Technical Information No. 1

Noise emissions

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Noise today plays a more and more important planning role, demanded by the work and environment regulations.

That is why reliable statements to the noise emission of control fittings are demanded from the valve manufacturers.

Valve noise is created mainly by:

- turbulence stripping and turbulent oncoming flow of solid construction parts, also occurrence of alternating forces
- open jet noise in the mixing zone
- occurence of shocks, if the speed of sound is reached or exceeded in the valve.

These noises are mainly emitted via connected pipeline and less via the valve casing. That is why pipelines belong to the most important acoustic sources (or transmission routes) in many industrial plants.

The fluid sound activates the pipeline wall to sound oscillations and will then partly be emitted as airborne sound to the outside.

For now being able to make statements to the sound emission of valves standardized calculation methods for determining this noise emission have been developed.

All these valve noise calculation methods serve the calculation:

- of the level of acoustic power and
- the acoustic pressure in 1 m distance

of non insulated fittings and pipelines.

The common noise calculations today are:

1. **VDMA 24422, January 1989**
   Fittings, guidelines for the noise calculation
   Control and shut-off fittings

2. **DIN EN Go 534-8-3**
   Control valves for the process control
   Noise examinations – calculation methods for the prediction of aerodynamic noise of control valves, December 2001

3. **ANSI/SA-S75.17.1989**
   Control Valve Aerodynamic Noise Prediction

It is to say that all these methods, considering the noise development in the free field or under laboratory conditions, give no results at the site of installation. At the site of installation there is a diffuse sonic field determined by the complex installation of the different plant components.

2 variants shall be explained in more details:

1. **VDMA 24422:**
   Calculation according to VDMA 24422
   VDMA 24422, fittings
   Guidelines for noise calculation, control and shut-off fittings, January 1989

   The guideline allows planners and operators of plants to determine the sound conduction level or the 1 m sonic pressure level of control and shut-off fittings of all kinds by means of
   - valve-specific characteristic values

   according to a standardized calculation method.

1. Calculation of the inner sound conduction level L_{wi} for gases and steam

1.1 Valve-specific information

The valve-specific characteristic values have to be given by the manufacturer for an efficiency of y = 0.75.

1.1.1 Critical differential pressure ratio X_{cr}

Critical ratios will occur, if the differential pressure ratio reaches the value X_{cr}. X_{cr} results from the information of the manufacturer.

$$x_{cr} = \frac{\Delta p}{p1}$$

Δp = Differential pressure above the valve
p1 = Pressure in front of the valve (absolute)

The emission power as well as the acoustic degree of conversion ηG is dependent on the mach number and the pressure ratio.

The mach number of the jet coming from the narrowest cross-section is a function of the pressure ratio:

$$Ma^2 = \frac{\lg(1-x)}{\lg(1-x_{cr})}$$

X = Differential pressure ratio at gases and steam $\Delta p/p1$
X_{cr} = Critical differential pressure ratio

1.1.2 Degree of conversion η_G

The acoustic degree of conversion η_G is determined by the processes in the conversion zone behind the narrowest cross-section and with this dependent on the structure and efficiency of the valve.

η_G can be shown as function of the pressure ratios:

$$\eta_G \approx 10^{G1} \left[\frac{\lg(1-x)}{\lg(1-x_{cr})} \right]^{G2}$$

G1 = level exponent in the functional equation of η_G
G2 = Slope exponent in the functional equation of η_G

The conversion zone η_G refers to the sound power emitted in the frequency range of the octavoses 500 to 8000 Hz.

For standard valves with parabolic cone:

$$\eta_G = 10^{-3,0} \left[\frac{\lg(1-x)}{\lg(1-x_{cr})} \right]^{0,8}$$

1.2 Inner sound power level L_{Wi}

Pressure in front of valve
Adiabatic exponent
Differential pressure ratio

$$L_{Wi} = 134{,}4 + 10\lg W + 10\lg \frac{k}{k+1} + 10\lg \frac{p1}{p1} + 10\lg \left[\frac{\lg(1-x)}{\lg(1-x_{cr})} \right] + 10\lg \eta_G$$

Acoustic degree of conversion for gases
Density of fluid in front of valve kg/m³
W = Mass flow of fluid kg/h
Critical differential pressure ratio

The inner sound power level of gas flown fittings is a noise spectrum in the average increasing in the examined frequency range 500 to 8000 Hz with approximately 3 dB per octave.

That is why the calculation of the spectrum happens according to:

$$L_{Wi}(f) = L_{Wi} + 10\lg\frac{f}{500} - 14{,}9$$

2. Calculation of the outer sound power level

2.1 Outer non-valued sound power level L_{Wa}

The outer sound power level L_{Wa} results from the inner sound power level L_{Wi} by means of the pipe sound damping $R_{R'}$ of the pipe length l to be considered and the pipe inner diameter d_I.

$$L_{Wa}(f) = L_{Wi}(f) - 17{,}37\frac{l}{2d_i} * 10^{-0,1*R_R(f)} - R_R(f) + 10\lg\frac{4*l}{d_i}$$

At gas/steam calculations the first subtrahend can be ignored.

