IS/IEC 60534-2-3 (1997): Industrial-Process Control Valves, Part 2: Flow Capacity, Section 3: Test Procedures [ETD 18: Industrial Process Measurement and Control]

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भारतीय मानक

औद्योगिक-प्रक्रम नियंत्रण वाल्व

भाग 2 प्रवाह क्षमता

अनुभाग 3 परीक्षण विधियाँ

Indian Standard

INDUSTRIAL-PROCESS CONTROL VALVES

PART 2 FLOW CAPACITY

Section 3 Test Procedures

ICS 29.060.40; 25.040.40

BUREAU OF INDIAN STANDARDS
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October 2008

Price Group 9

Industrial Process Measurement and Control Sectional Committee, ETD 18

NATIONAL FOREWORD

This Indian Standard (Part 2/Sec 3) which is identical with IEC 60534-2-3 : 1997 'Industrial-process control valves — Part 2-3: Flow capacity — Test procedures' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Industrial Process Measurement and Control Sectional Committee and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60534-1 : 1987 Industrial-process control valves — Part 1: Control valve terminology and general considerations	IS/IEC 60534-1 : 1987 Industrial-process control valves: Part 1 Control valve terminology and general considerations	Identical
IEC 60534-2-1 : 1978[1] Industrial-process control valves — Part 2: Flow capacity — Section 1: Sizing equations for incompressible fluid flow under installed conditions	IS/IEC 60534-2-1 : 1998 Industrial-process control valves: Part 2 Flow capacity, Section 1 Sizing equations for incompressible fluid flow under installed conditions	Technically Equivalent
IEC 60534-2-2 : 1980[2] Industrial-process control valves — Part 2: Flow capacity — Section 2: Sizing equations for compressible fluid flow under installed conditions	IS/IEC 60534-2-2 : 1993 Industrial-process control valves: Part 2 Flow capacity, Section 2 Sizing equations for compressible fluid flow under installed conditions	do

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60534-8-2 : 1991	Industrial-process control valves — Part 8: Noise considerations — Section 2: Laboratory measurement of noise generated by hydrodynamic flow through control valves
IEC 61298-1 : 1995	Process measurement and control devices — General methods and procedures for evaluating performance — Part 1: General considerations

[1] Since revised in 1998.

[2] Since revised in 1993.

(*Continued on third cover*)

The three values obtained at each test point shall be such that the largest value is not more than 4 % greater than the smallest value. If the difference exceeds this tolerance, the tests at that point shall be repeated.

The flow coefficient at each travel shall be the arithmetic mean of the three test values rounded off to no more than three significant figures.

11.2 Calculation of pressure differential ratio factor x_T

Calculate x_T using the data obtained in 10.2:

When $x = F_\gamma \, x_T$, then $Q = Q_{max(T)}$ and $Y = 0{,}667$.

$$x_T = \left[\frac{Q_{max(T)}}{0{,}667 \, N_9 \, C \, p_1}\right]^2 \left[\frac{M \, T_1 \, Z}{F_\gamma}\right] \qquad (23)$$

If air is used as the test fluid, $F_\gamma = 1$, $M = 28{,}97$ kg/kmol and $Z = 1$.

11.3 Calculation of pressure differential ratio factor x_{TP}

Calculate x_{TP} using the data obtained in 10.2.

When $x = F_\gamma \, x_{TP}$, then $Q = Q_{max(TP)}$ and $Y = 0{,}667$

$$x_{TP} = \left[\frac{Q_{max(TP)}}{0{,}667 \, N_9 \, F_p \, C \, p_1}\right]^2 \left[\frac{M \, T_1 \, Z}{F_\gamma}\right] \qquad (24)$$

If air is used as the test fluid, $F_\gamma = 1$, $M = 28{,}97$ kg/kmol and $Z = 1$.

11.4 Calculation of piping geometry factor F_p

Calculate F_p using average values obtained in 10.3.

$$F_p = \frac{C \text{ for valve installed with attached fittings}}{C_R} = \frac{\dfrac{Q}{N_9 \, p_1}\sqrt{\dfrac{M \, T_1}{x}}}{C_R} \qquad (25)$$

If air is used as the test fluid, $M = 28{,}97$ kg/kmol.

11.5 Calculation of Reynolds number factor F_R for compressible fluids

Use test data, obtained as described under 10.4 and in equation (26) to obtain values of an apparent C. This apparent C is equivalent to $C \, F_R$. Therefore, F_R is obtained by dividing the apparent C by the experimental C determined for the test valve under standard conditions at the same valve travel.

$$C \, F_R = \frac{Q}{N_{22}}\sqrt{\frac{M \, T_1}{\Delta p \left(p_1 + p_2\right)}} \qquad (26)$$

Although the data may be correlated in any manner suitable to the experimenter, a method that has proven to provide satisfactory correlations involves the use of the valve Reynolds number, which may be calculated from equation (13) where F_d is calculated as per 11.6.

11.6 Calculation of valve style modifier F_d

Using the data obtained in 10.1, calculate F_d using equation (14) or (15) as appropriate.

11.7 Calculation of flow coefficient C for small flow trim

Using the data obtained in 10.2.6, calculate C from the following equation and average the results:

