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Globe and Ball Valves

Selecting Valves: Globe vs. Ball

The control valve is the most important single element in any fluid handling system, because it regulates the flow of fluid to the process. To properly select a control valve, a general knowledge of the process and components is usually necessary. This reference section can help you select and size the control valve that most closely matches the process requirements.

The sizing of a valve is very important if it is to render good service. If it is undersized, it will not have sufficient capacity. If it is oversized, the controlled variable may cycle, and the seat, and plug will be subject to wire drawing because of the restricted opening.

Systems are designed for the most adverse conditions expected (i.e., coldest weather, greatest load, etc.). In addition, system components (boiler, chiller, pumps, coils, etc.) are limited to sizes available and frequently have a greater capacity than system requirements. Correct sizing of the control valve for actual expected conditions is considered essential for good control.

A basic rule of control valve sizing is:

The higher the percentage of drop across the wide open valve in relation to the percentage of pressure drop through the line and process coil, the better the control.

Technical Comparison Between Globe and Ball Valves

Technically, the globe valve has a stem and plug, which strokes linearly, commonly referred to as “stroke” valves. The ball valve has a stem and ball, which turns horizontally, commonly referred to as “rotational” valves.

Early ball valves used a full port opening, allowing large amounts of water to pass through the valve. This gave HVAC controls contractors the ability to select a ball valve two to three pipe sizes smaller than the piping line size. Compared to traditional globe valves that would be only one pipe size smaller than the line size, this was often a more cost-effective device-level solution. In addition, the ball valve could be actuated by a damper actuator, rather than expensive box-style “Mod” motors.

Pricing Comparison

Today, with equivalent pricing between ball and globe valves, the full port ball valve is falling out of favor for most HVAC control applications. This is also due to its poor installed flow characteristic that leads to its inability to maintain proper control. New “flow optimized” or characterized ball valves, specifically designed for modulating applications, have been developed. Characterized ball valves are sized the same way as globe valves. They provide an equal percentage flow characteristic, enabling stable control of fluids. Additionally, there are more cost-effective valve actuators now available for globe valves. Better control and more-competitive pricing now puts globe valves on the same playing field as characterized ball valves.

Selection Guidelines

Globe Valve

- High differential pressure across valve
- Rebuilding of the valve is desired
- Better control performance
- Better low flow (partial load) performance
- Use for steam, water or water/glycol media
- Smaller physical profile than a comparable ball valve

Characterized Ball Valve

- Tight shutoff or high close offs of around 100 psi* are required
- Isolation or two position control**
- Use for water or water/glycol solution only

* This equates to a pump head pressure of approximately 230 ft. Not very common HVAC applications.
** Valve can be line sized to minimize pressure losses; butterfly valves are also used for these applications.

Sizing a Valve

Pressure Drop for Water Flow

A pressure drop must exist across a control valve if flow is to occur. The greater the drop, the greater the flow at any fixed opening. The pressure drop across a valve also varies with plug position – from minimum when fully open, to 100% of the system drop when fully closed.

To size a valve properly, it is necessary to know the full flow pressure drop across it. The pressure drop across a valve is the difference in pressure between the inlet and outlet under flow conditions. When it is specified by the engineer and the required flow is known, the selection of a valve is simplified. When this pressure drop is not known, it must be computed or assumed.

If the pressure drop across the valve when fully open is not a large enough percentage of the total system drop, there will be little change in fluid flow until the valve actually closes, forcing the valve's characteristic toward a quick opening form.

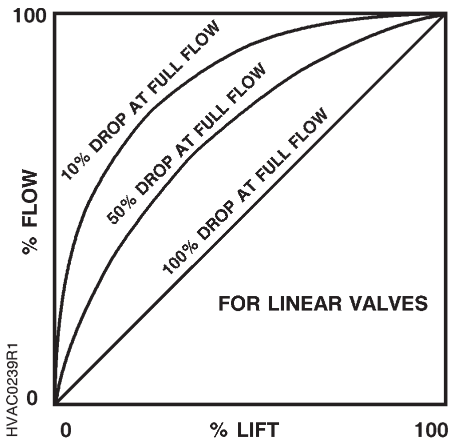


Figure 1.

Figure 1 shows flow-lift curves for a linear valve with various percentages of design pressure drop. Note the improved characteristic as pressure drop approaches 100% of system pressure drop at full flow.