At gases the calculated noise power level refers to the l = 2 m long piece of pipe at the output of the valve.

The noise level emitted from the valve casing and the pipeline at the input generally is for more than 10 dB below the noise level emitted from the pipeline at the output, because at the relaxation of gases the noise emission mainly happens from the output side.

For the calculation of the noise damping measure for gases is:

$$R_R(f) = 10 + 10\lg\frac{C_R * \rho_R * S}{C_F * \rho_F * d_i} + 10\lg\left[\left(\frac{f_r}{5f}\right)^3 + \frac{5f}{f_r}\right] \text{ dB}$$

The ring expansion frequency f_r result to:

$$f_r = \frac{C_R}{\pi * d_i}$$

2.2 Outer A-valued noise power level $L_{WA,a}$

Correction values for the A evaluation of noise levels

f_m in Hz	500	1000	2000	4000	8000
Correction values in dB	-3.2	0	+1.2	+1.0	- 1.1

The A-valued total noise conduction level result from the band noise conduction levels of the middle frequencies 500 Hz to 8000 Hz

$$L_{WAa} = 10\lg\sum_{n=1}^{5} 10^{0,1*L_{WAa,n}}$$

2.3 Outer A-valued noise pressure level $L_{pA,a}$

For the noise pressure level 1 m besides the pipeline and in 1 m distance from the output flange of the valve result approximately under free field conditions and at cylindrical emission:

$$L_{pAa} \approx L_{WAa} - 10\lg\left[\frac{\pi * l}{l_0} * \left(\frac{d_i}{d_0} + 2\right)\right]$$

with l = 2 m for gases and steam or l = 3 m for fluids.

SUMMARY: VDMA 24 422

Calculation for gases and steam

Calculation of the acoustic degree of conversion ŋG from the valve specific values X_T, G_1 and G_2.

Calculation of the inner sound power level L_{Wi} from the differential pressure ratio x, mass flow W, η_G and fluid data.

Usage of the standardized octave spectrum (rise 3 dB/octave, peak frequency stays unconsidered!)

Calculation of the outer noise power level for L_{WA} l = 2 m pipe at the valve output with R_R (f) (considers f_R)

Calculation of L_{1m} from L_{wa} and A evaluation.

Application limits:

$$M \le 0{,}3$$

$$0{,}1 \le K_V \le 6000\frac{m^3}{h}$$

$$0{,}01 \le x \le 0{,}99$$

$$L_{wi} \ge 80dB$$

Uncertainty of calculation

$\sigma \approx 3 \ldots 4dB$ (rather at upper tolerance limit)

DIN EN 60 534 – 8 – 3

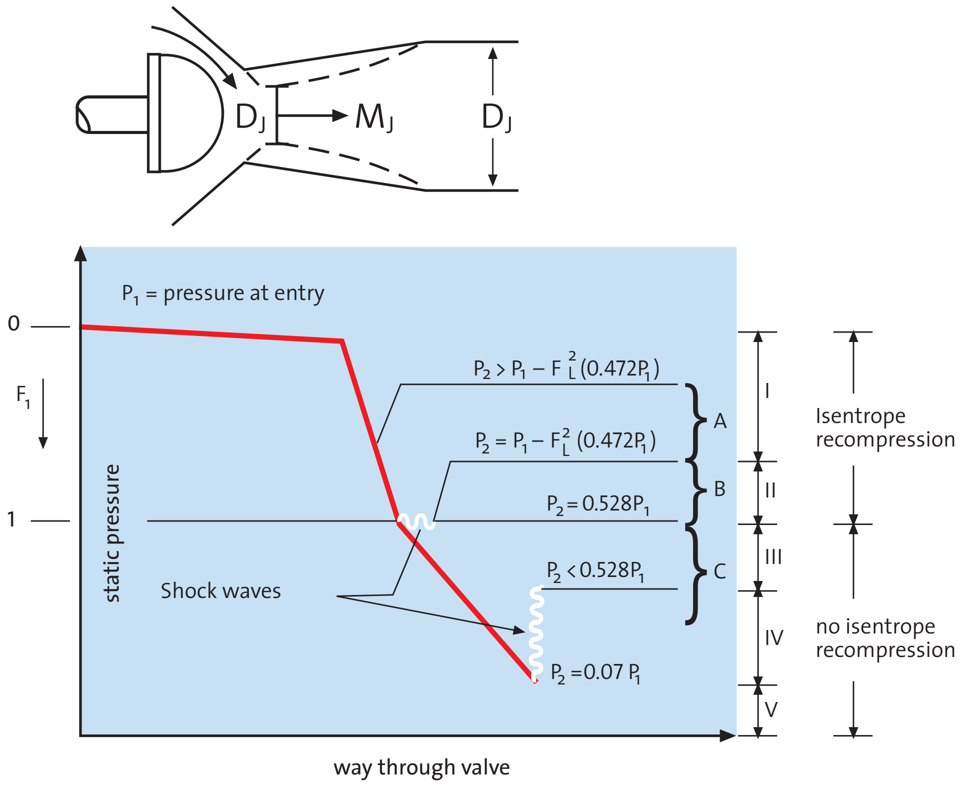
Calculation according to DIN EN 60534-8-3