$$C = \frac{Q}{N_{22}} \sqrt{\frac{M T_1}{0{,}75\, p_1}} \tag{27}$$

Table 3 – Numerical constants N

Constant	Flow coefficient C		Formulae units					
	K_v	C_v	Q	$p, \Delta p, p_v$	ρ	T	d	ν
N_1	$1{,}00 \times 10^{-1}$ $1{,}00$	$8{,}65 \times 10^{-2}$ $8{,}65 \times 10^{-1}$	m^3/h m^3/h	kPa bar	kg/m^3 kg/m^3	–	–	–
N_4	$7{,}07 \times 10^{-2}$	$7{,}60 \times 10^{-2}$	m^3/h	–	–	–	–	m^2/s
N_9 (t_s = 0 °C)	$2{,}46 \times 10^{1}$ $2{,}46 \times 10^{3}$	$2{,}12 \times 10^{1}$ $2{,}12 \times 10^{3}$	m^3/h m^3/h	kPa bar	–	K K	–	–
N_9 (t_s = 15 °C)	$2{,}60 \times 10^{1}$ $2{,}60 \times 10^{3}$	$2{,}25 \times 10^{1}$ $2{,}25 \times 10^{3}$	m^3/h m^3/h	kPa bar	–	K K	–	–
N_{18}	$8{,}65 \times 10^{-1}$	$1{,}00$	–	–	–	–	mm	–
N_{21}	$1{,}3 \times 10^{-3}$ $1{,}3 \times 10^{-1}$	$1{,}4 \times 10^{-3}$ $1{,}4 \times 10^{-1}$	–	kPa bar	–	–	–	–
N_{22} (t_s = 0 °C)	$1{,}73 \times 10^{1}$ $1{,}73 \times 10^{3}$	$1{,}50 \times 10^{1}$ $1{,}50 \times 10^{3}$	m^3/h m^3/h	kPa bar	–	K K	–	–
N_{22} (t_s = 15 °C)	$1{,}84 \times 10^{1}$ $1{,}84 \times 10^{3}$	$1{,}59 \times 10^{1}$ $1{,}59 \times 10^{3}$	m^3/h m^3/h	kPa bar	–	K K	–	–
N_{25}	$4{,}02 \times 10^{-2}$	$4{,}65 \times 10^{-2}$	--	–	–	–	mm	–
N_{26}	$1{,}28 \times 10^{7}$	$9{,}00 \times 10^{6}$	m^3/h	–	–	–	–	m^2/s
N_{31}	$2{,}1 \times 10^{4}$	$1{,}9 \times 10^{4}$	m^3/h	–	–	–	–	m^2/s
N_{32}	$1{,}40 \times 10^{2}$	$1{,}27 \times 10^{2}$	–	–	–	–	mm	–

NOTE – Use of the numerical constants provided in this table together with the practical metric units specified in the table will yield flow coefficients in the units in which they are defined.

Symbols *(continued)*

Symbol	Description	Unit
x	Ratio of pressure differential to inlet absolute pressure ($\Delta p/p_1$)	1
x_T	Pressure differential ratio factor of a control valve without attached fittings for choked flow	1
x_{TP}	Pressure differential ratio factor of a control valve with attached fittings for choked flow	1
Y	Expansion factor	1
Z	Compressibility factor (Z = 1 for gases that exhibit ideal gas behaviour)	1
γ	Specific heat ratio	1
ν	Kinematic viscosity	m^2/s (see note 4)
ζ	Velocity head loss coefficient of a reducer, expander or other fitting attached to a control valve	1
ρ_1/ρ_0	Relative density (ρ_1/ρ_0 = 1 for water at 15,5 °C)	1

NOTE 1 – To determine the units for the numerical constants, dimensional analysis may be performed on the appropriate equations using the units given in table 3.

NOTE 2 – 1 bar = 10^2 kPa = 10^5 Pa.

NOTE 3 – For compressible fluid volumetric flow rates in m^3/h, identified by the symbol Q, refer to standard conditions which are an absolute pressure of 101,325 kPa (1,013 25 bar) and a temperature of either 0 °C or 15 °C (see table 3).

NOTE 4 – 1 centistoke = 10^{-6} m^2/s.

5 Test system

A basic flow test system is shown in figure 1.

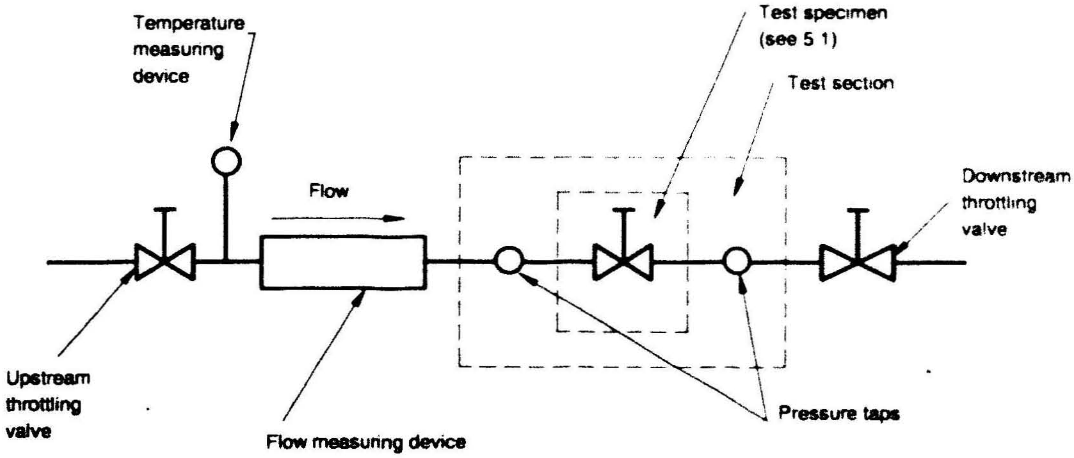


Figure 1 – Basic flow test system

5.1 Test specimen

The test specimen is any valve or combination of valve, reducers, expanders, or other fittings for which test data are required.

Modeling of test specimens to a smaller scale is an acceptable practice in this section, although testing of full-size specimens or models is preferable. Good practice in modeling requires attention to significant relationships such as Reynolds number in the flow of fluid through a completely filled conduit, Mach number where compressibility is important, and geometric similarity.

5.2 Test section

The test section shall consist of two straight lengths of pipe as shown in table 1. The upstream and downstream piping adjacent to the test specimen shall conform to the nominal size of the test specimen connection.

The inside diameter of the pipe shall be within ±2 % of the actual inside diameter of the ends of the test specimen for valves up to and including DN 250 having a pressure rating up to and including PN 100. For valves larger than DN 250 or valves with a pressure rating higher than PN 100, the inside diameter at the inlet and outlet of the test specimen should be matched with the inside diameter of the adjacent piping.

The inside surface shall be free from rust, scale, or other obstructions which may cause excessive flow disturbance.

