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Industrial-process control valves - Part 2: Flow capacity - Section 2: Sizing equations for compressible fluid flow under installed conditions (IEC 60534-2-2:1980)

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ENGLISH VERSION

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

Vannes de régulation des processus industriels
Deuxième partie: Capacité d'écoulement
Section deux - Equations de dimensionnement pour l'écoulement des fluides compressibles dans les conditions d'installation
(CEI 534-2-2:1980)

Stellventile für die Prozeßregelung
Teil 2: Durchflußkapazität
Hauptabschnitt zwei - Bemessungsgleichungen für kompressible Fluide unter Einbaubedingungen
(IEC 534-2-2:1980)

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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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 CENELEC questionnaire procedure, performed for finding out whether or not the International Standard IEC 534-2-2:1980 could be accepted without textual changes, has shown that no common modifications were necessary for the acceptance as European Standard.

The reference document was submitted to the CENELEC members for formal vote and was approved by CENELEC as EN 60534-2-2 on 9 December 1992.

The following dates were fixed:

- latest date of publication of an identical national standard	(dop)	1993-12-01
- latest date of withdrawal of conflicting national standards	(dow)	1993-12-01

For products which have complied with the relevant national standard before 1993-12-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 1998-12-01.

ENDORSEMENT NOTICE

The text of the International Standard IEC 534-2-2:1980 was approved by CENELEC as a European Standard without any modification.

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Vannes de régulation des processus industriels

Deuxième partie: Capacité d'écoulement

Section deux – Equations de dimensionnement pour l'écoulement des fluides compressibles dans les conditions d'installation

Industrial-process control valves

Part 2: Flow capacity

Section Two – Sizing equations for compressible fluid flow under installed conditions

Mots clés: commande et mesure dans les processus industriels; régulateurs de débit; rhéomètres; marquage des propriétés par symboles littéraux; définitions; équations.

Key words: industrial-process control and measurement; flow regulators; rheometers; marking of properties by means of letter symbols; definitions; equations.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) 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.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 65B: Elements of Systems, of IEC Technical Committee No. 65: Industrial-process Measurement and Control.

A first draft was discussed at the meeting held in Budapest in 1976. A revised draft, Document 65B(Central Office)14, was submitted to the National Committees for approval under the Six Months' Rule in June 1978.

The National Committees of the following countries voted explicitly in favour of publication:

Belgium
Brazil
Bulgaria
Canada
Denmark
Egypt
Hungary
Italy
Japan
Korea (Republic of)
Netherlands
Poland
South Africa (Republic of)
Switzerland
Turkey
United Kingdom
United States of America

This standard forms Section Two of Part 2 of IEC Publication 534: Industrial-process Control Valves. Part 1: General Considerations, applies in general. Appropriate clauses of Part 2, Section Three: Control Valve Capacity Test Procedures for Incompressible and Compressible Fluids, which is in preparation, contain instructions for determining the various factors used in the equations contained in this section.

INDUSTRIAL-PROCESS CONTROL VALVES

Part 2: Flow capacity

SECTION TWO — SIZING EQUATIONS FOR COMPRESSIBLE FLUID FLOW UNDER INSTALLED CONDITIONS

1. Scope

This section of Part 2 covers equations suitable for use in sizing industrial-process control valves when the flowing media are compressible fluids. At very low ratios of pressure differential to absolute inlet pressure ($\Delta p/p_1$), compressible fluids behave similarly to incompressible fluids. Under such conditions the sizing equations presented in this section can be traced to the basic Bernoulli equation for Newtonian incompressible fluids. However, increasing values of $\Delta p/p_1$ result in compressibility effects which require that the basic equations be modified by appropriate correction factors. The equations presented are for use with gas or vapour and are not intended for use with multiphase streams such as gas-liquid, vapour-liquid or gas-solid mixtures.

2. Definitions

All of the definitions given in Clause 2 of IEC Publication 534-1 shall apply with the addition of the following:

2.1 *Choked flow*

A maximum limiting flow condition which compressible fluids can reach in passing through control valves.

