Pipe noise

J.H. Granneman and R.P.M. Jansen, Peutz Consulting Engineers, The Netherlands, emphasise the need for an adequate pipe noise control procedure, with reference to the design phase, insulation and inplant screening.

Large petrochemical sites can often be characterised by the presence of different plants, with kilometres of piping, which can represent a major noise source and a major cause of noise screening. This article suggests ways to treat the noise aspects of piping and the abatement of flow induced noise caused by restrictions and discontinuities in gas and steam piping. Recognition of the noise problem in the design stage should result in the application of low noise valves and accurate acoustic insulation of piping.
When taken in combination with installations, piping can also have a screening effect on the transmission of noise. This article gives noise attenuation factors regarding this inplant screening.

NOISE CONTROL PROCEDURE

In the design phase of a new plant, an adequate noise control procedure is essential to prevent noise specifications being exceeded after realisation. The standard ISO/FDIS 15664, 'Acoustics - Noise control design procedures for open plant',[1] defines procedures for open plants such as oil refineries and chemical plants.
Noise specifications can be given as a maximum sound power level (PWL), which is the amount of noise a source generates, and/or maximum sound pressure level (SPL) at a certain distance from a noise source. This noise source can be defined as a separate installation, a combination of installations, or even an entire plant.

SUBSONIC FLOW NOISE CAUSED BY TURBULENCE

The following formula can be used to determine the sound power level (PWL_{ins} in dB(A)[2]) inside the pipe, which is caused by turbulence in a medium with a certain density, temperature and velocity:

$$PWL_{ins} = -5 + 60.\lg(v_f/v_0) + 10.\lg(S/S_0) - 25.\lg(T_f/T_0) + 8.6.\lg(D_f/D_0)$$

where:

v_f	=	flow speed in m/s ($v_0 = 1$ m/s).
S	=	area of cross section ($S_0 = 1\ m^2$).
T_f	=	temperature in K ($T_0 = 273$ K).
D_f	=	density in kg/m^3 ($D_0 = 1\ kg/m^3$).

It is important to recognise the strong dependence of velocity on subsonic flow noise. If the velocity in a piping system increases by a factor of two (due, for example, to a 90^o elbow), the PWL downstream increases according to this formula with 18 dB(A).

SONIC FLOW NOISE AT OVERCRITICAL PRESSURE DROP

At an overcritical pressure drop in a piping system near a restriction ($P_1/P_2 > 3$), the flow speed exceeds the speed of sound, resulting in a shock wise expansion behind the

restriction (shock waves). This mechanism is the most important cause of high sound pressure levels near valves, restriction orifices etc.
The most important criteria for sonic flow noise follow from the formula regarding the generated sound power level (below):

$PWL_{ins} = 10.lg(W^2.(\Delta P/P_1)^{3.6}.(T/MW)^{1.2}) + 126$

where:

W	=	flowrate in kg/s.
ΔP	=	pressure drop in kPa.
P_1	=	up stream pressure in kPa.
T	=	temperature in K.
MW	=	molecular weight.

The T/MW ratio provides an indication of the ratio between the flow speed and the speed of sound. The formula shows a strong pressure drop dependency.

