



**Instrument Engineer's Handbook
for
DURCO Quarter-turn Control Valves**

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Flowsolve Corporation, Flow Control Division, Cookeville, Tennessee, extends its appreciation to the Instrument Society of America for its permission to adapt Standard S75.01©, Instrument Society of America, 1985 and *Control Valve Sizing* by L.R. Driskell©, Instrument Society of America, 1976.

A valuable reference for further study of control valves is the *ISA Handbook of Control Valves, Second Edition, 1976*.

Instrument Engineer's Handbook for Durco Control Valves

Preface

This manual on control valve sizing brings together the mathematical tools required to select Durco valves properly for control valve applications. The equations presented for liquids, gases, and steam are based on the ISA standard S75.01 and are divided into sections to simplify manual calculation for the more common sizing problems. Examples of each type are presented for further comprehension. The selection of a correct valve size as mathematically determined depends on accurate knowledge of the actual flowing data. Frequently, one or more of the operating conditions are arbitrarily assumed. Most errors in control valve sizing are due to incorrect assumptions. Generally speaking, the tendency is to make the valve too large to be on the "safe side". Combining these so called "safety factors" can result in a valve which is oversized and one which contributes to poor control and system instability. There is no substitute for good engineering judgement. Only good common sense combined with experience can bring forth an acceptable solution in valve sizing. Control valve applications vary in degree from simple to complex. On occasion, guidance and assistance in selecting the proper control valve may be required.

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Section One

How to Size Valves

LIQUID SIZING

Liquid flow through Durco valves may be predicted by using the thermodynamic laws of fluid flow and the standards established in this manual by the Flowserve Corporation. There are two basic requirements that must be determined to properly size Durco control valves; first is the Cv required and second is the allowable pressure drop for a given service and valve.

Proper selection of any control valve requires some basic information that may or may not be readily available. Ideally, we would like to:

- 1) Get a general description of what is to be accomplished or a data sheet if possible.
- 2) Have the following data provided.
 - a) Inlet pressure.
 - b) Temperature – maximum and minimum.
 - c) Process fluid.
 - d) Flow rates - maximum, normal and minimum.
 - e) Vapor pressure.
 - f) Pipeline size - schedule and material.
 - g) Pressure drop - minimum, normal and maximum.
 - h) Specific gravity.
 - i) Critical pressure.

The following formulae shall be used in sizing Durco Valves.

$$1-1.0 \quad C_v = \frac{Q}{\sqrt{\frac{\Delta P}{S.G.}}}$$

Where: C_v = Flow coefficient required.
 Q = Flow in gpm.
 $S.G.$ = Specific gravity
 ΔP = Pressure drop in psi.

Definition: C_v is numerically equal to the number of U.S. gallons of water that will flow through a valve in one minute with water at 60°F and a one psi differential pressure across the valve.

$$1-1.1 \quad \Delta P_{\text{allow}} = F_L^2 (P_1 - r_c P_v)$$

Where: ΔP_{allow} = allowable pressure drop in psi.
 F_L^2 = Recovery coefficient from C_v chart.
 r_c = Critical pressure ratio from r_c chart.
 P_v = Vapor pressure in psia.

$$1-1.2 \quad C_v = \frac{Q}{\sqrt{\frac{\Delta P_{\text{allow}}}{S.G.}}} \quad (\text{for choked flow})$$

Note: This formula should be used when $\Delta P_{\text{actual}} \geq \Delta P_{\text{allow}}$, where: $\Delta P_{\text{actual}} = P_1 - P_2$

DETERMINING THE REQUIRED C_v

Formula 1-1.0 is the general-purpose equation for most liquid sizing applications. This formula utilizes the actual pressure drop or the inlet pressure minus the outlet pressure, to calculate the required C_v . Examination of the formula indicates that "if the pressure drop increased, the flow should also increase." There is, however, a point where further decreases in P_2 results in no change in flow rate and is referred to as "Choked Flow." Therefore, the actual ΔP no longer applies and a maximum ΔP_{allow} must be substituted to calculate the required C_v , (equation 1.1.2). Choked flow results from flashing or cavitation and could cause damage to the valve and/or piping. When solving a liquid sizing application, consider some or all of the following points to determine if ΔP_{allow} should be used.

- 1) If the inlet pressure (P_1) is relatively close to the vapor pressure.
- 2) If the outlet pressure (P_2) is relatively close to the vapor pressure.
- 3) If the actual pressure drop is large when compared to the inlet pressure.

This means that if there is any doubt that the liquid service is in close proximity to choked flow, the ΔP_{allow} must be calculated and compared to ΔP_{actual} (see section on cavitation and flashing beginning on page 10).

Using a valve smaller than line size will contribute to errors in the required C_v , due to losses caused by the expanders and reducers. Flowserve has calculated this effect on C_v , and printed the results for your convenience (see Section 2). Should the need arise to calculate the corrected C_v , for various combinations we have supplied a catalog of formulae from ISA Standards.

When an incompressible fluid has a high viscosity and/or low velocity, laminar flow may exist. The C_v previously discussed assumed turbulent flow and must be multiplied by a correction factor (F_R) to obtain the actual flow coefficient. Generally speaking, if the viscosity is less than SAE 10 motor oil (~30cp), this factor may be neglected.

C_v CALCULATIONS PROCEDURE

- 1) Using the given flow conditions, calculate the C_v , using equation 1-1.0.
- 2) Select a nominal valve size from the sizing charts based on the calculated C_v . This C_v value should generally fall between 20-80% of port opening.
- 3) Read F_L^2 value from sizing chart based on the percent of opening at which the valve will operate.
- 4) Using the F_L^2 value, calculate the ΔP_{allow} from equation 1-1.1. The r_c value is determined from the critical pressure ratio charts on page 13.
- 5) Compare the ΔP_{allow} to the ΔP_{actual} if ΔP_{allow} is greater than the actual pressure drop equation 1-1.0 is valid. If ΔP_{allow} is less than actual pressure drop, equation 1-1.2 must be used and flashing exists (see section on cavitation and flashing beginning on page 10).
- 6) If viscosity correction is required, use the F_R correction procedure.

VISCOSITY CORRECTION

When it is determined that the viscosity is greater than SAE 10 motor oil (30 cp @ 70F), the following correction should be made (Figure 1).

Based on the type of valve selected (plug or butterfly) calculate the Reynolds number using the following formulae and correct for the effects of laminar flow.

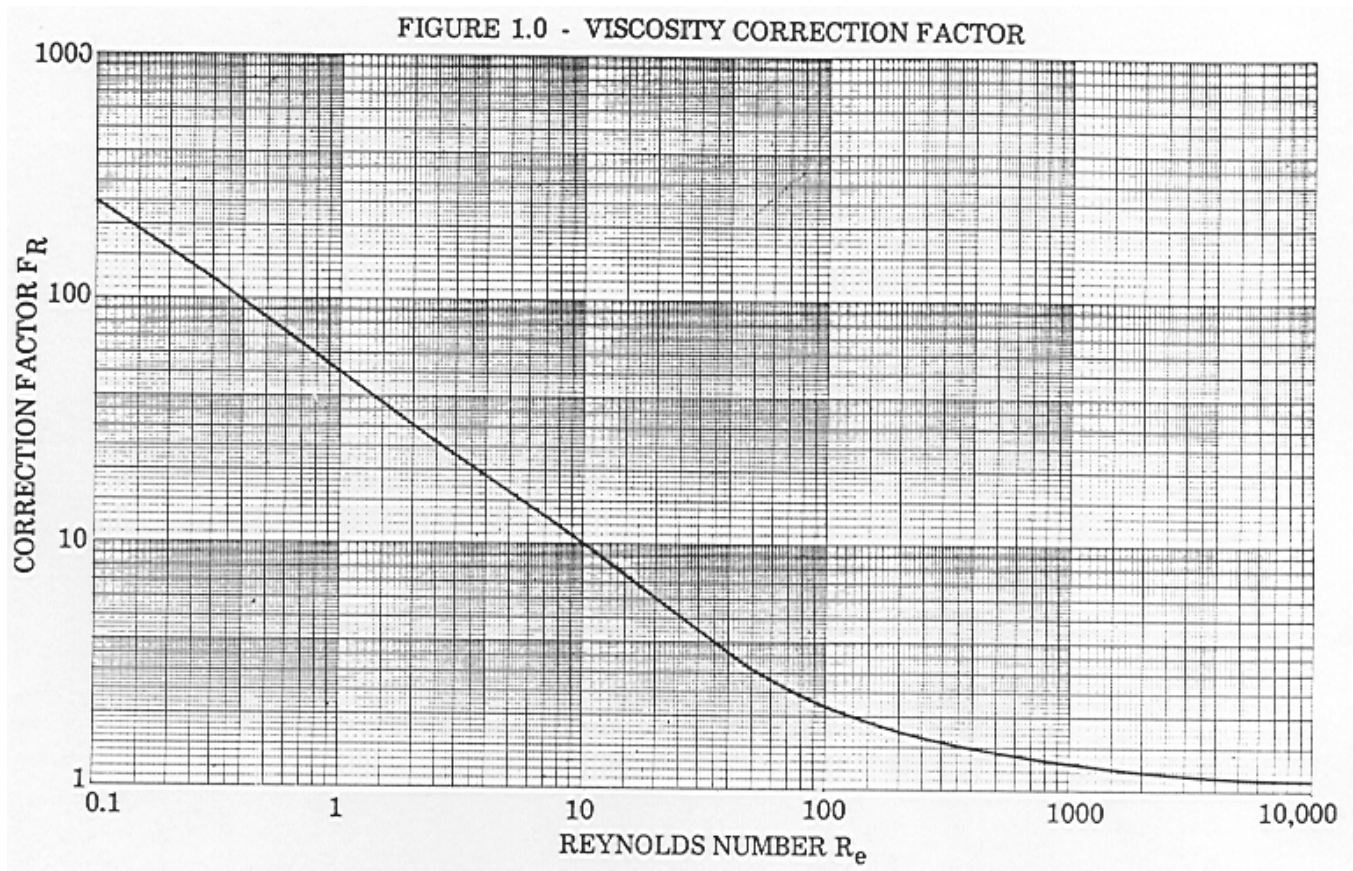
$$R_e = 17,300 \frac{Q}{v \sqrt{C_v}} \quad (\text{for plug valves})$$

where: R_e = Reynolds number
 Q = Flow rate, gpm
 v = Viscosity, centistokes*
 C_v = Flow coefficient

$$R_e = 12,283 \frac{Q}{v \sqrt{C_v}} \quad (\text{for butterfly valves})$$

*(centistokes = centipoise/S.G.)

The correction factor may be obtained from Figure 1.0 the Viscosity Correction Factor chart. Use the value (F_R) and calculate the corrected C_v . $C_v (\text{corrected}) = F_R C_v$



EXAMPLES FOR LIQUID SIZING

Example 1

Given information:

- Fluid = water
- $P_1 = 150 \text{ psig} = 14.7 = 164.7 \text{ psia}$
- $\Delta P = 10 \text{ psi}$

$Q = 50 \text{ gpm}$
 $T = 193^{\circ}$
 $P_V = 10 \text{ psia}$
 $S.G. = 1.0$
 $\text{Line size} = 1''$

1) Use equation 1-1.0.

$$C_V = Q \sqrt{\frac{\Delta P}{S.G.}} = \frac{50}{\sqrt{\frac{10}{1.0}}} = 15.8$$

2) Select a nominal valve size from the sizing chart for V-ported valves on page 29.

3) For V-port plug valves, a 1" valve and a 1" line has a maximum C_V of 29.9. The calculated C_V of 15.8 falls in at about 72% of port opening.

4) The F_L^2 value at 72% opening is approximately 0.65.

5) Calculate ΔP_{allow} from equation 1-1.1.

$$\Delta P_{\text{allow}} = F_L^2 (P_1 - r_C P_V)$$

Where: $F_L^2 = 0.65$

$P_1 = 164.7 \text{ psia}$

$P_V = 10 \text{ psia}$

$r_C = 0.95$ (from r_C charts)

$$\Delta P_{\text{allow}} = 0.59 [164.7 - (0.95)(10)] = 100.91 \text{ psi}$$

6) Compare the actual pressure drop to the allowable pressure drop.

$$\Delta P_{\text{actual}} = 10 \text{ psi}$$

$$\Delta P_{\text{allow}} = 100.91 \text{ psi}$$

The actual pressure drop is less than the maximum allowable pressure drop. Therefore, equation 1-1.0 is valid.

7) Water is less viscous than SAE 10 weight motor oil and the F_R factor may be neglected.

Conclusion: The 1" V-port plug valve would operate at about 72% of full open and would be a good selection in this example.

Example 2

Given information:

Fluid = Liquid chlorine

$P_1 = 125 \text{ psig} + 14.7 = 139.7 \text{ psia}$

$\Delta P = 75 \text{ psi}$

$Q = 150 \text{ gpm}$

$T = 60^{\circ}\text{F}$

$P_V = 100 \text{ psia}$

$S.G. = 1.42$

Line size = 3"

1) Use equation 1-1.0.

$$C_v = Q \sqrt{\frac{\Delta P}{S.G.}} = \frac{150}{\sqrt{\frac{75}{1.42}}} = 20.6$$

2) Select a nominal valve size from the sizing charts. For V-port plug valves, a 2" valve in a 3" line has a maximum C_v of 52.2. The calculated C_v of 20.7 falls in about 60% of port opening.

3) The F_L^2 value at 60% is approximately .86.

4) Calculate the ΔP_{allow} from equation 1-1.1.

$$\Delta P_{allow} = F_L^2 (P_1 - r_C P_V)$$

Where: $F_L^2 = .86$

$P_1 = 139.7$ psia

$P_V = 100$ psia

$r_C = 0.87$

Note: r_C was found by looking up the critical pressure P_C and dividing that value into P_V .

$P_C = 1119$ psia

$P_V = 100$ psia

$P_V/P_C = 100/1119 = 0.089$

Enter value into graph on page 13, figure 1.3.

Reading vertically $r_C = 0.87$.

$$\Delta P_{allow} = 0.86 [139.7 - 0.87 (100)] = 45.32 \text{ psi}$$

5) Compare the actual pressure drop to the allowable pressure drop.

$\Delta P_{actual} = 75$ psi

$\Delta P_{allow} = 45.32$ psi

The allowable pressure drop is less than the actual pressure drop. Therefore, equation 1-1.2 must be used to calculate the required C_v .

$$C_v = Q \sqrt{\frac{\Delta P_{allow}}{S.G.}} = \frac{150}{\sqrt{\frac{45.32}{1.42}}} =$$

Because the allowable pressure drop is less than the actual pressure drop, the required C_v increased. The C_v of 26.56 falls in at about 75% of opening indicating that our first selection has enough capacity to control the process.

Referring to the cavitation and flashing section, the outlet pressure is less than the vapor pressure and flashing exists. Proper material selection should handle this type of problem, however, if cavitation exists in a different application consult the Cookeville Valve Operation.

CAVITATION AND FLASHING

We previously stated that there are two basic requirements that must be determined to properly size control valves. Accuracy has been improved with the introduction of the factor, r_C and is called the critical pressure ratio.

We can now calculate the point where a liquid will result in choked flow and calculation of the allowable pressure drop is the technique used for this prediction.

$$\Delta P_{\text{allow}} = F_L^2 (P_1 - r_C P_V)$$

As a liquid flows through the control valve orifice it restricts the flow and causes the fluid to pick up velocity. The point where the fluid reaches maximum velocity results in an energy exchange that lowers the pressure. This point of lowest pressure and highest velocity is referred to as the vena contracta.

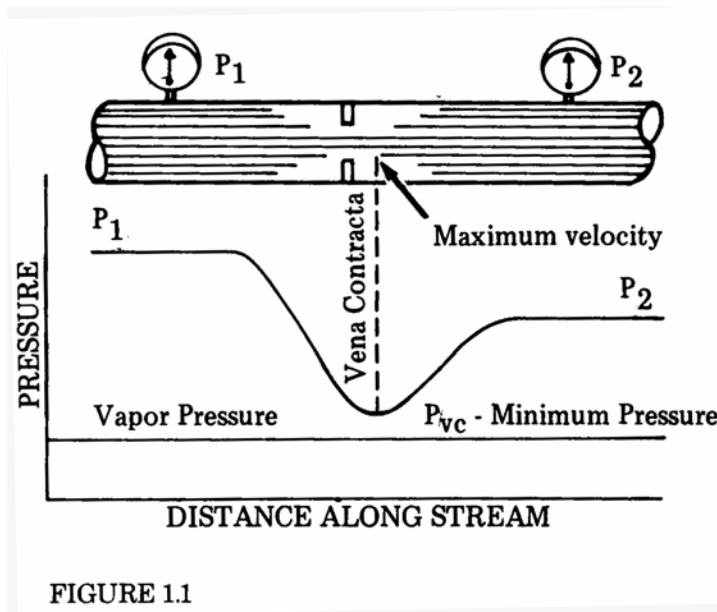
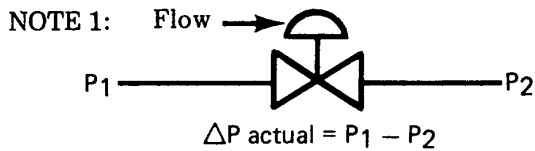
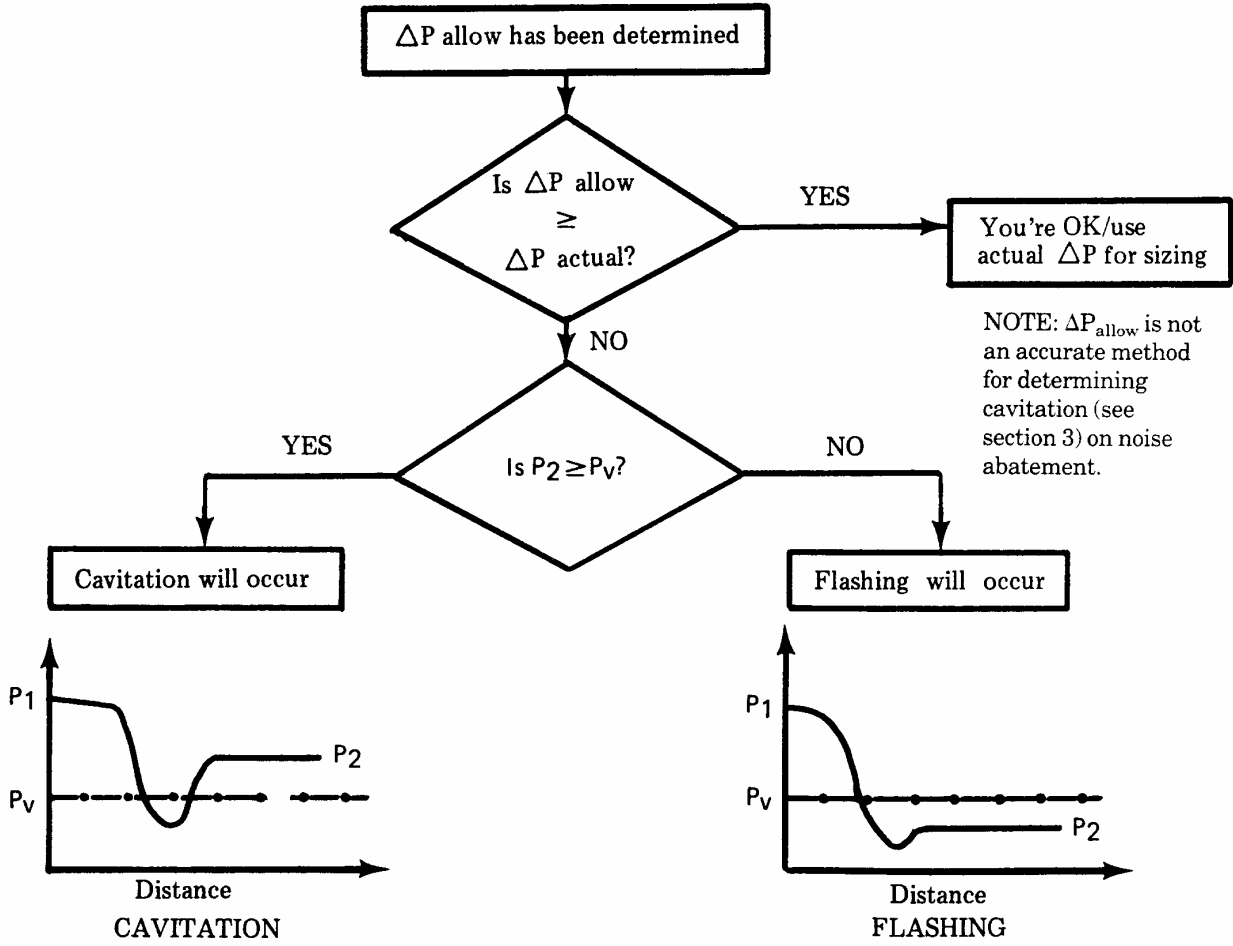


FIGURE 1.1

Figure 1.1 shows the flow pattern of the fluid passing through a restriction and depicts what actually happens to the pressure at the vena contracta. If the vena contracta pressure (P_{VC}) falls below the vapor pressure, vapor bubbles start to form. When the fluid passes the vena contracta the fluid velocity slows, thus raising the liquid pressure to some point (P_2) less than the inlet pressure. If the outlet pressure (P_2) recovers below the vapor pressure, flashing takes place. If the outlet pressure (P_2) recovers above the vapor pressure, the vapor bubbles will implode and cavitation is present. Cavitation produces noise, vibration and physical damage to the valve and/or down stream piping.

Therefore, calculation of the allowable pressure drop (ΔP_{allow}) predicts whether or not the vena contracta pressure (P_{VC}) will be below the vapor pressure. Avoiding cavitation or flashing means keeping the vena contracta pressure above the vapor pressure. We have included a flow chart to simplify determination of the fluid state for your convenience.

