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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial-process control valves –
Part 8-3: Noise considerations – Control valve aerodynamic noise prediction method

Vannes de régulation des processus industriels –
Partie 8-3: Considérations sur le bruit – Méthode de prédiction du bruit aérodynamique des vannes de régulation

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INDUSTRIAL-PROCESS CONTROL VALVES –

Part 8-3: Noise considerations – Control valve aerodynamic noise prediction method

FOREWORD

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International Standard IEC 60534-8-3 has been prepared by subcommittee 65B: Measurements and control devices, of IEC technical committee 65: Industrial-process measurement, control and automation.

This third edition cancels and replaces the second edition published in 2000. This edition constitutes a technical revision.

The significant technical changes with respect to the previous edition are as follows:

- predicting noise as a function of frequency;
- using laboratory data to determine the acoustical efficiency factor.

The text of this standard is based on the following documents:

FDIS	Report on voting
65B/765/FDIS	65B/780/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts of the IEC 60534 series, under the general title *Industrial-process control valves* can be found on the IEC website..

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The mechanical stream power as well as acoustical efficiency factors are calculated for various flow regimes. These acoustical efficiency factors give the proportion of the mechanical stream power which is converted into internal sound power.

This method also provides for the calculation of the internal sound pressure and the peak frequency for this sound pressure, which is of special importance in the calculation of the pipe transmission loss.

At present, a common requirement by valve users is the knowledge of the sound pressure level outside the pipe, typically 1 m downstream of the valve or expander and 1 m from the pipe wall. This standard offers a method to establish this value.

The equations in this standard make use of the valve sizing factors as used in IEC 60534-1 and IEC 60534-2-1.

In the usual control valve, little noise travels through the wall of the valve. The noise of interest is only that which travels downstream of the valve and inside of the pipe and then escapes through the wall of the pipe to be measured typically at 1 m downstream of the valve body and 1 m away from the outer pipe wall.

Secondary noise sources may be created where the gas exits the valve outlet at higher Mach numbers. This method allows for the estimation of these additional sound levels which can then be added logarithmically to the sound levels created within the valve.

Although this prediction method cannot guarantee actual results in the field, it yields calculated predictions within 5 dB(A) for the majority of noise data from tests under laboratory conditions (see IEC 60534-8-1). The current edition has increased the level of confidence of the calculation. In some cases the results of the previous editions were more conservative.

The bulk of the test data used to validate the method was generated using air at moderate pressures and temperatures. However, it is believed that the method is generally applicable to other gases and vapours and at higher pressures. Uncertainties become greater as the fluid behaves less perfectly for extreme temperatures and for downstream pressures far different from atmospheric, or near the critical point. The equations include terms which account for fluid density and the ratio of specific heat.

NOTE Laboratory air tests conducted with up to 1 830 kPa (18,3 bar) upstream pressure and up to 1 600 kPa (16,0 bar) downstream pressure and steam tests up to 225 °C showed good agreement with the calculated values.

A rigorous analysis of the transmission loss equations is beyond the scope of this standard. The method considers the interaction between the sound waves existing in the pipe fluid and the first coincidence frequency in the pipe wall. In addition, the wide tolerances in pipe wall thickness allowed in commercial pipe severely limit the value of the very complicated mathematical approach required for a rigorous analysis. Therefore, a simplified method is used.

Examples of calculations are given in Annex A.

This method is based on the IEC standards listed in Clause 2 and the references given in the Bibliography.

INDUSTRIAL-PROCESS CONTROL VALVES –

Part 8-3: Noise considerations – Control valve aerodynamic noise prediction method

1 Scope

This part of IEC 60534 establishes a theoretical method to predict the external sound-pressure level generated in a control valve and within adjacent pipe expanders by the flow of compressible fluids.

This method considers only single-phase dry gases and vapours and is based on the perfect gas laws.

This standard addresses only the noise generated by aerodynamic processes in valves and in the connected piping. It does not consider any noise generated by reflections from external surfaces or internally by pipe fittings, mechanical vibrations, unstable flow patterns and other unpredictable behaviour.

It is assumed that the downstream piping is straight for a length of at least 2 m from the point where the noise measurement is made.

This method is valid only for steel and steel alloy pipes (see Equations (21) and (23) in 5.5).

The method is applicable to the following single-stage valves: globe (straight pattern and angle pattern), butterfly, rotary plug (eccentric, spherical), ball, and valves with cage trims. Specifically excluded are the full bore ball valves where the product F_pC exceeds 50 % of the rated flow coefficient.