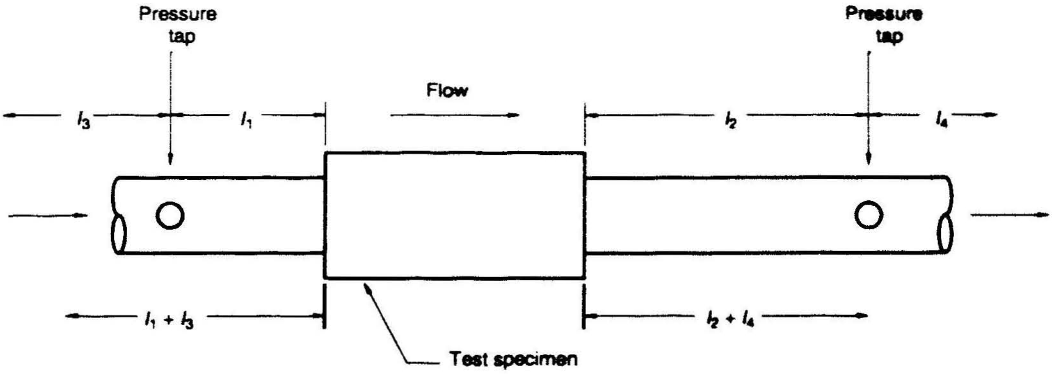
5.3 Throttling valves

The upstream throttling valve is used to control the inlet pressure to the test section. The downstream throttling valve is used for control during testing. Together they are used to control the pressure differential across the test section pressure taps and to maintain a specific downstream pressure. There are no restrictions as to the type of these valves. However, the upstream valve should be selected and located so as not to affect the accuracy of the flow measurement. The downstream throttling valve may be larger than the nominal size of the test specimen to ensure that choking will occur in the test specimen. Vaporization at the upstream valve shall be avoided when testing with liquids.

Table 1 – Test section piping requirements

l_1	l_2	l_3	l_4
Two times nominal pipe diameter	Six times nominal pipe diameter	Eighteen times nominal pipe diameter minimum	One times nominal pipe diameter minimum

Standard test section configuration



NOTE 1 – Straightening vanes may be used where beneficial. If employed, the length l_3 may be reduced to not less than eight times the nominal pipe diameter.

NOTE 2 – The location of the pressure taps are upstream and downstream of the test specimen as a whole. The test specimen may be simply the control valve or the control valve with any combination of attached fittings (see annex A).

NOTE 3 – If upstream flow disturbance consists of two elbows in series and they are in different planes, the dimension l_3 should exceed 18 nominal pipe diameters unless straightening vanes are used.

5.4 Flow measurement

The flow measuring instrument may be located upstream or downstream of the test section, and may be any device which meets the specified accuracy, and shall be calibrated as frequently as necessary to maintain this accuracy. This instrument shall be used to determine the true time-average flow rate within an accuracy of ±2 % of the actual value.

5.5 Pressure taps

Pressure taps shall be provided on the test section piping in accordance with the requirements in table 1 and shall conform to the construction illustrated in figure 2. When the flow pattern across the pipe is not uniform, multiple taps may be necessary to achieve the desired accuracy of measurement.

The pressure tap diameter *b* shall be at least 3 mm and shall be not larger than 12 mm, or one-tenth nominal pipe diameter, whichever is less. Upstream and downstream taps shall be of the same diameter.

The hole shall be circular and its edge shall be clean and sharp or slightly rounded, free from burrs, wire edges, or other irregularities.

Any suitable method of making physical connection is acceptable provided the above recommendations are adhered to; however, in no case shall any fitting protrude inside the pipe.

5.5.1 Incompressible fluid

Tap centrelines shall be located horizontally to reduce the possibility of air entrapment or dirt collection in the taps and shall intersect the pipe centreline at right angles.

5.5.2 Compressible fluid

Tap centrelines shall be oriented horizontally or vertically above the pipe to reduce the possibility of dirt entrapment and shall intersect the pipe centreline at right angles.

5.6 Pressure measurement

All pressure and pressure differential measurements shall be made to an accuracy of ±2 % of reading. Pressure measuring devices shall be calibrated as frequently as necessary to maintain specified accuracy.

5.7 Temperature measurement

The fluid inlet temperature shall be measured to an accuracy of ±1 °C. The temperature measuring probe should be chosen and positioned to have minimum effect on the flow and pressure measurements.

5.8 Valve travel

The valve travel shall be fixed within ±0,5 % of the rated travel during any one specific flow test.

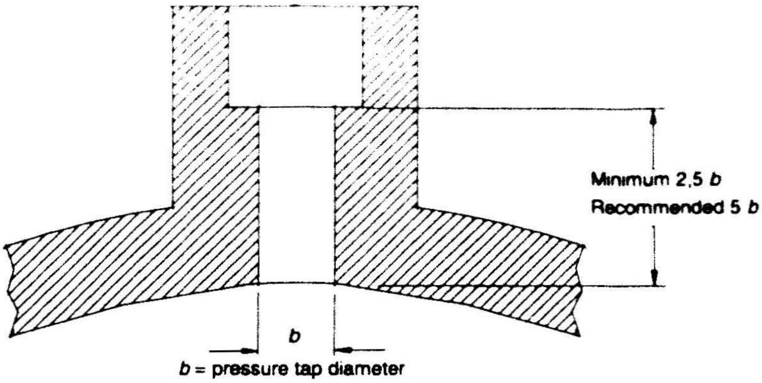
5.9 Installation of test specimen

Alignment between the centreline of the test section piping and the centreline of the inlet and outlet of the test specimen shall be within:

Pipe size	Allowable misalignment
DN 15 through DN 25	0,8 mm
DN 32 through DN 150	1,6 mm
DN 200 and larger	0,01 nominal pipe diameter

The test specimen shall be oriented so that the flow pattern does not produce a velocity head at the pressure tap. For example, when a rotary valve is being tested, the valve shaft shall be aligned with the test section pressure taps.

The inside diameter of each gasket shall be sized and the gasket positioned so that it does not protrude inside the pipe.



Size of pipe	Not exceeding	Not less than
Less than 50 mm	6 mm	3 mm
50 mm to 75 mm	9 mm	3 mm
100 mm to 200 mm	13 mm	3 mm
250 mm and greater	19 mm	3 mm

Figure 2 – Recommended pressure tap connection

6 Accuracy of tests

When the procedures outlined in this section are used, the value of all sizing coefficients is within ±5 % for valves having a C/d^2 ratio of equal to or less than N_{25}.

7 Test fluids

7.1 Incompressible fluids

Water within a temperature range of 5 °C to 40 °C shall be the basic fluid used in this test procedure. Inhibitors may be used to prevent or retard corrosion and to prevent the growth of organic matter provided that the test results are not adversely affected.