It is important to realize that the flow characteristic for any particular valve, such as the linear characteristic shown in Figure 1 is applicable only if the pressure drop remains nearly constant across the valve for full stem travel. In most systems, however, it is impractical to take 100% of the system drop across the valve.

A good working rule is, "at maximum flow, 25 to 50% of the total system pressure drop should be absorbed by the control valve." Although this generally results in larger pump sizes, it should be pointed out that the initial equipment cost is offset by a reduction in control valve size, and results in improved controllability of the system. Reasonably good control can be accomplished with pressure drops of 15 to 30% of total system pressures. A drop of 15% can be used if the variation in flow is small.

Recommended Pressure Drops for Valve Sizing — Water

1. With a differential pressure less than 20 psi, use a pressure drop equal to 5 psi.
2. With a differential pressure greater than 20 psi, use a pressure drop equal to 25% of total system pressure drop (maximum pump head), but not exceeding the maximum rating of the valve.

Sizing a Valve

Pressure Drop for Steam

The same methodology should be applied for selecting a valve for steam with the most important consideration is the pressure drop.

First, the correct maximum capacity of the coil must be determined. Ideally, there should be no safety factor in this determination and it should be based on the actual BTU heating requirements. The valve size must be based on the actual supply pressure at the valve. When the valve is fully open, the outlet pressure will assume a valve such that the valve capacity and coil condensing rate are in balance. If this outlet valve pressure is relatively large (small pressure drop), then as the valve closes, there will be no appreciable reduction in flow until the valve is nearly closed. To achieve better controllability, the smallest valve (largest pressure drop) should be selected. With the valve outlet pressure much less than the inlet pressure, a large pressure drop results. There will now be an immediate reduction in capacity as the valve throttles. For steam valves, generally the largest possible pressure drop should be taken, without exceeding the critical pressure ratio. Therefore, the steam pressure drop should approach 80% of the system differential pressure.

Examining the pressure drops under "Recommended Pressure Drops for Valve Sizing — Steam" , you might be concerned about the steam entering the coil at 0 psi when a large drop is taken across the control valve. Steam flow through the coil will still drop to vacuum pressures due to condensation of the steam. Consequently, a pressure differential will still exist. In this case, proper steam trapping and condensation piping is essential.

Recommended Pressure Drops for Valve Sizing — Steam

1. With gravity flow condensate removal and inlet pressure less than 15 psi, use a pressure drop equal to the inlet gauge pressure.
2. With vacuum return system up to 7" Hg vacuum and an inlet pressure less than 2 psi, a pressure drop of 2 psi should be used. With an inlet pressure of 2 to 15 psi, use a pressure drop equal to the inlet gauge pressure.
3. With an inlet pressure greater than 15 psi, use a pressure drop equal to 80% of system differential pressure. Example: Inlet pressure is 20 psig (35 psia) and a gravity return at atmospheric pressure 0 psig (14.7 psia), use a pressure drop of 16 psi.
4. When a coil size is selected on the basis that line pressure and temperature is available in the coil of a heating and ventilating application, a very minimum pressure drop is desired. In this case, use the following: pressure drop:

Initial Pressure	Pressure Drop
15 psi	5 psi
50 psi	7.5 psi
100 psi	10 psi
Over 100 psi	10% of line pressure

(typically on/off applications)

Sizing a Valve

Valve Sizing Formulas

The Most Important Variables to Consider When Sizing a Valve:

1. What medium will the valve control? Water? Steam? What effects will specific gravity and viscosity have on the valve size?
2. What will the inlet pressure be under maximum load demand? What is the inlet temperature?
3. What pressure drop (differential) will exist across the valve under maximum load demand?
4. What maximum capacity should the valve handle?
5. What is the maximum pressure differential the valve must close against?

When these are known, a valve can be selected by formula (Cv method) or water and steam capacities tables which can be found in the Valves section, pages A-7 through A-10. The valve size should not exceed the line size.