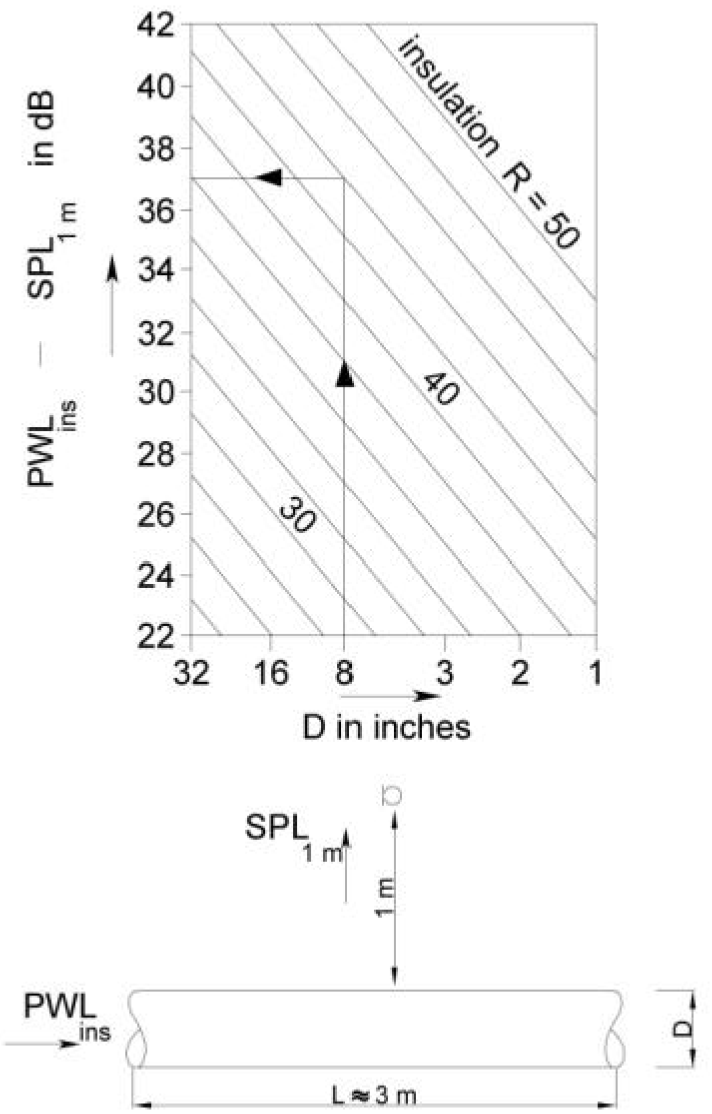


Figure 1: Difference between PWL_{ins} and SPL_{1m}

DETERMINATION OF DIFFERENCE BETWEEN PWL_{ins} AND SPL_{1m}

In practice, setting limits according to company guidelines often means that a certain sound pressure level (SPL) at 1 m from a sound source should not be exceeded. In the case of hearing loss prevention, the value of 85 dB(A) is often used. In order to recognise potential sound problems, an insight must be obtained into the difference between the sound power level inside a pipe (PWL_{ins}) and the SPL at 1 m (SPL_{1m}) as shown in Figure 1.

In Figure 1, the insulation value (R) of the piping is the relevant parameter. If steel piping with a schedule 60 - 80 (being common values for gas and steam piping) is used with diameters of 6 - 10 in., the sound insulation value (R) is 44 - 48 dB for high frequency noise. The difference between PWL_{ins} and SPL_{1m} is approximately 36 - 40 dB.

In practice, acoustic problems can therefore occur, beginning with PWLs inside the piping of approximately 120 dB(A).

TURBULENCE GENERATOR WITH SOUND RADIATING SURFACES

Typical turbulence amplifiers in piping systems, generating shock waves in many cases, are:

- Control valves.
- Restriction orifices.
- Tees.
- Elbows.

Typical sound radiating surfaces are:

- (Non-insulated) piping.
- Piping supports (Figure 2).
- Flanges.
- Control valves.
- Instrumentation.