Note. — With fixed inlet (upstream) conditions, choked flow is evidenced by the failure of increasing pressure differential to produce further increase in the flow rate.

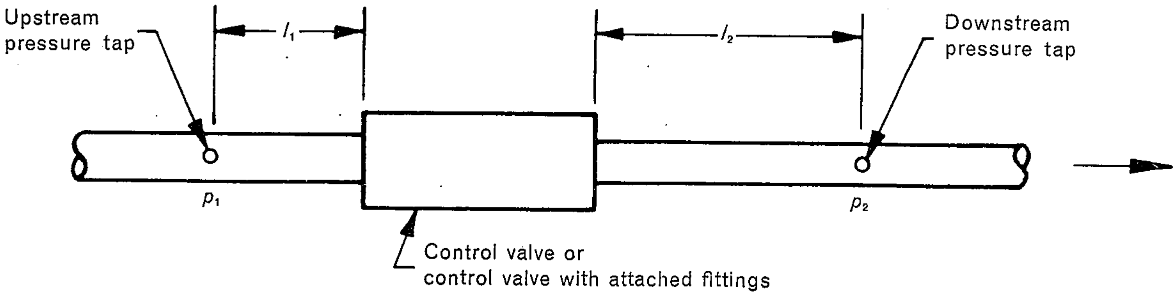
2.2 *Critical differential pressure ratio*

The maximum ratio of differential pressure to inlet absolute pressure that is effective in all of the valve sizing equations.

Note. — Choked flow as defined in Sub-clause 2.1 occurs when this maximum ratio has been reached.

2.3 *Fitting*

Any device such as a reducer, expander, elbow, T-piece, or bend, which is attached directly to an end connection of a control valve.



l_1 = 2 nominal pipe diameters
l_2 = 6 nominal pipe diameters

FIG. 1. — Pressure tap locations

3. Installation

In many industrial applications, control valves are installed using a variety of piping fittings attached to the upstream and downstream connections on the valve. These fittings usually have a significant reducing effect on the installed valve sizing coefficient. A correction factor is introduced to account for these effects.

In sizing control valves, using the relationships presented herein, the flow coefficients calculated include all head losses between pressure taps located as shown in Figure 1. It should be noted that the locations of the upstream and downstream pressure taps have been fixed at the outer limits shown in Figure 3 of IEC Publication 534-1: Industrial-process Control Valves, Part 1: General Considerations. These calculated flow coefficients will normally be compared with rated flow coefficients listed in valve manufacturers' literature. Rated coefficients also include all head losses from two pipe diameters upstream through six pipe diameters downstream but where the control valve has been installed without fittings attached.

4. Nomenclature

Symbols	*Description*	*Unit*
C	Flow coefficient (A_v, K_v, C_v)	Various (see Note 1)
d	Nominal valve size (DN)	mm
D	Internal diameter of the piping	mm
F_P	Piping geometry factor	Dimensionless
F_γ	Specific heat ratio factor	Dimensionless
M	Molecular mass of flowing fluid	—
N_2, N_5, N_6, N_8, N_9	Numerical constants	Various

Symbols	*Description*	*Unit*
p_1	Inlet absolute pressure measured at the upstream pressure tap	kPa or bar (see Note 2)
p_2	Outlet absolute pressure measured at the downstream pressure tap	kPa or bar
p_c	Absolute thermodynamic critical pressure	kPa or bar
p_r	Reduced pressure (p_1/p_c)	Dimensionless
Δp	Pressure differential ($p_1 - p_2$) between upstream and downstream pressure taps	kPa or bar
Q	Volumetric flow rate	m^3/h (see Note 3)
T_1	Inlet absolute temperature (°C + 273)	K
T_c	Absolute thermodynamic critical temperature	K
T_r	Reduced temperature (T_1/T_c)	Dimensionless
T_s	Absolute reference temperature for standard cubic metre	K (see Note 3)
W	Mass flow rate	kg/h
x	Ratio of pressure differential to inlet absolute pressure ($\Delta p/p_1$)	Dimensionless
x_T	Pressure differential ratio factor of a control valve without attached fittings	Dimensionless
x_{TP}	Pressure differential ratio factor of a control valve with attached fittings	Dimensionless
Y	Expansion factor	Dimensionless
Z	Compressibility factor—ratio of ideal to actual inlet specific mass (function of p_r, T_r)	Dimensionless
γ	Specific heat ratio	Dimensionless
ρ_1	Density (specific mass) of fluid at p_1 and T_1	kg/m^3
ζ	Head loss coefficient of a reducer, expander or other fitting attached to a control valve	Dimensionless