CAVITATION DETERMINATION



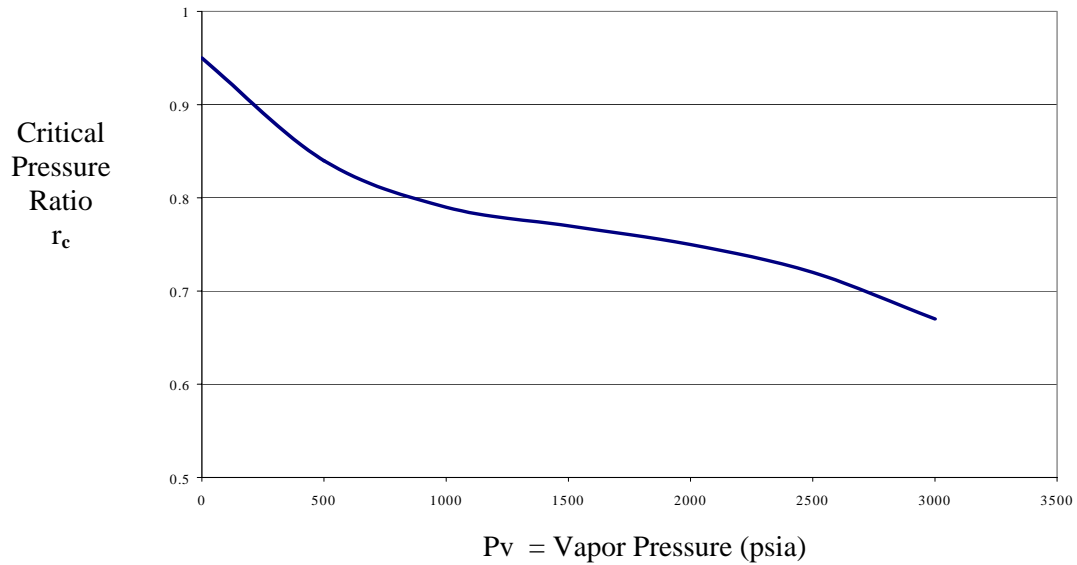
NOTE 2:

$$\Delta P_{allow} = F_L^2 (P_1 - r_c P_v)$$

NOTE 3: If you are close or equal to ΔP_{actual} further investigation is in order.

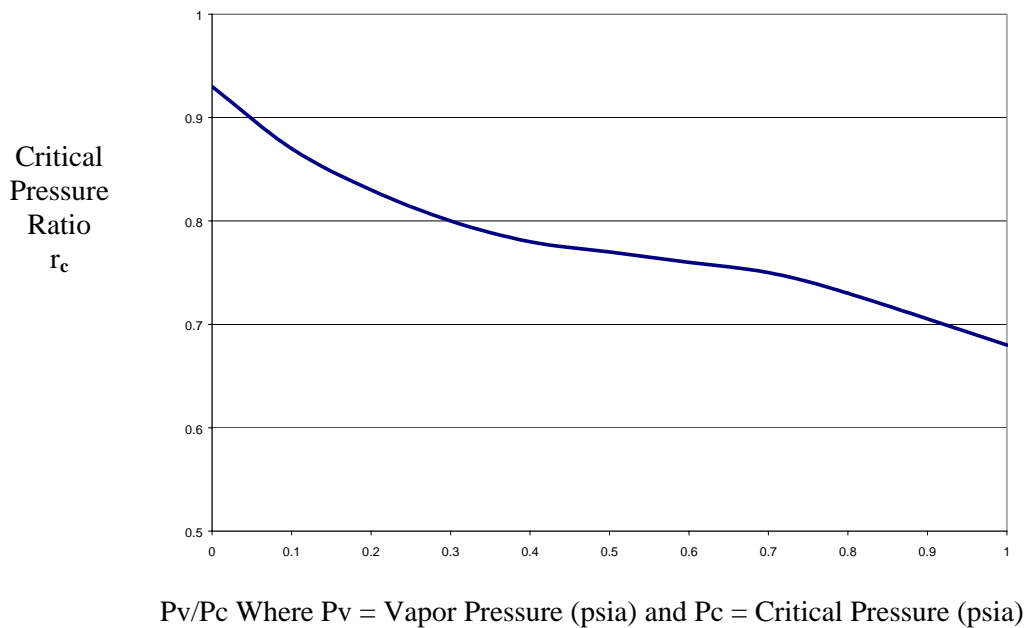
CONTROL VALVE SIZING CAVITATING AND FLASHING LIQUIDS

FIGURE 1.2 - CRITICAL PRESSURE RATIOS FOR WATER



Enter the water vapor pressure value at inlet temperature on the abscissa. Proceed vertically to intersect the curve. Read the critical pressure ratio r_c on the ordinate by moving horizontally to the left.

FIGURE 1.3 – CRITICAL PRESSURE RATIOS FOR OTHER LIQUIDS



Determine the vapor pressure/critical pressure ratio by dividing the liquid vapor pressure at the valve inlet (noting liquid temperature), by the critical pressure of the liquid. Enter this ratio on the abscissa and proceed vertically to intersect the curve. Read the critical pressure ratio r_c on the ordinate by moving horizontally to the left.

GAS SIZING

Ideal gases and vapors are compressible fluids and require a similar approach to liquid sizing while taking into account such terms as the compressibility factor (Z), the expansion factor (Y) and the terminal pressure ratio (Xt). The flow rate (Q) has units of standard cubic feet per hour and care should be taken to convert your required flow from the compressibility charts in the reference data section beginning on page 67.

The following formulae will be used to calculate the required flow coefficient for Durco valves.

$$1-2.0 \quad C_v = \frac{Q_{SCFH}}{1360 P_1 Y \sqrt{\frac{X}{GTZ}}}$$

$$1-2.1 \quad Y = 1 - \frac{X}{3F_k X_t}$$

$$1-2.2 \quad C_v = \frac{Q_{SCFH}}{1360 P_1 (0.667) \sqrt{\frac{X_t}{GTZ}}}$$

Where: X, Y, G, C_v, and Z are dimensionless

C_v = Flow coefficient

Q = Flow rate in SCFH

P₁ = Inlet pressure in psia

Y = Expansion factor

X = Pressure drop ratio $\Delta P/P_1$

G = Specific gravity

T = temperature, °R

F_k = Specific heat ratio

X_t = Terminal pressure drop ratio

Z = Compressibility factor

DETERMINING THE REQUIRED C_v

Formula 1-2.0 is the general purpose equation for most gas sizing applications. However, when gases flow through a restriction they will expand and contract. We stated earlier that gas sizing includes both expansion and compressibility factors and careful examination of the fluid characteristics is required to accurately predict flow for gases and vapors.

Formula 1-2.0 is based on the same premise that, as the pressure drop increases so will the flow increase. There is a point where the flow will choke off. Therefore, the value of Y has been limited 0.667. When Y can be calculated to be less than 0.667 the gas is at "Choked Flow" and equation 1-2.2 must be used to determine the required C_v.

The compressibility factor (Z) is a correction factor for gases that deviate from the laws of perfect gases and effect the accuracy of the C_v coefficient. Values of Z may be approximated using the compressibility charts in the reference data section beginning on page 67.

C_v CALCULATION PROCEDURE

- 1) Convert flow units to SCFH
- 2) Calculate the expansion factor.

$$Y = 1 - \frac{X}{3F_k X_t} \quad (\text{limit } 0.667)$$

Where: $X = \Delta P/P_1$ (P_1 in psia)

$$F_k = \frac{k}{1.4} = \frac{\text{Specific heat ratio of gas}}{\text{Specific heat ratio of air}}$$

$X_t =$ From sizing charts (start at $X_t = 0.5$)

- 3) If Y is greater than 0.667 calculate the C , using formula 1-2.0. Based on the degree of opening from the sizing charts, recheck Y using the actual X_t , and recalculate the C_v .
- 4) If Y is less than 0.667 calculate the C_v using formula 1-2.2. Based on the degree of opening from the sizing charts, recheck Y using the actual X_t and recalculate the C_v .

EXAMPLES FOR GAS SIZING

Example 1

Given information:

Fluid = Air
 $P_1 = 100 \text{ psig} + 14.7 = 114.7 \text{ psia}$
 $\Delta P = 30 \text{ psi}$
 $T = 90^\circ\text{F} + 460 = 550^\circ\text{R}$
 $Q = 50,000 \text{ SCFH}$
 $G = 1.0$
Line size = 2"

$$1) \quad Y = 1 - \frac{X}{3F_k X_t}$$
$$Y = 1 - \frac{0.26}{3(1.0)(0.5)}$$

$$Y = 0.83$$

Where: $X = 30/114.7 = 0.26$
 $F_k = 1.4/1.4 = 1.0$ (k is found in the reference data section)
 $X_t = 0.5$ (starting point)

- 2) Y is greater than 0.667, therefore, formula 1-2.0 should be used. The value of Z for air is 1.0 found in the reference data section.

$$C_v = \frac{Q_{SCFH}}{1360 P_1 (0.667) \sqrt{\frac{X_t}{GTZ}}}$$

$$= \frac{50,000 \text{ SCFH}}{1360 (114.7) (0.83) \sqrt{\frac{0.26}{1.0(550)(1.0)}}$$

$$C_v = 17.8$$

3) The given information showed that the line size was 2". Referring to the sizing chart for the 2" V-port it is found that the valve would operate at about 67% of full open. The respective X_t , is about 0.53 and therefore the C_v , would not be affected.

Example 2

Given Information:

Fluid = Ethane

$P_1 = 150 \text{ psig} = 14.7 = 164.7 \text{ psia}$

$\Delta P = 95 \text{ psi}$

$T = 100^\circ\text{F} + 460 = 560^\circ\text{F}$

$Q = 165,000 \text{ SCFH}$

$G = 1.05$

$k = 1.18$ (from reference data section)

Line size = 3"

$$1) Y = \frac{X}{3F_k X_t} \text{ (lim 0.667)}$$

$$Y = 1 - \frac{0.58}{3(0.84)(0.5)}$$

$Y \neq 0.54$ (choked flow) therefore, $Y = 0.667$

Where: $X = 95/164.7 = 0.58$
 $F_k = 1.18/1.4 = 0.84$
 $X_t = 0.5$

2) The calculated value for Y is less than 0.667, therefore use formula 1-2-2. Ethane is not an ideal gas under the stated pressures and temperatures and Z should be determined using the compressibility charts in the reference data section.

Critical temperature and critical pressure, T, and P, respectively, were looked up for Ethane in the physical constants section of reference data.

$P_C = 708 \text{ psia}$

$T_C = 550^\circ\text{R}$

Examining the first Z Graph, P, and T, must be calculated.

$$P_r = \frac{P_1}{P_C} = \frac{164.7}{708} = 0.23$$

$$T_r = \frac{T_1}{T_c} = \frac{560}{550} = 1.02$$

Referring to the graph and enter the values above for T_r and P_r , a value for Z may be found. In this case it turns out to be 0.92.

3) We now have all of the unknown values and may calculate the C_v .

$$C_v = \frac{Q_{SCFH}}{1360 P_1 (0.667) \sqrt{\frac{X_t}{GTZ}}}$$

$$C_v = \frac{165,000 \text{ SCFH}}{1360 (164.7) (0.667) \sqrt{\frac{0.5}{1.05(560)(0.92)}}$$

$$C_v = 36.8$$

4) It was given that the line size is 3" and referring to the 3" V-port sizing table on page 29, it is found that the valve will operate about 60-62% open. The corresponding X_t is about 0.64. Therefore, rechecking Y and C_v , Y is less than 0.667 or at choked flow.

$$C_v = \frac{165,000 \text{ SCFH}}{1360 (164.7) (0.667) \sqrt{\frac{0.64}{1.05(560)(0.92)}}$$

$$C_v = 32.5$$

The proper selection is a 3" EG411 with a maximum available C_v of 121.

STEAM SIZING

The effects of steam are similar to the previous discussion on gas sizing inasmuch as it also is a compressible fluid. The flow rate (W), however, is expressed as pounds per hour (lbs/hr) and care should be taken to convert your required flow to these units. **Also see Steam Recommendations, page 62.**

The following formulae should be used to calculate the required C_v for Durco valves.

$$1-3.0 \quad C_v = \frac{W \text{ lbs./hr.}}{63.3 Y \sqrt{X P_1 W_1}}$$

$$1-3.1 \quad Y = 1 - \frac{X}{3 F_k X_t} \quad (\text{lim } 0.667)$$

$$1-3.2 \quad C_v = \frac{W \text{ lbs./hr.}}{63.3 (0.667) \sqrt{X_t P_1 W_1}}$$

Where: Y, X C_v are dimensionless
W = Flow rate in lbs./hr.
C_v = Flow coefficient
P₁ = Inlet pressure in psia
Y = Expansion coefficient
X = Pressure drop ratio, ΔP/P₁
w₁ = Specific weight, lbs./ft.³
F_k = Specific heat ratio factor
X_t = Terminal pressure drop ratio

DETERMINING C_v FOR STEAM

- 1) Convert flow to lbs./hr.
- 2) Calculate the expansion factor.

$$Y = 1 - \frac{X}{3F_k X_t} \quad (\text{lim } 0.667)$$

Where: X = ΔP/P₁
F_k = k/1.4 (k from steam chart in reference data section)
X_t = from sizing charts beginning on page 29 (start at X_t = 0.5)

- 2) If Y is greater than 0.667 calculate the C_v using formula 1-3.0. Based on the degree of opening from the sizing charts beginning on page 29, recheck Y using actual X, and recalculate the C_v.
- 4) If Y is less than 0.667, calculate the C_v using formula 1-3.2. Based on the degree of opening, recheck Y using the actual X_t and recalculate the C_v.

EXAMPLES FOR STEAM SIZING

Example 1

Given information:

Fluid = Dry saturated steam
P₁ = 90 psig + 14.7 = 104.7 psia
ΔP = 20 psi
T = 331°F
W = 10,000 lbs./hr.
k = 1.31 (from Table 5.1 under Reference Data)
w₁ = 0.236 (from Table 5.2 under Reference Data)

$$1) \quad Y = 1 - \frac{X}{3F_k X_t}$$

$$Y = 1 - \frac{0.191}{3(0.936)(0.5)}$$

$$Y = 0.86$$

Where: X = 20/104.7 = 0.191
F_k = k/1.4 = 1.3/1.4 = 0.936
X_t = 0.5 (starting point)

2) Y is greater than 0.667, therefore, use formula

$$1-3.0 \quad C_V = \frac{W_{lbs/hr}}{63.3 Y \sqrt{X P_1 w_1}}$$

$$= \frac{10,000_{lbs/hr}}{63.6 (0.86) \sqrt{0.19 (104.7) (0.236)}} = 84.7$$

3) Assuming a 2" line and referring to the 2" standard SleeveLine sizing chart on page 29, it is found that the valve would operate at about 72% open. The corresponding X_t , is 0.5 indicating that the C_V is correct.

Example 2

Given information:

Fluid = Superheated Steam

$P_1 = 60 + 14.7 = 74.7$ psia

$\Delta P = 50$ psi

$T = 350^\circ F$

$W = 12,000$ lbs/hr

$k = 1.31$ (from Table 5.1 under Reference Data)

$w_1 = 0.16$ (from Table 5.2 under Reference Data)

Line size = 4"

$$1) \quad Y = 1 - \frac{X}{3F_k X_t} \quad (\text{lim } 0.667)$$

$$Y = 1 - \frac{0.669}{3(0.936)(0.5)}$$

$Y \pm 0.524$ (choked flow) therefore, $Y = 0.667$

Where: $X = 50/74.7 = 0.669$
 $F_k = 1.31/1.4 = 0.936$
 $X_t = 0.5$ (starting point)

2) Y is less than 0.667, therefore, use formula 1-3.2.

$$C_V = \frac{W_{lbs/hr}}{63.6 (0.667) \sqrt{X_t P_1 w_1}}$$

$$= \frac{12,000_{lbs/hr}}{63.6 (0.667) \sqrt{0.5 (74.7) (0.16)}}$$

$C_V = 116$

3) It was given that the line size was 4" and referring to the 3" Standard SleeveLine sizing chart on page 29, it is found that the valve would operate at about 65% open. The corresponding X_t , is about 0.58 and rechecking Y and C_V .

Y is less than 0.667 (choked flow)

$$= \frac{12,000 \text{ lbs/hr}}{63.6 (0.667) \sqrt{0.5 (74.7) (0.16)}} = 108$$

The proper selection is a 3" G411 in a 4" line with a maximum available C_v of 277.

FREQUENTLY USED FORMULA CONVERSIONS

$$\frac{\Delta P}{\text{LIQUID}} = \text{S.G.} \left(\frac{Q}{C_v} \right)^2 \quad \text{LIQUID}$$

$$\frac{\Delta P}{\text{GAS}} = P_1 - \sqrt{P_1^2 - \left(\frac{Q \sqrt{\text{S.G.} T_1}}{963 C_v} \right)^2}$$

$$\frac{\Delta P}{\text{STEAM}} = P_1 - \sqrt{P_1^2 - \left(\frac{W (1 + .0007 s)}{2.12 C_v} \right)^2}$$

Q=GPM

Q=SCFH

W = lbs. per hour



Section Two

Noise Abatement

HYDRODYNAMIC NOISE

In reducing hydrodynamic noise, it is necessary to go to the source (the valve). In order to lower the sound pressure level, cavitation must be reduced. Cavitation is the result of a liquid being forced through an orifice, creating a pressure drop which falls below the vapor pressure of the incoming fluid. The point of lowest pressure is known as the Vena Contracta (see Figure 1). If the Vena Contracta is below the vapor pressure (the pressure at which a liquid will boil at ambient 62°F temperature), flashing will occur causing the formation of vapor bubbles. As the pressure recovers the atmosphere inside, the bubble is at a lower pressure than the external liquid surrounding the bubble. This causes the vapor bubble to collapse. Usually, along the side, in an elbow or nearest fitting in the pipe, depending on the conditions and type of valve. As the bubble collapses, it usually will remove some material, leaving a small cavity.

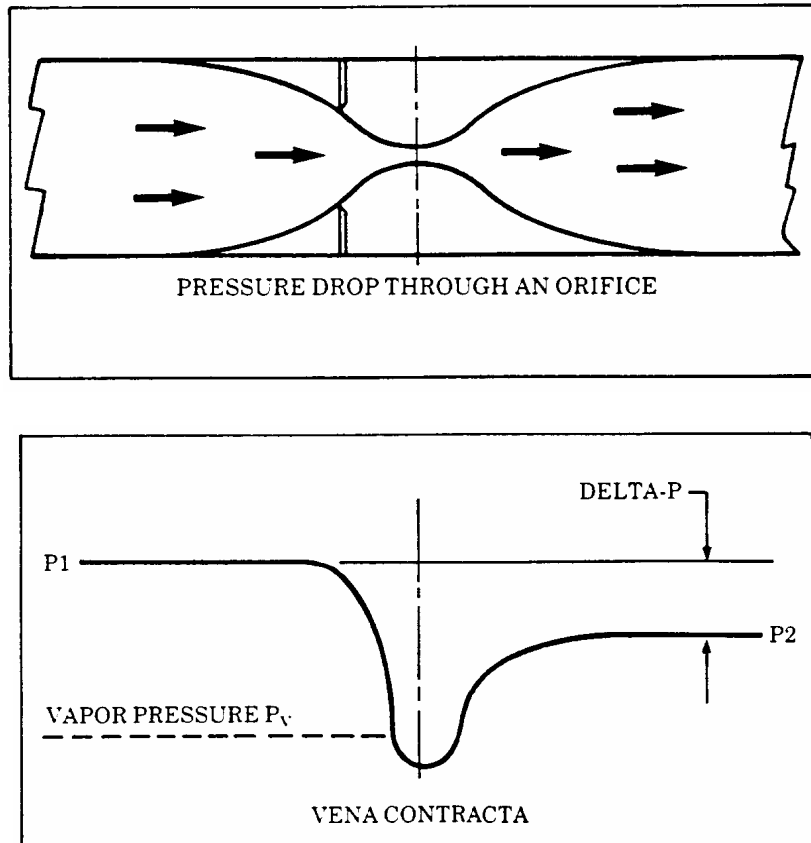


FIGURE 1

To reduce hydrodynamic noise, flashing/cavitation must be reduced. To reduce noise levels in a fluidic process, it has to be determined whether or not cavitation exists. This is accomplished by the following calculations:

U_i - Valve inlet velocity which will create incipient cavitation.