For limitations on special low noise trims not covered by this standard, see Clause 8. When the Mach number in the valve outlet exceeds 0,3 for standard trim or 0,2 for low noise trim, the procedure in Clause 7 is used

The Mach number limits in this standard are as follows:

Mach number location	**Mach number limit**		
	Clause 5 **Standard trim**	**Clause 6** **Noise-reducing trim**	**Clause 7** **High Mach number applications**
Freely expanded jet M_j	No limit	No limit	No limit
Valve outlet M_o	0,3	0,2	1,0
Downstream reducer inlet M_r	Not applicable	Not applicable	1,0
Downstream pipe M_2	0,3	0,2	0,8

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.

IEC 60534 (all parts), *Industrial-process control valves*

IEC 60534-1, *Industrial-process control valves – Part 1: Control valve terminology and general considerations*

3 Terms and definitions

For the purposes of this document, all of the terms and definitions given in the IEC 60534 series and the following apply:

3.1
acoustical efficiency
η
ratio of the stream power converted into sound power propagating downstream to the stream power of the mass flow

3.2
external coincidence frequency
f_g
frequency at which the external acoustic wavespeed is equal to the bending wavespeed in a plate of equal thickness to the pipe wall

3.3
internal coincidence frequency
f_o
lowest frequency at which the internal acoustic and structural axial wave numbers are equal for a given circumferential mode, thus resulting in the minimum transmission loss

3.4
fluted vane butterfly valve
butterfly valve which has flutes (grooves) on the face(s) of the disk. These flutes are intended to shape the flow stream without altering the seating line or seating surface

3.5
independent flow passage
flow passage where the exiting flow is not affected by the exiting flow from adjacent flow passages

3.6
peak frequency
f_p
frequency at which the internal sound pressure is maximum

3.7
valve style modifier
F_d
ratio of the hydraulic diameter of a single flow passage to the diameter of a circular orifice, the area of which is equivalent to the sum of areas of all identical flow passages at a given travel

4 Symbols

Symbol	Description	Unit
A	Area of a single flow passage	m^2
A_η	Valve correction factor for acoustical efficiency (see Table 4)	Dimensionless
A_n	Total flow area of last stage of multistage trim with n stages at given travel	m^2
C	Flow coefficient (K_v and C_v)	Various (see IEC 60534-1)
c_a	External speed of sound (dry air at standard conditions = 343 m/s)	m/s
C_n	Flow coefficient for last stage of multistage trim with n stages	Various (see IEC 60534-1)
c_s	Speed of sound of the pipe (for steel = 5 000 m/s)	m/s
c_{vc}	Speed of sound in the *vena contracta* at subsonic flow conditions	m/s
c_{vcc}	Speed of sound in the *vena contracta* at critical flow conditions	m/s
c_2	Speed of sound at downstream conditions	m/s
D	Valve outlet diameter	m
d	Diameter of a flow passage (for other than circular, use d_H)	m
d_H	Hydraulic diameter of a single flow passage	m
d_i	Smaller of valve outlet or expander inlet internal diameters	m
D_i	Internal downstream pipe diameter	m
D_j	Jet diameter at the *vena contracta*	m
d_o	Diameter of a circular orifice, the area of which equals the sum of areas of all flow passages at a given travel	m
F_d	Valve style modifier	Dimensionless
F_L	Liquid pressure recovery factor of a valve without attached fittings (see Note 4)	Dimensionless
F_{Ln}	Liquid pressure recovery factor of last stage of low noise trim	Dimensionless
F_{LP}	Combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings (see Note 4)	Dimensionless
F_p	Piping geometry factor	Dimensionless
f_g	External coincidence frequency	Hz
f_o	Internal coincidence pipe frequency	Hz
f_p	Generated peak frequency	Hz
f_{pR}	Generated peak frequency in valve outlet or reduced diameter of expander	Hz
f_r	Ring frequency	Hz
f_s	Structural loss factor reference frequency = 1 Hz	Hz

