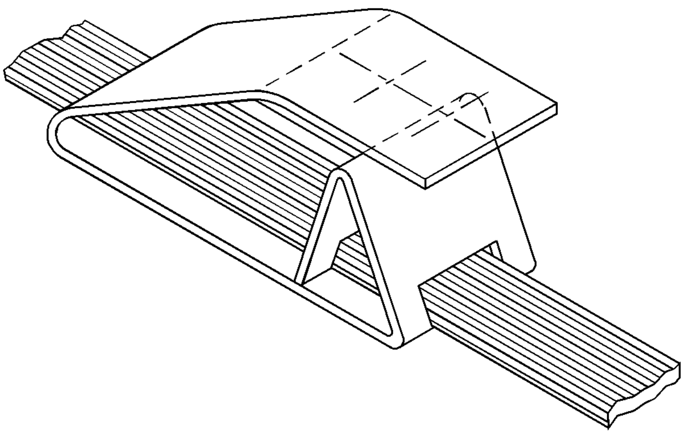
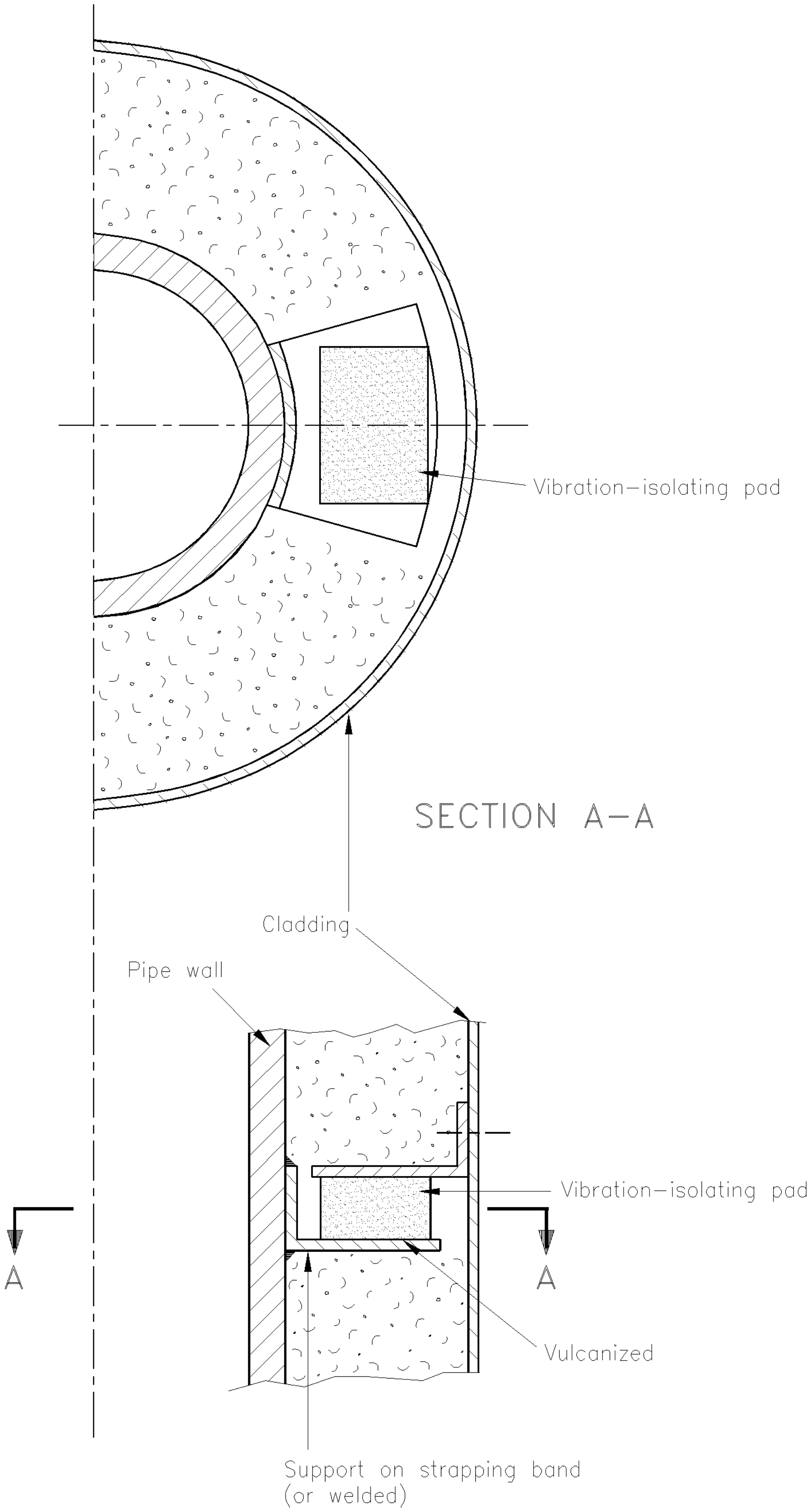