7.2 Compressible fluids

Air or other compressible fluids shall be used as the basic fluid in this test procedure. Saturated vapours are not acceptable as test fluids. Care shall be taken to avoid internal icing during the test.

8 Test procedure for incompressible fluids

In the following subclauses, specific instructions are given for the performance of various tests. Evaluation of data obtained from these tests is contained in clause 9.

8.1 Test procedure for flow coefficient C

Determination of the flow coefficient C requires the following test procedure. Data shall be evaluated using the procedure in 9.3.

8.1.1 Install the test specimen without attached fittings in accordance with piping requirements in table 1.

8.1.2 Flow tests shall include flow measurements at three widely spaced pressure differentials (but not less than 0,1 bar) within the turbulent, non-vaporizing region. The suggested differential pressures are

a) just below the onset of cavitation (incipient cavitation) or the maximum available in the test facility, whichever is less (see IEC 60534-8-2);

b) about 50 % of the pressure differential of a);

c) about 10 % of the pressure differential of a).

The pressures shall be measured across the test section pressure taps with the valve at the selected travel.

For very small valve capacities, non-turbulent flow may occur at the recommended pressure differentials. In this case, larger pressure differentials shall be used to ensure turbulent flow; however, a minimum valve Reynolds number Re_v of 10^5 is recommended (see equation (10)).

Deviations from the differential pressures specified above shall be recorded. Indicate reasons for the deviations.

8.1.3 In order to keep the downstream portion of the test section filled with liquid and to prevent vaporization of the liquid, the inlet pressure shall be maintained equal to or greater than the minimum values in table 2. This minimum inlet pressure is dependent on the liquid pressure recovery factor F_L of the test specimen. If F_L is unknown, a conservative estimate for the minimum inlet pressure shall be made.

8.1.4 Flow tests shall be performed to determine:

a) the rated flow coefficient C_R using 100 % of rated travel;

b) inherent flow characteristics (optional), using 5 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 % and 100 % of rated travel.

NOTE – To determine the inherent flow characteristic more fully, flow tests may be performed at travel intervals less than 5 % of rated travel.

Table 2 – Minimum inlet absolute test pressure in kPa (bar) as related to F_L and Δp

Δp kPa (bar)→ F_L↓	Minimum inlet absolute test pressure – kPa (bar)								
	35 (0,35)	40 (0,40)	45 (0,45)	50 (0,50)	55 (0,55)	60 (0,60)	65 (0,65)	70 (0,70)	75 (0,75)
0,5	280 (2,8)	320 (3,2)	360 (3,6)	400 (4,0)	440 (4,4)	480 (4,8)	520 (5,2)	560 (5,6)	600 (6,0)
0,6	190 (1,9)	220 (2,2)	250 (2,5)	270 (2,7)	300 (3,0)	330 (3,3)	360 (3,6)	380 (3,8)	410 (4,1)
0,7	150 (1,5)	160 (1,6)	180 (1,8)	200 (2,0)	220 (2,2)	240 (2,4)	260 (2,6)	280 (2,8)	300 (3,0)
0,8	150 (1,5)	160 (1,6)	160 (1,6)	170 (1,7)	170 (1,7)	190 (1,9)	200 (2,0)	220 (2,2)	230 (2,3)
0,9	150 (1,5)	160 (1,6)	160 (1,6)	170 (1,7)	170 (1,7)	180 (1,8)	180 (1,8)	190 (1,9)	190 (1,9)

NOTE 1 – For large valves where flow source limitations are reached, lower pressure differentials (but not less than 0,1 bar) may be used optionally as long as turbulent flow is maintained.

NOTE 2 – For pressures not listed, use the following equation to calculate the upstream pressure: $p_{1,min} = 2\Delta p/F_L^2$

8.1.5 Record the following data:

a) valve travel;

b) inlet pressure p_1;

c) pressure differential ($p_1 - p_2$) across the pressure taps;

d) fluid inlet temperature T_1;

e) volumetric flow rate Q;

f) barometric pressure;

g) physical description of test specimen (i.e. type of valve, nominal size, pressure rating, flow direction).

8.2 Test procedure for liquid pressure recovery factor F_L and combined liquid pressure recovery factor and piping geometry factor F_{LP}

The maximum flow rate Q_{max} (referred to as choked flow) is required in the calculation of the factors F_L (for a given test specimen without attached fittings) and F_{LP} (for a given test specimen which includes attached fittings). With fixed inlet conditions, choked flow is evidenced by the failure of increasing pressure differentials to produce further increases in the flow rate. The following test procedure shall be used to determine Q_{max}. The data evaluation procedure is found in 9.4. The tests for F_L and corresponding C shall be conducted at identical valve travel. Hence, the tests for both of these factors at any valve travel shall be made while the valve is locked in a fixed position.

8.2.1 The test section of 5.2 shall be used with the test specimen locked at the desired position.

8.2.2 The downstream throttling valve shall be in the wide-open position. With a preselected inlet pressure, the flow rate shall be measured and the inlet and outlet pressures recorded. This test establishes the maximum pressure differential ($p_1 - p_2$) for the test specimen in this test system. With the same inlet pressure, a second test shall be conducted with the pressure differential reduced to 90 % of the pressure differential determined in the first test. If the flow rate in the second test is within 2 % of the flow rate in the first test, the flow rate measured in the first test may be taken as Q_{max}.

If not, repeat the test procedure at a higher inlet pressure. If Q_{max} cannot be achieved at the highest inlet pressure for the test system, use the following procedure. Calculate a value of F_L substituting the flow rate obtained at maximum obtainable values of inlet pressure and pressure differential. For the valve under test, report that F_L is greater than the value calculated as described in the previous sentence.

8.2.3 Record the following data:

a) valve travel;

b) inlet pressure p_1;

c) outlet pressure p_2;

d) fluid inlet temperature T_1;

e) volumetric flow rate Q;

f) barometric pressure;

g) physical description of test specimen (i.e. type of valve, nominal size, pressure rating, flow direction).

8.3 Test procedure for piping geometry factor F_p

The piping geometry factor modifies the valve flow coefficient C for fittings attached to the valve. The factor F_p is the ratio of C for a valve installed with attached fittings to the rated C of the valve installed without attached fittings and tested under identical service conditions. To obtain this factor, replace the valve with the desired combination of valve and attached fittings. Conduct flow tests according to 8.1 treating the combination as the test specimen for the purpose of determining test section pipe size. For example, a DN 100 valve between a reducer and an expander in a DN 150 line would use pressure tap locations based on a DN 150 line.