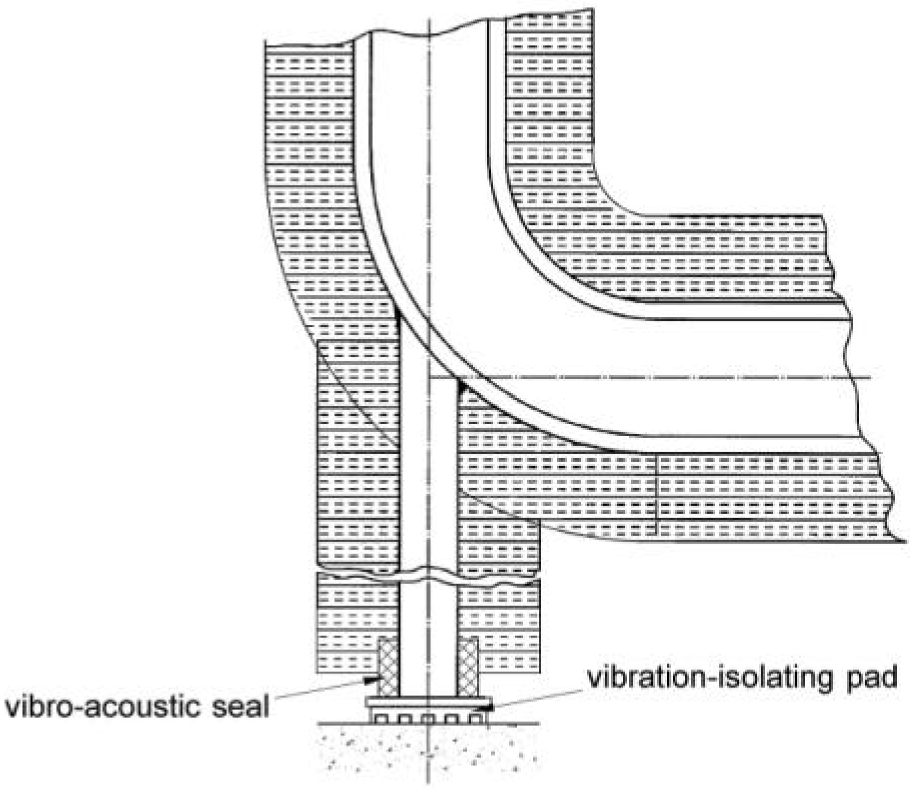


Figure 2: Insulation of piping supports.

The design stage of a gas or steam piping system should be used to determine potential acoustic problems. Given the company limit setting and the prognosis of SPL_{1m}, the noise abatement policy should be:

- Prevention of sound generation in the design phase by limiting flow speeds and preventing unnecessary turbulence amplification.
- Measures at (potential) turbulence amplifiers.
- Sound insulation.

This policy can also be used for noise abatement in existing situations, although given the existing pipe diameters and flows, measures to reduce the flow speed are often not feasible.

NOISE ABATEMENT AT THE SOURCE

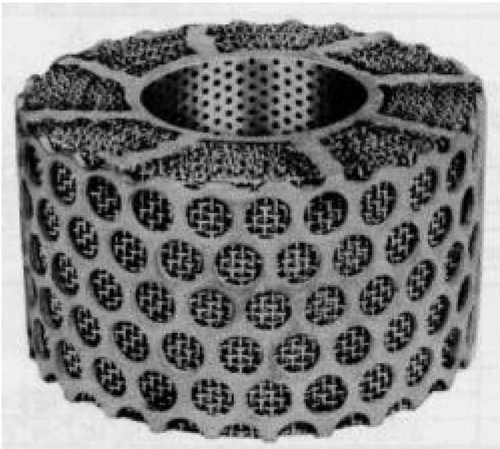
Some acoustic measures, which aim to influence the origin of sound, are given below.

Piping design

Piping to and from a (noise critical) control valve has to be designed so that the turbulence caused by the valve is not further amplified due to nearby elbows. The distance between elbow and valve (piping to the valve) has to be 10 times the diameter of the pipe. The distance between valve and elbow (piping from the valve) has to be 20 times the diameter of the pipe.
Junctions should not be made at an angle of 90^{o}, but rather should follow smooth curves.

Valves

Figure 3 shows an example of a turbulence reducing flow divider, applied as a standard in low noise control valves.



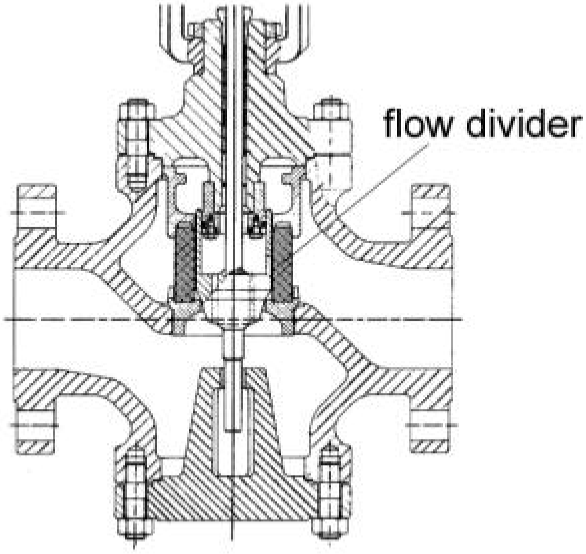
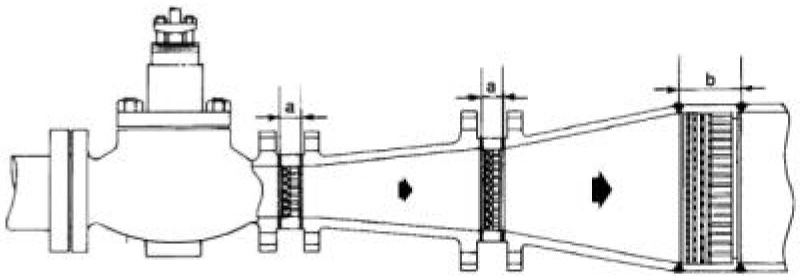


Figure 3: A turbulence reducing flow divider.