U_c - Valve inlet velocity which will create critical cavitation.

d - Valve inlet diameter, use inside pipe diameter of equivalent schedule 40 pipe. (See table "A")

C_d - Required C_v/d^2

P_1 - Inlet Pressure in psia

P_v - Vapor pressure in psia

$$U_i = J_o \times J_i \times J_n \times J_d$$

$$U_c = J_o \times J_c \times J_n \times J_d$$

$$\Delta P \text{ Incipient} = \left\{ \frac{6 \times (\text{S.G.} \times U_i)^2}{C_d^2} \right\} \text{ Pressure drop at which cavitation starts.}$$

$$\Delta P \text{ Critical} = \left\{ \frac{6 \times (\text{S.G.} \times U_c)^2}{C_d^2} \right\} \text{ Pressure drop at which heavy damage will occur.}$$

TABLE "A"
COMMERCIAL WROUGHT STEEL PIPE DATA
SCHEDULE 40

INCH NOMINAL SIZE	OUSIDE DIAMETER	WALL THICKNESS	INSIDE DIAMETER	WEIGHT #/FT.
1	1.315	.133	1.049	1.68
1.5	1.900	.145	1.610	2.72
2	2.375	.154	2.067	3.65
3	3.500	.216	3.068	7.58
4	4.500	.237	4.026	10.79
6	6.625	.280	6.065	18.97
8	8.625	.322	7.981	28.66
10	10.750	.365	10.020	40.48
12(STD)	12.750	.375	12.000	49.56

BASIC CALCULATIONS FOR J

$$J_d = 1 + \frac{\log \times (12/d)}{10(.329 - .615 \times \log J_k)} \quad J_n = \left[\frac{P_1 - P_v}{71.5} \right]^{.39}$$

$$J_k = \left[\frac{890 + 1}{cd^2} \right]^{-.5} \quad \begin{array}{l} J_o = 1.06 \text{ for } d < 12 \\ 1.00 \text{ for } d = 12 \\ 0.94 \text{ for } d > 12 \end{array}$$

$$J_i = 60.4 \times J_k \text{ for } J_k < 0.1 ; \text{ or} \\ 36.2 \times J_k + 2.42 \text{ for } J_k > 0.1$$

$$J_c = 71.0 \times J_k \text{ for } J_k < 0.1 ; \text{ or} \\ 43.0 \times J_k + 2.80 \text{ for } J_k > 0.1$$

Depending on the process, piping, and valve, if the differential pressure indicates incipient cavitation or greater, steps may be taken to reduce cavitation, noise, and permanent damage to the process equipment.

Figure 4

PRESSURE RECOVERY
COMPARE

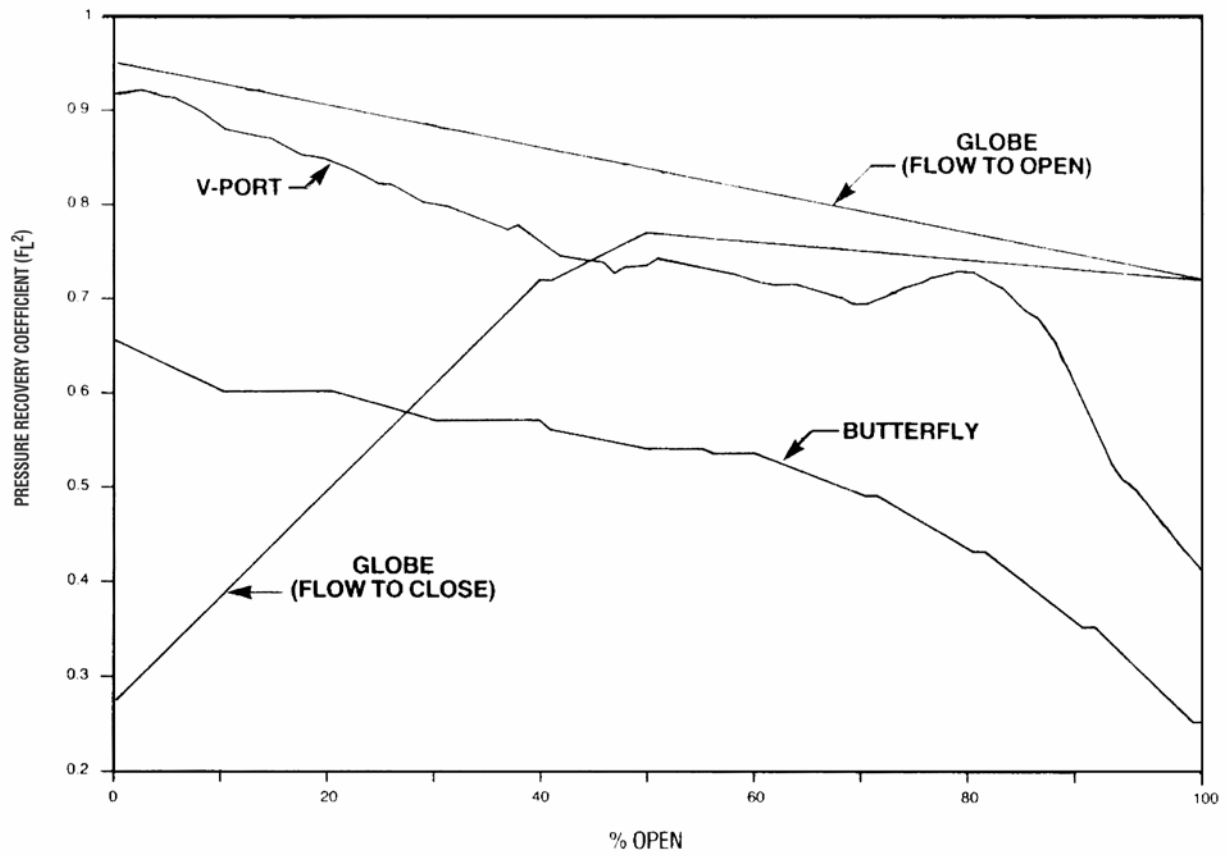
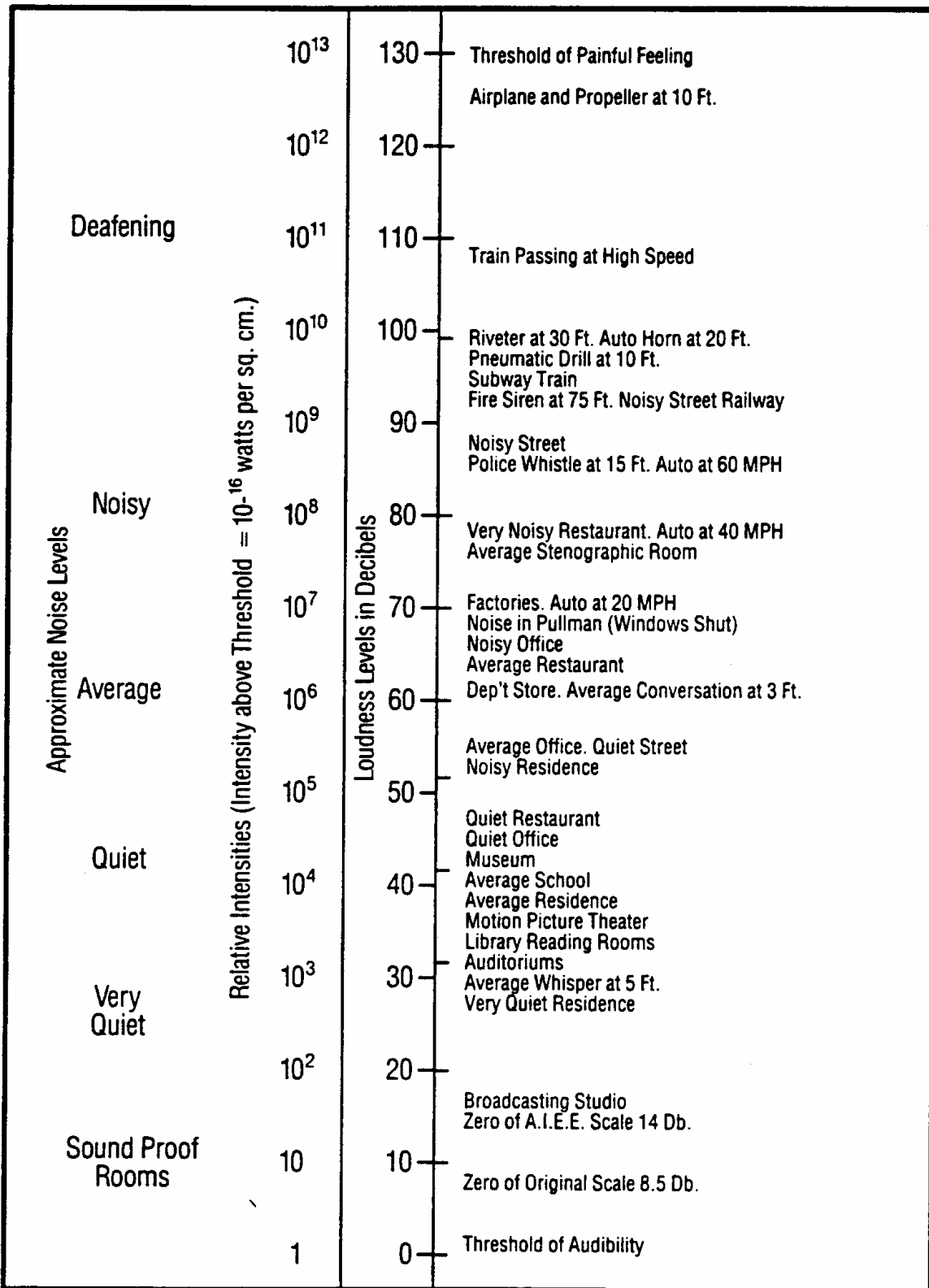


FIGURE 4

LOUDNESS LEVELS OF FAMILIAR NOISES

(APPROXIMATE AVERAGE INCLUDING EAR NETWORK)





Section Three

Cv and Torque Tables

for

Valve and Actuator Sizing

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Sleeved Plug Valves (standard port only)
G4, G4B Marathon, TSG4, TSG4Z

Cv

Valve Size	Pipe Size	% Of Rotation 0 – 90 Degrees									
		10	20	30	40	50	60	70	80	90	100
.5	.5	NA	N/A	NA	NA	N/A	NA	N/A	NA	N/A	7.4
.75	.75	NA	N/A	NA	N/A	NA	N/A	NA	N/A	NA	19.6
1	2	.4	1.48	3.19	5.50	8.39	11.9	15.9	20.4	25.6	31.2
	1.5	.5	1.85	3.99	6.88	10.5	14.8	19.9	25.6	32.0	39.0
	1	.61	2.28	4.91	8.46	12.9	18.2	24.4	31.5	39.3	48.0
1.5	3	.7	2.8	6.1	10.4	16	22	30	39	49	59
	2	.9	3.5	7.6	13.1	20	28	38	49	61	74
	1.5	1.1	3.9	8.5	14.7	22	32	42	55	68	83
2	4	1.3	4.8	10.3	17.8	27	38	51	66	84	101
	3	1.6	5.9	12.9	22.2	34	48	66	87	107	126
	2	1.9	7.2	15.6	27.0	41	58	78	100	125	153
3	6	3	10	22	38	58	82	110	142	177	216
	4	4	13	28	49	74	105	141	182	227	277
	3	4	16	33	57	87	122	164	211	264	322
4	8	5	17	37	64	97	137	184	237	296	361
	6	6	20	44	76	116	165	220	284	355	433
	4	7	26	57	98	149	211	282	364	455	555
6	10	10	37	80	138	211	298	398	513	641	783
	8	11	39	85	146	224	316	423	544	681	831
	6	12	45	98	168	257	363	486	626	782	955
8	8	24	88	190	477	500	707	946	1219	1522	1859
10	10	30	112	241	606	635	897	1202	1548	1933	2361
12	12	43	161	348	872	915	1292	1730	2229	2784	3400*
14	14	44	163	351	880	923	1304	1746	2248	2809	3430*
16	16	89	332	715	1795	1884	2661	3562	4588	5732	7000*
18	18	89	332	715	1795	1884	2661	3562	4588	5732	7000*
F_L^2		0.94	0.94	0.92	0.88	0.82	0.79	0.75	0.67	0.57	0.50
X_t		0.16	0.64	0.64	0.72	0.79	0.61	0.51	0.37	0.24	0.61

* Estimated Values

USED IN CONJUNCTION WITH CONCENTRIC REDUCERS

Use appropriate torque tables on **next** page for:
G4 and G4B Marathon Plug Valve
TSG4 TSG4Z Plug Valve

Sleeved Plug Valve

G4, G4B Marathon

(use for standard and V-port plugs)

SIZING TORQUES (Inch-lbs.)

VALVE SIZE	PTFE			UHMWPE		DURALON II	
	C/C	SLY	ALKY	C/C	SLY	C/C	SLY
<1	300	405	450	380	475	300	405
1	335	452	565	660	720	450	608
1.5	497	671	838	680	740	540	729
2	675	911	1138	1200	1620	750	1013
2.5	1180	1458	1822	1800	2430	1300	1755
3	1180	1458	1822	1800	2430	1300	1755
4&5	2400	3240	4050	3750	5063	2500	3375
6	6000	8100	10125	9900	12500	7500	10165
8*	9300	12555	15693	15000	17500	11200	15300
8**	6960	9396	N/A	CF	CF	8352	11300
10*	29400	39690	49612	40000	42500	35200	42000
10**	22020	29300	N/A	CF	CF	26222	32000
12°F	39900	42000	50000	40000	42500	40000	42000
12**	29926	40403	N/A	CF	CF	30000	35000
14	39900	42000	50000	40000	42500	42000	44000
16	60000	N/A	65000	N/A	N/A	70000	75000
18	60000	N/A	65000	N/A	N/A	70000	75000

*150# DCI & 300# Alloy Body

**150# Alloy Body G4N Style

Note: For dry services, use slurry torque requirements

CF= Consult Factory

C/C= Clean Clear

SLY= Slurry

For CZ100 (DNI) Nickel Plugs Consult Factory. Consult factory for other sleeve materials.

Triple Sealed Sleeved Plug Valve

TSG4, TSG4Z

(use for standard and V-port plugs)

SIZING TORQUES (Inch-lbs.)

VALVE SIZE	TSG4 - PTFE			TSG4Z - PTFE		
	C/C	SLY	ALKY	C/C	SLY	ALKY
<1	345	450	475	414	500	570
1	518	699	838	621	740	900
1.5	621	740	940	710	765	940
2	1035	1397	1676	1207	1630	1956
2.5	1380	1863	2235	2070	2600	3150
3	1380	1863	2235	2070	2600	3150
4&5	2760	3726	4471	3969	5356	6427
6	7256	9798	11757	10350	12500	14500
8*	15000	17000	21000	15500	17500	22000
8**	N/A	N/A	N/A	N/A	N/A	N/A
10*	40000	42000	50000	42000	44000	52000
10**	N/A	N/A	N/A	N/A	N/A	N/A
12°F	40000	42000	50000	42000	44000	52000
12**	N/A	N/A	N/A	N/A	N/A	N/A
14	40000	42000	50000	42000	44000	52000
16	N/A	N/A	N/A	N/A	N/A	N/A
18	N/A	N/A	N/A	N/A	N/A	N/A

Sleeved Plug Valves (V-port only)
G4, G4B Marathon, TSG4, TSG4Z

Cv

Valve Size	Pipe Size	% Of Rotation 0 – 90 Degrees									
		10	20	30	40	50	60	70	80	90	100
1	1	0.03	0.14	0.31	0.53	0.81	1.14	1.52	1.96	2.46	3.00
1	1	0.05	0.18	0.42	0.71	1.08	1.52	2.05	2.62	3.28	4.00
1	1	0.10	0.38	0.82	1.41	2.15	3.04	4.07	5.24	6.55	8.00
1	2	0.31	1.15	2.47	4.27	6.51	9.20	12.3	15.7	19.8	24.2
	1.5	0.35	1.29	2.78	4.80	7.32	10.3	13.8	17.8	22.3	27.2
	1	0.38	1.42	3.06	5.27	8.04	11.4	15.2	19.6	24.5	29.9
1.5	3	0.4	1.4	3.0	5.2	8	11	15	19	24	29
	2	0.4	1.4	3.1	5.4	8	12	16	20	25	31
	1.5	0.4	1.5	3.2	5.5	8	12	16	20	26	31
2	4	0.6	2.4	5.1	8.8	13	19	25	33	41	50
	3	0.7	2.5	5.3	9.2	14	20	27	34	43	52
	2	0.7	2.5	5.5	9.5	14	20	27	35	44	54
3	6	1.4	5.3	11.4	19.8	30	43	57	73	92	112
	4	1.5	5.6	12.1	20.8	32	45	60	77	97	118
	3	1.5	5.7	12.4	21.3	33	46	62	79	99	121
4	8	2.3	8.4	18.1	31.2	48	67	90	116	145	177
	6	2.3	8.7	18.8	32.4	49	70	94	121	151	184
	4	2.4	9.01	19.4	33.5	51	72	97	124	156	190
6	10	4.9	18.2	39.3	67.7	103	146	195	252	315	384
	8	4.9	18.4	39.7	68.4	104	147	197	254	318	388
	6	5.1	19.0	40.9	70.5	107	152	204	262	328	400
FL ²		0.96	0.96	0.95	0.94	0.93	0.86	0.73	0.64	0.56	0.45
Xt		0.23	0.39	0.64	0.75	0.73	0.64	0.49	0.33	0.28	0.28

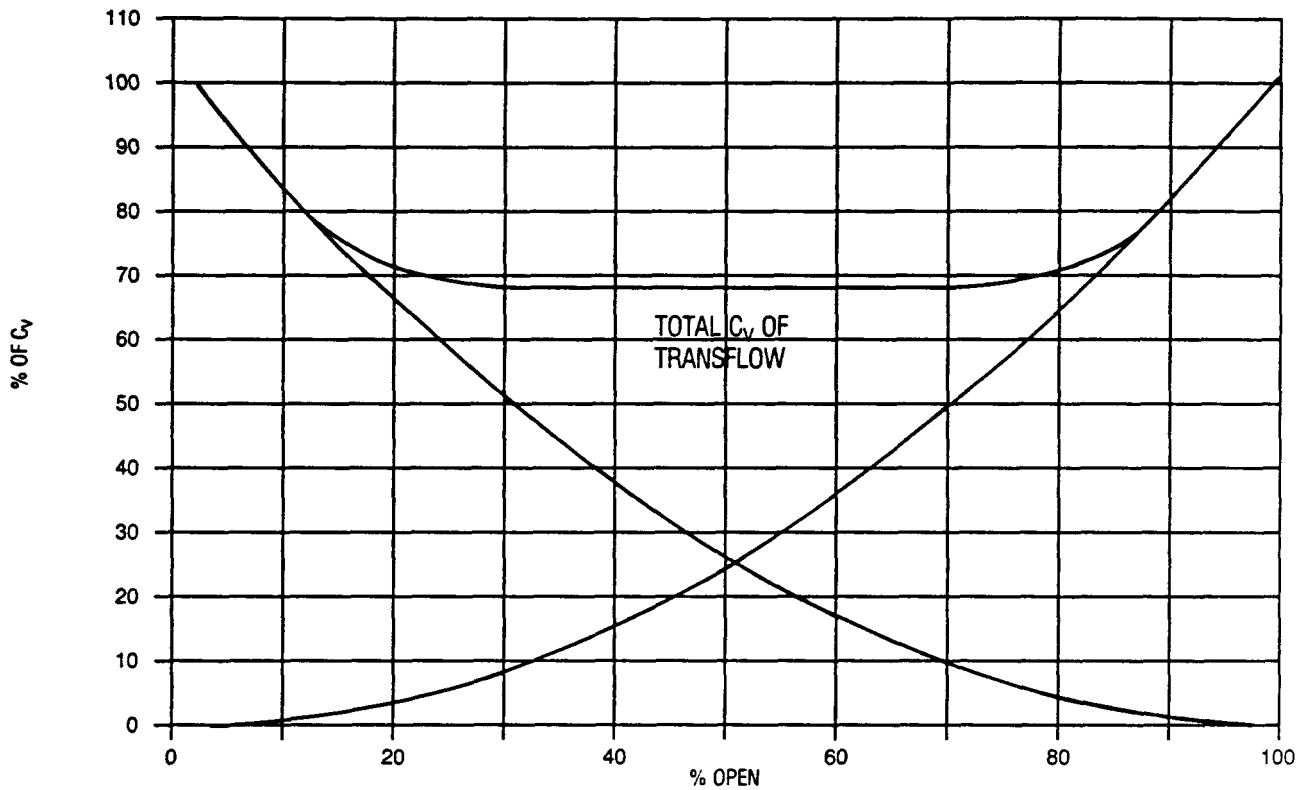
USED IN CONJUNCTION WITH CONCENTRIC REDUCER

Use appropriate torque tables on **PREVIOUS** page for:
G4 and G4B Marathon Plug Valve
TSG4 TSG4Z Plug Valve

Cv

Valve Size	#1	#3		#5		#7		#8		#13
	A<->C B<->C	B<->C	C<->A&B MAX	A<->B	B<->C	A<->C B<->C	C<->A&B MAX	A<->C B<->C	A<->B	A<->C B<->C
.5	5.4	5.4	7.4	2.4	2.4	5.4	7.4	2.4	2.4	5.4
.75	15.8	15.8	19.6	7.0	7.0	15.8	19.6	7.0	7.0	19.4
1	23.5	23.5	48.8	15.9	18.0	23.5	48.8	18.0	15.9	22.7
1.5	30.8	30.8	83.5	22.9	21.6	30.8	83.5	21.6	22.9	33.9
2	61.6	61.6	153	45.9	35.6	61.6	153	35.6	45.9	56.1
3	109	109	322	78	64	108	322	64	78	94
4	169	169	555	152	130	169	555	130	152	171
6	365*	365*	955*	272*	250*	365*	955*	250*	272	333*
8	525*	525*	1410*	500*	370*	525*	1410*	370*	500*	525*
10	770*	770*	2130*	720*	670*	770*	2130*	670*	720*	770*
12	872*	NA	NA	815*	758*	NA	NA	758*	815*	872*
FL ²	0.43	0.43	NA	0.47	0.47	0.43	NA	0.47	0.47	0.43
Xt	0.28	0.28	NA	0.30	0.30	0.28	NA	0.30	0.30	0.28

*Estimated Value



Characteristic Curve for MG Valve with Transflow Plug
For Typical Arrangement Numbers See Bulletin V-24

Mach 1
Sleeved Plug Valves
(Standard and V-Port)

Mach 1 Sizing torque.						
Size	(Port-seal)			(Sleeve)		
	C-C	Slurry	ALKY	C-C	Slurry	ALKY
1	260	351	439	310	419	523
1.5	370	500	624	430	581	726
2	550	743	928	600	810	1013
3	860	1161	1451	1020	1377	1721
4	2000	2700	3375	2200	2970	3713
6	4320	5832	7290	5200	7020	8775

