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**Control Valve Capacity  
Test Procedures**

Approved 21 April 2009

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Control Valve Capacity Test Procedures

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## 1 Scope

This test standard utilizes the mathematical equations outlined in ANSI/ISA-75.01.01 (IEC 60534-2-1 Mod)-2007, Flow Equations for Sizing Control Valves, in providing a test procedure for obtaining the following:

- a) Valve flow coefficient,  $C$  ( $C_v$ ,  $K_v$ )
- 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  $x_{TP}$
- g) Valve style modifier,  $F_d$

This standard is intended for industrial process control valves used in flow control of Newtonian fluids. See 4.2 for more information regarding specific valve styles.

## 2 Purpose

The purpose of this standard is to support ANSI/ISA-75.01.01 (IEC 60534-2-1 Mod)-2007, Flow Equations for Sizing Control Valves, and ANSI/ISA-75.11.01-1985 (R2002), Inherent Flow Characteristic and Rangeability of Control Valves, by providing procedures for testing control valve capacity and related flow coefficients for both compressible and incompressible Newtonian fluids. This standard also provides a procedure to evaluate the major data to calculate the coefficients.

### 3 Nomenclature

#### Symbol description

| Symbol     | Description                                                                                                                                                                                                                        | Unit                                      |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| C          | Flow coefficient ( $C_V$ , $K_V$ )                                                                                                                                                                                                 | Various (see IEC 60534-1)<br>(see note 4) |
| d          | Nominal valve size                                                                                                                                                                                                                 | mm (in)                                   |
| D          | Internal diameter of the piping                                                                                                                                                                                                    | mm (in)                                   |
| $D_1$      | Internal diameter of upstream piping                                                                                                                                                                                               | mm (in)                                   |
| $D_2$      | Internal diameter of downstream piping                                                                                                                                                                                             | mm (in)                                   |
| $D_o$      | Orifice diameter                                                                                                                                                                                                                   | mm (in)                                   |
| $F_d$      | Valve style modifier (see Annex A)                                                                                                                                                                                                 | Dimensionless (see note 4)                |
| $F_F$      | Liquid critical pressure ratio factor                                                                                                                                                                                              | Dimensionless                             |
| $F_L$      | Liquid pressure recovery factor of a control valve without attached fittings                                                                                                                                                       | Dimensionless (see note 4)                |
| $F_{LP}$   | Combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings                                                                                                                      | Dimensionless (see note 4)                |
| $F_P$      | Piping geometry factor                                                                                                                                                                                                             | Dimensionless                             |
| $F_R$      | Reynolds number factor                                                                                                                                                                                                             | Dimensionless                             |
| $F_\gamma$ | Specific heat ratio factor                                                                                                                                                                                                         | Dimensionless                             |
| $G_g$      | Gas specific gravity (ratio of density of flowing gas to density of air with both at standard conditions, which is considered in this practice to be equal to the ratio of the molecular weight of gas to molecular weight of air) | Dimensionless                             |
| M          | Molecular mass of flowing fluid                                                                                                                                                                                                    | kg/kg-mol (lb/lb-mol)                     |
| N          | Numerical constants (see Table 3)                                                                                                                                                                                                  | Various (see note 1)                      |
| $P_1$      | Inlet absolute static pressure measured at point A (see Figure 1)                                                                                                                                                                  | kPa or bar (psia) (see note 2)            |
| $P_2$      | Outlet absolute static pressure measured at point B (see Figure 1)                                                                                                                                                                 | kPa or bar (psia)                         |
| $P_c$      | Absolute thermodynamic critical pressure                                                                                                                                                                                           | kPa or bar (psia)                         |
| $P_v$      | Absolute vapor pressure of the liquid at inlet temperature                                                                                                                                                                         | kPa or bar (psia)                         |
| $\Delta P$ | Differential pressure between upstream and downstream pressure taps ( $P_1 - P_2$ )                                                                                                                                                | kPa or bar (psi)                          |
| Q          | Volumetric flow rate (see note 5)                                                                                                                                                                                                  | $m^3/h$ (gpm, scfh)                       |
| $Q_{max}$  | Maximum flow (choked flow conditions) at given upstream condition                                                                                                                                                                  | $m^3/h$ (gpm, scfh)                       |
| $Re_V$     | Valve Reynolds number                                                                                                                                                                                                              | Dimensionless                             |
| $T_1$      | Inlet absolute temperature                                                                                                                                                                                                         | K ( $^{\circ}R$ )                         |
| $T_c$      | Absolute thermodynamic critical temperature                                                                                                                                                                                        | K ( $^{\circ}R$ )                         |
| $t_s$      | Absolute reference temperature for standard cubic meter                                                                                                                                                                            | K ( $^{\circ}R$ )                         |
| W          | Mass flow rate                                                                                                                                                                                                                     | kg/h (lbs/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 at choked flow                                                                                                                                     | Dimensionless (see note 4)                |