The data evaluation procedure is found in 9.5.

8.4 Test procedure for liquid critical pressure ratio factor F_F

The liquid critical pressure ratio factor F_F is almost exclusively a property of the fluid and its temperature. It is the ratio of the apparent *vena contracta* pressure at choked flow conditions to the vapour pressure of liquid at inlet temperature.

The quantity of F_F may be determined experimentally by using a test specimen for which F_L and C are known. The valve without attached fittings is installed in accordance with the piping requirements in table 1. The test procedure outlined in 8.2 for obtaining Q_{max} shall be used with the fluid of interest as the test fluid.

The data evaluation procedure is found in 9.6.

8.5 Test procedure for Reynolds number factor F_R for incompressible flow

To produce values of the Reynolds number factor F_R, non-turbulent flow conditions shall be established through the test valve. Such conditions will require low pressure differentials, high viscosity fluids, small values of C, or some combination of these. With the exception of valves with very small values of C, turbulent flow will always exist when flowing tests are performed in accordance with the procedure outlined in 8.1, and F_R under these conditions will have the value of 1,0.

Determine values of F_R by carrying out flowing tests with the valve installed in the standard test section without attached fittings. These tests should follow the procedure for C determination except that

a) test pressure differentials may be any appropriate values provided that no vaporization of the test fluid occurs within the test valve;

b) minimum upstream test pressure values shown in table 2 may not apply if the test fluid is not fresh water at 20 °C ± 14 °C;

c) the test fluid should be a Newtonian fluid having a viscosity considerably greater than that of water unless instrumentation is available for accurately measuring very low pressure differentials.

Carry out a sufficient number of tests at each selected valve travel by varying the pressure differential across the valve so that the entire range of conditions, from turbulent to laminar flow, is spanned.

The data evaluation procedure is given in 9.7.

8.6 Test procedure for valve style modifier F_d

The valve style modifier takes into account the effect of trim geometry on the Reynolds number. It is defined as 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.

The value of F_d should be measured at the desired travels. This value can only be measured when fully laminar flow is obtained using the test procedure outlined in 8.5.

Fully laminar flow is defined as a condition where $\sqrt{Re_v} / F_R$ is constant with a ±5 % tolerance range (typically with Re_v values below 50).

The data evaluation procedure is given in 9.8.

9 Data evaluation procedure for incompressible fluids

9.1 Non-choked flow

The basic flow equation for non-choked, incompressible fluids is:

$$Q = N_1 F_R F_p C \sqrt{\frac{\Delta p}{\rho / \rho_0}} \tag{1}$$

For a valve installed without attached fittings, $F_p = 1$, and for turbulent flow conditions, $F_R = 1$.

9.2 Choked flow

For choked flow, two conditions shall be considered:

9.2.1 Without attached fittings

When the control valve is installed without attached fittings:

$$Q_{max(L)} = N_1 F_L C \sqrt{\frac{p_1 - F_F p_v}{\rho / \rho_o}} \tag{2}$$

NOTE – For a valve installed without attached fittings, the maximum pressure differential that is effective in producing flow under choked conditions is:

$$\Delta p_{max(L)} = F_L^2 (p_1 - F_F p_v) \tag{3}$$

9.2.2 With attached fittings

When the control valve is installed with attached fittings:

$$Q_{max(LP)} = N_1 F_p C \sqrt{\left(\frac{F_{LP}}{F_p}\right)^2 \left(\frac{p_1 - F_F p_v}{\rho / \rho_o}\right)} \tag{4}$$

The common form of equation (4) is:

$$Q_{max(LP)} = N_1 F_{LP} C \sqrt{\left(\frac{p_1 - F_F p_v}{\rho / \rho_o}\right)} \tag{5}$$

NOTE – For a valve installed with attached fittings, the maximum pressure differential that is effective in producing flow under choked conditions is:

$$\Delta p_{max(LP)} = \left(\frac{F_{LP}}{F_p}\right)^2 (p_1 - F_F p_v) \tag{6}$$

9.3 Calculation of flow coefficient C

The flow coefficient C may be calculated as K_v or C_v. See table 3 for the appropriate value of N_1, which will depend upon the coefficient selected and the pressure measurement unit.

Using the data obtained in 8.1, calculate C for each flow test using the equation:

$$C = \frac{Q}{N_1} \sqrt{\frac{\rho / \rho_o}{\Delta p}} \tag{7}$$

For water in the prescribed temperature range, $\rho/\rho_o = 1$.

The three values obtained for each flow test shall be such that the largest value is not more than 4 % greater than the smallest value. If the difference exceeds this tolerance, the flow tests shall be repeated. If excessive differences are caused by cavitation, the tests shall be repeated at a higher inlet pressure.

The flow coefficient at each travel shall be the arithmetic mean of the three test values rounded off to no more than three significant figures.

9.4 Calculation of liquid pressure recovery factor F_L and the combined liquid pressure recovery factor and piping geometry factor F_{LP}

The factors F_L and F_{LP} shall be calculated using the data obtained in 8.2 and the following equations:

9.4.1 Without attached fittings

When the control valve is installed without attached fittings:

$$F_L = \frac{Q_{max(L)}}{N_1 C} \sqrt{\frac{\rho / \rho_0}{p_1 - F_F p_v}} \qquad (8)$$

For water in the prescribed temperature range, $\rho/\rho_0 = 1$ and $F_F = 0{,}96$.

9.4.2 With attached fittings

When the control valve is installed with attached fittings:

$$F_{LP} = \frac{Q_{max(LP)}}{N_1 C} \sqrt{\frac{\rho / \rho_0}{p_1 - F_F p_v}} \qquad (9)$$

For water in the prescribed temperature range, $\rho/\rho_0 = 1$ and $F_F = 0{,}96$.

9.5 Calculation of piping geometry factor F_p

Calculate F_p as follows using average values obtained in 8.3:

$$F_p = \frac{C \text{ for valve installed with attached fittings}}{C_R} = \frac{\frac{Q}{N_1}\sqrt{\frac{\rho / \rho_0}{\Delta p}}}{C_R} \qquad (10)$$

For water in the prescribed temperature range, $\rho/\rho_0 = 1$.