Flow Coefficient (Cv) for Mach 1, V-Port valves, Port-Seal or Sleeved											
Valve Size	Pipe Size	Percent of rotation 0-90 degrees									
		10	20	30	40	50	60	70	80	90	100
1.00	1.00	0.16	0.61	1.33	2.29	3.55	4.94	6.66	8.49	10.64	13.00
1.00	1.50	0.15	0.56	1.21	2.08	3.23	4.50	6.06	7.72	9.68	11.83
1.00	2.00	0.13	0.50	1.08	1.85	2.87	4.00	5.39	6.87	8.61	10.52
1.00	1.00	0.09	0.33	0.72	1.23	1.91	2.66	3.59	4.57	5.73	7.00
1.00	1.50	0.08	0.30	0.65	1.12	1.74	2.42	3.26	4.16	5.21	6.37
1.00	2.00	0.07	0.27	0.58	1.00	1.55	2.15	2.90	3.70	4.64	5.67
1.00	1.00	0.05	0.19	0.41	0.70	1.09	1.52	2.05	2.61	3.27	4.00
1.00	1.50	0.05	0.17	0.37	0.64	0.99	1.38	1.86	2.38	2.98	3.64
1.00	2.00	0.04	0.15	0.33	0.57	0.88	1.23	1.66	2.11	2.65	3.24
1.50	1.50	0.38	1.46	3.18	5.46	8.45	11.79	15.88	20.24	25.36	31.00
1.50	2.00	0.37	1.41	3.07	5.28	8.18	11.40	15.37	19.59	24.55	30.00
1.50	3.00	0.36	1.37	2.97	5.10	7.91	11.02	14.86	18.93	23.73	29.00
2.00	2.00	0.57	2.17	4.71	8.10	12.55	17.49	23.57	30.03	37.64	46.00
2.00	3.00	0.55	2.09	4.54	7.80	12.08	16.84	22.70	28.92	36.24	44.30
2.00	4.00	0.53	2.01	4.36	7.50	11.62	16.19	21.82	27.81	34.85	42.59
3.00	3.00	1.14	4.33	9.43	16.20	25.09	34.98	47.14	60.07	75.27	92.00
3.00	4.00	1.11	4.23	9.19	15.79	24.47	34.11	45.97	58.58	73.41	89.72
3.00	6.00	1.06	4.01	8.73	14.99	23.22	32.37	43.63	55.60	69.67	85.16
4.00	4.00	2.08	7.91	17.22	29.57	45.82	63.87	86.08	109.69	137.45	168.00
4.00	6.00	2.02	7.66	16.67	28.64	44.37	61.85	83.36	106.22	133.11	162.69
4.00	8.00	1.94	7.37	16.04	27.55	42.68	59.50	80.19	102.18	128.05	156.51
6.00	6.00	3.87	14.70	31.97	54.92	85.09	118.61	159.87	203.70	255.27	312.00
6.00	8.00	3.75	14.26	31.01	53.27	82.54	115.05	155.07	197.59	247.61	302.64
6.00	10.00	3.71	14.11	30.69	52.73	81.69	113.87	153.47	195.55	245.06	299.52

Flow Coefficient (Cv) for Mach 1, Standard Port valves, Port-Seal or Sleeved											
Valve Size	Pipe Size	Percent of rotation 0-90 degrees									
		10	20	30	40	50	60	70	80	90	100
1.00	1.00	0.52	1.93	4.21	7.21	11.03	15.58	20.86	26.88	33.57	41.00
1.00	1.50	0.47	1.76	3.83	6.56	10.04	14.18	18.98	24.45	30.54	37.30
1.00	2.00	0.42	1.56	3.41	5.84	8.93	12.61	16.89	21.75	27.17	33.18
1.50	1.50	1.00	3.82	8.30	14.26	22.09	30.79	41.50	52.88	66.27	81.00
1.50	2.00	0.97	3.69	8.03	13.80	21.38	29.80	40.17	51.18	64.13	78.39
1.50	3.00	0.94	3.57	7.77	13.34	20.67	28.81	38.83	49.47	62.00	75.77
2.00	2.00	2.00	7.58	16.50	28.34	43.91	61.21	82.50	105.12	131.73	161.00
2.00	3.00	1.92	7.30	15.89	27.29	42.28	58.94	79.44	101.22	126.85	155.04
2.00	4.00	1.85	7.02	15.28	26.24	40.66	56.67	76.39	97.33	121.97	149.07
3.00	3.00	3.31	12.58	27.36	47.00	72.82	101.50	136.81	174.32	218.45	267.00
3.00	4.00	3.23	12.27	26.68	45.84	71.01	98.99	133.42	170.00	213.04	260.38
3.00	6.00	3.06	11.64	25.33	43.50	67.40	93.95	126.63	161.36	202.21	247.14
4.00	4.00	6.79	25.81	56.16	96.47	149.45	208.33	280.79	357.79	448.36	548.00
4.00	6.00	6.58	25.00	54.39	93.42	144.73	201.75	271.93	346.49	434.20	530.69
4.00	8.00	6.33	24.05	52.32	89.87	139.23	194.08	261.58	333.31	417.69	510.51
6.00	6.00	12.41	47.15	102.58	176.21	273.00	380.55	512.91	653.55	819.00	1001.00
6.00	8.00	12.04	45.74	99.50	170.92	264.81	369.13	497.52	633.94	794.43	970.97
6.00	10.00	11.91	45.27	98.48	169.16	262.08	365.32	492.39	627.40	786.24	960.96

Reduced capacities are calculated for installation with concentric reducers.

Fluorocarbon Lined Plug Valves (standard port only)

T4

Cv

Valve Size	Pipe Size	% Of Rotation 0 – 90 Degrees									
		10	20	30	40	50	60	70	80	90	100
.5	.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.00
.75	.75	NA	NA	NA	NA	NA	NA	NA	NA	NA	16.0
1	2	0.3	1.2	2.5	4.3	6.6	9.3	12.4	16.0	20.0	24.4
	1.5	0.4	1.4	3.0	5.2	7.9	11.2	15.0	19.3	24.1	29.4
	1	0.4	1.6	3.5	6.0	9.1	12.9	17.3	22.2	27.8	33.9
1.5	3	0.9	3.3	7.1	12.3	18.7	26.4	35.4	45.6	57.0	69.6
	2	1.1	4.1	8.8	15.1	23.1	32.6	43.6	56.2	70.2	85.8
	1.5	1.2	4.5	9.8	16.8	25.7	36.3	48.6	62.5	78.2	95.4
2	4	1.4	5.3	11.5	19.9	30	43	57	74	92	113
	3	1.7	6.3	13.6	23.4	36	50	68	87	109	133
	2	2.5	9.4	20.3	35.1	53	76	101	130	1639	199
3	6	2.6	9.8	21.2	36.6	56	79	106	136	170	208
	4	3.7	13.8	29.7	51.3	78	110	148	190	238	291
	3	4.4	16.3	35	60.4	92	130	174	225	281	343
4	8	7.1	26.3	56.8	97.9	150	211	283	364	455	556
	6	7.7	28.7	61.9	107	163	230	308	397	496	606
	4	10.4	38.6	83.1	143	219	309	414	533	666	813
6	10	10.0	37.0	79.8	138	210	297	397	511	639	780
	8	10.2	37.8	81.5	140	214	303	406	522	653	797
	6	14.1	52.4	113	195	297	420	562	724	905	1105
8	12	15.3	56.9	122	212	323	456	610	786	983	1200
	10	16.4	60.9	131	226	345	488	653	841	1052	1284
	8	18.2	67.6	146	251	383	541	725	934	1167	1425
10	10	27.6	102	221	380	580	820	1098	1415	1768	2159
12	12	41.0	152	328	564	860	1215	1628	2097	2621	3200
FL ²		0.94	0.94	0.92	0.88	0.82	0.79	0.75	0.67	0.57	0.50
Xt		0.16	0.64	0.64	0.72	0.79	0.61	0.51	0.37	0.24	0.16

USED IN CONJUNCTION WITH CONCENTRIC REDUCERS

See torque table on next page.

Fluorocarbon Lined Plug Valves

T4, ET41 & T43

(use for standard port and V-port plugs)

SIZING TORQUES (Inch-lbs.)

VALVE SIZE	T-LINE	
	C/C	SLY
<1	300	405
1	398	535
1.5	504	680
2	720	972
2.5	1060	1458
3	1060	1458
4	2100	2835
6	5700	7695
8	10000	13500
10	70000	C/F
12	80000	C/F

Note: For dry services, use slurry torque requirements

C/C= Clean Clear

SLY= Slurry

CF= Consult Factory

Fluorocarbon Lined Plug Valves (V-port only)

ET4

Cv

Valve Size	Pipe Size	% Of Rotation 0 – 90 Degrees									
		10	20	30	40	50	60	70	80	90	100
1	1	0.01	0.04	0.11	0.18	0.26	0.38	0.51	0.65	0.82	1
1	1	0.04	0.13	0.32	0.53	0.79	1.14	1.54	1.96	2.47	3
1	1	0.11	0.35	0.85	1.42	2.12	3.04	4.10	5.24	6.58	8
1	2	0.24	0.91	1.96	3.38	5.17	7.30	9.77	12.6	15.7	19.2
	1.5	0.28	1.02	2.21	3.81	5.81	8.21	11	14.2	17.7	21.6
	1	0.30	1.11	2.38	4.11	6.27	8.86	11.9	15.3	19.1	23.3
1.5	3	0.5	1.7	3.8	6.5	9.9	14.1	18.8	24.2	30.3	37.0
	2	0.5	1.8	3.9	7.0	10.7	15.1	20.2	26.0	32.5	39.6
	1.5	0.5	1.9	4.0	7.0	10.7	15.1	20.2	26.0	32.5	39.6
2	4	0.5	1.9	4.1	7.1	10.8	15.2	20.4	26.3	32.8	40.1
	3	0.5	2.0	4.3	7.4	11.4	16.0	21.5	27.7	34.6	42.2
	2	0.6	2.1	4.5	7.7	11.8	16.7	22.3	28.7	35.9	43.8
3	6	0.8	2.9	6.3	10.8	16	23	31	40	50	61
	4	0.8	3.1	6.6	11.4	17	25	33	42	60	65
	3	0.8	3.1	6.8	11.7	18	25	34	43	54	66
FL²		0.96	0.96	0.95	0.94	0.93	0.86	0.73	0.64	0.56	0.45
Xt		0.23	0.39	0.64	0.75	0.73	0.64	0.49	0.33	0.28	0.28

USE IN CONJUNCTION WITH CONCENTRIC REDUCERS

See torque table on previous page.

BX2001 Valve
Big Max Butterfly Valves
ANSI Class 150# Series

Cv

Valve Size	% Of Rotation 0-90 Degees									
	10	20	30	40	50	60	70	80	90	100
2	2	9	19	38	49	59	62	65	68	68
3	3	15	33	63	87	102	110	115	120	120
4	7	37	75	120	160	185	225	260	295	305
6	20	100	195	275	350	415	505	615	782	900
8	54	158	269	396	560	747	948	1153	1409	1516
10	99	277	437	650	950	1351	1808	2182	2686	3503
12	180	386	635	1011	1477	2070	2710	3582	4534	4859
FL²	0.74	0.72	0.70	0.67	0.64	0.63	0.60	0.57	0.55	0.54
Xt	0.46	0.41	0.39	0.37	0.34	0.29	0.27	0.24	0.23	0.21
14	231	544	884	1428	2108	3060	4080	5100	6120	6800
16	305	704	1144	1848	2728	3960	5280	6600	7920	8800
18	345	805	1380	2300	3450	5175	6900	8625	10350	11500
20	420	1120	1820	2940	4340	6300	8400	10500	12600	14000
24	615	1640	2665	4305	6355	9225	12300	15375	18450	20500
30	930	2480	4030	6510	9610	13950	18600	23250	27900	31000
36	1340	3570	5800	9370	13840	20090	26780	33480	40180	44640
FL²	0.60	0.60	0.57	0.56	0.54	0.53	0.49	0.43	0.35	0.25
Xt	0.42	0.42	0.42	0.42	0.39	0.38	0.34	0.25	0.20	0.16

See torque tables on pages 37 and 38.

BX2001 Valve
BIG MAX Butterfly Valves
ANSI Class 150# Series and 300# Series

BX2001 Valve Sizing Torque (inch pounds)
 Torques Are Based On Closing Upstream - max flow 10 ft/sec
 for flows greater than 10 ft/sec use max delta P on chart.

BX2001	Standard PFA/Viton Seat Only													
	Shut Off Pressure													
Size	50	100	150	200	250	285	300	400	500	600	700	740		
2	150	190	210	230	250	262	270	315	360	410	450	480		
3	210	250	345	410	465	525	545	660	780	850	960	980		
4	315	475	545	624	684	744	749	780	860	1,032	1,260	1,320		
5* & 6	720	840	1,020	1,200	1,284	1,440	1,491	1,780	2,040	2,260	2,480	2,560		
8	900	950	1,350	1,600	1,900	2,000	2,080	2,535	3,225	3,825	4,375	4,550		
10	1800	2,650	2,900	3,300	3,960	4,560	4,659	5,220	5,940	6,470	7,460	7,850		
12	2200	3,200	3,850	4,620	5,280	5,950	6,130	7,150	8,000	8,975	10,150	11,000		
	2" - 12" (1) 2" -12" Triple Seal-use standard seat values times 1.5. (2) For BX series valves (standard seat), use Firesealed BX2001													
	NOTES: values.													
Size	Shut Off Pressure													
	25	50	75	100	125	150	200	285	300	400	500	600	700	740
14	5,400	6,200	6,700	6,820	7,000	7,200	7,500	9,000	9,288	10,920	12,546	14,172	14,988	15,396
16	6,300	7,100	7,200	7,200	7,320	7,800	8,640	11,040	11,364	13,200	14,286	15,372	16,724	17,400
18	7,452	8,400	8,520	9,120	9,600	10,200	11,880	15,000	15,225	16,500	17,858	19,215	20,905	21,750
20	8,640	9,840	10,320	10,800	11,400	12,000	14,640	19,800	20,730	26,000	30,300	34,600	37,200	39,100
24	11,880	13,200	13,200	13,440	14,280	15,000	16,800	23,760						
30	18,900	21,600	21,840	22,800	24,000	25,800	27,420	43,440						
36	26,037	30,240	31,140	32,040	33,595	35,150	41,520	63,745						
* 5" available in 150# only														

BX2001	Apex, Firesealed, Std. PFA/Inconel and UHMWPE seats Only													
	Shut Off Pressure (psig)													
Size	50	100	150	200	250	285	300	400	500	600	700	740		
2	200	253	279	306	333	359	389	419	479	545	599	638		
3	280	335	460	545	620	700	710	760	820	880	960	1000		
4	420	630	725	830	910	990	1005	1080	1190	1310	1410	1470		
5* & 6	960	1120	1360	1595	1710	1915	1947	2125	2420	2700	3400	3750		
8	1195	1265	1795	2130	2530	2660	2726	3100	3560	4000	4475	4800		
10	2395	3525	3860	4390	5265	6065	6197	6943	7900	8605	9922	10441		
12	2926	4256	5121	6145	7022	7914	8153	9510	10640	11937	13500	14630		
Size	Shut Off Pressure													
	25	50	75	100	125	150	200	285	300	400	500	600	700	740
14	6000	6200	6700	6820	7000	7200	7500	9000	9288	10920	12546	14172	14980	15396
16	7000	7100	7200	7200	7320	7800	8640	11040	11364	13200	14251	15372	16710	17400
18	8280	8400	8520	9120	9600	10200	11880	15000	15225	16500	17858	19215	20888	21750
20	9600	9840	10320	10800	11400	12000	14640	19800	23570	32500	37875	43250	46500	48875
24	13200	13200	13200	13440	14280	15000	16800	23760						
30	21000	21600	21840	22800	24000	25800	27420	43440						
36	28930	30240	31140	32040	33595	35150	41520	63745						
* 5" available in 150# only														

SIZING TORQUES (Inch - lbs.)
BX2001 Valve Sizing Torque (inch pounds)

Torques Are Based On Closing Upstream - max flow 10 ft/sec
 for flows greater than 10 ft/sec use max delta P on chart.

BX2001 Valve
BIG MAX Butterfly Valves
ANSI Class 150# and 300# Series
Triflex Metal Seat (70°F)

BX2001 Size	BX2001 - Triflex Metal Seat (70 Deg. F)												
	Shut Off Pressure (psig)												
	50	100	150	200	250	285	300	400	500	600	700	740	
2	308	345	390	435	480	623	684	792	900	963	981	981	
3	410	460	520	580	640	830	912	1056	1200	1284	1308	1308	
4	765	855	970	1200	1430	1605	1680	1956	2184	2258	2292	2292	
6	1410	1570	1735	1920	2100	2472	2904	3276	3540	3732	3780	3780	
8	2630	2930	3305	3670	4030	5115	5580	6300	6840	7104	7200	7200	
10	4590	4995	5510	6070	6630	8373	9120	10320	11160	11168	12000	12000	
12	7140	8060	9080	10100	11120	13836	15000	16800	18240	18250	19200	19200	
Size	Shut Off Pressure												
	0	50	100	150	200	250	285	300	400	500	600	700	740
14	10320	11520	12840	14340	15600	17160	1800	19260	23780	29350	36240	44740	48720
16	13800	15300	17040	18900	20880	22800	24000	25210	30450	36770	44400	53620	57860
18	15600	17400	19560	21600	24000	26280	27600	28980	34100	42260	51040	61630	66510
20	17400	19800	21840	24000	27000	29400	30600	32600	38363	47543	57420	69334	74824
24	19560	22260	24540	27000	30300	32930	34660						
30	22020	25020	27600	30360	34140	37110	39060						

SIZING TORQUES (Inch - lbs.)

BX2001 Size	BX2001 - Triflex Metal Seat (800 Deg. F)								
	Shut Off Pressure (psig)								
	0	20	40	60	80	100	200	300	410
2	338	368	399	430	461	576	729	864	981
3	450	491	532	573	614	768	972	1152	1308
4	715	782	849	916	983	1236	1560	1848	2040
6	1430	1558	1686	1814	1942	2436	3036	3480	3780
8	2755	3000	3245	3490	3735	4680	5820	6660	7200
10	5100	5465	5834	6200	6586	8160	9840	11280	12000
12	8160	8731	9302	9873	10444	12960	15840	17880	19200
14	16800	17100	17400	17700	18000	18370	20320	22480	25120
16	22200	22656	23100	23556	24000	24490	27060	29970	33500
18	25800	26256	26700	27156	27600	28160	31160	34470	38520
20	44400	45300	46200	47100	48000	49280	54530	60323	67410
24	76560	78120	79655	81216	82800				
30	1E+05	1E+05	1E+05	1E+05	1E+05				

BX2001 Valve
BIG MAX Butterfly Valves
ANSI Class 150# and 300# Series
Triflex Metal Seat (800°F)

SIZING TORQUES (Inch - lbs.)

BX2001 Size	BX2001 - Triflex Metal Seat (1000 Deg. F)							
	Shut Off Pressure (psig)							
	0	10	20	50	100	200	300	355
2	445	623	741	780	913	1170	1397	1490
3	495	692	823	867	1014	1300	1552	1656
4	870	915	945	1020	1193	1530	1826	1948
6	1580	1658	1710	1836	2111	2621	3060	3213
8	3010	3163	3265	3519	4029	4998	5814	6120
10	5510	5756	5920	6324	7140	8670	9792	10200
12	8160	8619	8925	9690	11118	13668	13804	15470
14	16800	17400	18000	20030	23100	30560	43640	55303
16	22200	23100	24000	26710	30800	33160	48850	63700
18	25800	26700	27600	30620	35160	49700	70230	87950
20	44400	46200	48000	52054	59772	84490	1E+05	1E+05
24	76560	79655	82800					
30	1E+05	1E+05	1E+05					

BX2001 Valve
BIG MAX Butterfly Valves
ANSI Class 150# and 300# Series
Triflex Metal Seat (1000°F)

BTV Valve
Fluorocarbon Lined Butterfly Valves
ANSI Class 150# Series

Cv

Valve Size	Pipe Size	Degrees Open						
		30deg.	40deg.	50deg.	60deg.	70deg.	80deg.	90deg.
			45deg.=50%Open					100% open
2	2 - 3	3	8	16	25	43	69	93
3	3 - 6	9	28	55	85	148	234	316
4	4 - 8	16	47	94	146	253	399	540
6	6 - 10	42	122	243	376	653	1033	1396
8	8 - 12	92	268	535	827	1435	2269	3068
FL²		0.74	0.75	0.75	0.76	0.69	0.59	0.51
Xt		0.51	0.53	0.54	0.53	0.48	0.44	0.40
10	10 - 14	152	443	885	1368	2373	3754	5075
12	12 - 16	233	676	1353	2091	3628	5739	7758
14	14 - 18	282	820	1639	2533	4395	6953	9400
16	16 - 20	372	1080	2160	3338	5792	9163	12387
18	18 - 22	474	1379	2757	4261	7393	11695	15810
20	20 - 24	586	1703	3406	5263	9132	14446	19530
24	24 - 30	655	1926	3852	6642	11452	18177	24564
FL²		0.65	0.66	0.67	0.70	0.47	0.39	0.30
Xt		0.51	0.53	0.54	0.53	0.48	0.44	0.40

See torque tables on next page.

BTV Valve
 Fluorocarbon Lined Butterfly Valves
 ANSI Class 150# Series
 Clean / Clear Service*

SIZING TORQUES (Inch - lbs.)