| Symbol                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Description                                                                                 | Unit                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------|
| $X_{TP}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Pressure differential ratio factor of a control valve with attached fittings at choked flow | Dimensionless (see note 4)     |
| $Y$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Expansion factor                                                                            | Dimensionless                  |
| $\nu$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Kinematic viscosity                                                                         | $m^2/s$ (cS) (see note 3)      |
| $\rho_1$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Density of fluid at $P_1$ and $T_1$                                                         | $kg/m^3$ (lb/ft <sup>3</sup> ) |
| $\rho_1/\rho_0$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Relative density ( $\rho_1/\rho_0 = 1.0$ for water at 15°C)                                 | Dimensionless                  |
| $\gamma$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Specific heat ratio                                                                         | Dimensionless                  |
| Subscripts                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                             |                                |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Upstream conditions                                                                         |                                |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Downstream conditions                                                                       |                                |
| <p>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.</p> <p>NOTE 2 — <math>1 \text{ bar} = 10^2 \text{ kPa} = 10^5 \text{ Pa}</math></p> <p>NOTE 3 — <math>1 \text{ centistoke} = 10^{-6} m^2/s</math></p> <p>NOTE 4 — These values are travel-related and shall be stated by the manufacturer.</p> <p>NOTE 5 — Volumetric flow rates in cubic meters per hour, identified by the symbol <math>Q</math>, refer to standard conditions. The standard cubic meter is taken at 1013.25 mbar and 288.6 K (see Table 3).</p> |                                                                                             |                                |

## 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; and
- f) temperature sensor.

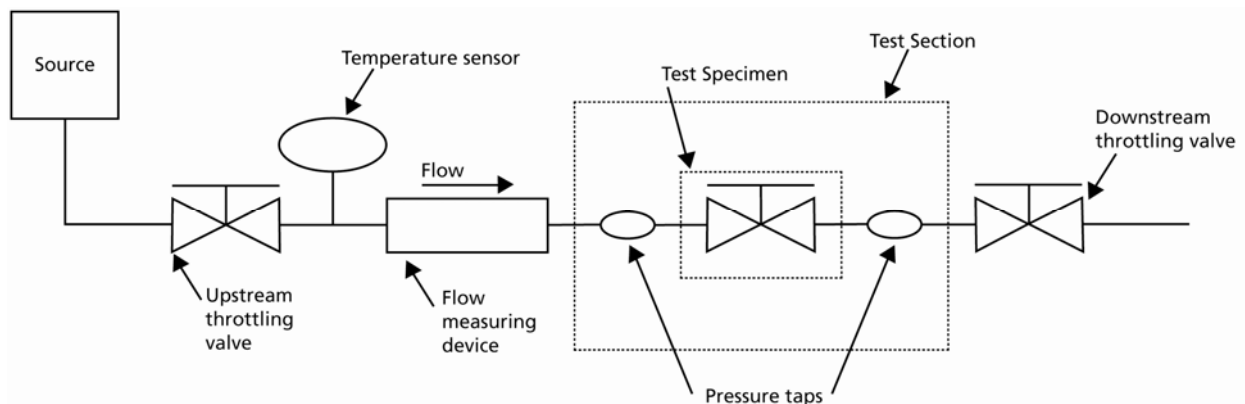


**Figure 1 — Basic flow test system**

### 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. See Annex B for additional examples of test specimens representative of typical field installations.

Additional considerations apply when testing certain styles of control valves. (1) Fractional  $C$  ( $C_v$ ,  $K_v$ ) valves (valves where  $C < 1.00$ ) require the procedures outlined in Annex D if fully turbulent flow cannot be established because of either high viscosity or low velocities or both. (2) Line-of-sight (e.g., rotary) valves may produce free jets in the downstream test section impacting the location of the pressure recovery zone. See 4.11 for expected accuracies.