If a valve only has a cut off function, a ball valve is preferred over a globe valve for prevention of turbulence. Another example of prevention of noise generation is to create a pressure drop in stages (Figure 4).



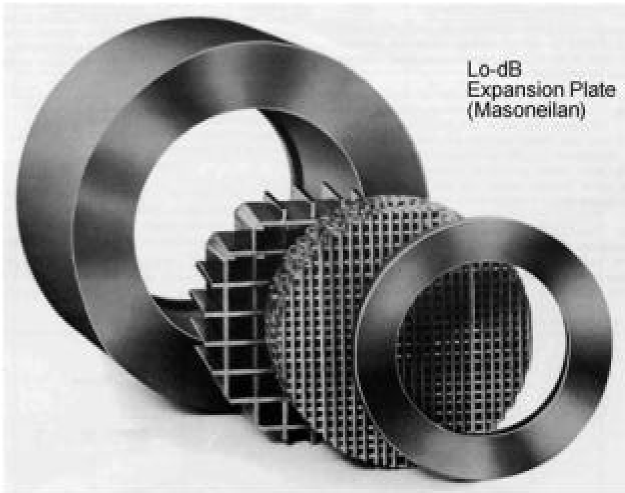


Figure 4: Pressure drop in stages.

<u>Restriction orifices</u>

A restriction orifice can be made with one hole or a number of holes. While the free crosssection areas are the same in both cases, the reduction of turbulence in the orifice with several holes, as compared with a single hole, can reach approximately 7.lg(n) dB(A), where n is the number of holes.

<u>Muffler</u>

In an effective muffler, gas flows through a diffuser in combination with sound absorbing material (steel wool and/or rock wool). As the muffler only reduces sound radiating at the downstream side of piping, insulation of the muffler housing itself, including the nearby turbulence generating valve, can also be necessary.

<u>INSULATION</u>

<u>Effect limitations</u>

Acoustical insulation of sound radiating surfaces is an effective and relatively cheap way of reducing the high frequency flow noise radiated by piping, piping supports, instrumentation, etc.

In practice, piping will often be constructed as a thermal insulation. However, this can only provide effective sound insulation if it is mounted in an acoustically correct way.

Sound insulating construction

Acoustic insulation is generally constructed using a metal outer layer or cladding (steel or aluminium) without any rigid connections with the pipe. Acoustic leaks are avoided using adequate overlaps and sealings. Between the outer layers and the pipe wall, a porous layer is generally provided, for instance mineral fibre (glass or rock) or open cell flexible plastic foam.

The mass of the outer layer needs to be sufficient to obtain the required level of insulation. Table 1 gives insulation classes based on the recent standard ISO/FDIS 15665[3].

Table 1 Minimum insertion loss required for each class[3]

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 ≤ D < 650	-4	-4	2	9	16	22	29
A3	650 ≤ D < 1000	-4	2	7	13	19	24	30
B1	D < 300	-9	-3	3	11	19	27	35
B2	300 ≤ D < 650	-9	-3	6	15	24	33	42
B3	650 ≤ D < 1000	-7	2	11	20	29	36	42
C1	D < 300	-5	-1	11	23	34	38	42
C2	300 ≤ D < 650	-7	4	14	24	34	38	42
C3	650 ≤ D < 1000	1	9	17	26	34	38	42

In order to conform to a given class, the insertion loss of all seven octave bands will either exceed or be equal to the levels specified.

Sound insulation at low frequencies can be negative due to the mass spring resonance and, with smaller pipe diameters, the increase of the noise radiating surface of the outer cladding. This means that in these frequency bands, sound radiation increases as a result of sound insulation.

Effective insulation

Effective insulation of pipe systems means that each part of the system with a SPL_{1m} higher than the limit must be insulated. In many cases, supports and parts of the instrumentation that are linked directly to the sound radiating pipe wall also have to be insulated. In some cases, and as an alternative to the insulation of supports, vibration insulators can be applied between a pipe and its support within the acoustic insulation.

If, for maintenance reasons, the insulation must be taken off and again be applied in a simple way, removable enclosures should be applied. An example of insulation in a case where the flange has to be ventilated is given in Figure 5[3].