VALVE SIZE	SHUT OFF PRESSURE (psi)		
	0-100	125	150
2	360	360	360
3	420	420	420
4	720	720	720
6	1440	1440	1440
8	1800	1800	1800
10	3600	3600	3600
12	4800	4800	4800
14	6900	7560	8160
16	9000	9960	10920
18	10920	11400	12000
20	12500	12960	13440
24	20270	21280	21800

*For slurry service, multiply torque values above by 1.35.

BUV Valve
 UHMWPE Lined Butterfly Valves
 ANSI Class 150# Series
 Clean / Clear Service*

SIZING TORQUES (Inch - lbs.)

VALVE SIZE	SHUT OFF PRESSURE (psi)		
	0 100	125	150
2	648	648	648
3	756	756	756
4	1296	1296	1296
6	3110	3110	3110
8	3888	3888	3888
10	6480	6480	6480
12	8640	8640	8640
14	13200	14040	14880
16	19200	21960	24000
18	24000	30000	39600
20	30000	38400	45600
24	48385	59030	68475

*For slurry service, multiply torque values above by 1.35.

Atomac AKH3 Valve

Standard Port Ball Valve

FEP & PFA Lined

Cv

Valve Size	% Of Rotation, 0-90 Degrees									
	10	20	30	40	50	60	70	80	90	100
1	0.3	0.6	1.0	1.7	2.9	4.7	7.9	12.2	22.0	36.7
2	0.5	0.9	1.4	2.4	4.0	6.6	11.1	17.0	30.7	51.3
2	1.7	3.1	5.2	8.6	14.3	23.8	39.8	61.0	110.2	184.1
3	1.9	3.5	5.8	9.7	16.1	26.7	44.7	68.6	123.9	207.0
4	6.3	11.5	18.9	31.5	52	87	146	223	404	675
6	8.6	15.7	25.7	42.8	71	118	198	304	549	917
8	17.7	32.5	53.2	88.7	148	245	411	630	1139	1902
10	39.6	72.6	118.8	198.0	330	548	918	1406	2542	4245
12	30.3	55.5	90.9	151.5	252	419	702	1075	1944	3246
FL ²	0.94	0.94	0.92	0.88	0.82	0.79	0.75	0.67	0.57	0.5
X _t	0.16	0.64	0.64	0.72	0.79	0.61	0.51	0.37	0.24	0.16

Atomac AKH3V Valve

V- Port Ball Valve

FEP & PFA Lined

Cv

Valve Size	% Of Rotation 0-90 Degees									
	10	20	30	40	50	60	70	80	90	100
1	N/A	0	0	0.4	1.0	2.0	2.9	3.9	5.0	5.7
1	N/A	0	0	0.6	1.5	3.0	4.9	7.2	10.5	13.9
1.5	N/A	0	0	0.6	1.8	3.7	6.0	8.6	12.5	14.8
2	N/A	0.3	1.7	4.2	7.1	11.6	18.3	27.1	37.7	40.6
3	N/A	0.7	3.0	6.5	11.6	18.6	28.2	41.0	56.9	64.7
FL ²	0.96	0.96	0.95	0.94	0.93	0.86	0.73	0.64	0.56	0.45
X _t	0.23	0.39	0.64	0.75	0.73	0.64	0.49	0.33	0.28	0.28

See torque tables next page.

Atomac CAKH3V Valve

C-Ball Standard Port Ball Valve

FEP & PFA Lined

Cv

Valve Size	% Of Rotation 0-90 Degees									
	10	20	30	40	50	60	70	80	90	100
1	0.29	0.47	0.79	1.4	2.4	4	6.7	11.2	18.7	31.2
1.5	0	0	0.87	3.5	8.75	13.5	21.1	34.3	46.4	50.2
2	0.1	2.5	6	11	17	28	43	66	122	195
3	2.7	4.5	7.5	12.5	20.8	34.8	55.8	93	136.5	227.7
4	0	7.3	25.3	60.6	107.6	170.5	268	372.2	651	651
FL ²	0.96	0.96	0.95	0.94	0.93	0.86	0.73	0.64	0.56	0.45
X _t	0.23	0.39	0.64	0.75	0.73	0.64	0.49	0.33	0.28	0.28

See torque tables next page.

Atomac AKH3 Valve
 Standard Port Ball Valve
 FEP & PFA Lined
 Clean / Clear Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
1	60	65	70
1.5	65	70	75
2	180	240	300
3	240	300	400
4	525	750	960
6	700	1050	1400
8	1593	2390	2921
10	4248	6195	7965
12	4248	6195	7965

Atomac CAKH3V Valve
 C-Ball Standard Port Ball Valve
 FEP & PFA Lined
 Clean / Clear Service

Atomac AKH3 Valve
 Standard Port Ball Valve
 FEP & PFA Lined
 Slurry Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (PSIG)		
	0	150	275
1	78	85	91
1.5	78	85	91
2	234	312	390
3	312	390	520
4	683	975	1248
6	910	1365	1820
8	2071	3107	3797
10	5523	8054	10355
12	5523	8054	10355

Atomac CAKH3V Valve
 C-Ball Standard Port Ball Valve
 FEP & PFA Lined
 Slurry Service

Atomac AKH2* Valve
 Full Port Ball Valve
 FEP & PFA Lined

Cv

Valve Size	Cv At Full Open
.5	10
.75	24
1	40
1.5	173
2	323
3	831
4	1700
6	4860
8RP	3144
8FP	8320
10	11900
12	18342
FL²	.14
Xt	.30

See torque tables next page.

*See page 46 for AKH2A data.

Note: Some documents refer to Atomac capacities in K_v

To convert: $K_v = 0.86 \times C_v$

$C_v = 1.16 \times K_v$

Atomac AKH2 Valve
 Full Port Ball Valve
 FEP & PFA Lined
 Clean / Clear Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
0.5	60	65	70
0.75	60	65	70
1	65	70	75
1.5	180	240	300
2	240	300	400
3	525	750	960
4	700	1050	1400
6	1593	2390	2921
8RP	1593	2390	2921
8FP	4248	6195	7965
10	4425	11770	14691
12	6638	17700	22125

RP = Reduced Port
 FP = Full Port

Atomac AKH2 Valve
 Full Port Ball Valve
 FEP & PFA Lined
 Slurry Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (PSIG)		
	0	150	275
0.5	78	85	91
0.75	78	85	91
1	85	91	98
1.5	234	312	390
2	312	390	520
3	683	975	1248
4	910	1365	1820
6	2071	3107	3797
8RP	2071	3107	3797
8FP	5522	8054	10355
10	5753	15301	19098
12	8629	23010	28763

RP = Reduced Port
 FP = Full Port

Atomac AKH5 Valve
 Full Port Ball Valve
 Ceramic Lined

Cv

Valve Size	Cv At Full Open
1	40
1.5	173
2	323
3	831
4	1700
FL ²	.14
Xt	.30

Atomac AKH5 Valve
 Full Port Ball Valve
 Ceramic Lined (Liner & Ball)*
 Clean / Clear Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
1	27	31	44
1.5	53	84	93
2	97	186	221
3	443	841	1106
4	487	1106	1460

*For metal stems only, contact factory for ceramic stem torques.

Atomac AKH5 Valve
 Full Port Ball Valve
 Ceramic Lined (Liner & Ball)*
 Slurry Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (PSIG)		
	0	150	275
1	50	81	134
1.5	100	175	306
2	181	412	750
3	825	2062	3650
4	925	2625	3937

Atomac AKH2A Valve
 Full Port Ball Valve
 FEP & PFA Lined

Cv

Valve Size	Cv At Full Open
1	54.1
1.5	147.5
2	235.4
3	590.2
4	1108.8
6	1833
FL ²	.14
Xt	.30

Atomac AKH2A Valve
 Full Port Ball Valve
 FEP & PFA Lined
 Clean / Clear Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
1	65	70	75
1.5	180	240	300
2	240	300	400
3	443	558	752
4	558	858	1097
6	1416	2124	2744

Atomac AKH2A Valve
 Full Port Ball Valve
 FEP & PFA Lined
 Slurry Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (PSIG)		
	0	150	275
1	85	91	98
1.5	234	312	390
2	312	390	520
3	576	725	978
4	725	1115	1426
6	1841	2761	3567

Atomac AKH6 Valve
 Tank Drain Ball Valve
 FEP & PFA Lined

Cv

Valve Size	Cv At Full Open
1 x 2	70
1.5 x 3	186
2 x 3	290
2 x 3	290
3 x 4	767
4 x 6	1200
6 x 8	3525
FL ²	.50
Xt	.16

Atomac AKH6 Valve
 Tank Drain Ball Valve
 FEP & PFA Lined
 Clean / Clear Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
1 x 2	65	70	75
1.5 X 3	180	240	300
2 x 3	240	300	400
2 x 4	240	300	400
3 x 4	700	1050	1400
4 x 6	1593	2390	2921

Atomac AKH6 Valve
 Tank Drain Ball Valve
 FEP & PFA Lined
 Slurry Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (PSIG)		
	0	150	275
1 x 2	85	91	98
1.5 X 3	234	312	390
2 x 3	312	390	520
2 x 4	312	390	520
3 x 4	683	975	1248
4 x 6	910	1365	1820
6 X 8	2071	3107	3797

Atomac AMP3 Valve
 3-Way Ball Valve
 FEP & PFA Lined

Cv

Valve Size	Cv At Full Open
1	14.9
1.5	38.6
2	60.6
3	126
4	222
FL ²	.47
Xt	.30

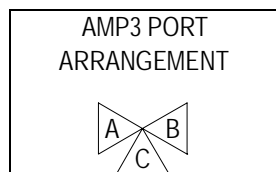
Atomac AMP3 Valve
 3-Way Ball Valve
 FEP & PFA Lined
 Clean / Clear Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
1	124	177	202
1.5	195	266	304
2	266	363	553
3	725	1018	1550
4	970	1355	2015

All AMP3 Sizing Torques are for the Following Flow Arrangements:

- L Arrangement - Ports A or B to C
- T Arrangement - Port A to B & C
- Or Port B to A & C Only.
- For all Others, Consult Factory.



Atomac AMP3 Valve
 3-Way Ball Valve
 FEP & PFA Lined
 Slurry Service

SIZING TORQUES (Inch - lbs.)

Valve Size	Shut-Off Pressure (psig)		
	0	150	275
1	161	230	263
1.5	254	346	395
2	346	472	719
3	943	1323	2015
4	1261	1762	2620

Microfinish BR2 Valve
 150# Flanged, Regular Port Ball Valve

Cv

Valve Size	% Of Rotation 0 – 90 Degrees									
	10	20	30	40	50	60	70	80	90	100
.5	0	0.1	0.2	0.5	0.8	1.4	2.5	3.9	6.4	8.0
.75	0	0.2	0.4	0.9	1.5	2.7	4.7	7.4	12.0	15.0
1	0	0.4	0.9	2.1	3.5	6.1	10.5	16.7	27.2	34.0
1.5	0	1.3	3.2	7.3	12.3	21.6	37	59	96	120
2	0	1.5	3.7	8.5	14.4	25.2	43	69	112	140
3	0	3.4	8.6	19.7	33	59	101	159	260	325
4	2.1	5.7	14.3	33	55	97	167	265	432	540
6	3.2	8.4	21	48	81	142	245	387	632	790
8	10.8	21	53	121	205	360	620	980	1600	2000
FL ²	0.94	0.94	0.92	0.88	0.82	0.79	0.75	0.67	0.57	0.50
Xt	.78	.75	.70	.66	.63	.56	.49	.38	.26	.16

Microfinish BR2 Valve
 150# Flanged, Regular Port Ball Valve

SIZING TORQUES (Inch - lbs.)

VALVE SIZE		Shut off pressure (psig)	
(Inches)	(mm)	100 PSI	285 PSI
		Inch-pound	Inch
.5	15	35	40
.75	20	35	40
1	25	70	85
1.5	40	163	197
2	50	224	243
3	80	556	673
4	100	750	1170
6	150	1840	2530
8	200	2640	3360

Microfinish BF2 Valve
Full Port Flanged Ball Valve

Cv

Valve Size	% Of Rotation With Live Zero									
	10	20	30	40	50	60	70	80	90	100
.5	0	0.2	0.5	1.2	2.1	3.6	6.2	9.8	16.0	20.0
.75	0	0.4	1.1	2.4	4.1	7.2	12.4	19.6	32	40
1	0	1.0	2.4	5.4	9.2	16.2	27.9	44	72	90
1.5	0	2.4	6.1	13.9	23.6	41	71	113	184	230
2	0	4.8	11.9	27.2	46	81.0	140	221	360	450
3	3.8	11.7	29.1	67	113	198	341	539	880	1100
4	8.3	23.3	58	133	226	396	682	1078	1760	2200
6	17.8	55	138	315	534	936	1612	2548	4160	5200
8	39	106	264	605	1026	1800	3100	4900	8000	10000
FL ²	.94	.92	.88	.79	.68	.54	.44	.34	.24	.15
Xt	.78	.75	.70	.66	.63	.56	.49	.38	.26	.16

Microfinish BF2 Valve
Full Port Flanged Ball Valve

SIZING TORQUES (Inch - lbs.)

VALVE SIZE		Shut off pressure (psig)	
		100 PSI	285 PSI
(Inches)	(mm)	Inch-pound	Inch
.5	15	40	46
.75	20	70	85
1	25	80	98
1.5	40	230	276
2	50	259	460
3	80	660	1170
4	100	1287	2038
6	150	3269	4800
8	200	4800	6000

MICROFINISH BR38 VALVE
Regular Port Threaded 800# Ball Valve

Cv

Valve Size	% Of Rotation 0 – 90 Degrees									
	10	20	30	40	50	60	70	80	90	100
.5	0	0.1	0.2	0.5	0.8	1.4	2.5	3.9	6.4	8.0
.75	0	0.2	0.4	0.9	1.5	2.7	4.7	7.4	12.0	15.0
1	0	0.4	0.9	2.1	3.5	6.1	10.5	16.7	27.2	34.0
1.5	0	1.3	3.2	7.3	12.3	21.6	37	59	96	120
2	0	1.5	3.7	8.5	14.4	25.2	43	69	112	140
FL ²	NA	0.94	0.92	0.88	0.82	0.79	0.75	0.67	0.57	0.50
Xt	NA	.78	.75	.70	.66	.63	.56	.49	.38	.26

MICROFINISH BR38 VALVE
Regular Port Threaded 800# Ball Valve

SIZING TORQUES (Inch - lbs.)

VALVE SIZE	Class 800	
	Full Port	Regular Port
.5	68	68
.75	135	68
1	225	135
1.5	506	383
2		506

Torques based on standard seat (e.g. glass filled TFE).

Microfinish BR38 Valve
Full Port Threaded 800# Ball Valve

Cv

Valve Size	% Of Rotation 0 – 90 Degrees									
	10	20	30	40	50	60	70	80	90	100
.5	0	0.2	0.5	1.2	2.1	3.6	6.2	9.8	16.0	20.0
.75	0	0.4	1.1	2.4	4.1	7.2	12.4	19.6	32	40
1	0	1.0	2.4	5.4	9.2	16.2	27.9	44	72	90
1.5	0	2.4	6.1	13.9	23.6	41	71	113	184	230
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FL ²	NA	.92	.83	.73	.63	.53	.44	.34	.24	.15
Xt	NA	.75	.70	.66	.63	.56	.49	.38	.26	.16

Microfinish BF2K Valve
Full Port Threaded WOG Ball Valve

Cv

Valve Size	% Of Rotation 0 – 90 Degrees									
	10	20	30	40	50	60	70	80	90	100
.25	0	0.1	0.2	0.5	0.8	1.4	2.5	3.9	6.4	8.0
.375	0	0.1	0.3	0.6	1.0	1.8	3.1	4.9	8.0	10.0
.5	0	0.2	0.6	1.4	2.4	4.1	7.1	11.3	18.4	23.0
.75	0	0.5	1.2	2.7	4.6	8.1	14.0	22.1	36.0	45.0
1	0	1.0	2.4	5.4	9.2	16.2	27.9	44.1	72.0	90.0
1.25	0	1.7	4.4	10.0	16.9	29.7	51.2	80.9	132	165
1.5	0	2.4	6.1	13.9	23.6	41.4	71.3	113	184	230
2	0	4.8	11.9	27.2	46.2	81.0	140	220	360	450
FL ²	NA	.92	.88	.79	.68	.54	.44	.34	.24	.15
Xt	NA	.78	.75	.70	.66	.63	.56	.49	.38	.26

Microfinish BF2K Valve
Full Port Threaded WOG Ball Valve

SIZING TORQUES (Inch - lbs.)

VALVE SIZE	PORT SIZE	BF2K
.25	FB	43
.375	FB	43
.5	FB	55
.75	FB	85
1	FB	115
1.25	FB	170
1.5	FB	219
2	FB	340

Torques based on standard seat (e.g. glass filled TFE)

Microfinish BF3K Valve
Full Port Threaded WOG Ball Valve

Cv

Valve Size	% Of Rotation 0 – 90 Degrees									
	10	20	30	40	50	60	70	80	90	100
.25	0	0.1	0.2	0.5	0.8	1.4	2.5	3.9	6.4	8.0
.375	0	0.1	0.3	0.6	1.0	1.8	3.1	4.9	8.0	10.0
.5	0	0.2	0.6	1.4	2.4	4.1	7.1	11.3	18.4	23.0
.75	0	0.5	1.2	2.7	4.6	8.1	14.0	22.1	36.0	45.0
1	0	1.0	2.4	5.4	9.2	16.2	27.9	44.1	72.0	90.0
1.25	0	1.7	4.4	10.0	16.9	29.7	51.2	80.9	132	165
1.5	0	2.4	6.1	13.9	23.6	41.4	71.3	113	184	230
2	0	4.8	11.9	27.2	46.2	81.0	140	220	360	450
FL ²	NA	.92	.88	.79	.68	.54	.44	.34	.24	.15
Xt	NA	.78	.75	.70	.66	.63	.56	.49	.38	.26

MICROFINISH BF3K VALVE
Full Port Threaded WOG Ball Valve

SIZING TORQUES (Inch - lbs.)

VALVE SIZE	PORT SIZE	BF3K
.25	FB	49
.375	FB	49
.5	FB	79
.75	FB	105
1	FB	164
1.25	FB	255
1.5	FB	316
2	FB	365

Torques based on standard seat (e.g. glass filled TFE)



Section Four

Reference Data

PRESSURE

To accurately size control valves, we must fully understand the various pressure terms used in the instrument world. The pressure measurement identifications most frequently encountered in valve applications are: *absolute pressure, gauge pressure, vacuum, and differential pressure.*

DEFINITIONS:

- a) ABSOLUTE PRESSURE -expressed "pounds per square inch absolute," or psia.
- b) GAUGE PRESSURE -expressed "pounds per square inch gauge," or psig.
- c) VACUUM -is a special case of gauge pressure; i.e., vacuum is negative gauge pressure or any pressure less than atmospheric pressure.
- d) DIFFERENTIAL PRESSURE-is the difference between two pressure points in a system and is expressed as ΔP .

Here are some basic relationships between gauge pressure, absolute pressure and vacuum.

- a) absolute pressure = atmospheric pressure + gauge pressure.
- b) absolute pressure = atmospheric pressure - vacuum.
- c) gauge pressure = -vacuum.

EXAMPLES:

1. Convert 100 psig to absolute

- a) $P_{abs} = 100 + 14.7 = 114.7$ at sea level
- b) $P_{abs} = 100 + 12.7 = 112.7$ at 4,000 feet

2. Convert 20.36 in Hg Vacuum to psia

- a) $P_{gauge} = \frac{in-Hg}{2.036} = \frac{20.36}{2.036} = 10$ psig
 $P_{gauge} = -vacuum = -10$ psig vacuum
- b) $P_{abs} = P_{atmos} - vacuum$
 $P_{abs} = 14.7 - 10$ psig = 4.7 psia at sea level
 $P_{abs} = 12.7 - 10$ psig = 2.7 psia at 4,000 feet

3. Convert 100 psia to psig

- a) $P_{abs} = P_{atmos} + P_{gauge}$
- b) $P_{gauge} = P_{abs} - P_{atmos}$
 $P_{gauge} = 100$ psi - 14.7 psia = 85.3 psig at sea level

USEFUL EQUIVALENTS

- 1 US Gallon of Water = 8.33 pounds @ 60⁰ F
1 Cubic Foot of Water = 62.34 pounds @ 60⁰ F

1 Cubic Foot of Air = .076 pounds (Std. Pressure and temperature)
 1 Pound of Air = 13.1 Cubic Feet (Std. pressure and temperature)

$$\frac{\text{Gas Molecular Weight}}{29} = \text{Specific gravity of that gas}$$

Molecular Weight of Air = 29

Density = Specific Weight

1 Nautical Mile = Dist. Subtended By One Min. at Equator.

1 Light Band = 0.0000118"

1 Micron = 0.001 Millimeter

1 Micron = One Millionth of A Meter

Big Calorie = 1 Kilogram: 1°C.

Little Calorie = 1 Gram: 1°C.

$$\text{Visibility in Miles} = \sqrt{1.5 \times \text{Ht. in Feet}}$$

1 Part Per Million = 0.0001 per cent

1 mil (Corrosion) = 0.001"

$$\text{Surface Speed (Rotating Shaft) In Feet/Sec.} = \frac{\text{Dia. (Inches)} \times \text{RPM}}{229}$$

$$\text{Torsional Shaft Stress (Pds/Sq. in.)} = \frac{321,000 \times \text{HP}}{\text{RPM} \times \text{Dia}^3 \text{ (Inches)}}$$

MASS RATE

Where:

Standard conditions (scfh) are 14.7 psia and 60⁰ F

Normal conditions (norm) are 760 mm Hg and 0⁰ C

SG₁ Water = 1 at 60⁰ F

SG₂ Water = 1 at 4⁰ C

M = Molecular weight

W₁ = Specific weight lb/ft³ (std.)