9.6 Calculation of liquid critical pressure ratio factor F_F

Calculate F_F as follows:

$$F_F = \frac{1}{p_v}\left[p_1 - (\rho / \rho_0)\left(\frac{Q_{max}}{N_1 F_L C}\right)^2\right] \qquad (11)$$

where p_v is the fluid vapour pressure at the inlet temperature. $C\,F_L$ is determined for the test specimen by the standard method in 8.2.

9.7 Calculation of Reynolds number factor F_R

Use the test data, obtained as described under 8.5 and in equation (12) to obtain values of an apparent C. This apparent C is equivalent to $C\,F_R$. Therefore, F_R is obtained by dividing the apparent C by the experimental C determined for the test valve under conditions specified in 8.1 and at the same valve travel.

$$C\,F_R = \frac{Q}{N_1}\sqrt{\frac{\rho / \rho_0}{\Delta p}} \qquad (12)$$

Although the data may be correlated in any manner suitable to the experimenter, a method that has proven to provide satisfactory correlations involves the use of the valve Reynolds number, which may be calculated from:

$$Re_v = \frac{N_4 F_d Q}{\nu \sqrt{C F_L}} \tag{13}$$

where F_d is calculated as per 9.8.

9.8 Calculation of valve style modifier F_d

Using the data obtained in 8.5, calculate F_d using the following equation:

$$F_d = \frac{N_{26}\, \nu\, F_R^2\, F_L^2 (C/d^2)^2 \sqrt{C F_L}}{Q\left(\frac{F_L^2 C^2}{N_2 D^2}+1\right)^{1/4}} \tag{14}$$

It is recommended that F_d be calculated at rated valve travel only. Significant errors may occur at reduced travel positions.

For reduced trim valves where $C/d^2 \leq 0{,}016\, N_{18}$ at rated travel, F_d is calculated as follows:

$$F_d = \frac{N_{31}\, \nu\, F_R^2\, F_L^2 \sqrt{C F_L}}{Q\left[1+N_{32}\left(\frac{C}{d^2}\right)^{\frac{2}{3}}\right]} \tag{15}$$

The test shall be conducted at Re_v values of less than 100 or F_R values of less than 0,26. F_d values should be determined from a minimum of three tests and the values averaged.

10 Test procedure for compressible fluids

Specific instructions are given for the performance of various tests.

Evaluation of data obtained from these tests is contained in clause 11.

10.1 Test procedure for flow coefficient C

Determination of the flow coefficient C requires the following test procedure. Data shall be evaluated using the procedure in 11.1.

10.1.1 Install the test specimen without attached fittings in accordance with the piping requirements in table 1.

10.1.2 Flow tests shall include flow measurements at three pressure differentials. In order to approach flowing conditions which can be assumed to be incompressible, the pressure differential ratio ($x = \Delta p/p_1$) shall be less than or equal to 0,02. For the alternative procedure, see 10.2.5.

10.1.3 Flow tests shall be performed to determine:

a) the rated flow coefficient *C*, using 100 % of rated travel;

b) inherent flow characteristics (optional), using 5 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 % and 100 % of rated travel.

NOTE – To determine the inherent flow characteristics more fully, flow tests may be performed at travels less than 5 % of rated travel.

10.1.4 Record the following data:

a) valve travel;

b) inlet pressure p_1;

c) pressure differential $(p_1 - p_2)$ across pressure taps;

d) fluid inlet temperature T_1;

e) volumetric flow rate Q;

f) barometric pressure;

g) physical description of test specimen (i.e. type of valve, nominal size, pressure rating, flow direction).

10.2 Test procedure for pressure differential ratio factors x_T and x_{TP}

The quantities x_T and x_{TP} are the terminal ratios of the differential pressure to absolute inlet pressure $(\Delta p/p_1)$ for fluids with $F_\gamma = 1$ $(\gamma = 1,4)$. However, these quantities can be obtained when using test gases for which F_γ does not equal 1 as shown in equations (23) and (24). The maximum flow rate Q_{max} (referred to as choked flow) is required in the calculation of x_T (for a given test specimen without attached fittings) and x_{TP} (for a given test specimen with attached fittings). With fixed inlet conditions, choked flow is evidenced by the failure of increasing pressure differentials to produce further increases in the flow rate. Values of x_T and x_{TP} shall be calculated using the procedures in 11.2 and 11.3, respectively.

The following test procedure shall be used to determine Q_{max}.

10.2.1 The test section of 5.2 shall be used, with the test specimen at 100 % of rated travel.

10.2.2 Any upstream supply pressure sufficient to produce choked flow is acceptable, as is any resulting pressure differential across the test specimen provided the criteria of choked flow (specified in 10.2.3) are met.

10.2.3 The downstream throttling valve shall be in the wide-open position. With a preselected inlet pressure, the flow rate shall be measured and the inlet and outlet pressures recorded. This test establishes the maximum pressure differential $(p_1 - p_2)$ for the test specimen in this test system. Using the same inlet pressure, a second test shall be conducted with the pressure differential reduced to 90 % of the pressure differential determined in the first test. If the flow rate of this second test is within 0,5 % of the flow rate for the first test, the flow rate measured in the first test may be taken as Q_{max}. If not, repeat the test procedure at a higher inlet pressure.

Although the absolute value of the flow rate shall be measured to an error not exceeding ±2 %, the repeatability of the tests for x_T shall be better than ±0,5 % in order to attain the prescribed accuracy. This series of tests shall be made consecutively, using the same instruments, and without alteration to the test set-up.

10.2.4 Record the following data:

a) valve travel;

b) inlet pressure p_1;

c) outlet pressure p_2;

d) fluid inlet temperature T_1;

e) volumetric flow rate Q;

f) barometric pressure;

g) physical description of test specimen (i.e. type of valve, nominal size, pressure rating, flow direction).

10.2.5 Alternative test procedure for pressure differential ratio factors x_T and x_{TP} and flow coefficient C

If a laboratory is unable to determine the x_T value for a valve using the procedure described above, this alternative procedure may be used.

The test section of 5.2 shall be used with the test specimen at 100 % of rated travel.

With a preselected inlet pressure, measurements shall be made of flow rate Q, fluid inlet temperature T_1 and downstream pressure for a minimum of five well-spaced values of x (the ratio of pressure differential to absolute inlet pressure).