The following definitions apply in the following formulas:

Cv	Valve flow coefficient, U.S. GPM with P = 1 psi
P_1	Inlet pressure at maximum flow, psia (abs.)
P_2	Outlet pressure at maximum flow, psia (abs.)
ΔP	$P_1 — P_2$ at maximum flow, psi
Q	Fluid flow, U.S. ∆M
W	Steam flow, pounds per hour (lb./hr.)
S	Specific gravity of fluid relative to water @ 60°F
K	1 + (0.0007 x °F superheat), for steam
K_r	Viscosity correction factor for fluids (See Page G-6)

Formulas:	Remarks:
1. For liquids (water, oil, etc.): $Cv = Q\sqrt{\frac{S}{\Delta P}}$	Specific gravity correction is negligible for water below 200°F (use S=1.0). Use actual specific gravity S of other liquids at actual flow temperature.
$Cv = K_rQ\sqrt{\frac{S}{\Delta P}}$	Use this for fluids with viscosity correction fact. Use actual specific gravity S for fluids at actual flow temperature.
2. For steam (saturated or superheated): $Cv = \frac{WK}{2.1\sqrt{\Delta P\ (P_1 + P_2)}}$	Use this when P_2 is *greater* than $1/2P_1$
$Cv = \frac{WK}{1.82\ P_1}$	Use this when P2 is *less than* or *equal to* $1/2P_1$

Sizing a Valve

Sizing Formulas and Tables

Viscosity Factors

The relationship between kinematic and absolute viscosity:

$$\text{Centistoke} = \frac{\text{Centipoise}}{\text{Specific Gravity}}$$

Saybolt* Univ Seconds (S.S.U.)	Engler Time Seconds	Kinematic Viscosity	Correction Factors (K_1)
46,350	—	10,000	—
37,080	—	8,000	—
27,810	—	6,000	—
18,540	—	4,000	—
13,900	—	3,000	—
11,590	—	2,500	—
9,270	—	2,000	1.93
6,950	10,800	1,500	1.90
4,635	7,100	1,000	1.82
3,708	5,700	800	1.78
2,781	4,250	600	1.74
1,854	2,820	400	1.67
1,390	2,120	300	1.63
1,159	1,760	250	1.61
927	1,400	200	1.57
695	1,050	150	1.43
464	700	100	1.45
371	555	80	1.42
278	420	60	1.37
186	290	40	1.30
141	225	30	1.25
119	191	25	1.22
97.8	157	20	120
77.4	127	15	1.16
58.9	97	10	1.11
52.1	85.5	8	1.08
45.6	76.0	6	1.07
39.1	67.5	4	1.05
36.0	62.5	3	1.03
32.6	58.0	2	—
31.6	55.5	1.5	—
31.3 ←PURE WATER AT 60°F→ 1.1			—

Chart Note

*Redwood time (seconds) approximately same as S.S.U.

Specific Gravity of Water

Temp T(°F)	Abs. Pressure	Specific Gravity — S (W=62.4 lb./ft.³ @ 60°F)	$\sqrt{S}$
60	—	1.000	1.000
100	—	0.993	0.999
150	—	0.981	0.985
200	—	0.963	0.981
250	30	0.942	0.971
300	67	0.920	0.959
350	135	0.891	0.944
400	247	0.860	0.927
450	423	0.827	0.910

Process Formulas

For Heating or Cooling Water:

$$\text{GPM} = \frac{\text{Btu/hr.}}{(\text{°F water temp. rise or drop} \times 500)}$$

$$\text{GPM} = \frac{\text{CFM} \times .009 \times \text{H}}{\text{°F water temperature change}}$$

(H = change in enthalpy of air expressed in Btu/lb. of air)

For Heating Water with Steam:

lbs. steam/hr. = 0.50 x GPM x (°F water temp. rise)

For Heating or Cooling Water:

$$\text{GPM}_1 = \text{GPM}_2 \times \frac{(\text{°F water}_2\ \text{temp. rise or drop})}{\text{°F water}_1\ \text{temp. drop}}$$

For Heating Air with Steam Coils:

$$\text{lbs. steam/hr.} = 1.08 \times (\text{°F air temp. rise}) \times \frac{\text{CFM}}{1000}$$

For Heating Air with Water Coils:

$$\text{GPM} = 2.16 \times \frac{\text{CFM} \times (\text{°F air temp. rise})}{1000 \times (\text{°F water}_1\ \text{temp. drop})}$$

For Radiation:

lbs. steam/hr. = 0.24 x ft.² EDR (Low pressure steam)

EDR = Equivalent Direct Radiation

1 EDR (steam) = 240 BTU/Hr. (Coil Temp. = 215°F)

1 EDR (water) = 200 BTU/Hr. (Coil Temp. = 197°F)

$$\text{GPM} = \frac{\text{ft.}^2\ \text{EDR}}{50}$$ (Assume 20°F water TD)

Sizing a Valve

Valve Sizing and Selection Example

Select a valve to control a chilled water coil that must have a flow of 35 GPM with a valve differential pressure (ΔP) of 5 psi.

