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Industrial-process control valves - Part 8: Noise considerations - Section 3: Control valve aerodynamic noise prediction method (IEC 60534-8-3:1995)

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Partie 8: Considérations sur le bruit
Section 3: Calcul du bruit généré par un débit aérodynamique
(CEI 534-8-3:1995)

Stellventile für die Prozeßregelung
Teil 8: Geräuschemission
Hauptabschnitt 3: Berechnungsverfahren zur Vorhersage der aerodynamischen Geräusche von Stellventilen
(IEC 534-8-3:1995)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 65B/231/DIS, future edition 1 of IEC 534-8-3, prepared by SC 65B, Devices, of IEC TC 65, Industrial-process measurement and control, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60534-8-3 on 1995-09-20.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	1996-07-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	1996-07-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex ZA is normative and annexes A and B are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 534-8-3:1995 was approved by CENELEC as a European Standard without any modification.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE: When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 534-1	1987	Industrial-process control valves Part 1: Control valve terminology and general considerations	EN 60534-1	1993
IEC 534-2-1	1978	Part 2: Flow capacity Section 1: Sizing equations for incompressible fluid flow under installed conditions	EN 60534-2-1	1993
IEC 534-2-2	1980	Section 2: Sizing equations for compressible fluid flow under installed conditions	EN 60534-2-2	1993
IEC 534-2-3	1983	Section 3: Test procedures	EN 60534-2-3	1993
IEC 534-8-1	1986	Part 8: Noise considerations Section 1: Laboratory measurement of noise generated by aerodynamic flow through control valves	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL-PROCESS CONTROL VALVES –

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

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international cooperation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

3) They have the form of recommendations for international use published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

International Standard IEC 534-8-3 has been prepared by sub-committee 65B: Devices, of IEC technical committee 65: Industrial-process measurement and control.

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

DIS	Report on voting
65B/231/DIS	65B/254/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.

Annexes A and B are for information only.

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 and 1 m from the pipe wall. This section offers a method to establish this value.

The equations in this section make use of the valve sizing factors as used in IEC 534-1, IEC 534-2, and IEC 534-2-2.

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.

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 (reference IEC 534-8-1).

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.

The transmission loss equations are based on a rigorous analysis of the interaction between the sound waves existing in the pipe and the many coincidence frequencies in the pipe wall. 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.

Example calculations are given in annex A.

This method is based on the IEC standards listed in clause 2 and the references given in annex B.

INDUSTRIAL-PROCESS CONTROL VALVES –

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

1 Scope and limitations

This section of International Standard IEC 534-8 establishes a theoretical method to predict the external sound-pressure level generated in a control valve 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 section addresses only the noise generated by aerodynamic processes in valves and in the connected piping. It does not consider any noise generated by reflections, mechanical vibrations, unstable flow patterns, and other unpredictable behaviour.

At this time, predictions are limited to a downstream maximum velocity in the valve outlet port of 0,3 Mach. Ideal straight pipe is assumed downstream.

The method is applicable to the following single-stage valves: globe (single and double seated), butterfly, angle, 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 section, see 6.5.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 534-8. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this section of IEC 534-8 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid normative documents.

IEC 534-1: 1987, *Industrial-process control valves – Part 1: Control valve terminology and general considerations*

IEC 534-2: 1978, *Industrial-process control valves – Part 2: Flow capacity – Section One: Sizing equations for incompressible fluid flow under installed conditions*

IEC 534-2-2: 1980, *Industrial-process control valves – Part 2: Flow capacity – Section Two: Sizing equations for compressible fluid flow under installed conditions*

IEC 534-2-3: 1983, *Industrial-process control valves – Part 2: Flow capacity – Section Three: Test procedures*

IEC 534-8-1: 1986, *Industrial-process control valves – Part 8: Noise considerations – Section One: Laboratory measurement of noise generated by aerodynamic flow through control valves*

3 Definitions

For the purpose of this International Standard, all of the definitions given in other parts of IEC 534 shall apply with the addition of the following:

3.1 **acoustical efficiency:** The ratio of the stream power converted into sound to the stream power of the mass flow.