From these data points, calculate values of the product $Y\,C$ using the equation:

$$Y\,C = \frac{Q}{N_9\,p_1}\sqrt{\frac{M\,T_1}{x}} \qquad (16)$$

where Y is the expansion factor defined by:

$$Y = 1 - \frac{x}{3\,F_\gamma\,x_T} \qquad (17)$$

in which $F_\gamma = \gamma/1,4$.

The test points shall be plotted on linear coordinates as $(Y\,C)$ versus x and a linear curve fitted to the data. If any point deviates by more than 5 % from the curve, additional test data shall be taken to ascertain that the specimen truly exhibits anomalous behaviour.

The value of C_0 for the specimen shall be taken from the curve at $x = 0$, $Y = 1$.

At least one test point $(Y\,C)_1$ shall fulfill the requirement that $(Y\,C)_1 \geq 0,97\,(Y\,C)_0$, where $(Y\,C)_0$ corresponds to $x \approx 0$.

At least one test point $(Y\,C)_n$ shall fulfill the requirement that $(Y\,C)_n \leq 0,83\,(Y\,C)_0$.

The value of x_T for the specimen shall be taken from the curve at $(Y\,C) = 0,667\,(Y\,C)_0$.

If this method is used, that fact shall be stated.

10.3 Test procedure for piping geometry factor F_p

The piping geometry factor modifies the valve flow coefficient C for fittings attached to the valve. The factor F_p is the ratio of C for a valve installed with attached fittings to the rated C of the valve installed without attached fittings and tested under identical service conditions.

To obtain this factor, replace the valve with the desired combination of valve and attached fittings. Then conduct the flow tests according to 10.1 treating the combination as the test specimen for the purpose of determining test section pipe size. For example, a DN 100 valve between a reducer and expander in a DN 150 line would use pressure tap locations based on a DN 150 line.

The data evaluation procedure is given in 11.4.

10.4 Test procedure for Reynolds number factor F_R

To establish values of the Reynolds number factor F_R, non-turbulent flow conditions shall be established through the test valve. Such conditions will typically only occur, using compressible fluid, if the C_R value is less than 0,5 for C_v or 0,43 for K_v.

Non-turbulent flow conditions are deemed to exist when, using the procedure outline in 10.2, the amount of gas flow measured is still increasing even though $x \geq x_T$ for the specific valve, i.e., there is no choked flow.

In order to obtain such non-turbulent flow, the inlet pressure to the test specimen should be less than:

$$p_{1\,max} = \frac{0{,}035}{F_d \sqrt{C F_L}} \qquad (18)$$

in bar, but no less than 2 bar absolute.

Determine values of F_R by carrying out flow tests with the valve installed in the standard test section without attached fittings. Carry out a sufficient number of tests at each selected valve travel by varying the inlet pressure so that the entire range from turbulent to laminar flow is spanned.

The data evaluation procedure is given in 11.5.

10.5 Test procedure for valve style modifier F_d

The valve style modifier accounts for the effect of trim geometry on the Reynolds number. It is defined as the ratio of the hydraulic diameter of a specific flow passage to the equivalent circular diameter of the total flow area.

The value of F_d should be measured at the desired travels. This value can only be measured when fully laminar flow is obtained using the test procedure given in 8.5.

Fully laminar flow is defined as a condition where $\sqrt{Re_v} / F_r$ is constant with a ±5 % tolerance range (typically with Re_v values below 50).

The data evaluation procedure is given in 11.6.

10.6 Test procedure for small flow trim

Trim having a flow coefficient C less than 0,05 for C_v (0,043 for K_v) is defined as small flow trim. To ensure that the flow coefficient C for small flow trim is fully in the turbulent regime, the inlet pressure p_1 should be no less than the value given in the following equation:

$$p_1 = \frac{N_{21}}{F_d \sqrt{C F_L}} \quad (19)$$

where the outlet pressure is less than 0,3 p_1. The test section of 5.2 shall be used with the test specimen at 100 % of rated travel. With constant inlet pressure, vary the outlet pressure to obtain three separate flow rates.

The data evaluation procedure is given in 11.7.

11 Data evaluation procedure for compressible fluids

The basic flow equation for compressible fluids is:

$$Q = N_9 F_p C p_1 Y \sqrt{\frac{x}{M T_1 Z}} \quad (20)$$

where

$$Y = 1 - \frac{x}{3 F_\gamma x_T} \quad (21)$$

in which $F_\gamma = \gamma/1,4$.

For flow tests where no fittings are attached to the valve, $F_p = 1$.

For a control valve handling a gas different from air, the terminal value of x (i.e., $F_\gamma x_T$) shall be corrected in the term $F_\gamma x_T$. The value of x used in any of the sizing equations or the relationship for Y shall be held to this limit even though the actual pressure differential ratio is greater. In practice the numerical value of Y will range from almost one for very low differential pressures to 0,667 for choked flow ($x = F_\gamma x_T$).

11.1 Calculation of flow coefficient C

The flow coefficient C may be calculated as K_v or C_v. See table 3 for the appropriate value of N_9 which will depend upon the coefficient selected and the inlet pressure measurement unit.

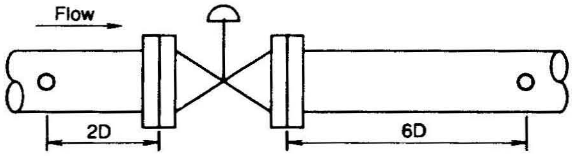
Using the data obtained in 10.1 and assuming that $Y = 1$, calculate the flow coefficient C for each test point using:

$$C = \frac{Q}{N_9 p_1} \sqrt{\frac{M T_1}{x}} \quad (22)$$

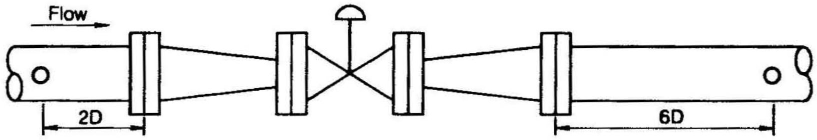
For air, M = 28,97 kg/kmol.

