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Standard

Control Valve Capacity Test Procedures

ANSI/ISA-S75.02 — Control Valve Capacity Test Procedures

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Preface

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1 Scope

This test standard utilizes the mathematical equations outlined in ANSI/ISA-S75.01, *Flow Equations for Sizing Control Valves,* in providing a test procedure for obtaining the following:

a) Valve flow coefficient, C_v

b) Liquid pressure recovery factors, F_L and F_{LP}

c) Reynolds Number factor, F_R

d) Liquid critical pressure ratio factor, F_F

e) Piping geometry factor, F_P

f) Pressure drop ratio factor, x_T and x_{TP}

This standard is intended for control valves used in flow control of process fluids and is not intended to apply to fluid power components as defined in the National Fluid Power Association Standard NFPA T.3.5.28-1977.

2 Purpose

The purpose of this standard is to provide a procedure for testing control valve capacity and related flow coefficeints for both compressible and incompressible fluids. This standard also provides a procedure to evaluate the major data.

3 Nomenclature

Symbol	Description
C_v	Valve flow coefficient
d	Valve inlet diameter
D	Internal diameter of the pipe
F_d	Valve style modifier
F_F	Liquid critical pressure ratio factor, dimensionless
F_k	Ratio of specific heats factor, dimensionless
F_L	Liquid pressure recovery factor of a valve without attached fittings, dimensionless
F_{LP}	Product of the liquid pressure recovery factor of a valve with attached fittings (no symbol has been identified) and the piping geometry factor, dimensionless

F_P	Piping geometry factor, dimensionless
F_R	Reynolds Number factor, dimensionless
G_f	Liquid specific gravity at upstream conditions [ratio of density of liquid at flowing temperature to density of water at 15.6°C (60°F)], dimensionless
G_g	Gas specific gravity (ratio of flowing gas to density of air with both at standard conditions, which is equal to the ratio of the molecular weight of gas to the molecular weight of air), dimensionless
k	Ratio of specific heats, dimensionless
m	The number of similar flow paths (i.e., m = 1 for single-ported valves, m = 2 for double-ported, etc.)
N_1, N_2, *etc.*	Numerical constants for units of measurement used
p_1	Upstream absolute static pressure, measured two nominal pipe diameters upstream of valve-fitting assembly
p_2	Downstream absolute static pressure, measured six nominal pipe diameters downstream of valve-fitting assembly
Δp	Pressure differential, p_1-p_2
p_v	Absolute vapor pressure of liquid at inlet temperature
q	Volumetric flow rate
q_{max}	Maximum flow rate (choked flow conditions) at a given upstream condition
Re_v	Valve Reynolds Number, dimensionless
T_1	Absolute upstream temperature (in K or degrees R)
x	Ratio of pressure drop to absolute inlet pressure ($\Delta p/p_1$), dimensionless
x_T	Pressure drop ratio factor of the valve without attached fittings, dimensionless
x_{TP}	Value of x_T for valve-fitting assembly, dimensionless
Y	Expansion factor, ratio of flow coefficient for a gas to that for a liquid at the same Reynolds Number,dimensionless
v(nu)	Kinematic viscosity, centistokes

Subscripts:

1	Upstream conditions
2	Downstream conditions

4 Test system

4.1 General description: A basic flow test system as shown in Figure 1 includes

a) test specimen

b) test section

c) throttling valves

d) flow-measuring device

e) pressure taps

f) temperature sensor

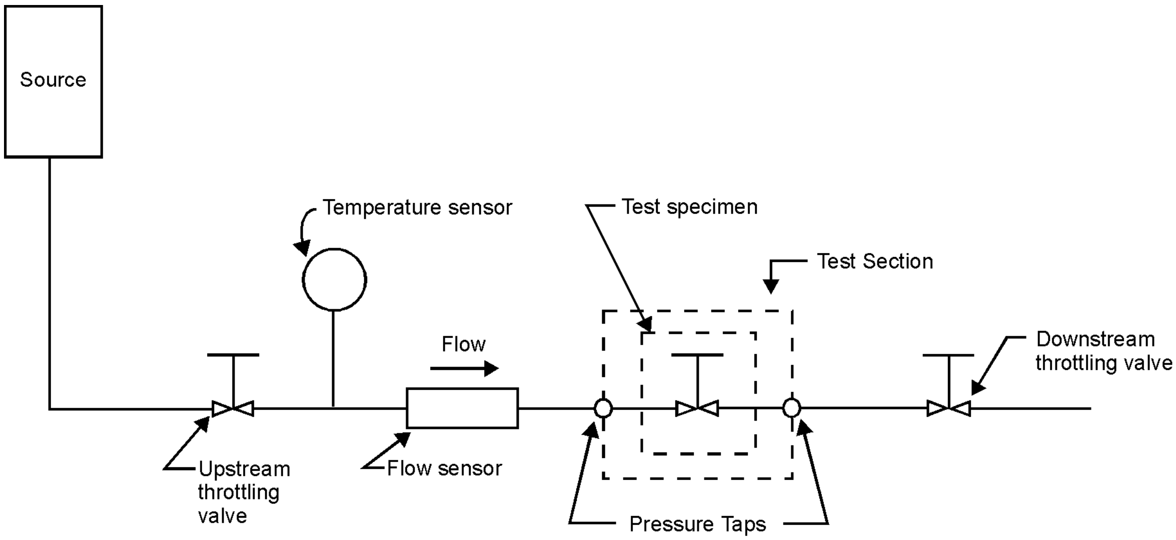


Figure 1 — Basic flow test system

4.2 Test specimen: The test specimen is any valve or combination of valve, pipe reducer, and expander or other devices attached to the valve body for which test data are required. Modeling of valves to a smaller scale is an acceptable practice in this standard, although testing of full-size valves or models is preferable. Good practice in modeling requires attention to significant relationships such as Reynolds Number, the Mach number where compressibility is important, and geometric similarity.

4.3 Test section: The upstream and downstream piping adjacent to the test specimen shall conform to the nominal size of the test specimen connection and to the length requirements of Table 1.

The piping on both sides of the test specimen shall be Schedule 40 pipe for valves through 250-mm (10-in.) size having a pressure rating up to and including ANSI Class 600. Pipe having 10-mm (0.375-in.) wall may be used for 300-mm (12-in.) through 600-mm (24-in.) sizes. An effort should be made to match the inside diameter at the inlet and outlet of the test specimen with the inside diameter of the adjacent piping for valves outside the above limits.

The inside surfaces shall be reasonably free of flaking rust or mill scale and without irregularities that could cause excessive fluid frictional losses.

4.4 Throttling valves: The upstream and downstream throttling valves 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 style of these valves. However, the downstream valve should be of sufficient capacity to ensure that choked flow can be achieved at the test specimen for both compressible and incompressible flow. Vaporization at the upstream valve must be avoided when testing with liquids.

4.5 Flow measurement: The flow-measuring instrument may be any device that meets specified accuracy. This instrument will be used to determine the true time average flow rate within an error not exceeding ± 2 percent of the actual value. The resolution and repeatability of the instrument shall be within ± 0.5 percent. The measuring instrument shall be calibrated as frequently as necessary to maintain specified accuracy.

4.6 Pressure taps: Pressure taps shall be provided on the test section piping in accordance with the requirements listed in Table 1. These pressure taps shall conform to the construction illustrated in Figure 2.

Orientation:

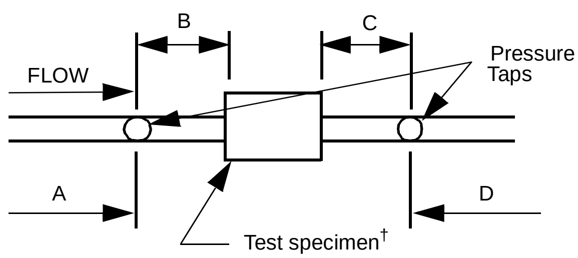
> Incompressible fluids—Tap center lines shall be located horizontally to reduce the possibility of air entrapment or dirt collection in the pressure taps.
>
> Compressible fluids—Tap center lines shall be oriented horizontally or vertically above pipe to reduce the possibility of dirt or condensate entrapment.

Multiple pressure taps can be used on each test section for averaging pressure measurements. Each tap must conform to the requirements in Figure 2.

4.7 Pressure measurement: All pressure and pressure differential measurements shall be made to an error not exceeding ± 2 percent of actual value. Pressure-measuring devices shall be calibrated as frequently as necessary to maintain specified accuracy.

Pressure differential instruments are required in the measurement of the pressure differential across the test specimen to avoid additional inaccuracies resulting from taking the difference of two measurements. Exceptions to this are the procedures in Sections 6.2 and 8.2 for determining maximum flow rates for incompressible and compressible flow, respectively.