Symbol	**Description**	**Unit**
G_x, G_y	Frequency factors (see Table 4)	Dimensionless
l	Length of a radial flow passage	m
l_w	Wetted perimeter of a single flow passage	m
L_g	Correction for Mach number	dB (ref p_o)
$L_{pe,1m}$ (f)	Frequency-dependent external sound-pressure level 1 m from pipe wall	dB(ref p_o)
$L_{pAe,1m}$	A-weighted overall sound-pressure level 1 m from pipe wall	dB(A) (ref p_o)
L_{pi}	Overall Internal sound-pressure level at pipe wall	dB (ref p_o)
L_{pi} (f)	Frequency-dependent internal sound-pressure level at pipe wall	dB (ref p_o)
L_{piR}	Overall Internal sound-pressure level at pipe wall for noise created by outlet flow in expander	dB (ref p_o)
L_{piR} (f)	Frequency-dependent internal sound-pressure level at pipe wall for noise created by outlet flow in expander	dB (ref p_o)
L_{piS} (f)	Combined internal frequency-dependent sound-pressure at the pipe wall, caused by the valve trim and expander	dB (ref p_o)
L_{wi}	Total internal sound power level	dB (ref W_o)
M	Molecular mass of flowing fluid	kg/kmol
M_j	Freely expanded jet Mach number in regimes II to IV	Dimensionless
M_{jn}	Freely expanded jet Mach number of last stage in multistage valve with n stages	Dimensionless
M_{j5}	Freely expanded jet Mach number in regime V	Dimensionless
M_o	Mach number at valve outlet	Dimensionless
M_R	Mach number in the entrance to expander	Dimensionless
M_{vc}	Mach number at the *vena contracta*	Dimensionless
M_2	Mach number in downstream pipe	Dimensionless
$\dot{m}$	Mass flow rate	kg/s
N	Numerical constants (see Table 1)	Various
n_o	Number of independent and identical flow passages in valve trim	Dimensionless
p_a	Actual atmospheric pressure outside pipe	Pa (see Note 3)
p_n	Absolute stagnation pressure at inlet of the last stage of multistage valve with n stages	Pa
p_o	Reference sound pressure = 2×10^{-5} (see Note 5)	Pa
p_s	Standard atmospheric pressure (see Note 1)	Pa
p_{vc}	Absolute *vena contracta* pressure at subsonic flow conditions	Pa
p_1	Valve inlet absolute pressure	Pa
p_2	Valve outlet absolute pressure	Pa
R	Universal gas constant = 8 314	J/kmol × K
St	Strouhal number for peak frequency calculation (see Table 4)	Dimensionless

Symbol	Description	Unit
T_n	Inlet absolute temperature at last stage of multistage valve with *n* stages	K
T_{vc}	*Vena contracta* absolute temperature at subsonic flow conditions	K
T_{vcc}	*Vena contracta* absolute temperature at critical flow conditions	K
T_1	Inlet absolute temperature	K
T_2	Outlet absolute temperature	K
$TL(f)$	Frequency-dependent transmission loss	dB
t_s	Pipe wall thickness	m
U_p	Gas velocity in downstream pipe	m/s
U_R	Gas velocity in the inlet of diameter expander	m/s
W_a	Sound power for noise crated by valve flow and propagating downstream	W
W_{aR}	Sound power for noise generated by the outlet flow and propagating downstream	W
W_m	Stream power of mass flow	W
W_{ms}	Stream power of mass flow rate at sonic velocity	W
W_{mR}	Converted stream power in the expander	W
W_o	Reference sound power = 10^{-12} (see Note 5)	W
x	Differential pressure ratio	Dimensionless
x_{vcc}	*Vena contracta* differential pressure ratio at critical flow conditions	Dimensionless
x_B	Differential pressure ratio at break point	Dimensionless
x_C	Differential pressure ratio at critical flow conditions	Dimensionless
x_{CE}	Differential pressure ratio where region of constant acoustical efficiency begins	Dimensionless
α	Recovery correction factor	Dimensionless
β	Contraction coefficient for valve outlet or expander inlet	Dimensionless
γ	Specific heat ratio	Dimensionless
$\Delta L_A(f)$	A-Weighting correction based on frequency	dB
ΔTL	Damping factor for transmission loss	dB
η	Acoustical efficiency factor for noise created by valve flow (see Note 2)	Dimensionless
η_R	Acoustical efficiency factor for noise created by outlet flow in expander	Dimensionless
$\eta_s(f)$	Frequency-dependent structural loss factor	Dimensionless
ρ_1	Density of fluid at p_1 and T_1	kg/m^3
ρ_2	Density of fluid at p_2 and T_2	kg/m^3
ρ_n	Density of fluid at last stage of multistage valve with *n* stages at p_n and T_n	kg/m^3
ρ_s	Density of the pipe	kg/m^3
Φ	Relative flow coefficient	Dimensionless

Symbol	**Description**	**Unit**
Subscripts		
e	Denotes external	
i	Denotes internal or used as an index for the frequency band number	
n	Denotes last stage of trim	
p	Denotes peak	
R	Denotes conditions in downstream pipe or pipe expander	

NOTE 1 Standard atmospheric pressure is 101,325 kPa or 1,01325 bar.