3.2 **first coincidence frequency***:* The lowest frequency at which the acoustic and structural axial wave numbers are equal for a given circumferential mode, thus resulting in the minimum transmission loss.

3.3 **fluted vane butterfly valve:** A 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.

3.4 **independent flow passage***:* A flow passage where the exiting flow is not affected by the exiting flow from adjacent flow passages.

3.5 **peak frequency:** The frequency at which the internal sound pressure is a maximum.

3.6 **valve style modifier F_d:** The 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_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 534-1)
C_n	Flow coefficient for last stage of multistage trim with n stages	Various (see IEC 534-1)
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

Symbol	Description	Unit
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	Internal 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_{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_o	First coincidence pipe frequency	Hz
f_p	Generated peak frequency	Hz
f_r	Ring frequency	Hz
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_{pAe}	A-weighted sound-pressure level external of pipe	dB(A) (ref P_o)
$L_{pAe,1m}$	A-weighted sound-pressure level 1 m from pipe wall	dB(A) (ref P_o)
L_{pi}	Internal sound-pressure level at pipe wall	dB (ref P_o)
L_{wi}	Total internal sound power level	dB (ref P_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_{vc}	Mach number at the *vena contracta*	Dimensionless
M_2	Mach number in downstream pipe	Dimensionless
$\dot{m}$	Mass flow rate	kg/s
$\dot{m}_s$	Mass flow rate at sonic velocity	kg/s
N	Numerical constants (see table 1)	Various
N_o	Number of independent and identical flow passages in valve trim	Dimensionless

Symbol	Description	Unit
p_a	Actual atmospheric pressure outside pipe	Pa (see note 3)
p_n	Absolute stagnation pressure at last stage of multistage valve with n stages	Pa
P_o	Reference sound pressure = 2×10^{-5}	Pa
p_s	Standard atmospheric pressure (see note 1)	Pa
p_{vc}	Absolute *vena contracta* pressure at subsonic flow conditions	Pa
p_{vcc}	Absolute *vena contracta* pressure at critical flow conditions	Pa
p_1	Valve inlet absolute pressure	Pa
p_2	Valve outlet absolute pressure	Pa
p_{2B}	Valve outlet absolute pressure at break point	Pa
p_{2C}	Valve outlet absolute pressure at critical flow conditions	Pa
p_{2CE}	Valve outlet absolute pressure where region of constant acoustical efficiency begins	Pa
R	Universal gas constant = 8 314	J/kmol x K
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	Transmission loss corrected for peak frequency	dB
TL_{fr}	Transmission loss at ring frequency	dB
ΔTL_{fr}	Differential between TL_{rf} and TL	dB
t_p	Pipe wall thickness	m
U_{vc}	*Vena contracta* velocity at subsonic flow conditions	m/s
W_a	Sound power	W
W_m	Stream power of mass flow	W
W_{ms}	Stream power of mass flow rate at sonic velocity	W
W_o	Reference sound power = 10^{-12}	W
α	Recovery correction factor	Dimensionless
γ	Specific heat ratio	Dimensionless

Symbol	Description	Unit
η	Acoustical efficiency factor (see note 2)	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
Φ	Relative flow coefficient	Dimensionless

NOTES

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

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

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

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

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.

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

$$p_{vc} = p_1 - \frac{p_1 - p_2}{F_L^2} \tag{1}$$

NOTES

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

2 When the valve has attached fittings, replace F_L with F_{LP}/F_p.

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* is:

$$p_{vcc} = p_1 \left(\frac{2}{\gamma + 1} \right)^{\gamma/(\gamma - 1)} \tag{2}$$

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

$$p_{2C} = p_1 - F_L^2 (p_1 - p_{vcc}) \tag{3}$$

NOTE 4 – When the valve has attached fittings, replace F_L with F_{LP}/F_p.