Fig. 2

APPENDIX 9 TYPICAL ARRANGEMENT FOR VIBRATION-ISOLATED CLADDING AND INSULATION SUPPORTS IN VERTICAL PIPES



APPENDIX 10 DERIVATION OF INSERTION LOSS IN TERMS OF dB(A)

The decision to apply acoustic insulation will usually be based on a measured or calculated noise level in dB(A) of the unsilenced pipe, but a calculation of the effectiveness of acoustic insulation in terms of dB(A) can only be done 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 noise level in dB(A) is the only quantity available, the octave band spectrum may be estimated using Table 3. This table gives a typical spectral shape of noise from pipes attached to various types of sources in the form of a correction to be subtracted from the overall noise level in dB(A).

Table 3 Typical spectral shapes for noise from pipes attached to various types of sources

	Octave band centre frequency (Hz)						
	125	250	500	1000	2000	4000	8000
Source	Difference between A-weighted overall level in dB(A) and octave band level, also in dB(A)						
Control valve 1)	36	25	20	9	5	4	8
Centrifugal compressor 2)	31	21	12	7	2	9	13
Centrifugal pump	20	11	7	5	6	8	13

NOTES:
1. In gas service with gas reaching sonic velocity in the valve, typical pipe diameters DN 150 to DN 350.
2. Typical pipe diameter exceeding DN 300.

The effect of acoustic insulation can now be obtained by subtracting the insertion loss of the type of insulation considered, per octave band. The sound level in dB(A) after insulation may be obtained by adding these A-weighted octave band levels using the following equation:

$$L_p\,(A) = 10 \log (\text{antilog } L_{p63}/10 + ... + \text{antilog } L_{p8k}/10)$$

in which: L_p (A) = A-weighted sound level

L_{p63} = A-weighted octave band levels for 63 Hz octave band, etc.

The insertion loss in dB(A) equals the difference between the dB(A) levels for bare and insulated pipe.

***Example*: Pipe noise (size DN 200) due to a control valve**

Octave band Hz	Bare pipe connected to control valve dB(A)	Octave band estimate (Table 3) dB(A)	Insertion loss Class A (Table 1) dB	Octave band spectrum (insulated pipe)	Total noise reduction dB
125		64	-10	74	
250		75	-10	85	
500		80	1	79	
1K		91	9	82	
2K		95	20	75	
4K		96	30	66	
8K		92	35	57	
dB(A)	100	100		88	12

Similarly, insertion losses may be calculated for different types of sources and various types of insulation.

On the basis of the octave band spectra of Table 3 and the insertion losses of (4.1, Table 1) the following approximate total noise reductions in dB(A) are obtained with the various classes of insulation for different types of source.

		Source		
		Centrifugal pump	Centrifugal compressor	Valve
Class	Nominal Diameter range (DN)	Expected reduction of the overall A-weighted sound level in dB(A)		
A		***0***	8	12
B		6	15	20
C	< 300	8	18	22
	300 < 650	12	21	26
	≥ 650	17	25	29
D	300 < 650	***12***	***22***	***27***
	≥ 650	***18***	28	32

The ***bold italic*** figures indicate that the particular type of insulation is hardly or no more effective than a lower insulation class.