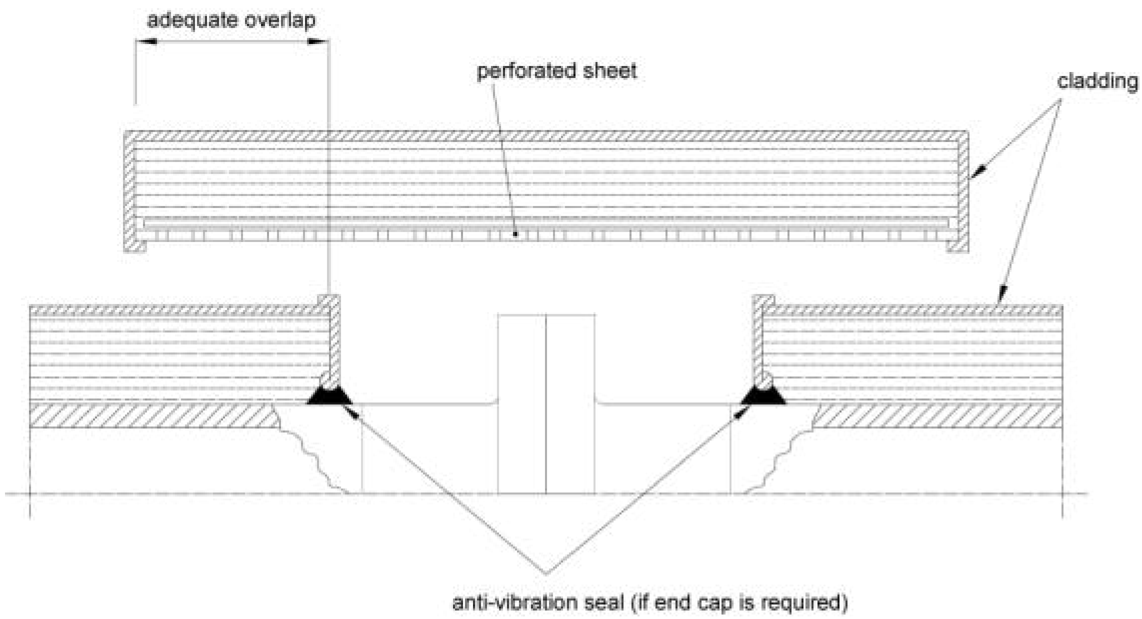


Figure 5: Vented acoustic insulation of flanged joints.

<u>ATTENTUATION FACTORS DUE TO INPLANT SCREENING</u>

In the design phase of a new plant, one usually starts by adding up the sound power levels of separate apparatus, installations and piping. This prognosis can be based on noise data obtained from manufacturers and/or experimental data. As a result of neglecting inplant screening, the sum of these different sound power levels generally provides an exaggerated view of the total noise emissions of the plant, particularly when a relatively high density of piping and other equipment surrounds the most dominant noise sources.[4]

Inplant screening is defined as the excess attenuation of sound due to diffraction and absorption when transmitted through open process installations. Generally applicable attenuation factors are derived for situations where relevant inplant screening is expected, but where they cannot be determined by practical measurements (in case of predictions or too much disturbing noise in practice). These values of attenuation factors[5] are incorporated in the revised Dutch guideline regarding measuring and calculating industrial noise, (issued in April 1999).[6] However, if inplant screening is to be considered, one should not take into account screening/reflection due to buildings and other objects in the plant of interest.

The reduction (D), due to inplant screening, is calculated according to the following formulae:

D = $t(f) . r_t$ (1)

D # D_{max} (2)

where:

t(f) = Frequency depended factor regarding inplant screening [dB/m]; indicative factors are given in Table 2.

r_t = Part of the noise path through the open process installation (Figure 6). Only the part of the curved sound path that transmits through the installations is considered as part of r_t; the part mainly above the installations is not taken into account. In the Dutch guideline the radius R of the curved sound path is defined as R = 8.r, where r is the distance between the sound source and the receiving point.

D_{max} = Maximum type dependent reduction (Table 2).