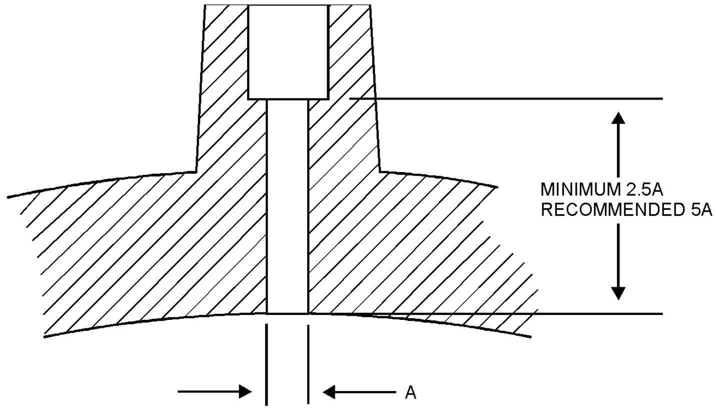
Table 1 — Piping requirements, standard test section

A*,**	B	C	D	Standard Test Section Configuration
At least 18 nominal pipe diameters of straight pipe	2 nominal pipe diameters of straight pipe	6 nominal pipe diameter of straight pipe	At least 1 nominal pipe diameter of straight pipe	

* Dimension "A" may be reduced to 8 nominal diameters if straightening vanes are used.
Information concerning the design of straightening vanes can be found in ASME Performance Test Code PTC 19.5-1972, "Applications."
** If an upstream flow disturbance consists of two ells in series and they are in different planes, dimension "A" must exceed 18 nominal pipe diameters unless straightening vanes are used.
†See Section 4.2 for definition of the test specimen

4.8 Temperature measurement: The fluid temperature shall be measured to an error not exceeding ±1°C (± 2°F) of actual value.

The inlet fluid temperature shall remain constant within ±3°C (±5°F) during the test run to record data for each specific test point.



Size of Pipe	A Not Exceeding	A Not less Than
Less than 50 mm (2 in.)	6 mm (1/4 in.)	3 mm (1/8 in.)
50 mm to 75 mm (2 to 3 in.)	9 mm (3/8 in.)	3 mm (1/8 in.)
100 mm to 200 mm (4 to 8 in.)	13 mm (1/2 in.)	3 mm (1/8 in.)
250 mm and greater (10 in. and greater)	19 mm (3/4 in.)	3 mm (1/8 in.)

* Edge of hole must be clean and sharp or slightly rounded, free from burrs, wire edges or other irregularities. In no case shall any fitting protude inside the pipe.
Any suitable method of making the physical connection is acceptable if above recommendations are adhered to.

Reference: ASME Performance Test Code PTC 19.5-1972, "Applications. Part II of Fluid Meters, Interim Supplement on Instruments and Apparatus."

Figure 2 — Recommended pressure connection

4.9 Installation of test specimen: The alignment between the center line of the test section piping and the center line of the inlet and outlet of the test specimen shall be as follows:

Pipe size	Allowable misalignment
15 mm thru 25 mm (1/2 in. thru 1 in.)	0.8 mm (1/32 in.)
32 mm thru 150 mm (1-1/4 in. thru 6 in.)	1.6 mm (1/16 in.)
200 mm and larger (8 in. and larger)	1 percent of the diameter

When rotary valves are being tested, the valve shafts shall be aligned with test section pressure taps.

Each gasket shall be positioned so that it does not protrude into the flow stream.

4.10 Accuracy of test: Valves having an N_3C_v/d^2 ratio of less than 30 will have a calculated flow coefficient, C_v, of the test specimen within a tolerance of ± 5 percent.

5 Test fluids

5.1 Incompressible fluids

Fresh water shall be the basic fluid used in this procedure. Inhibitors may be used to prevent or retard corrosion and to prevent the growth of organic matter. The effect of additives on density or viscosity shall be evaluated by computation using the equations in this standard. The sizing coefficient shall not be affected by more than 0.1 percent. Other test fluids may be required for obtaining F_R and F_F.

5.2 Compressible fluids

Air or some other compressible fluid shall be used as the basic fluid in this test procedure. Vapors that may approach their condensation points at the vena contracta of the specimen are not acceptable as test fluids. Care shall be taken to avoid internal icing during the test.

6 Test procedure — incompressible fluids

The following instructions are given for the performance of various tests using incompressible fluids.

The procedures for data evaluation of these tests follow in Section 7.

6.1 C_v Test procedure

The following test procedure is required to obtain test data for the calculation of the flow coefficient C_v. The data evaluation procedure is provided in Section 7.1.

6.1.1 Install the test specimen without reducers or other attached devices in accordance with piping requirements in Table 1.

6.1.2 Flow tests shall include flow measurements at three widely spaced pressure differentials within the turbulent, non-vaporizing region. The suggested differential pressures are:

a) just below the onset of cavitation or the maximum available in the test facility, whichever is less;

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

c) about 10% of the pressure differential of (a) and shall be measured across the test section pressure taps with the valve at the rated travel.

The line velocity should not exceed 13.7 m/s (45 ft/s).