W₂ = Specific weight kg/m³ (norm)

G₁ = Specific gravity air = 1 at (std.)

G₂ = Specific gravity air = 1 at (norm)

GASES

$$\text{scfh} = \frac{(\text{lb} / \text{hr}) \times 379}{M}$$

$$\text{m}^3 / \text{hr}(\text{norm}) = \frac{(\text{kg} / \text{hr}) \times 22.40}{M}$$

$$\text{scfh} = \frac{\text{lb} / \text{hr}}{W}$$

$$\text{m}^3 / \text{hr}(\text{norm}) = \frac{\text{kg} / \text{hr}}{W}$$

$$\text{scfh} = \frac{(\text{lb} / \text{hr}) \times 13.1}{G_1}$$

$$\text{m}^3 / \text{hr}(\text{norm}) = \frac{(\text{kg} / \text{hr}) \times 0.82}{G}$$

LIQUID

$$USgal / \text{min} = \frac{lb / hr}{500 \times SG_1}$$

$$m^3 / hr = \frac{0.001kg / hr}{SG_2}$$

VACUUM EQUIVALENTS

PSIA	INCHES IN MERCURY	MILLIMETERS OF MERCURY (Torr)*	MICRONS
14.7	29.92	760.0	760,000
1.0	2.04	51.7	51,700
0.49	1.0	25.4	25,400
0.0193	0.0394	1.0	1,000
0.000386	0.000787	0.020	20
0.0000193	0.000039	0.001	1

* Torr is another term that is the same as Millimeters of Mercury.

TEMPERATURE

Rapid Conversion of °C to °F:

1-Double °C

2-Deduct 10%

3-Add 32

Rapid Conversion of °F to °C:

1-Deduct 32

2-Divide by 1.8

Degrees Celsius	Kelvin	Degrees Fahrenheit	Degrees Rankine
°C	°K	°F	°R
°C	K-273.15	5/9 (°F-32)	5/9 (°R-491.67)
°C + 273.15	K	5/9 (°F+ 459.67)	5/9 °R
9/5 °C + 32	9/5K-459.67	°F	°R -459.67
9/5 °C + 491.67	9/5K	°F + 459.67	°R

TABLE 5.1
PHYSICAL CONSTANTS

Name	Formula	Liquid/Gas Specific Gravity		psia Critical Pressure	Critical Temp. °R	Viscosity Centi-stokes	Ratio Specific Heats K	psia Vapor Pressure Ambient Temp.
Acetaldehyde	CH ₃ CHO	0.78			830	0.295		
Acetic Acid	HC ₂ H ₃ O ₂	1.05		840	1,069	1.17		
Acetone	C ₃ H ₆ O	0.79	2.01	691	915	0.41	1.13	5.50
Acetylene	C ₂ H ₂	0.61	0.90	890	555		1.26	
Air	N ₂ O ₂	0.86	1.00	547	239		1.40	
Alcohol, Ethyl	C ₂ H ₆ O	0.794	1.59	925	930	1.52	1.15	12.30
Alcohol, Methyl	CH ₄ O	0.796	1.11	1,174	923	0.74	1.24	19.63
Ammonia	NH ₃	0.62	0.59	1,636	730	0.30	1.29	129.00
Ammonium Chloride	NH ₄ CL	1.07						
Ammonium Hydroxide	NH ₄ OH	0.91						
Ammonium Sulfate	(NH ₄)SO ₄	1.15						
Aniline	C ₆ H ₇ N	1.02		770	1258	4.37		
Argon	A	1.65	1.38	705	272		1.67	
Arsene	AsH ₃		2.69					
Beer		1.01						
Benzene	C ₆ H ₆	0.88	2.70	710	1012	0.744		3.20
Bromine	Br ₂	2.93	5.52	1,485	1035	0.34		2.90
Butane	C ₄ H ₁₀		2.07	529				39.60
Butylene	C ₄ H ₈		1.90	583	756		1.11	
Butyric Acid						1.61		
Calcium Chloride	CaCl ₂	1.23						
Camphor	C ₁₀ H ₁₆ O							0.005
Carbon Dioxide	CO ₂	0.801	1.52	1,072	548		1.30	854.00
Carbon Disulfide	CS ₂	1.29	2.63	1,071	994	0.298		8.40
Carbon Monoxide	CO	0.80	0.97	507	240			5338
Carbon Tetrachloride	C Cl ₄	1.59	5.31	661	1002	0.612		2.70
Chlorine	Cl ₂	1.42	2.45	1,119	751		1.35	100.00
Chloroform	CHCl ₃	1.49		793	965	0.38		4.80
Chromic Acid	H ₂ CrO ₄	1.21						
Cis-2-Butene	C ₄ H ₈	0.63	1.94	610	784		1.11	46.00
Citric Acid	C ₆ H ₈ O ₇	1.54						
Copper Sulfate	CuSO ₄	1.17						
Cyanogen	(CN) _x			839	722			
Cydohexame	C ₅ H ₁₂							
Cyclopentane	C ₅ H ₁₀	0.75	2.42	654	922			9.9
Dichloromethane-	CH ₂ Cl ₂			882				
Di-Isobutyl	C ₈ H ₁₈	0.70	3.94	361	990			1.10
Ethane	C ₂ H ₆	0.36	1.05	708	550		1.18	800.00
Ether	(CaH ₅) ₂ O	0.74	2.55	505	841			12.50
Ethyl Chloride	C ₂ H ₅ Cl	0.90		740	829	0.668		27.10
Ethylbenzene	C ₈ H ₁₀	0.87	3.67	524	1111		1.23	0.37
Ethylene	C ₂ H ₄		0.97	730	509		1.25	765
Ferric Chloride	FeCl ₃	1.23						
Fluorine	F ₂	1.11	1.31	809	260			300.00
Formaldehyde	H ₂ CO	0.82	1.08					
Formic Acid	C ₆ H ₁₂ O ₂	1.23		501	1036	1.48		
Furfural	C ₅ H ₄ O ₂	1.16						

TABLE 5.1
PHYSICAL CONSTANTS (Continued)

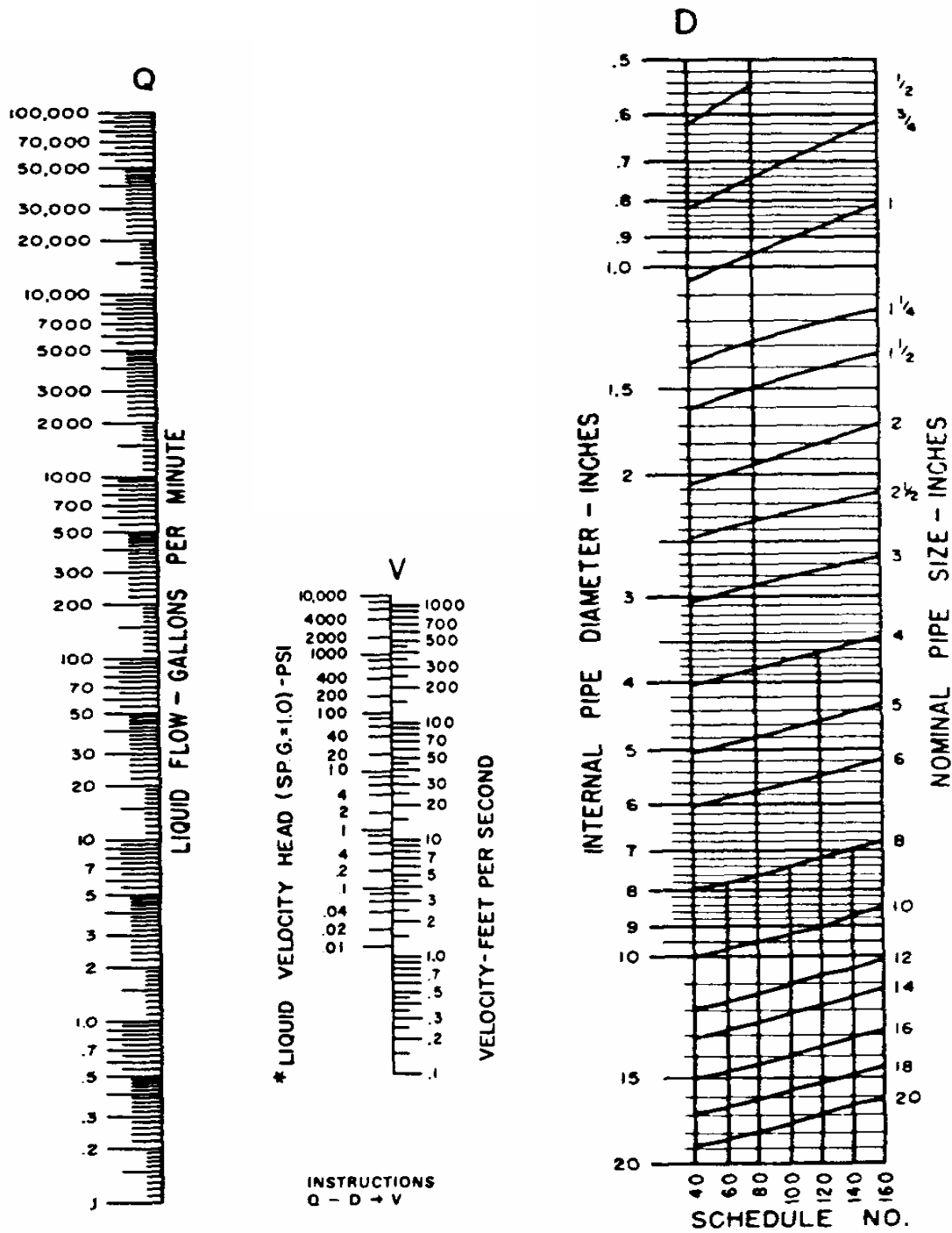
Name	Formula	Liquid/Gas Specific Gravity		psia Critical Pressure	Critical Temp. °R	Viscosity Centi-stokes	Ratio Specific Heats K	psia Vapor Pressure Ambient Temp.
Glycerin	C ₃ H ₈ O ₃	1.26		970	1,307		1.08	0.0001
Glycol	C ₂ H ₆ O ₂	1.11		1,117	1,161	17.80	1.09	0.01
Helium	He	0.18	0.14	33	10		1.66	2651
Hexane	C ₆ H ₁₄	0.65		433	913		1.06	2.03
Hexylene	C ₆ H ₁₂	0.67		447	920		1.07	2.63
Hydrochloric Acid	HCl	1.64		1,205	584	1.90	1.40	559
Hydrofluoric Acid	HF	0.92		940	906		1.40	15.90
Hydrogen	H ₂	0.07	0.07	188	60		1.41	
Hydrogen Chloride	HCl	0.86	1.26	1,198	585			628.00
Hydrogen Sulfide	H ₂ S	0.79	1.17	1,307	673			267.00
Iodine	I ₂	2.40		1,690	1,487		1.29	0.01
Iso-Butane	C ₄ H ₁₀	0.56	2.00	529	735		1.11	72.20
iso-Butene	C ₄ H ₈	0.60	1.94	580	753		1.12	63.40
Iso-Octane	C ₈ H ₁₈	0.70	3.94	372	979			1.70
Iso-Prene	C ₅ H ₈	0.69	2.35	558	872			17.00
Iso-Pentane	C ₅ H ₁₂	0.62	2.49	490	829			20.40
Iso-Propyl-Alcohol	C ₃ H ₈ O	0.78	2.08	779	915			743
Iso-Propyl-Benzene	C ₉ H ₁₂	0.87	4.15	465	1,136			0.19
Krypton	Kr		2.87	797	378			2676
m-Xylene	C ₈ H ₁₀	0.87	3.67	514	1,111			0.33
Magnesium Chloride	MgCl ₂	1.22						
Mercury	Hg	13.60	6.93	23,326	3,120			
Methane	CH ₄	0.30	0.55	668	343		1.31	5,000
Methyl Cyclohexane	C ₇ H ₁₄	0.77	3.40	504	1,030		1.32	1.60
Methyl Cyclopentane	C ₆ H ₁₂	0.75	2.90	549	959			4.50
Methyl Bromide	CH ₃ Br	1.73	3.27		836			28.00
Methyl Chloride	CH ₃ Cl	0.99	1.74	969	750			74.00
Milk								
n-Octane	C ₈ H ₁₈	0.71	3.94	361	1,024	0.77		0.54
n-Butane	C ₄ H ₁₀	0.58	2.00	551	776		1.10	51.60
n-Decane	C ₁₀ H ₂₂	0.73	4.90	304	1,112	1.24		0.06
n-Heptane	C ₇ H ₁₆	0.69	3.46	397	973	0.60	1.05	1.62
n-Hexane	C ₆ H ₁₄	0.66	2.98	437	914	0.49	1.06	4.96
n-Nonane	C ₉ H ₂₀	0.72	4.43	332	1,071	0.97		0.18
n-Pentane	C ₅ H ₁₂	0.63	2.49	489	846	0.37	1.08	15.60
Napthalene	C ₁₀ H ₈	1.14	4.43		1,347	0.90		0.15
Natural Gas					326			
Neohexane	C ₆ H ₁₄	0.65	2.98	447	880		1.06	9.90
Neon	Ne		0.70	384	80			11,736
Neopentane	C ₅ H ₁₂	0.60	2.49	464	781		1.07	35.90
Nitric Acid	HNO ₃	1.50				1.87		
Nitric Oxide	NO		1.04	925	323			35,679
Nitrobenzene						1.67		
Nitrogen	N ₂	0.81	0.97	493	227		1.40	7,499
Nitrogyl Chloride	NOCl		2.31					
Nitrous Oxide	N ₂ O		1.53	1,048			1.30	539

TABLE 5.1
PHYSICAL CONSTANTS (Continued)

Name	Formula	Liquid/Gas Specific Gravity		psia Critical Pressure	Critical Temp. °R	Viscosity Centi-stokes	Ratio Specific Heats K	psia Vapor Pressure at Ambient Temp.
o-Xylene	C ₈ H ₁₀	0.88	3.67	541	1,135		1.07	0.26
Oil, Olive						93.00		0.34
Oil, Vegetable		0.92						
Oxygen	O ₂	1.14	1.11	737	279		1.40	
p-Xylene	C ₈ H ₁₀	0.87	3.67	509	1,110		1.07	0.34
Phenol	C ₆ H ₅ OH	1.08		889		11.83		
Phosgene	COCl ₂	1.39	3.42	823	820			25.70
Phosphine	PH ₃		1.18	948	583			
Phosphoric Acid	H ₃ PO ₄	1.83						
Potassium Carbonate	K ₂ CO ₃	1.24						
Potassium Chloride	KCl	1.16						
Potassium Hydroxide	KOH	1.24						
Propane	C ₃ H ₈	0.51	1.52	616	666		1.13	190.00
Propene	C ₃ H ₆	0.52	1.45	669	657		1.15	226.00
Propionic Acid						1.13		
Raden				912	679			
Refrigerant 11	CCl ₃ F		5.04	635	848	0.32		28.40
Refrigerant 12	CCl ₂ F ₂		4.20	597	694	0.21		85.20
Refrigerant 13	CClF ₃			561	544			473.70
Refrigerant 21	CHCl ₂ F		3.82	750	813	0.27		23.40
Refrigerant 22	CHClF			716	665			137.50
Refrigerant 23	CHF ₃			691	551			650.00
Silicon Tetrafluoride	SiF ₄		3.62					
Sodium Chloride	NaCl	1.19						
Sodium Hydroxide	NaOH	1.27						
Sodium Sulfate	Na ₂ SO ₄	1.24						
Sodium Thiosulfate	Na ₂ S ₂ O ₃	1.23						
Starch	(C ₆ H ₁₀ O ₅) X	1.50						
Styrene	C ₈ H ₈	0.91	3.60	580	1,166			0.24
Sulfuric Acid	H ₂ SO ₄	1.83				14.60		
Sulfur Dioxide	SO ₂	1.39	2.27	1,145	776		1.25	49.40
Sulfur Trioxide	SO ₃							
Toluene	C ₇ H ₈	0.87	3.18	596	1,066		1.09	1.00
Trans-2- Butene	C ₄ H ₈	0.61	1.94	595	772		1.10	50.00
Triptane	C ₇ H ₁₆	0.69	3.46	428	956		1.05	3.40
Turpentine		0.87				1.83		
Xenon	Xe		4.53	853	523			
Xylene-o						93.0		
Water	H ₂ O	1.00	0.62	3,206	1,166	1.1		0.95
Zinc Chloride	ZnCl ₂	1.24						
Zinc Sulfate	ZnSO ₄	1.31						
1 -Butene	C ₅ H ₈	0.60	1.94	583	756		1.10	63.00
1 -Pentene	C ₅ H ₁₀	0.65	2.42	590	837		1.08	19.00
1, 2-Butadiene	C ₄ H ₆	0.66	1.87	653	799		1.12	20.00
1, 3-Butadiene	C ₄ H ₆	0.63	1.87	628	766		1.12	60.00
2-Methylhexane	C ₇ H ₁₆	0.68	3.46	397	955		1.05	2.30
2-Methylpentane	C ₆ H ₁₄	0.66	2.98	437	896		1.05	6.80
2, 2-Dimethylpentane	C ₇ H ₁₆	0.68	3.46	402	937		1.05	3.5
2, 3-Dimethylbutane	C ₆ H ₁₄	0.67	2.98	454	900		1.05	7.4
3 -Etylhpentane	C ₇ H ₁₆	0.70	3.46	419	973		1.05	2.00

LIQUID VELOCITY DETERMINATION

FIGURE 5.0



*Multiply velocity head value from chart by liquid specific gravity if specific gravity is other than one.

NOTE: The internal diameter of the various pipe schedules may be found by noting the intersection of the diagonal line representing the nominal size of pipe with the vertical line representing the pipe schedule, then projecting horizontally to the D-scale.

Durco Teflon Seated Valves for Steam Service

Many Durco Teflon seated valves are suitable for a wide variety of steam services. It is important, however, that modifications be made to some valve types.

1. **Manual On / Off Service** – clean saturated steam up to 100 PSIG inlet (337° F).
2. **Automated On / Off Service** – clean saturated steam up to 150 PSIG inlet (366° F).
3. **Automated Throttling Service** – clean saturated steam up to 150 PSIG inlet (366° F with a maximum ΔP of 100 PSIG and the valve operating in the 40% to 60% open position.)

Big Max Valves

All Big Max valves can be applied as outlined above without any modifications.

G4 and SG4 Valves

All G4 and SG4 valves for use on any steam service must have the plug vented to the bottom cavity and have a **glass filled** sleeve. Modulating / throttling service valves should also utilize a V-port (EG / SEG) plug with the V-port installed upstream.

Atomac, T4, BL and BTV Valves

All Teflon lined valves are **NOT** recommended for steam service.

Mach 1 Valves

Mach 1 valves on steam have the same restrictions as the G4 and should use the full SLEEVE and NOT Port Seals.