Physical or computer based modeling of control valves as the basis for flow coefficient determination is outside the scope of this standard<sup>1</sup>.

#### 4.3 Test section

The upstream and downstream piping adjacent to the test specimen should conform to the nominal size of the test specimen connection and to the length requirements of Figure 2.

The piping on both sides of the test specimen should 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 diameter ( $D_1$ ,  $D_2$ ) of the pipe normally should be within  $\pm 2\%$  of the actual inside diameter of the inlet and outlet of the test specimen for all valve sizes. As the  $C/d^2$  ratio (of the test valve) increases, the mismatch in diameters becomes more problematic. Potential pressure losses associated with the inlet and outlet joints become significant in comparison to the loss associated the valve. Also, as significant discontinuity at the valve outlet could affect the downstream ( $P_2$ ) pressure measurement. One indication of the significance of mismatched diameters is the value of the piping geometry factor ( $F_P$ ) based on the internal diameters. This value approaches unity for a standard test, i.e., for equal line and specimen inside diameters. Therefore, to ensure the proper accuracy for the test it shall be demonstrated by either calculation or test that  $0.99 \leq F_P \leq 1.01$ . If  $F_P < 0.99$  it shall be so noted in the test data (see 6.1.5 or 8.1.5). See Annex F for a sample calculation.

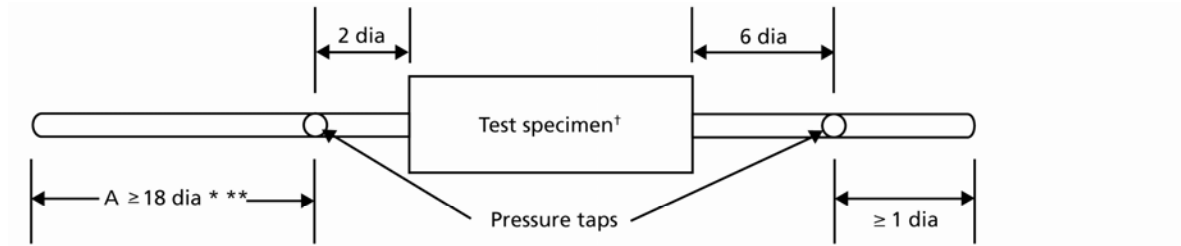
The inside surfaces shall be reasonably free of flaking rust or mill scale and without irregularities that could cause excessive fluid frictional losses.

#### 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 throttling valve must be avoided when testing with liquids.

---

<sup>1</sup> When modeling it is incumbent on the practitioner to utilize sound modeling techniques, to validate the model and scaling relationships to actual flow data, and to document the nature of the model.



All pipe lengths are in nominal diameters 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, additional flow conditioning is required. See ASME *Fluid Meters* for additional guidelines for line length.

† See 4.2 for definition of the test specimen.

**Figure 2 — Piping requirements, standard test section**

#### 4.5 Flow measurement

The flow-measuring instrument may be any device that meets specified accuracy. The accuracy rating of the instrument shall be  $\pm 2$  percent of actual output reading. The resolution and repeatability of the instrument shall be within  $\pm 0.5$  percent. The measuring instrument shall be calibrated as frequently as necessary to maintain specified accuracy. All guidelines specific to the flow-measuring instrument regarding flow conditioning (e.g., the number of straight pipe diameters, upstream and downstream of the instrument, etc.) shall be followed.

#### 4.6 Pressure taps

Pressure taps shall be provided on the test section piping in accordance with the requirements listed in Figure 2. These pressure taps shall conform to the construction illustrated in Figure 3.

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.

For butterfly and other rotary valves, the pressure taps shall be aligned (parallel) to the main shaft of the valve to reduce the effect of the velocity head of the flowing fluid on the pressure measurement.