Determine the valve Cv using the formula for liquids.

$$Cv = Q \sqrt{\frac{S}{P}} = 35\text{ GPM} \sqrt{\frac{1}{5\text{ psi}}} = 15.6$$

Select a valve that is suitable for this application and has a Cv as close as possible to the calculated value.

One choice is 277-03186: a 1-1/4" NC valve with a Cv of 16. Refer to Flowrite Valves Reference section.

Valve Selection Criteria

1. Flow characteristic — Modified Equal Percentage which provides good control for a water coil.
2. Body rating and material — Suitable for water.
3. Valve type and action — A single seat NC valve with an adjustable spring range which can be sequenced with a NO valve used for heating.
4. Valve actuator — Actuator close-off rating is higher than the system differential pressure.
5. Valve line size — Its Cv is close to and slightly larger than the calculated Cv (15.6).
6. For Ball Valves — use the same selection criteria.

Valve Body Rating

The temperature-pressure ratings for ANSI Classes 125 and 250 valve bodies made of bronze or cast iron are shown below.

Description	Temperature	Pressure	
		ANSI Class 125	ANSI Class 250
Bronze Screwed Bodies			
Specification #B16.15-1978 ANSI Amer. Std.; USA; ASME	-20 to + 150°F (-30 to + 66°C)	200 psi (1378 kPa)	400 psi (2758 kPa)
	-20 to + 200°F (-30 to + 93°C)	190 psi (1310 kPa)	385 psi (2655 kPa)
	-20 to + 250°F (-30 to + 121°C)	180 psi (1241 kPa)	365 psi (2586 kPa)
	-20 to + 300°F (-30 to + 149°C)	165 psi (1138 kPa)	335 psi (2300 kPa)
	-20 to + 350°F (-30 to + 177°C)	150 psi (1034 kPa)	300 psi (2068 kPa)
	-20 to + 400°F (-30 to + 204°C)	125 psi (862 kPa)	250 psi (1724 kPa)
Cast Iron Flanged Bodies			
Class B-sizes 1 to 12 Specification #B16.1 1975 ANSI Amer. Std.; USA; ASME	-20 to + 150°F (-30 to + 66°C)	200 psi (1378 kPa)	500 psi (3445 kPa)
	-20 to + 200°F (-30 to + 93°C)	190 psi (1310 kPa)	460 psi (3169 kPa)
	-20 to + 225°F (-30 to + 106°C)	180 psi (1241 kPa)	440 psi (3032 kPa)
	-20 to + 250°F (-30 to + 121°C)	175 psi (1206 kPa)	415 psi (2859 kPa)
	-20 to + 275°F (-30 to + 135°C)	170 psi (1171 kPa)	395 psi (2722 kPa)
	-20 to + 300°F (-30 to + 149°C)	165 psi (1138 kPa)	375 psi (2584 kPa)
	-20 to + 325°F (-30 to + 163°C)	155 psi (1069 kPa)	355 psi (2448 kPa)
	-20 to + 350°F (-30 to + 177°C)	150 psi (1034 kPa)	335 psi (2308 kPa)
	-20 to + 375°F (-30 to + 191°C)	145 psi (1000 kPa)	315 psi (2170 kPa)
	-20 to + 400°F (-30 to + 204°C)	140 psi (965 kPa)	290 psi (1998 kPa)
	-20 to + 425°F (-30 to + 218°C)	130 psi (896 kPa)	270 psi (1860 kPa)
	-20 to + 450°F (-30 to + 232°C)	125 psi (862 kPa)	250 psi (1734 kPa)

Refer to Conversion Factors on page G-32.

Close-off Pressures

MZ Series

Valve Size	Electronic 2-Way	Electronic 3-Way
	Normally Open	
1/2", Cv ≤ 1.6	60 (414)	25 (172)
1/2", Cv ≤ 4	35 (241)	15 (103)
3/4 to 1", Cv ≤ 10	30 (207)	10 (69)
	Normally Closed	
1/2", Cv ≤ 1.6	70 (482)	70 (482)
1/2", Cv ≤ 4	40 (276)	40 (276)
3/4 to 1", Cv ≤ 10	30 (207)	30 (207)

Table Note:

All close-off values within table are in psi (kPa) unless otherwise indicated.