A minimum valve Reynolds Number, Re_v, of 10^5 is recommended (see Equation 5). Deviations from standard requirements shall be recorded.

For large valves where flow source limitations are reached, lower pressure differentials may be used optionally as long as turbulent flow is maintained. Deviations from standard requirements shall be recorded.

6.1.3 In order to keep the downstream portion of the test section liquid filled and to prevent vaporization of the liquid, the upstream pressure must be maintained equal or greater than the minimum values in Table 2. This minimum upstream 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 should be made using the values in Table 2.

6.1.4 The valve flow test shall be performed at 100 percent of rated valve travel. Optional tests may be performed at each 10 percent of rated valve travel or any other points to more fully determine the inherent characteristic of the specimen.

6.1.5 The following data shall be recorded:

a) Valve travel (measurement error not exceeding ±0.5 percent of rated travel)

b) Upstream pressure (p_1) (measurement error not exceeding ±2 percent of actual value)

c) Pressure differential (Δp) across test section pressure taps (measurement error not exceeding ± 2 percent of actual value)

d) Volumetric flow rate (q) (measurement error not exceeding ±2 percent of actual value)

e) Fluid inlet temperature (T_1) (measurement error not exceeding ±1°C[±2°F])

f) Barometric pressure (measurement error not exceeding ±2 percent of actual value).

g) Physical description of test specimen (i.e., type of valve, flow direction, etc.)

h) Physical description of test system and test fluid.

6.2 F_L Test procedure

The maximum flow rate, $q_{max,}$ is required in the calculation of the liquid pressure recovery factor, F_L. For a given upstream pressure, the quantity q_{max} is defined as that flow rate at which a decrease in downstream pressure will not result in an increase in the flow rate. The test procedure required to determine q_{max} is included in this section. The data evaluation procedure including the calculation of F_L is contained in this section. The test for F_L and corresponding C_v must be conducted at identical valve travels. Hence, the tests for both these factors at any valve travel shall be made while the valve is locked in a fixed position.

6.2.1 Install the test specimen without reducers or other attached devices in accordance with piping requirements in Table 1. The test specimen shall be at 100 percent of rated travel.

6.2.2 The downstream throttling valve shall be in the fully open position. Then, with a preselected upstream pressure, the flow rate will be measured and the downstream pressure recorded. Table 2 has been provided to assist the user in selecting an upstream pressure. This test establishes a "maximum" pressure differential for the test specimen in this test system. A second test run shall be made with the pressure differential maintained at 90 percent of the pressure differential determined in the first test with the same upstream pressure. If the flow rate in the second test is within 2 percent of the flow rate in the first test, the "maximum" or choked flow rate has been established. If not, the test procedure must be repeated at a higher upstream pressure. If choked flow cannot be obtained, the published value of F_L must be based on the maximum measurement attainable, with an accompanying notation that the actual value exceeds the published value, e.g., $F_L > 0.87$.

NOTE — that values of upstream pressure and pressure differential used in this procedure are those values measured at the pressure taps.

Table 2 — Minimum upstream test pressure for a temperature range of 5°C to 40°C (41°F to 104°F)

Δp	kPa	35	70	100	140	350	700	1400
	bar	0.35	0.7	1.0	1.4	3.5	7	14
	psi	5	10	15	20	50	100	200
				Absolute Upstream Pressure, p_1				
F_L								
0.5	kPa	280	550	830	1100	2800	5500	11000
	bar	2.8	5.5	8.3	11.0	28.0	55.0	110.0
	psia	40	80	120	160	400	800	1600
0.6	kPa	190	380	570	760	1900	3900	7700
	bar	1.9	3.8	5.7	7.6	19.0	39.0	77.0
	psia	28	56	83	110	280	560	1110
0.7	kPa	150	280	420	560	1400	2800	5700
	bar	1.5	2.8	4.2	5.6	14.0	28.0	57.0
	psia	22	41	61	82	200	410	820
0.8	kPa	150	220	320	430	1100	2100	4300
	bar	1.5	2.2	3.2	4.3	11.0	21.0	43.0
	psia	22	31	47	62	160	310	620
0.9	kPa	150	180	260	340	830	1700	3400
	bar	1.5	1.8	2.6	3.4	8.3	17.0	34.0
	psia	22	27	37	49	120	250	490

NOTES:

1. Minimum upstream pressures have been calculated to provide a downstream gage pressure of at least 14 kPa (0.14 bar) (2 psig) above atmospheric pressure.

2. Upstream pressures were calculated using $p_1 \text{min} = 2\Delta p / F_L^2$

3. Upstream pressures were rounded to 2 significant digits while still maintaining a minimum pressure as specified in note 1.