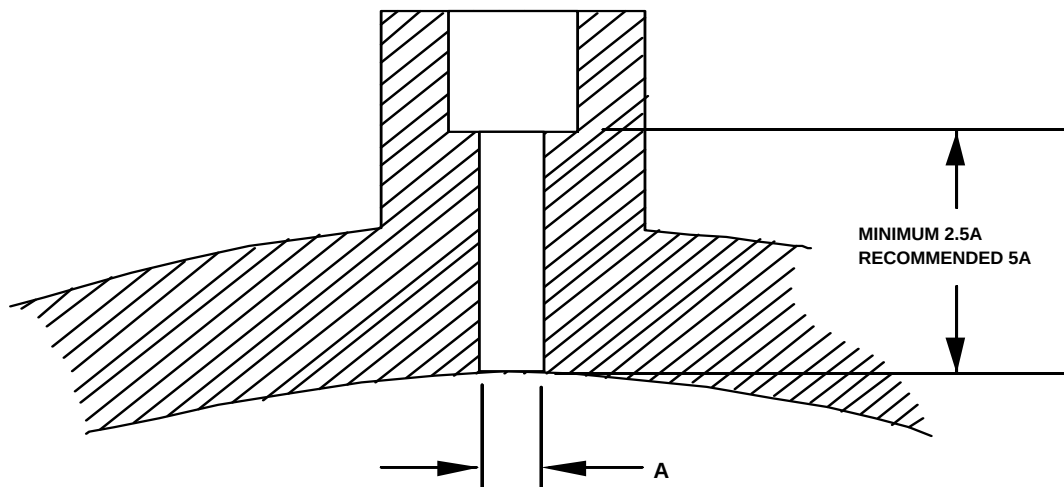
Multiple pressure taps can be used on each test section for averaging pressure measurements. Each tap must conform to the requirements in Figure 3.

See 4.10 for other installation guidelines.

|                                         | A               | A              |
|-----------------------------------------|-----------------|----------------|
| Size of pipe                            | Not exceeding   | 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 (i.e., check for corrosion and/or erosion) or slightly rounded, free from burrs, wire edges or other irregularities. In no case shall any fitting protrude 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 3 — Recommended pressure connection**

#### 4.7 Pressure measurement

All pressure and pressure differential measurements shall be made using instruments with an accuracy rating of  $\pm 2$  percent of actual output reading. Pressure-measuring devices shall be calibrated as frequently as necessary to maintain specified accuracy.

If individual pressure measurements ( $P_1$ ,  $P_2$ ) are used in lieu of a single differential pressure measurement ( $\Delta P$ ), care must be taken to select instruments which are accurate enough that the calculated pressure differential value ( $P_1 - P_2$ ) is known with an accuracy at least as good as the accuracy rating stated above for pressure differential measurements.

#### 4.8 Temperature measurement

The fluid temperature shall be measured using an instrument with an accuracy rating of  $\pm 1$  °C ( $\pm 2$  °F) of actual output reading.

The inlet fluid temperature shall remain constant within  $\pm 3\text{ }^{\circ}\text{C}$  ( $\pm 5\text{ }^{\circ}\text{F}$ ) during the test run to record data for each specific test point.

#### 4.9 Travel measurement

The accuracy rating of the travel-measuring instrument shall be  $\pm 0.5$  percent of rated travel.

#### 4.10 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:

**Table 1 — Test specimen alignment**

| Pipe Size                                   | Allowable Misalignment    |
|---------------------------------------------|---------------------------|
| 15 mm thru 25 mm<br>(1/2 in. thru 1 in.)    | 0.8 mm<br>(1/32 in.)      |
| 32 mm thru 150 mm<br>(1-1/4 in. thru 6 in.) | 1.6 mm<br>(1/16 in.)      |
| 200 mm and larger<br>(8 in. and larger)     | 1 percent of the diameter |

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

#### 4.11 Accuracy of test

Valves having an  $\frac{C}{N_{18}d^2} < 0.047$  at tested travel and  $x_T < 0.84$  will have a calculated flow coefficient,

$C$  ( $C_v$ ,  $K_v$ ) of the test specimen within a tolerance of  $\pm 5$  percent. The tolerance for valves that do not meet these criteria may exceed 5%. These accuracy statements apply when fully turbulent flow can be established. See Annex D for further information when this is not the case.

See cautions presented in 4.2.

## 5 Test fluids

### 5.1 Incompressible fluids

Fresh water or some other incompressible fluid 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. Test fluids other than fresh water may be required for obtaining  $F_R$  and  $F_F$ . Test fluid temperature range for fresh water should be  $5\text{ }^{\circ}\text{C}$  ( $41\text{ }^{\circ}\text{F}$ ) to  $40\text{ }^{\circ}\text{C}$  ( $104\text{ }^{\circ}\text{F}$ ).