Annex A
(normative)

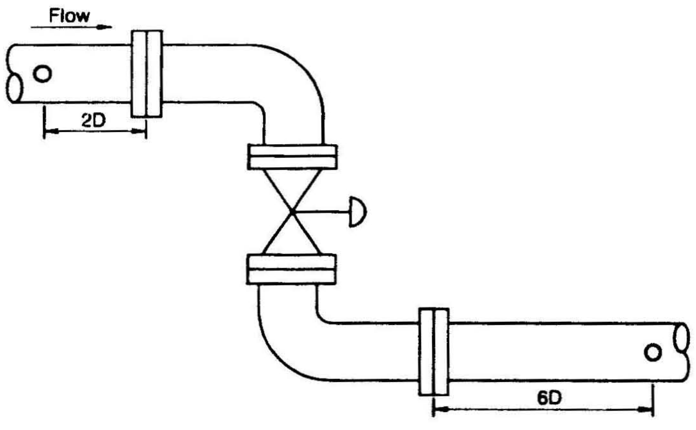
Typical examples of test specimens showing appropriate pressure tap locations



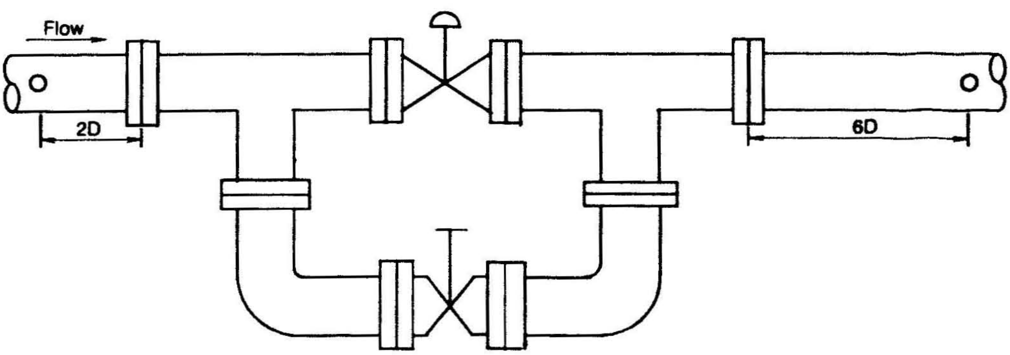
a) Control valve



b) Control valve with reducer and expander



c) Control valve with elbows



d) Control valve with by-pass

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Indian Standard
INDUSTRIAL-PROCESS CONTROL VALVES

PART 2 FLOW CAPACITY
Section 3 Test Procedures

1 Scope

This section of IEC 60534-2 is applicable to industrial-process control valves and provides the flow capacity test procedures for determining the following variables used in the equations given in IEC 60534-2-1 and IEC 60534-2-2:

a) flow coefficient C;

b) liquid pressure recovery factor without attached fittings F_L;

c) combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings F_{LP};

d) piping geometry factor F_p;

e) pressure differential ratio factors x_T and x_{TP};

f) valve style modifier F_d;

g) Reynolds number factor F_R.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this section of IEC 60534-2. 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 60534-2 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 International Standards.

IEC 60534-1:1987, *Industrial-process control valves – Part 1: Control valve terminology and general considerations*

IEC 60534-2:1978, *Industrial-process control valves – Part 2: Flow capacity* – Section One: *Sizing equations for incompressible fluid flow under installed conditions*

IEC 60534-2-2:1980, *Industrial-process control valves – Part 2: Flow capacity* – Section Two: *Sizing equations for compressible fluid flow under installed conditions*

IEC 60534-8-2:1991, *Industrial-process control valves – Part 8: Noise considerations* – Section 2: *Laboratory measurement of noise generated by hydrodynamic flow through control valves*

IEC 61298-1:1995, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 1: General considerations*

IEC 61298-2:1995, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 2: Tests under reference conditions*

3 Definitions

For the purpose of this section of IEC 60534-2, the definitions given in IEC 60534-1, IEC 60534-2, IEC 60534-2-2, IEC 61298-1, and IEC 61298-2 apply.

4 Symbols

Symbol	Description	Unit
C	Flow coefficient (K_v, C_v)	Various (see IEC 60534-1)
C_R	Flow coefficient at rated travel	Various (see IEC 60534-1)
d	Nominal valve size (DN)	mm
F_d	Valve style modifier	1
F_F	Liquid critical pressure ratio factor	1
F_L	Liquid pressure recovery factor of a control valve without attached fittings	1
F_{LP}	Combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings	1
F_p	Piping geometry factor	1
F_R	Reynolds number factor	1
F_γ	Specific heat ratio factor	1
M	Molecular mass of flowing fluid	kg/kmol
N	Numerical constants (see table 3)	Various (see note 1)
p_c	Thermodynamic critical pressure	kPa or bar (see note 2)
p_v	Vapour pressure of liquid at inlet temperature	kPa or bar
p_1	Inlet absolute static pressure measured at the upstream pressure tap	kPa or bar
p_2	Outlet absolute static pressure measured at the downstream pressure tap	kPa or bar
Δp	Differential pressure ($p_1 - p_2$) between upstream and downstream pressure taps	kPa or bar
Δp_{max}	Maximum pressure differential	kPa or bar
$\Delta p_{max(L)}$	Maximum effective Δp without attached fittings	kPa or bar
$\Delta p_{max(LP)}$	Maximum effective Δp with attached fittings	kPa or bar
Q	Volumetric flow rate	m^3/h (see note 3)
Q_{max}	Maximum volumetric flow rate (choked flow conditions)	m^3/h
$Q_{max(L)}$	Maximum volumetric flow rate for incompressible fluids (choked flow conditions without attached fittings)	m^3/h
$Q_{max(LP)}$	Maximum volumetric flow rate for incompressible fluids (choked flow conditions with attached fittings)	m^3/h
$Q_{max(T)}$	Maximum volumetric flow rate for compressible fluids (choked flow conditions without attached fittings)	m^3/h
$Q_{max(TP)}$	Maximum volumetric flow rate for compressible fluids (choked flow conditions with attached fittings)	m^3/h
Re_v	Valve Reynolds number	1
T_1	Inlet absolute temperature	K
t_s	Reference temperature for standard conditions	°C

(*Continued from second cover*)

International Standard	*Title*
IEC 61298-2 : 1995	Process measurement and control devices — General methods and procedures for evaluating performance — Part 2: Test under reference conditions

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc: No. ETD 18 (5673).

Amendments Issued Since Publication

Amendment No.	Date of Issue	Text Affected

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Printed by the Manager, Govt. of India Press, Faridabad