DIN EN 60534-8-8, control valve for process control, part 8–3: Noise examinations – calculation method for the prediction of aerodynamic noise of control valves, December 2001

From introduction:
“Although the prediction method can guarantee no updated results, it gives calculation predictions within 5 dB(A) for most of the noise data under laboratory conditions.”

Distinguishes 5 sections regarding the flow mechanics:

Section I	Subsonic section (dipole dominated)
Section II	sonic near flow
Section III	Supersonic flow (no isentrope recompression anymore)
Section IV	Formation of a mach disk (shock-GS-WW)
Section V	constant acoustic efficiency ratio



Test, which section is valid.

Then calculation of the generated sound power W_a Wa from the emission power and the acoustic efficiency ratio for this section.

Calculation of the peak frequency f_p, of the inner coincidence frequency f_o and the ring expansion frequency f_R.

Calculation of the singular pipe sound damping value T_L, weight dependent on the condition of f_p to f_o and f_R.

Calculation of L_{A1m} from W_a, T_L and correction terms.

Required valve characteristic data:
Valve construction factor F_d or information about “flow channels” ($A,/_W$)
Fluid pressure recovery factor F_L (if necessary, consider reduction parts)
Flow coefficient (K_v, C_v)

Further calculation possibilities:
Valves with noise reduced set (one-level-multichannel and one-channel-multi-level pressure reduction)
Valves with higher mach number in the output.

The calculation method used from W&T is based on VDMA 24422 and extended for multiple-level control valves. The noise level is calculated for each level separately and then summarized to a total noise level.

The control valves offered and delivered by W&T consider all known primary sound protective measures like:

- Avoidance of cavitations at water valves by controlled multi-level fittings
- Distribution of the free opening cross-section to many small openings
- Relaxation in several levels
- Installation of flow resistances (piercing cylinders, breaker plates)

By multilevel relaxation the total pressure difference is distributed over the valve to several relaxing levels. Because of the smaller pressure differences there is less sound at the different relaxation levels.

The number of relaxation levels should be limited to 10 levels for economic aspects.

Secondary measures like sound damping mantlings are mostly a cheaper solution than an exorbitant number of levels in the valves.

In ISO 15665 : 2003 three classes (A,B,C) of demands for noise minimization in dependence of the pipe diameter and octavos are specified:

Table 1 – Minimum insertion loss required for each class

Class	Range of nominal diameter	Octave band centre frequency, Hz						
	D	125	250	500	1000	2000	4000	8000
	mm	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

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In the following table specific noise value reductions by the insulation of pipeline with different sound sources are given.

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	Centrifugal	Control valves	Reciprocating Compressors
A1 and A2	D < 650	4	10	14	5
A3	D ≥ 650	9	15	18	9
B1	D < 300	5	11	16	5
B2	300 ≤ D < 650	6	14	18	6
B3	D ≥ 650	10	18	22	10
C1	D < 300	9	18	22	9
C2	300 ≤D < 650	11	20	24	10
C3	D ≥ 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.

The descriptions of insulation which fulfills the classes (A,B,C) are given in the following table.

Table 5 – Insulation constructions meeting classes of acoustic insulation

Class	Description	Value
A	min. thickness of pocous layer	50 mm
	max. stiffness of porous layer	2,0 x 10^6 N/m³
	min. mass per unit area of metal cladding	4,5 kg/m² (e.g. 0,6 mm steel plate)
B	min. thickness of porous layer	100 mm
	max. stiffness of porous layer	10^6 N/m³
	min. mass per unit area of metal cladding	6,0 kg/m² (e.g. 0,8 mm steel plate)
C	min. thickness of porous layer	100 mm
	max. stiffness of porous layer	10^6 N/m³
	min. mass per unit area of metal cladding	
	for nominal pipe diameters < 300 mm	7,8 kg/m² (e.g. 1,0 mm steel plate)
	for nominal pipe diameters ≥ 300 mm	10,0 kg/m² (e.g. 1,3 mm steel plate)

The exact description can be read in ISO 15665.