4. Example: Estimated F_L for valve is 0.7.
   Pressure differential is 10 psi.
   From table: Minimum upstream pressure is 41 psia.

6.2.3 Record the following data:

a) Valve travel (measurement error not exceeding ±0.5 percent of rated travel)

b) Upstream pressure (p_1) and downstream pressure (p_2) (measurement error not exceeding ±2 percent of actual value)

c) Volumetric flow rate (q) (measurement error not exceeding ± 2 percent of actual value)

d) Fluid temperature (measurement error not exceeding ±1°C[± 2°F])

e) Barometric pressure (measurement error not exceeding ±2 percent of actual value).

6.3 F_P Test procedure

The piping geometry factor, F_P, modifies the valve sizing coefficient for reducers or other devices attached to the valve body that are not in accord with the test section. It is the ratio of the installed C_V with these reducers or other devices attached to the valve body to the rated C_V of the valve installed in a standard test section and tested under identical service conditions. This factor is obtained by replacing the valve with the desired combination of valve, reducers, and/or other devices and then conducting the flow test outlined in Section 6.1, treating the combination of the valve and reducers as the test specimen for the purpose of determining test section line size. For example, a 100-mm (4-in.) valve between reducers in a 150-mm (6-in.) line would use pressure tap locations based on 150-mm (6-in.) nominal diameter. The data evaluation procedure is provided in Section 7.3.

6.4 F_{LP} Test procedure

Perform the tests outlined for F_L in Section 6.2, replacing the valve with the desired combination of valve and pipe reducers or other devices and treating the combination of valve and reducers as the test specimen. The data evaluation procedure is provided in Section 7.4.

6.5 F_R Test procedure

To produce values of the Reynolds Number factor, F_R, nonturbulent flow conditions must be established through the test valve. Such conditions will require low pressure differentials, high viscosity fluids, small values of C_V, or some combination of these. With the exception of valves with very small values of C_V, turbulent flow will always exist when flowing tests are performed in accordance with the procedure outlined in Section 6.1, and F_R under these conditions will have the value of 1.0.

Determine values of F_R by performing flowing tests with the valve installed in the standard test section without reducers or other devices attached. These tests should follow the procedure for C_V 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 (68°F ± 25°F); and

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

Perform a sufficient number of these 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 provided in Section 7.5.

6.6 F_F Test procedure

The liquid critical pressure ratio factor, F_F, is ideally a property of the fluid and its temperature. It is the ratio of the apparent vena contracta pressure at choked flow conditions to the vapor 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_V are known. The standard test section without reducers or other devices attached will be used with the test specimen installed. The test procedure outlined in Section 6.2 for obtaining q_{max} will be used with the fluid of interest as the test fluid. The data evaluation procedure is in Section 7.6.

7 Data evaluation procedure — incompressible fluids

The following procedures are to be used for the evaluation of the data obtained using the test procedures in Section 6. The pressure differentials used to calculate the flow coefficients and other flow factors were obtained using the test section defined in Table 1. These pressure measurements were made at the pressure taps and include the test section piping between the taps as well as the test specimen.

7.1 C_v Calculation

7.1.1 Using the data obtained in Section 6.1, calculate C_v for each test point at a given valve travel using the equation:

$$C_v = \frac{q}{N_1 F_p}\left(\frac{G_f}{\Delta p}\right)^{\frac{1}{2}} \qquad \text{(Eq.1)}$$

Round off the calculated value to no more than three significant digits.

7.1.2 The rated C_v of the valve is the arithmetic average of the calculated values for 100 percent of rated travel obtained from the test data in Section 6.1.5. A critical examination of the individual values calculated should reveal equal values of C_v within the tolerance given in Section 4.10.

7.2 F_L Calculation

$$F_L = \frac{q_{max}}{N_1 C_v[(p_1 - 0.96 p_v)/G_f]^{1/2}} \qquad \text{(Eq.2)}$$

where P_1 is the pressure at the upstream pressure tap for the q_{max} determination. (Section 6.2)

7.3 F_P Calculation. Calculate F_P as follows at rated valve travel:

$$F_P = \frac{q}{N_1 C_v[(\Delta p)/G_f]^{1/2}} \qquad \text{(Eq.3)}$$

7.4 F_{LP} Calculation

$$F_{LP} = \frac{q_{max}}{N_1 C_v[(p_1 - 0.96 p_v)/G_f]^{1/2}} \qquad \text{(Eq.4)}$$

where p_1 is the pressure at the upstream pressure tap for the q_{max} determination. (Section 6.2)