For 3-Way valve close-offs, use this chart to determine upper port (NC) and bottom port (NO).

MT Series

2-Way Valve Size	Pneumatic 599-01088 3 to 8 psi (21 to 55 kPa)	Pneumatic 599-01088 8 to 13 psi (55 to 90 kPa)	Pneumatic 599-01088 10 to 15 psi (69 to 103 kPa)	Electronic SQS	Electronic SSC
			Normally Open		
1/2", Cv ≤ 1.6	95 (655)	45 (310)	20 (138)	160 (1103)	120 (868)
1/2", Cv ≤ 4	45 (310)	25 (172)	15 (103)	85 (586)	65 (448)
3/4 to 1", Cv ≤ 10	35 (241)	10 (69)	—	70 (482)	55 (379)
			Normally Closed		
1/2", Cv ≤ 1.6	40 (276)	95 (655)	95 (655)	95 (655)	95 (655)
1/2", Cv ≤ 4	28 (193)	50 (345)	50 (345)	50 (345)	50 (345)
3/4 to 1", Cv ≤ 10	18 (124)	40 (276)	40 (276)	40 (276)	40 (276)

3-Way Valve Size	Pneumatic 599-01088 3 to 8 psi (21 to 55 kPa)	Pneumatic 599-01088 8 to 13 psi (55 to 90 kPa)	Pneumatic 599-01088 10 to 15 psi (69 to 103 kPa)	Electronic SQS	Electronic SSC
			Normally Open		
1/2", Cv ≤ 1.6	95 (655)	45 (310)	20 (138)	160 (1103)	95 (655)
1/2", Cv ≤ 4	45 (310)	25 (172)	15 (103)	85 (586)	50 (379)
3/4 to 1", Cv ≤ 10	35 (241)	10 (69)	—	70 (482)	40 (276)
			Normally Closed		
1/2", Cv ≤ 1.6	40 (276)	95 (655)	120 (827)	95 (655)	95 (655)
1/2", Cv ≤ 4	28 (193)	50 (345)	65 (448)	50 (345)	50 (345)
3/4 to 1", Cv ≤ 10	18 (124)	40 (276)	50 (345)	40 (276)	40 (276)

Table Notes:

All close-off values within table are in psi (kPa) unless otherwise indicated.

For 3-Way valve close-offs, use this chart to determine upper (NC) and bottom port (NO).

Normally open close-off pressures are at 20 psi actuator pressure.

Normally closed close-off pressures are at 0 psi actuator pressure.

Close-off Pressures

Electronic

Valve Size in.	(mm)	Rack & Pinion APC 298, 299	SAX NSR APC 371, 373	SKD APC 267, 274-276	SKB APC 289-291	SKC APC 292-294
		Normally Open				
1/2	(15)	250 (1724)	250 (1724)	250 (1724)	250 (1724)	—
3/4	(20)	231 (1593)	211 (1456)	250 (1724)	250 (1724)	—
1	(25)	149 (1028)	137 (945)	201 (1386)	250 (1724)	—
1-1/4	(32)	92 (634)	85 (586)	124 (855)	250 (1724)	—
1-1/2	(40)	59 (407)	55 (379)	80 (552)	250 (1724)	—
2	(50)	36 (248)	34 (235)	49 (338)	201 (1386)	—
2-1/2	(65)	25 (172)	26 (179)	38 (262)	153 (518)	—
3	(80)	18 (124)	17 (117)	25 (172)	101 (342)	—
4	(100)	—	—	—	—	65 (448)
5	(125)	—	—	—	—	42 (289)
6	(150)	—	—	—	—	29 (199)
		Normally Closed				
1/2	(15)	250 (1724)	250 (1724)	250 (1724)	250 (1724)	—
3/4	(20)	250 (1724)	250 (1724)	250 (1724)	250 (1724)	—
1	(25)	173 (1193)	159 (1097)	203 (1400)	250 (1724)	—
1-1/4	(32)	100 (690)	92 (634)	117 (807)	250 (1724)	—
1-1/2	(40)	61 (421)	57 (393)	73 (503)	208 (1434)	—
2	(50)	37 (255)	35 (241)	44 (303)	126 (869)	—
2-1/2	(65)	25 (172)	26 (179)	34 (234)	97 (668)	—
3	(80)	18 (124)	17 (117)	22 (152)	63 (434)	—
4	(100)	—	—	—	—	39 (268)
5	(125)	—	—	—	—	25 (172)
6	(150)	—	—	—	—	17 (117)

Table Notes:

All close-off values within table are in psi (kPa) unless otherwise indicated.