The values of these attenuation factors are highly dependent on the specific features and 'density' of piping and equipment in the plant. The more installations present, the more reflection and diffraction of noise will occur, causing a higher inplant screening effect. In existing situations, it is preferable to measure the excess attenuation of this inplant screening effect. Special measurement and analytical techniques using cross correlation can diminish the problem of disturbing noise[5]. In the case of other situations, Table 2 provides indicative values for three different plant types. Type A relates to plants with a density of installations of approximately 20%/30 m transmission path length through the plant (in the relevant direction). Type B relates to plants with a density of more than 20 %. 'Tank parks' values concern areas with a high number of storage tanks.

Table 2 Indicative values of attenuation factor t (f) due to inplant screening (dB/m)

Description	31.5	63	125	250	500	1 000	2 000	4 000	8 000	D_{max} [dB]
type A	0	0	0.02	0.03	0.06	0.09	0.1	0.1	0.1	10
type B	0	0	0.04	0.06	0.11	0.17	0.2	0.2	0.2	20
tank parks	0	0	0.002	0.005	0.005	0.02	0.02	0.02	0.02	10

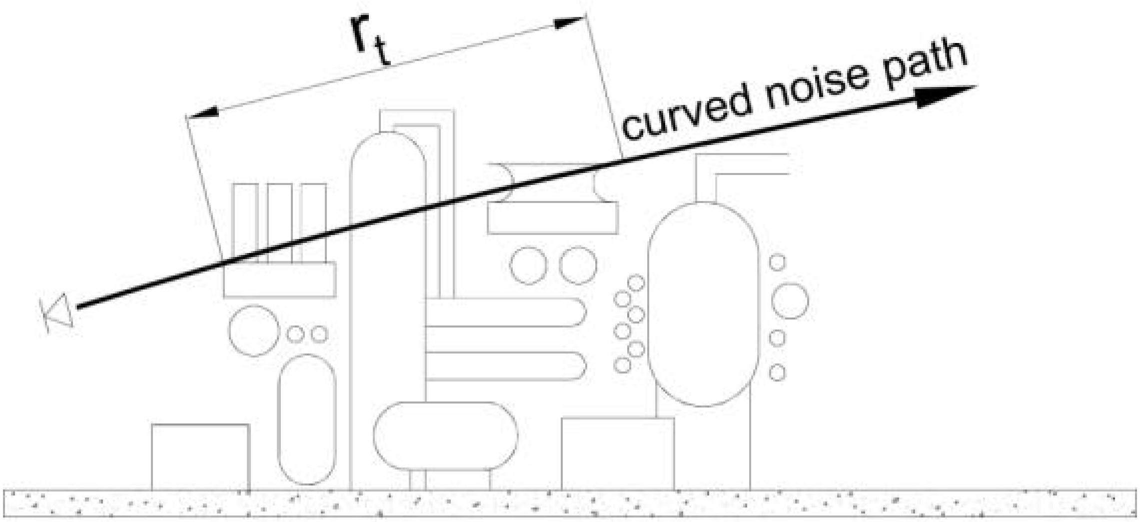


Figure 6: Explanation of r_t.

The sound pressure levels in the (living) area around an existing industrial site, with many separate open process plants, are often determined by means of a computer model in which the contribution of each plant to the sound pressure level at certain points in the surrounding area is calculated. The necessary sound power levels of separate plants are often based on 'contour measurements' around each plant, in accordance with ISO 8297[7]. In these situations, the application of inplant screening attenuation factors has proven to be very useful when the emitted sound of a certain plant is transmitted through adjacent open plant(s).

Neglecting this excess attenuation can cause significant differences between calculated and measured sound levels in the surrounding areas, and as a consequence strongly influences the need and extent of sound reduction measures. If measurement of the reduction effect of inplant screening is not possible, the inplant screening factors, as mentioned in Table 2, can be useful.

CONCLUSION

In the design phase of an open plant, adequate noise control procedures such as ISO/FDIS 15664 are essential. Noise aspects of piping are important in open plants because of the vast number of pipe systems. When sound limits must be met at 1 m from pipe systems, valves, etc., the acoustic behaviour of the system should be foreseen in the design phase.

Noise abatement at the source can significantly reduce sound emissions, and can sometimes lead to the elimination of the sound source. Implementation in existing situations is more expensive than the recognition of potential acoustic problems and determination of measures in the design phase.

Given the contributions of specific parts of the pipe system, sound insulation must be executed with great care if it is to be effective.

When noise limits must be met in the environment of an industrial plant, inplant screening must be considered because, due to this effect, the real emissions of an industrial plant might be lower than those calculated.

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