7.5 F_R Calculation

Use test data, obtained as described under Section 6.5 and in Equation (1), Section 7.1, to obtain values of an apparent C_v. This apparent C_v is equivalent to $F_R C_v$. Therefore, F_R is obtained by dividing the apparent C_v by the experimental value of C_v determined for the test valve under standard conditions at the same valve travel. Although 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:

$$\mathrm{Re}_v = \frac{N_4 F_d q}{\nu F_L^{1/2} C_v^{1/2}} \left(\frac{F_L^2 C_v^2}{N_2 D^4} + 1 \right)^{1/4} \quad \text{(Eq.5)}$$

where

F_d = valve style modifier, accounts for the effect of geometry on Reynolds Number. F_d has been found to be proportional to $1/m^{1/2}$.

m = the number of similar flow paths (i.e., m = 1 for single-ported valves, m = 2 for double-ported, etc.).

ν = kinematic viscosity in centistokes.

Plotting values of F_R versus Re_v will result in the curve that appears as Figure 3 in ISA-S75.01-1995, *Flow Equations for Sizing Control Valves*.

7.6 F_F Calculation

Calculate F_F as follows:

$$F_F = \frac{1}{p_v}\left[p_1 - G_f \left(\frac{q_{max}}{N_1 F_L C_v} \right)^2 \right] \quad \text{(Eq.6)}$$

where p_v is the fluid vapor pressure at the inlet temperature. $F_L C_v$ is determined for the test specimen by the standard method (Section 6.2—F_L Test Procedure).

8 Test procedure — compressible fluids

The following instructions are given for the performance of various tests using compressible fluids.

The procedures for data evaluation of these tests follow in Section 9.

8.1 C_v Test procedure

The determination of the flow coefficient, C_v requires flow tests using the following procedure to obtain the necessary test data. The data evaluation procedure is in Section 9.1. An alternative procedure for calculating C_v is provided in Section 8.3.

8.1.1 Install the test specimen without reducers or other devices in accordance with the piping requirements in Table 1.

8.1.2 Flow tests will include flow measurements at three pressure differentials. In order to approach flowing conditions that can be assumed to be incompressible, the pressure drop ratio ($x = \Delta p/p_1$) shall be ≤ 0.02.

8.1.3 The valve flow test shall be performed at 100 percent of rated valve travel. Optional tests may be performed at each 10 percent of rated valve travel or any other points to more fully determine the inherent characteristic of the specimen.

8.1.4 The following data shall be recorded:

a) Valve travel (measurement error not exceeding ±0.5 percent of rated valve travel)

b) Upstream pressure (p_1) (measurement error not exceeding ±2 percent of actual value)

c) Pressure differential (Δp) across test section pressure taps (measurement error not exceeding ±2 percent of actual value)

d) Volumetric flow rate (q) (measurement error not exceeding ±2 percent of actual value)

e) Fluid temperature (T_1) upstream of valve (measurement error not exceeding ±1°C [±2°F])

f) Barometric pressure (measurement error not exceeding ±2 percent of actual value)

g) Physical description of test specimen (e.g., type of valve, flow direction, etc.) and test fluid.

8.2 x_T Test procedure

The maximum flow rate, q_{max}, (referred to as choked flow) is required in the calculation of x_T, the pressure drop ratio factor. This factor is the terminal ratio of the differential pressure to absolute upstream pressure ($\Delta p/p_1$), for a given test specimen installed without reducers or other devices. The maximum flow rate is defined as that flow rate at which, for a given upstream pressure, a decrease in downstream pressure will not produce an increase in flow rate. The test procedure required to obtain q_{max} is contained in this section with the data evaluation procedure in Section 9.2. An alternative procedure for determining x_T is provided in Section 8.3.

8.2.1 Install the test specimen without reducers or other attached devices in accordance with piping requirements in Table 1. The test specimen shall be at 100 percent of rated travel.

8.2.2 Any upstream supply pressure sufficient to produce choked flow is acceptable, as is any resulting pressure differential across the valve, provided that the criteria for determination of choked flow specified in Section 8.2.3 are met.

8.2.3 The downstream throttling valve will be in the wide-open position. Then, with a preselected upstream pressure, the flow rate will be measured and the downstream pressure recorded. This test establishes the maximum pressure differential for the test specimen in this test system. A second test shall be conducted using the downstream throttling valve to reduce the pressure differential by 10 percent of the pressure differential determined in the first test (with the same upstream pressure). If the flow rate of this second test is within 0.5 percent of the flow rate for the first test, then the maximum flow rate has been established.

Although the absolute value of the flow rate must be measured to an error not exceeding ±2 percent, the repeatability of the tests for x_T must be better than ±0.5 percent in order to attain the prescribed accuracy. This series of tests must be made consecutively, using the same instruments, and without alteration to the test setup.