Notes 1. — Refer to IEC Publication 534-1: refer also to Note 4, Clause 5.
2. — 10^5 Pa = 10^2 kPa = 1 bar.
3. — Volumetric flow rates in cubic metres per hour, identified by the symbol Q, refer to standard conditions. The standard cubic metre is taken at 1 013.25 mbar and either 273 K or 288.5 K (see Table I).

5. Sizing equations

The equations listed below identify the relationships between flow rates, flow coefficients, related installation factors and pertinent service conditions for control valves handling compressible fluids. Flow rates for compressible fluids may be encountered in either mass or volume units and thus equations are necessary to handle both situations. Flow rates may be calculated using the appropriate equation selected from the following:

$$W = N_6 \cdot F_P \cdot C \cdot Y \sqrt{x \cdot p_1 \cdot \rho_1} \qquad (1)$$

$$W = N_8 \cdot F_P \cdot C \cdot p_1 \cdot Y \sqrt{\frac{x \cdot M}{T_1 \cdot Z}} \qquad (2)$$

$$Q = N_9 \cdot F_P \cdot C \cdot p_1 \cdot Y \sqrt{\frac{x}{M \cdot T_1 \cdot Z}} \qquad \text{(see Note 1) (3)}$$

When the flow rate is known and the valve sizing coefficient C is to be determined, the following respective rearrangements of the above equations shall be used:

$$C = \frac{W}{N_6 \cdot F_P \cdot Y \sqrt{x \cdot p_1 \cdot \rho_1}} \qquad (4)$$

$$C = \frac{W}{N_8 \cdot F_P \cdot p_1 \cdot Y} \sqrt{\frac{T_1 \cdot Z}{x \cdot M}} \qquad (5)$$

$$C = \frac{Q}{N_9 \cdot F_P \cdot p_1 \cdot Y} \sqrt{\frac{M \cdot T_1 \cdot Z}{x}} \qquad \text{(see Note 1) (6)}$$

Notes 1. — In some cases, volumetric valve sizing equations for compressible fluids contain the term G. This term defines the relative density of the flowing fluid to air when both are at standard conditions. The relationship reduces to the following:

$$G = \frac{M}{M_a}$$

where:
M = molecular mass of flowing fluid
M_a = molecular mass of air = 28.97

2. — F_P is unity when the control valve is installed without fittings. Refer to Clause 6 for F_P values with other installation configurations.

3. — Refer to Clause 7 for details of the expansion factor Y.

4. — N_6, N_8, N_9 are numerical constants, the values of which account for the necessary conversion of measurement units used in the equations and also for the specific flow coefficient desired. Flow coefficients included are A_v, K_v and C_v and values of the constants may be obtained from Table I.

5. — Several other equations for sizing control valves for compressible fluids are in common world-wide usage. Some of these equations are given in Appendix B.

6. Piping geometry factor F_P

The piping geometry factor F_P modifies the flow coefficient for reducers, expanders or other fittings attached to the valve body. F_P is the ratio of the flow coefficient for a valve with fittings attached to its inlet and/or outlet to the rated flow coefficient.

To meet the maximum permissible tolerance of ±5% the F_P factor shall be determined by test.

When calculated values are permissible, the following equation may be used:

$$F_P = \frac{1}{\sqrt{1 + \frac{\Sigma\zeta}{N_2}\left(\frac{C}{d^2}\right)^2}} \qquad (7)$$

Note. — Values for N_2 are given in Table I.