TABLE 5.2
SATURATED STEAM PROPERTIES

Vapor Pressure		Temp. °F	Specific Weight Lbs.cu ft	Water Specific Gravity
Absolute psia	Vacuum psig			
0.20	29.51	53.14	0.000655	1.00
0.25	29.41	59.30	0.000810	1.00
0.30	29.31	64.47	0.000962	1.00
0.35	29.21	68.93	0.00111	1.00
0.40	29.11	72.86	0.00126	1.00
0.45	29.00	76.38	0.00141	1.00
0.50	28.90	79.58	0.00156	1.00
0.60	28.70	85.21	0.00185	1.00
0.70	28.49	90.08	0.00214	1.00
0.80	28.29	94.38	0.00243	1.00
0.90	28.09	98.24	0.00271	0.99
1.00	27.88	101.74	0.00300	0.99
1.20	27.48	107.92	0.00356	0.99
1.40	27.07	113.26	0.00412	0.99
1.60	26.66	117.99	0.00467	0.99
1.80	26.26	122.23	0.00521	0.99
2.00	25.85	126.08	0.00576	0.99
2.20	25.44	129.62	0.00630	0.99
2.40	25.03	132.89	0.00683	0.99
2.60	24.63	135.94	0.00737	0.99
2.80	24.22	138.79	0.00790	0.98
3.00	23.81	141.48	0.00842	0.98
3.50	22.79	147.57	0.00974	0.98
4.00	21.78	152.97	0.0110	0.98
4.50	20.76	157.83	0.0123	0.98
5.00	19.74	162.24	0.0136	0.98
5.50	18.72	166.30	0.0149	0.98
6.00	17.70	170.06	0.0161	0.98
6.50	16.69	173.56	0.0174	0.97
7.00	15.67	176.85	0.0186	0.97
7.50	14.65	179.94	0.0199	0.97
8.00	13.63	182.86	0.0211	0.97
8.50	12.61	185.64	0.0224	0.97
9.00	11.60	188.28	0.0236	0.97
9.50	10.58	190.80	0.0248	0.97
10.00	9.56	193.21	0.0260	0.97
11.00	7.52	19775	0.0285	0.97
12.00	5.49	20196	0.0309	0.96
13.00	3.45	205.88	0.0333	0.96
14.00	1.42	209.56	0.0357	0.96

Vapor Pressure		Temp. °F	Specific Weight Lbs.cu ft	Water Specific Gravity
Absolute psia	Gauge psig			
14.696	0.00	212.00	0.0373	0.96
15.00	0.30	213.03	0.0380	0.96
16.00	1.30	216.32	0.0404	0.96
17.00	2.30	219.44	0.0428	0.96
18.00	3.30	222.41	0.0451	0.96
19.00	4.30	225.24	0.0474	0.95
20.00	5.3	227.96	0.0498	0.95
21.00	6.30	230.57	0.0521	0.95
22.00	7.30	233.07	0.0544	0.95
23.00	8.30	235.49	0.0567	0.95
24.00	9.30	237.82	0.0590	0.95
25.00	10.30	240.07	0.0613	0.95
26.00	11.30	242.25	0.0636	0.95
27.00	12.30	244.36	0.0659	0.95
28.00	13.30	246.41	0.0682	0.94
29.00	14.30	248.40	0.0705	0.94
30.00	15.30	250.33	0.0727	0.94
31.00	16.30	252.22	0.0750	0.94
32.00	17.30	254.05	0.0773	0.94
33.00	18.30	255.84	0.0795	0.94
34.00	19.30	257.58	0.0818	0.94
35.00	20.30	259.28	0.0940	0.94
36.00	21.30	260.95	0.0863	0.94
37.00	22.30	262.57	0.0885	0.94
38.00	23.30	264.16	0.0908	0.94

Vapor Pressure		Temp. °F	Specific Weight Lbs.cu ft	Water Specific Gravity
Absolute psia	Gauge psig			
39.00	24.30	265.72	0.0930	0.94
40.00	25.30	267.25	0.0953	0.94
41.00	26.30	268.74	0.0975	0.93
42.00	27.30	270.21	0.0997	0.93
43.00	28.30	271.64	0.102	0.93
44.00	29.30	273.05	0.104	0.93
45.00	30.30	274.44	0.106	0.93
46.00	31.30	275.80	0.109	0.93
47.00	32.30	277.13	0.111	0.93
48.00	33.30	278.45	0.113	0.93
49.00	34.30	279.74	0.115	0.93
50.00	35.30	281.01	0.117	0.93
51.00	36.30	282.26	0.120	0.93
52.00	37.30	283.49	0.122	0.93
53.00	38.30	284.70	0.124	0.93
54.00	39.30	285.90	0.126	0.94
55.00	40.30	287.07	0.128	0.93
56.00	41.30	288.23	0.131	0.93
57.00	42.30	289.37	0.133	0.93
58.00	43.30	290.50	0.135	0.92
59.00	44.30	291.61	0.137	0.92
60.00	45.30	292.71	0.139	0.92
61.00	46.30	293.79	0.142	0.92
62.00	47.30	294.85	0.144	0.92
63.00	48.30	295.90	0.146	0.92
64.00	49.30	296.94	0.148	0.92
65.00	50.30	297.97	0.150	0.92
66.00	51.30	298.99	0.152	0.92
67.00	52.30	299.99	0.155	0.92
68.00	53.30	300.98	0.157	0.92
69.00	54.30	301.96	0.159	0.92
70.00	55.30	302.92	0.161	0.92
71.00	56.30	303.88	0.163	0.92
72.00	57.30	304.83	0.165	0.92
73.00	58.30	305.76	0.168	0.92
74.00	59.30	306.68	0.170	0.92
75.00	60.30	307.60	0.172	0.92
76.00	61.30	308.50	0.174	0.91
77.00	62.30	309.40	0.176	0.91
78.00	63.30	310.29	0.178	0.91
79.00	64.30	311.16	0.181	0.91
80.00	65.30	312.03	0.183	0.91
81.00	66.30	312.89	0.185	0.91
82.00	67.30	313.74	0.187	0.91
83.00	68.30	314.59	0.189	0.91
84.00	69.30	315.42	0.191	0.91
85.00	70.30	316.25	0.193	0.91
86.00	71.30	317.07	0.196	0.91
87.00	72.30	317.88	0.198	0.91
88.00	73.30	318.68	0.200	0.91
89.00	74.30	319.48	0.202	0.91
90.00	75.30	320.27	0.204	0.91
91.00	76.30	321.06	0.206	0.91
92.00	77.30	321.83	0.209	0.91
93.00	78.30	322.60	0.211	0.91
94.00	79.30	323.36	0.213	0.91
95.00	80.30	324.12	0.215	0.91
96.00	81.30	324.87	0.217	0.91
97.00	82.30	325.61	0.219	0.91
98.00	83.30	326.35	0.221	0.91
99.00	84.30	327.08	0.224	0.90
100.00	85.30	327.81	0.226	0.90
101.00	86.30	328.53	0.228	0.90
102.00	87.30	329.25	0.230	0.90
103.00	88.30	329.96	0.232	0.90
104.00	89.00	330.66	0.234	0.90
105.00	90.30	331.36	0.236	0.90
106.00	91.30	332.05	0.238	0.90
107.00	92.30	332.74	0.241	0.90
108.00	93.30	333.42	0.243	0.90
109.00	94.30	334.10	0.245	0.90

Vapor Pressure		Temp. °F	Specific Weight Lbs/cu ft	Water Specific Gravity
Absolute psia	Guage psig			
110.00	95.30	334.77	.247	0.90
111.00	96.30	335.44	.249	0.90
112.00	97.30	336.11	.251	0.90
113.00	98.30	336.77	.253	0.90
114.00	99.30	337.42	.255	0.90
115.00	100.30	338.07	.258	0.90
116.00	101.30	338.72	.260	0.90
117.00	102.30	339.36	.262	0.90
118.00	103.30	339.99	.264	0.90
119.00	104.30	340.62	.266	0.90
120.00	105.30	341.25	.268	0.90
121.00	106.30	341.88	.270	0.90
122.00	107.30	342.50	.272	0.90
123.00	108.30	343.11	.275	0.90
124.00	109.30	343.72	.277	0.90
125.00	110.30	344.33	.279	0.90
126.00	111.30	344.94	.281	0.89
127.00	112.30	345.54	.283	0.89
128.00	113.30	346.13	.285	0.89
129.00	114.30	346.73	.287	0.89
130.00	115.30	347.32	.289	0.89
131.00	116.30	347.90	.292	0.89
132.00	117.30	348.48	.294	0.89
133.00	118.30	349.06	.296	0.89
134.00	119.30	349.64	.298	0.89
135.00	120.30	350.21	.300	0.89
136.00	121.30	350.78	.302	0.89
137.00	122.30	351.35	.304	0.89
138.00	123.30	351.91	.306	0.89
139.00	124.30	352.47	.308	0.89
140.00	125.30	353.02	.311	0.89
141.00	126.30	353.57	.313	0.89
142.00	127.30	354.12	.315	0.89
143.00	128.30	354.67	.317	0.89
144.00	129.30	355.21	.319	0.89
145.00	130.30	355.76	.321	0.89
146.00	131.30	356.29	.323	0.89
147.00	132.30	356.83	.325	0.89
148.00	133.30	357.36	.327	0.89
149.00	134.30	357.89	.330	0.89
150.00	135.30	358.42	.332	0.89
152.00	137.30	359.46	.336	0.89
154.00	139.30	360.49	.340	0.89
156.00	141.30	361.52	.344	0.88
158.00	143.30	362.53	.349	0.88
160.00	145.30	363.53	.353	0.88
162.00	147.30	364.53	.357	0.88
164.00	149.30	365.51	.361	0.88
166.00	151.30	366.48	.365	0.88
168.00	153.30	367.45	.370	0.88
170.00	155.30	368.41	.374	0.88
172.00	157.30	369.35	.378	0.88
174.00	159.30	370.29	.382	0.88
176.00	161.30	371.22	.387	0.88
178.00	163.30	372.14	.391	0.88
180.00	165.30	373.06	.395	0.88
182.00	167.30	373.96	.399	0.88
184.00	169.30	374.86	.403	0.88
186.00	171.30	375.75	.407	0.88
188.00	173.30	376.64	.412	0.88
190.00	175.30	377.51	.416	0.88
192.00	177.30	378.38	.420	0.87
194.00	179.30	379.24	.424	0.87
196.00	181.30	380.10	.429	0.87
198.00	183.30	380.95	.433	0.87
200.00	185.30	381.79	.437	0.87
205.00	190.30	383.86	.448	0.87
210.00	195.30	385.90	.458	0.87
215.00	200.30	387.89	.469	0.87
220.00	205.30	389.86	.479	0.87
225.00	210.30	391.79	.490	0.87
230.00	215.30	393.68	.500	0.87
235.00	220.30	395.54	.511	0.86
240.00	225.30	397.37	.522	0.86
245.00	230.30	399.18	.532	0.86

Vapor Pressure		Temp. °F	Specific Weight Lbs/cu ft	Water Specific Gravity
Absolute psia	Guage psig			
250.00	235.30	400.95	0.542	0.86
255.00	240.30	402.70	0.553	0.86
260.00	245.30	404.42	0.563	0.86
265.00	250.30	406.11	0.574	0.86
270.00	255.30	407.78	0.585	0.86
275.00	260.30	409.43	0.595	0.85
280.00	265.30	411.05	0.606	0.85
285.00	270.30	412.65	0.616	0.85
290.00	275.30	414.23	0.627	0.85
295.00	280.30	415.79	0.637	0.85
300.00	285.30	417.33	0.648	0.85
320.00	305.30	423.29	0.690	0.85
340.00	325.30	428.97	0.733	0.84
360.00	345.30	434.40	0.775	0.84
380.00	365.30	439.60	0.818	0.83
400.00	385.30	444.59	0.861	0.83
420.00	405.30	449.39	0.904	0.83
440.00	425.30	454.02	0.947	0.82
460.00	445.30	458.50	0.991	0.82
480.00	465.30	462.82	1.03	0.81
500.00	485.30	467.01	1.08	0.81
520.00	505.30	471.07	1.12	0.81
540.00	525.30	475.01	1.17	0.81
560.00	545.30	478.85	1.21	0.80
580.00	565.30	482.58	1.25	0.80
600.00	585.30	486.21	1.30	0.80
620.00	605.30	489.75	1.34	0.79
640.00	625.30	493.21	1.39	0.79
660.00	645.30	496.58	1.43	0.79
680.00	665.30	499.88	1.48	0.79
700.00	685.30	503.10	1.53	0.78
720.00	705.30	506.25	1.57	0.78
740.00	725.30	509.34	1.62	0.77
760.00	745.30	512.36	1.66	0.77
780.00	765.30	515.33	1.71	0.77
800.00	785.30	518.23	1.76	0.77
820.00	805.30	521.08	1.81	0.77
840.00	825.30	523.88	1.85	0.76
860.00	845.30	526.63	1.90	0.76
880.00	865.30	529.33	1.95	0.76
900.00	885.30	531.98	2.00	0.76
920.00	905.30	534.59	2.05	0.75
940.00	925.30	537.16	2.10	0.75
960.00	945.30	539.68	2.14	0.75
980.00	965.30	542.17	2.19	0.75
1000.00	985.30	544.61	2.24	0.74
1050.00	1035.30	550.57	2.37	0.74
1100.00	1085.30	556.31	2.50	0.73
1150.00	1135.30	561.86	2.63	0.73
1200.00	1185.30	567.22	2.76	0.72
1250.00	1235.30	572.42	2.90	0.71
1300.00	1285.30	577.46	3.04	0.71
1350.00	1335.30	582.35	3.18	0.70
1400.00	1385.30	587.10	3.32	0.69
1450.00	1435.30	591.73	3.47	0.69
1500.00	1485.30	596.23	3.62	0.68
1600.00	1585.30	604.90	3.92	0.67
1700.00	1685.30	613.15	4.25	0.66
1800.00	1785.30	621.03	4.59	0.65
1900.00	1885.30	628.58	4.95	0.64
2000.00	1985.30	635.82	5.32	0.62
2100.00	2085.30	642.77	5.73	0.61
2200.00	2185.30	649.46	6.15	0.60
2300.00	2285.30	655.91	6.61	0.59
2400.00	2385.30	662.12	7.11	0.57
2500.00	2485.30	668.13	7.65	0.56
2600.00	2585.30	673.94	8.24	0.54
2700.00	2685.30	679.55	8.90	0.53
2800.00	2785.30	684.99	9.66	0.51
2900.00	2885.30	690.26	10.60	0.49
3000.00	2985.30	695.36	11.70	0.46
3100.00	3085.30	700.31	13.30	0.43
3200.00	3185.30	705.11	17.20	0.36
3206.20	3191.50	705.40	19.90	0.32

FIGURE 5.2

RATIO OF SPECIFIC HEAT AT CONSTANT PRESSURE
TO SPECIFIC HEAT AT CONSTANT VOLUME

$$K = Sp/Sv$$

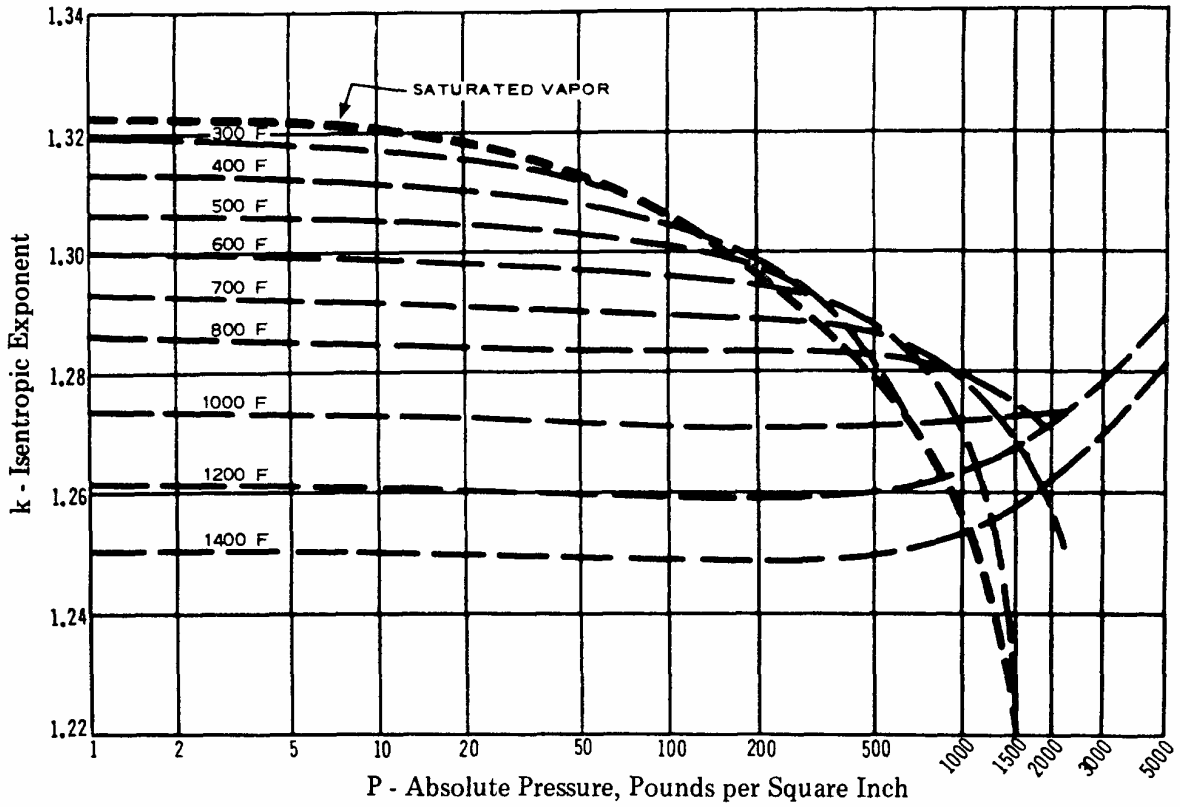
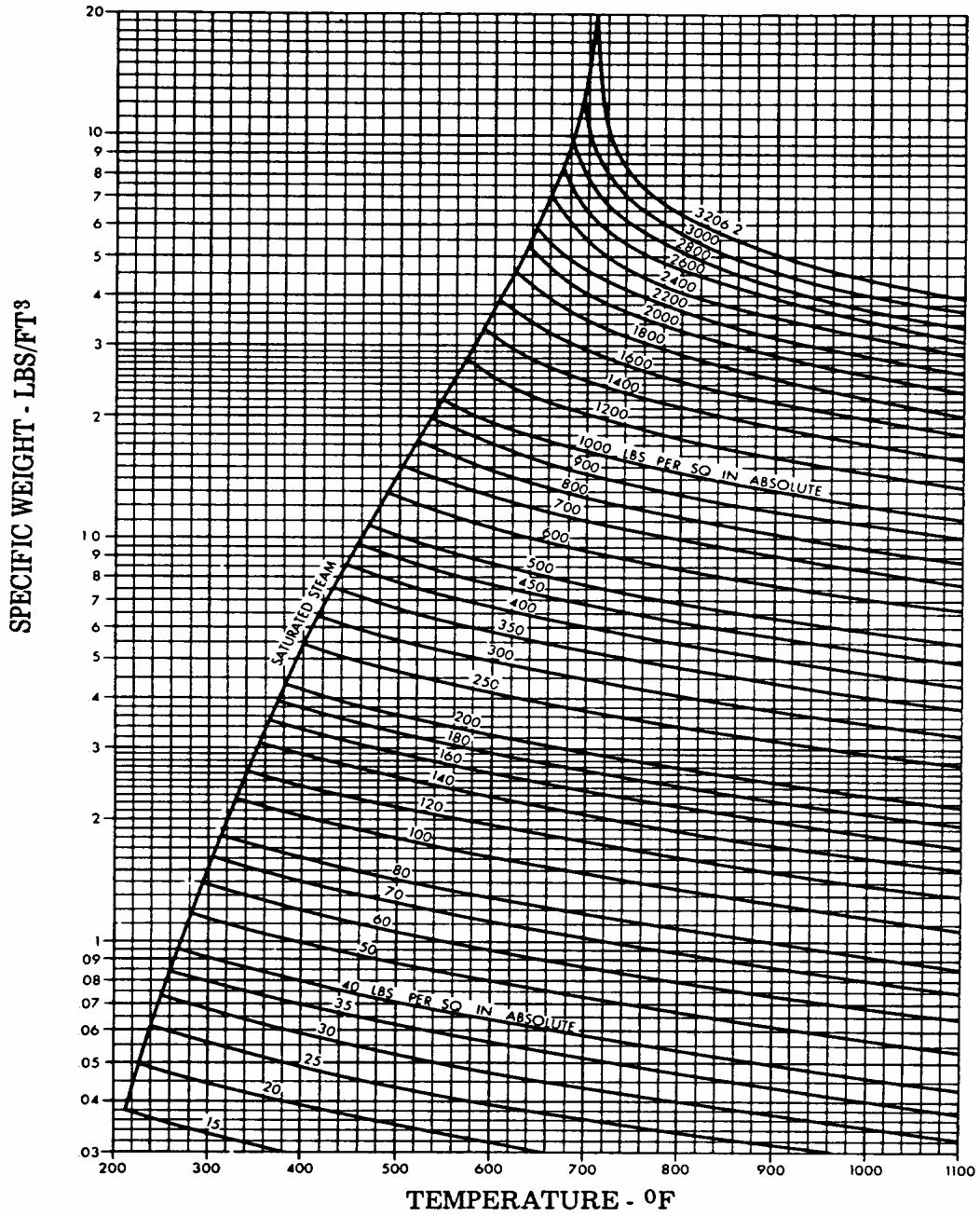