NOTE 2 Subscripts 1, 2, 3, 4 and 5 denote regimes I, II, III, IV and V respectively.

NOTE 3 1 bar = 10^2 kPa = 10^5 Pa.

NOTE 4 For the purpose of calculating the *vena contracta* pressure, and therefore velocity, in this standard, pressure recovery for gases is assumed to be identical to that of liquids.

NOTE 5 Sound power and sound pressure are customarily expressed using the logarithmic scale known as the decibel scale. This scale relates the quantity logarithmically to some standard reference. This standard reference is 2×10^{-5} Pa for sound pressure and 10^{-12} W for sound power.

5 Valves with standard trim

5.1 Pressures and pressure ratios

There are several pressures and pressure ratios needed in the noise prediction procedure. They are given below. For noise considerations related to control valves the differential pressure ratio *x* is often used.

$$x = \frac{p_1 - p_2}{p_1} \tag{1}$$

The *vena contracta* is the region of maximum velocity and minimum pressure. This minimum pressure related to the inlet pressure, which cannot be less than zero absolute, is calculated as follows:

$$\frac{p_{vc}}{p_1} = 1 - \frac{x}{F_L{}^2} \tag{2}$$

NOTE 1 This equation is the definition of F_L for subsonic conditions.

NOTE 2 When the valve has attached fittings, F_L should be replaced with F_{LP}/F_p.

NOTE 3 The factor F_L is needed in the calculation of the *vena contracta* pressure. The *vena contracta* pressure is then used to calculate the velocity, which is needed to determine the acoustical efficiency factor.

At critical flow conditions, the pressure in the *vena contracta* and the corresponding differential pressure ratio when $p_2 = p_{vcc}$ are calculated as follows:

$$x_{vcc} = 1 - \left(\frac{2}{\gamma + 1} \right)^{\gamma/(\gamma - 1)} \tag{3}$$

The critical downstream pressure ratio where sonic flow in the *vena contracta* begins is calculated from the following equation:

$$x_C = F_L^{\,2}\, x_{vcc} \tag{4}$$

NOTE 4 When the valve has attached fittings, F_L should be replaced with F_{LP}/F_p.

The correction factor α is the ratio of two pressure ratios:

a) the ratio of inlet pressure to outlet pressure at critical flow conditions;

b) the ratio of inlet pressure to *vena contracta* pressure at critical flow conditions.

It is defined as follows:

$$\alpha = \frac{1 - x_{vcc}}{1 - x_C} \tag{5}$$

The point at which the shock cell-turbulent interaction mechanism (regime IV) begins to dominate the noise spectrum over the turbulent-shear mechanism (regime III) is known as the break point. See 5.2 for a description of these regimes. The differential pressure ratio at the break point is calculated as follows:

$$x_B = 1 - \frac{1}{\alpha}\left(\frac{1}{\gamma}\right)^{\gamma/(\gamma-1)} \tag{6}$$

The differential pressure ratio at which the region of constant acoustical efficiency (regime V) begins is calculated as follows:

$$x_{CE} = 1 - \frac{1}{22\,\alpha} \tag{7}$$

5.2 Regime definition

A control valve controls flow by converting potential (pressure) energy into turbulence. Noise in a control valve results from the conversion of a small portion of this energy into sound. Most of the energy is converted into heat.

The different regimes of noise generation are the result of differing sonic phenomena or reactions between molecules in the gas and the sonic shock cells. In regime I, the flow is subsonic and the gas is partially recompressed, thus the involvement of the factor F_L. Noise generation in this regime is predominantly dipole.

In regime II, sonic flow exists with interaction between shock cells and with turbulent choked flow mixing. Recompression decreases as the limit of regime II is approached.

In regime III, no isentropic recompression exists. The flow is supersonic, and the turbulent flow-shear mechanism dominates.

In regime IV, the shock cell structure diminishes as a Mach disk is formed. The dominant mechanism is shock cell-turbulent flow interaction.

In regime V, there is constant acoustical efficiency; a further decrease in p_2 will result in no increase in noise.

For a given set of operating conditions, the regime is determined as follows:

Regime I	If	$x \le x_C$
Regime II	If	$x_C < x \le x_{vcc}$