8.2.4 Record the following data:

a) Valve travel (measurement error not exceeding ±0.5 percent of rated travel)

b) Upstream pressure (p_1) (measurement error not exceeding ±2 percent of actual value)

c) Downstream pressure (p_2) (measurement error not exceeding ±2 percent of actual value)

d) Volumetric flow rate (q) (measurement error not exceeding ±2 percent of actual value)

e) Fluid temperature upstream (T_1) of valve (measurement error not exceeding ±1°C [±2°F])

f) Barometric pressure (measurement error not exceeding ±2 percent of actual value)

g) Physical description of test specimen (e.g., type of valve, flow direction, etc.) and test fluid.

8.3 Alternative test procedure for C_v and x_T

8.3.1 Install the test specimen without reducers or other attached devices in accordance with piping requirements in Table 1. The test specimen shall be at 100 percent of rated travel.

8.3.2 With a preselected upstream pressure, p_1, measurements shall be made of flow rate, q, upstream fluid temperature, T_1, downstream pressure, p_2, for a minimum of five well-spaced values of x (the ratio of pressure differential to absolute upstream pressure).

8.3.3 From these data points calculate values of the product YC_v using the equation:

$$YC_v = \frac{q}{(N_7 P_1)}\left[\frac{(G_g T_1)}{x}\right]^{1/2} \quad \text{(Eq.7)}$$

where Y is the expansion factor defined by:

$$Y = 1 - \frac{x}{3 F_k x_T}$$

where

$$F_k = \frac{k}{1.40}$$

8.3.4 The test points shall be plotted on linear coordinates as (YC_v) vs. x and a linear curve fitted to the data. If any point deviates by more than 5 percent from the curve, additional test data shall be taken to ascertain if the specimen truly exhibits anomalous behavior.

8.3.5 At least one test point, $(YC_v)_1$, must fulfill the requirement that:

$$(YC_v)_1 \geq 0.97(YC_v)_0$$

where $(YC_v)_0$ corresponds to $x \cong 0$.

8.3.6 At least one test point, $(YC_v)_n$, must fulfill the requirement that:

$$(YC_v)_n \leq 0.83(YC_v)_0$$

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

The value of x_T for the specimen shall be taken from the curve at $YC_v = 0.667C_v$.

8.4 F_P Test procedure

The piping geometry factor, F_P, modifies the valve sizing coefficient for reducers or other devices attached to the valve body that are not in accord with the test section. The factor F_P is the ratio of the installed C_v with the reducers or other devices attached to the valve body to the rated C_v of the valve installed in a standard test section and tested under identical service conditions. This factor is obtained by replacing the valve with the desired combination of valve, reducers, and/or other devices and then conducting the flow test outlined in Section 8.1, treating the combination of valve and reducers as the test specimen for the purpose of determining test section line size. For example, a 100-mm (4-inch) valve between reducers in a 150-mm (6-inch) line would use pressure tap locations based on a 150-mm (6-inch) nominal diameter. The data evaluation procedure is provided in Section 9.3.

8.5 x_{TP} Test procedure

Perform the tests outlined for x_T in Section 8.2, replacing the valve with the desired combination of valve and pipe reducers or other devices and treating the combination of valve and reducers as the test specimen. The data evaluation procedure is provided in Section 9.4.

9 Data evaluation procedure — compressible fluids

The following procedures are to be used for the evaluation of the data obtained using the test procedures in Section 8. The pressure differentials used to calculate the flow coefficients and other flow factors were obtained using the test section defined in Table 1. These pressure measurements were made at the pressure taps and include the test section piping between the taps as well as the test specimen.

9.1 C_v Calculation. Using the data obtained in Section 8.1 and assuming the expansion factor Y = 1.0, calculate the flow coefficient, C_v for each test point using:

$$C_v = \frac{q}{N_7 p_1}\left(\frac{T_1 G_g}{x}\right)^{1/2} \quad \text{(Eq.8)}$$

Calculate the arithmetic average of the three test valves obtained at rated travel to obtain the rated C_v.