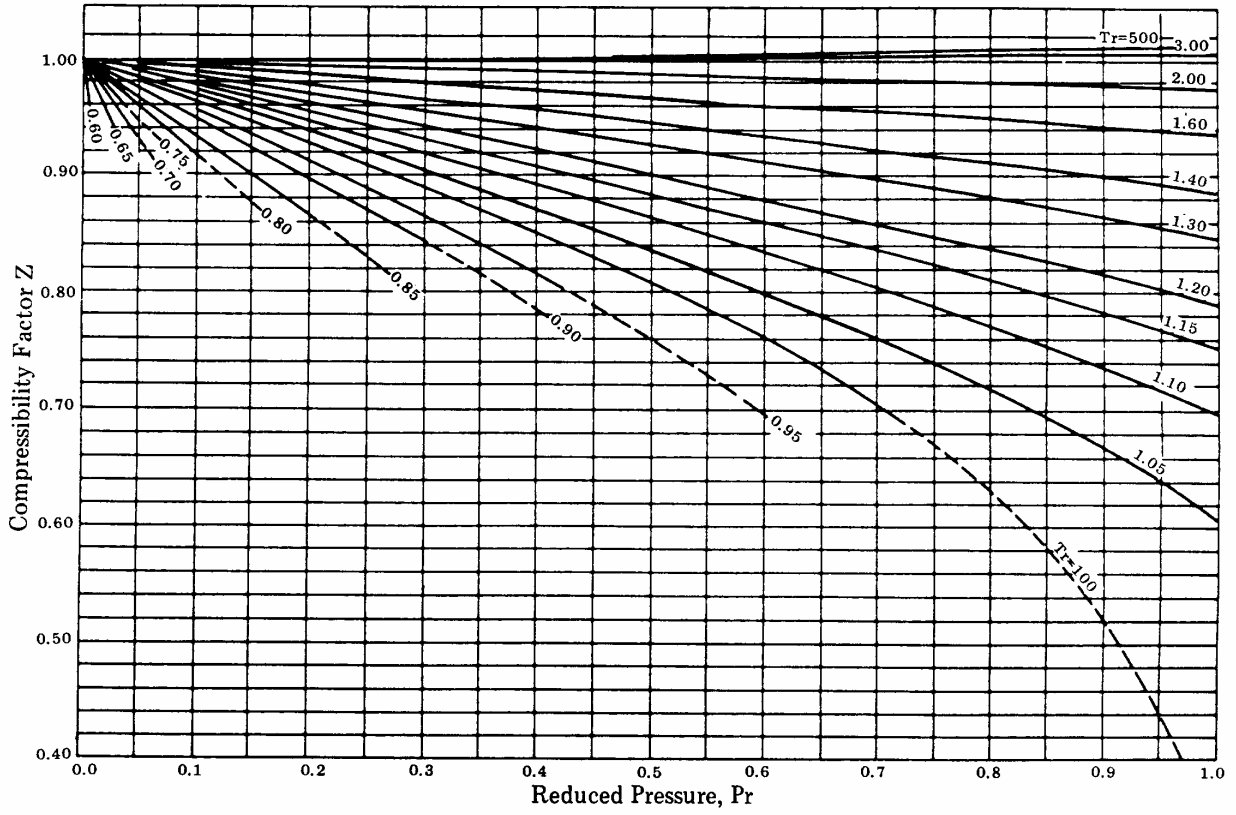
FIGURE 5.1

SATURATED AND SUPERHEATED STEAM
SPECIFIC WEIGHT vs. TEMPERATURE



COMPRESSIBILITY CHARTS
FIGURE 5.3

COMPRESSIBILITY CHART NO. 1



$$Pr = P1/Pc$$
$$Tr = T1/Tc$$

FIGURE 5.4 COMPRESSIBILITY CHART NO. 2

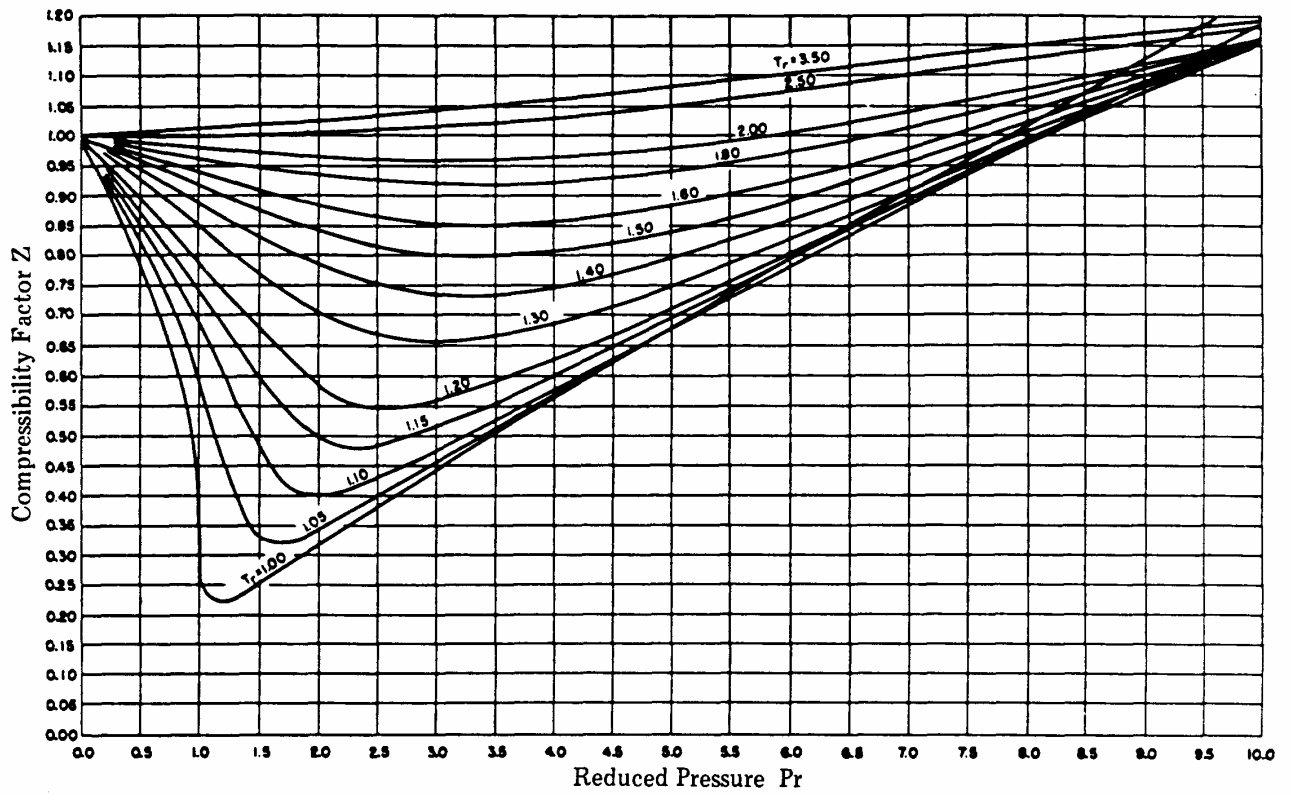
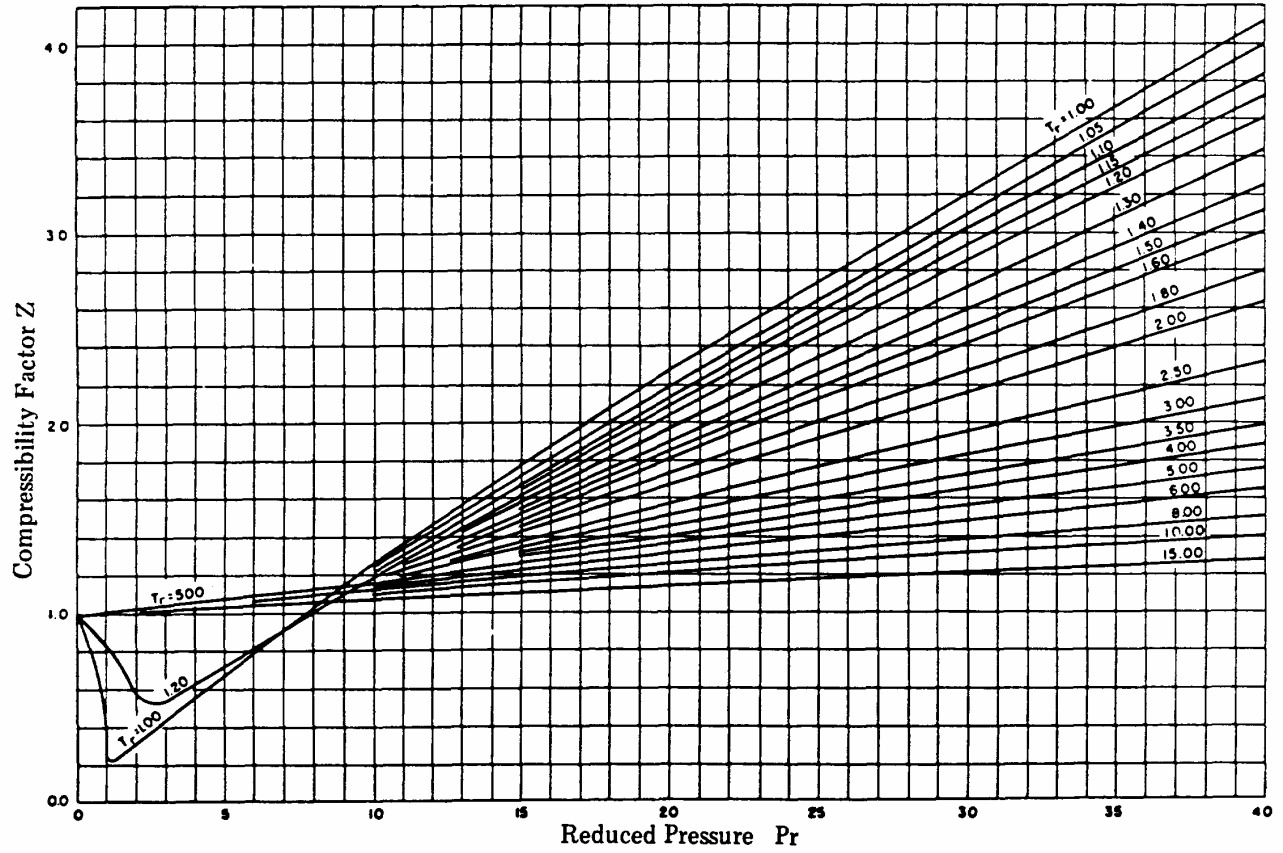


FIGURE 5.5 COMPRESSIBILITY CHART NO. 3



The following material is taken from :

CONTROL VALVE SIZING
Topic 3

BY L. R. Driskell
Chemical Plants Division
Dravo Corporation

INSTUMENT SOCIETY OF AMERICA
400 Stanwix Street, Pittsburgh, PA. 15222

TERMINOLOGY

- BERNOULLI COEFFICIENT** - In any stream, if the area is changed, as by a reducer, there is a corresponding change in the static pressure, or "head". This pressure change is measured in units of "velocity head". The dimensionless coefficient used for this purpose is the Bernoulli Coefficient K_B .
- CHOKED FLOW** - The condition which exists when, with the upstream pressure remaining constant, the flow through a valve cannot be further increased by lowering the downstream pressure.
- COEFFICIENT OF DISCHARGE** - The ratio of actual flow to theoretical flow. It includes the effects of jet contraction and turbulence.
- COMPRESSIBILITY FACTOR** - A factor used to compensate for deviation from the laws of perfect gases. If the gas laws are used to compute the specific weight of a gas, the computed value must be adjusted by the compressibility factor (Z) to obtain the true specific weight.
- COMPRESSIBLE** - Capable of being compressed. Gas and vapor are compressible fluids.
- CRITICAL FLOW** - This is a somewhat ambiguous term which signifies a point where the characteristics of flow suffer a finite change. In the case of a liquid, critical flow could mean the point where the flow regime changes from laminar to transitional. It is more often used to mean choked flow. In the case of a gas, critical flow may mean the point where the velocity at the vena contracts attains the velocity of sound, or it may mean the point where the flow is fully choked.
- CRITICAL PRESSURE** - The equilibrium pressure of a fluid which is at its critical temperature.
- CRITICAL TEMPERATURE** - The temperature of a fluid above which the fluid cannot be liquefied by pressure.
- INCOMPRESSIBLE** - Liquids are referred to as being incompressible since their change in volume due to pressure is negligible.
- INCREASER** - A pipe fitting identical to a reducer except specifically referred to for enlargements in the direction of flow.
- LAMINAR FLOW** - Also known as viscous or streamline flow. A non-turbulent flow regime in which the stream filaments glide along the pipe axially with essentially no transverse mixing. This occurs at low Reynolds numbers, is usually associated with viscous liquids, and rarely occurs with gas flows in valves. Flow rate varies linearly with $6P$.
- RANGEABILITY** - Installed rangeability may be defined as the ratio of maximum to minimum flow within which the deviation from a desired installed flow characteristic does not exceed some stated limits. Inherent rangeability, a property of the valve alone, may be defined as the ratio of maximum to minimum flow coefficients between which the gain of the valve does not deviate from a specified gain by some stated tolerance.
- REDUCER** - A pipe fitting which is used to couple a pipe of one size to a pipe of a different size.
- REYNOLDS NUMBER** - A dimensionless criterion of the nature of flow pipes. It is proportional to the ratio of dynamic forces to viscous forces: The product of diameter, velocity and density, divided by absolute viscosity.

SPECIFIC HEAT - The ratio of the thermal capacity of a substance to that of water. The specific heat at constant pressure of a gas is designated c_p . The specific heat at constant volume of a gas is designated c_v .

The ratio of the two ($c_p/c_v = k$) is called the Ratio of Specific Heats.

STREAMLINE FLOW - See "Laminar Flow".

TRANSITIONAL FLOW - A flow regime which lies between turbulent flow and laminar flow.

TRANSITIONAL FLOW - A flow regime characterized by random motion of the fluid particles in the transverse direction, as well as motion in the axial direction. This occurs at high Reynolds numbers and is the type of flow most common in industrial fluid systems. Flow varies as the square root of ΔP .

TURNDOWN - The ratio of the maximum plant design flow rate to the minimum plant design flow rate.

VAPOR PRESSURE - The equilibrium pressure which would exist in a confined space over a liquid.

VELOCITY OF APPROACH - A factor (F) determined by the ratio (m) of the valve orifice area to the inlet pipe area.

VELOCITY HEAD - The pressure, measured in height of fluid column, needed to create a fluid velocity.

Numerically velocity head is the square of the velocity divided by twice the acceleration of gravity ($U^2/2g$).

VENA CONTRACTA - The place along the axis of flow, just beyond the orifice, where the jet stream contracts to its minimum cross-sectional area.

VISCOUS FLOW - See "Laminar Flow"

CATALOG OF EQUATIONS

LIQUID

REMARKS

$$(1) \quad q = F_P C_V \sqrt{\frac{\Delta P}{G}}$$

Turbulent and

$$(2) \quad w = 63.3 F_P C_V \sqrt{\Delta P \gamma}$$

non-cavitating.

$$\Delta P < K_C (P_I - P_V)$$

$$(3) \quad q = F_{LP} C_V \sqrt{\frac{P_I - P_{VC}}{G}}$$

$$(4) \quad w = 63.3 F_{LP} C_V \sqrt{\gamma (P_I - P_{VC})}$$

Choked

$$(5) \quad P_{VC} = F_F P_V$$

$$\Delta P \Rightarrow F_L^2 (P_I - F_F P_V)$$

$$(6) \quad F_F \approx 0.96 - 0.28 \sqrt{\frac{P_V}{P_C}}$$

$$(7) \quad F_{LP} = \left[\frac{1}{F_L^2} + \frac{K_i C_d^2}{890} \right]^{-\frac{1}{2}}$$

(See Eq. 25 for K_i)

$$(8) \quad q = 52 \frac{\Delta P}{\mu} (F_S F_P C_V)^{\frac{3}{2}}$$

Laminar

$$(9) \quad F_S = \left(\frac{F_P F_d^2}{F_{LP}} \right)^{\frac{1}{3}} \left[\frac{(F_{LP} C_D)^2}{890} + 1 \right]^{\frac{1}{6}}$$

$$(10) \quad q = F_R F_P C_V \sqrt{\frac{\Delta P}{G}} \quad \text{Transitional (See Table III for } F_R \text{)}$$

GAS OR VAPOR –(ALL EQUATIONS: $X \leq F_k X_T$)

$$(11) \quad w = 63.3 F_P C_V Y \sqrt{X P_1 \gamma_1} \quad \text{Using: Lb./Hr., Sp. Wt.}$$

$$(12) \quad q = 1360 F_P C_V P_1 Y \sqrt{\frac{X}{G T_1 Z}} \quad \text{Using: SCFH, Sp. G.}$$

$$(13) \quad w = 19.3 F_P C_V P_1 Y \sqrt{\frac{X M}{T_1 Z}} \quad \text{Using: Lb./Hr., Molecular Weight}$$

$$(14) \quad q = 7320 F_P C_V P_1 Y \sqrt{\frac{X}{M T_1 Z}} \quad \text{Using: SCFH, Molecular Weight}$$

$$(15) \quad Y = 1 - \frac{X}{3 F_k X_T} \quad \text{Expansion factor, lower limit = 0.67}$$

$$(16) \quad F_k = k / 1.40 \quad \text{Sp. Ht. Ratio factor}$$

$$(17) \quad X_T = \frac{C_1^2}{1600} = 0.84 C_f^2 \quad \text{Manufacturers' Sizing Factors in current use.}$$

$$(18) \quad X_{TP} = \frac{X_T}{F_P^2} \left[\frac{X_T K_i C_d^2}{1000} + 1 \right]^{-1} \quad X_T \text{ with reducers}$$

STEAM (DRY-SATURATED) Error –5% for $p_1=20$ to 1600 psia.

$$(19) \quad w = F_P C_V P_1 \left(3 - \frac{X}{X_{TP}} \right) \sqrt{X} \quad \text{For } X < X_{TP}$$

$$w = 2 F_P C_V P_1 \sqrt{X_{TP}} \quad \text{For } X > X_{TP} \text{ (Choked Flow)}$$

PIPING GEOMETRY FACTOR

$$(20) \quad F_P = \left[\frac{\sum K C_d^2}{890} + 1 \right]^{-1/2} \quad \text{See } F_{LP} \text{ for liquid choked flow (Eq.7)}$$

$$(21) \quad \sum K = K_1 + K_2 + K_{B1} - K_{B2} \quad \text{Sum of velocity head coefficients}$$

$$(22) \quad K_{B1} \text{ or } K_{B2} = 1 - \left(\frac{d}{D} \right)^4 \quad \text{Bernoulli coefficient}$$

$$(23) \quad K_1 = 0.5 \left[1 - \left(\frac{d}{D} \right)^2 \right]^2$$

Resistance coefficients for abrupt transitions

$$(24) \quad K_2 = 1.0 \left[1 - \left(\frac{d}{D} \right)^2 \right]^2$$

Resistance coefficients for abrupt transitions

$$(25) \quad K_i = K_1 + K_{B1}$$

Inlet fitting coefficients (For F_{LP} Eq. 7 and X_{TP} Eq. 18)

REFERENCE FORMULAS

$$(26) \quad Re_v = \frac{17300 F_d q}{v \sqrt{F_{LP} C_v}} \left[\frac{(F_{LP} C_d)^2}{890} + 1 \right]^{1/4}$$

Valve Reynolds Number

$$(27) \quad F_L = \frac{F_L'}{F_P} \left[\frac{(F_L')^2}{890} (C_d) + 1 \right]^{-1/2}$$

F_L of valve/fitting assembly when F_L of valve alone is F_L'

$$(28) \quad q = F_P F_y F_R C_v \sqrt{\frac{\Delta P}{G}}$$

Composite liquid sizing equation

$$(29) \quad F_y = F_L \sqrt{\frac{P_1 - F_F P_v}{\Delta P}}$$

Liquid choked flow factor

VELOCITY-Feet/Second

$$(30) \text{Liquid} \quad U = \frac{q}{2.45 D^2}$$

Lined Products	Alloy Products
5 – 8 Normal	5 – 10 Normal
10 – 12 Max.	20 – 40 Max.

$$(31) \text{Gas} \quad U = \frac{qT}{694 P D^2}$$

All products 250 – 400 Typical

$$(32) \text{Vapor} \quad U = \frac{w}{19.6 \gamma D^2}$$

See STEAM Recommendations, page 62

$$(33) \text{Steam} \quad U = \frac{23w}{p D^2}$$

0-25 psig	70-100
>25 psig	100-170
>200 psig	
Superheated	115-330

ACOUSTIC VELOCITY-(Mach 1.0)

(34)Gas	$U_a = 223\sqrt{\frac{kT}{M}}$	Recommend <0.3 Mach
(35)Air	$U_a = 49\sqrt{T}$	Recommend <0.3 Mach
(36)Steam, Superheated	$U_a = 60\sqrt{T}$	Recommend <0.15 Mach
(37)Steam, Dry Saturated	$U_a \cong 1650$	Recommend <0.10 Mach
(38)Vapor	$U_a = 68.1\sqrt{kp\nu}$	Recommend <0.10 Mach

NOMENCLATURE
(Based on U.S. Units)

SYMBOL	DESCRIPTION
a	Area
c	Coefficient of discharge, dimensionless
C_d	Unit capacity of valve, C_v/d^2
C_D	Unit capacity of valve assembly, C_v/D^2
C_f	Gas sizing factor used by some manufacturers
C_v	Valve sizing coefficient (See ISA-S39.2 and S39.4)
C_1	Gas sizing factor used by some manufacturers
d	Valve inlet diameter, inches
D	Pipe diameter, inches
F	Velocity of approach factor, $1/\sqrt{1 - m^2}$, dimensionless
F_d	Valve style modifier, dimensionless
F_F	Liquid critical pressure ratio factor, dimensionless
F_k	Ratio of specific heats factor, dimensionless
F_L	Liquid pressure recovery factor, dimensionless
F_{LP}	Combined F_L and F_P factors for valve with reducers, dimensionless
F_p	Piping geometry factor, dimensionless
F_R	Reynolds number factor, dimensionless
F_s	Laminar, or streamline, flow factor
F_y	Liquid choked flow factor, dimensionless
g	Acceleration of gravity
G	Specific gravity (ratio of densities). For a liquid, G is taken at flowing temperature referred to water at standard condition (60°F.). For a gas, G is referred to air, with both gases at standard conditions (14.73 psia and 60°F.), dimensionless.
k	Ratio of specific heats of gas
K	Velocity head coefficient, dimensionless
K_B	Bernoulli coefficient, $1 - (d/D)^4$, dimensionless
K_c	Coefficient of incipient cavitation. [Actually the ratio $\Delta p/(p_1 - p_v)$ at which cavitation measurably affects the coefficient C_v], dimensionless
K_I	Inlet velocity head coefficient ($K_1 + K_{B1}$), dimensionless
K_1	Resistance coefficient for inlet fitting, dimensionless
K_2	Resistance coefficient for outlet fitting, dimensionless
M	Molecular weight
m	Ratio of orifice area to pipe area, dimensionless
p	Absolute static pressure, psia
p_c	Thermodynamic critical pressure, psia
p_r	Reduced pressure, p/p_c , dimensionless
p_v	Vapor pressure of liquid at inlet temperature, psia
q	Volumetric flow rate, gpm or scfh
Re_v	Valve Reynolds number, dimensionless
T	Absolute temperature($^{\circ}F + 460 = ^{\circ}R$)

T_c	Thermodynamic critical temperature, ° R
T_r	Reduced temperature, T/T_c , dimensionless
v	Specific volume, ft^3/lb .
U	Average velocity, ft./sec .
W	Weight rate of flow, lb./hr .
X	Ratio of pressure drop to absolute inlet static pressure, $\Delta p/p_1$, dimensionless
X_T	Pressure drop ratio factor, 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
Z	Compressibility factor, dimensionless
λ (gamma)	Specific weight(weight per unit volume) lb./ft^3
Δ (delta)	Difference(e.g. $\Delta p = p_1 - p_2$)
μ (mu)	Absolute viscosity, centipoise
ν (nu)	Kinematic viscosity, centistokes(μ/G)
Σ (sigma)	Summation

SUBSCRIPTS

1	Upstream
2	Downstream
A	Acoustic
Vc	Vena contracta

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