9.2 x_T Calculation

Calculate x_T as follows:

From Equation (7):

$$q = N_7 Y C_v p_1\left(\frac{x}{G_g T_1}\right)^{1/2}$$

When $x = F_k x_T$, then $q = q_{max}$

$$q_{max} = N_7 Y C_v p_1\left(\frac{F_k x_T}{G_g T_1}\right)^{1/2}$$

and

$$x_T = \left(\frac{q_{max}}{N_7 Y C_v p_1}\right)^2 \frac{G_g T_1}{F_k} \qquad \text{(Eq.9)}$$

Assuming air as test fluid and substituting $Y = 0.667$, $G_g = 1.0$, and $F_k = 1.0$:

$$x_T = \left(\frac{q_{max}}{0.667 N_7 C_v p_1}\right)^2 T_1 \qquad \text{(Eq.10)}$$

9.3 F_P Calculation

Calculate F_P at rated valve travel:

$$F_P = \frac{q}{N_7 p_1 \left(\frac{x}{T_1 G_g}\right)^{1/2} C_{v\ \text{rated}}} \qquad \text{(Eq.11)}$$

9.4 x_{TP} Calculation

Calculate x_{TP} as follows:

From Equation (7):

$$q = N_7 F_P Y C_v p_1 \left(\frac{x_{TP}}{G_g T_1}\right)^{1/2} \qquad \text{(Eq.12)}$$

with F_P added to account for reducers and other devices. When $x = x_{TP}$, $q = q_{max}$

$$q_{max} = N_7 F_P Y C_v p_1 \left(\frac{x_{TP}}{G_g T_1}\right) \qquad \text{(Eq.13)}$$

Assuming air as the test fluid:

$Y = 0.667$

$G_g = 1.0$

$F_k = 1.0$

$$x_{TP} = \left(\frac{q_{max}}{0.667 N_7 F_P C_v p_1}\right)^2 T_1 \qquad \text{(Eq.14)}$$

10 Numerical constants

The numerical constants, *N*, depend on the measurement units used in the general sizing equations. Values for *N* are listed in Table 3.

Table 3 — Numerical constants

	N	q*	p	v	T	d,D
N_1	0.0865	m^3/h	kPa	—	—	—
	0.865	m^3/h	bar	—	—	—
	1.00	gpm	psia	—	—	—
N_2	0.00214	—	—	—	—	mm
	890	—	—	—	—	in.
N_3	645	—	—	—	—	mm
	1.00	—	—	—	—	in.
N_4	76,000	m^3/h	—	Centistoke**	—	mm
	17,300	gpm	—	Centistoke**	—	in.
N_7	4.17	m^3/h	kPa	—	K	—
	417	m^3/h	bar	—	K	—
	1,360	scfh	psia	—	°R	—

* The standard cubic foot is taken at 14.73 psia and 60°F and the standard cubic meter at 101.3 kPa and 15.61°C.

** Centistoke = $10^{-6} m^2/sec$.

All pressures are absolute.

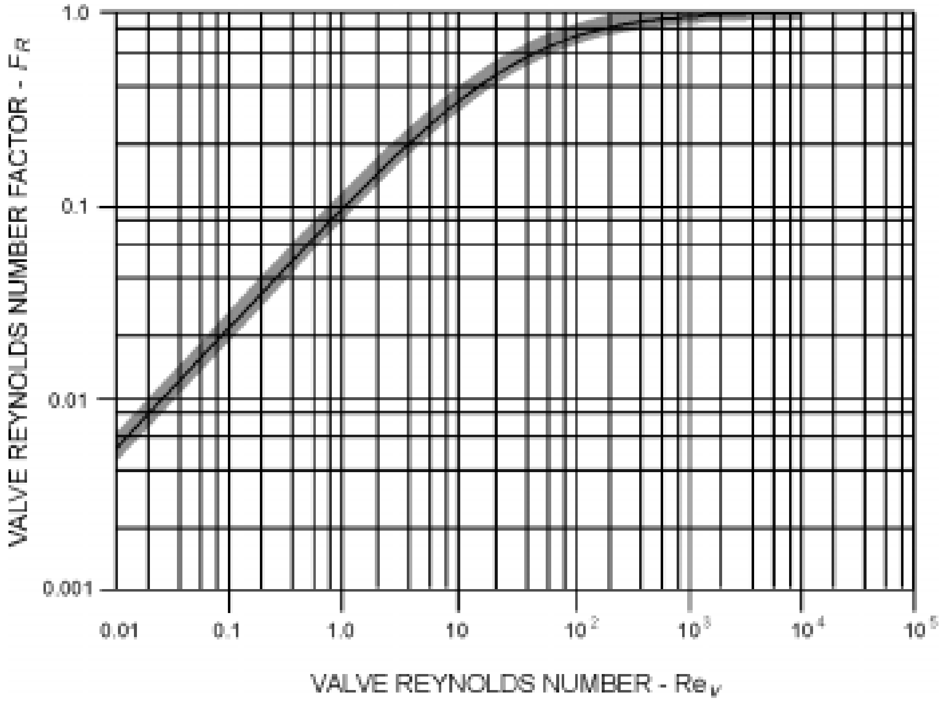


Figure 3 — Reynolds number factor

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