Electronic High Pressure Close-off

Valve Size in.	(mm)	Electro-Hydraulic 24 VAC	
		SKD	SKC
		Normally Open	
2-1/2	(65)	200 (1378)	—
3	(80)	200 (1378)	—
4	(100)	—	200 (1378)
5	(125)	—	200 (1378)
6	(150)	—	200 (1378)
		Normally Closed	
2-1/2	(65)	200 (1378)	—
3	(80)	200 (1378)	—
4	(100)	—	200 (1378)
5	(125)	—	200 (1378)
6	(150)	—	200 (1378)

Table Notes:

All close-off values within table are in psi (kPa) unless otherwise indicated.

Close-off Pressures

Pneumatic

Valve Size in. (mm)	Spring Range: 3 to 8 psi (21 to 55 kPa), 4" Actuator, 15 psi (103 kPa)	3 to 8 psi, 8" Actuator, 15 psi (103 kPa)	3 to 8 psi, 8" Actuator, 30 psi (207 kPa)	3 to 8 psi, 12" Actuator, 15 psi (103 kPa)	3 to 8 psi, 12" Actuator, 30 psi (207 kPa)	10 to 15 psi (69 to 103 kPa), 4" Actuator, 0 psi (0 kPa)	10 to 15 psi, 8" Actuator, 0 psi (0 kPa)	10 to 15 psi, 12" Actuator, 0 psi (0 kPa)
	Normally Open					Normally Closed		
1/2 (15)	142 (979)	250 (1724)	250 (1724)	—	—	236 (1627)	250 (1724)	—
3/4 (20)	80 (552)	231 (1593)	250 (1724)	—	—	155 (1069)	250 (1724)	—
1 (25)	52 (359)	150 (1034)	250 (1724)	250 (1724)	250 (1724)	91 (627)	250 (1724)	250 (1724)
1-1/4 (32)	32 (221)	93 (641)	250 (1724)	250 (1724)	250 (1724)	52 (359)	148 (1020)	250 (1724)
1-1/2 (40)	20 (138)	60 (414)	198 (1365)	205 (1413)	250 (1724)	32 (331)	92 (634)	250 (1724)
2 (50)	12 (83)	37 (255)	123 (848)	130 (896)	250 (1724)	20 (138)	55 (379)	185 (1275)
2-1/2 (65)	—	31 (213)	100 (689)	95 (655)	250 (1724)	—	36 (248)	114 (786)
3 (80)	—	20 (138)	66 (444)	63 (434)	200 (1378)	—	23 (158)	74 (610)
4 (100)	—	—	—	40 (275)	129 (889)	—	—	46 (317)
5 (125)	—	—	—	26 (179)	82 (565)	—	—	29 (199)
6 (150)	—	—	—	18 (124)	57 (393)	—	—	20 (137)

Table Notes:

All close-off values within table are in psi (kPa) unless otherwise indicated.

For 3-Way valve close-offs, use this chart to determine upper port (NC) and bottom port (NO).

Normally open close-off pressures are at 15 psi actuator pressure.

Normally closed close-off pressures are at 0 psi actuator pressure.

Pneumatic High Pressure Close-off

Valve Size in. (mm)	Spring Range: 3 to 8 psi (21 to 55 kPa), 8" Actuator	3 to 8 psi, 12" Actuator	10 to 15 psi (69 to 103 kPa), 8" Actuator	10 to 15 psi, 12" Actuator
	Normally Open		Normally Closed	
2-1/2 (65)	200 (1378)	—	200 (1378)	—
3 (80)	200 (1378)	—	200 (1378)	—
4 (100)	—	200 (1378)	—	200 (1378)
5 (125)	—	200 (1378)	—	200 (1378)
6 (150)	—	200 (1378)	—	200 (1378)

Table Notes:

All close-off values within table are in psi (kPa) unless otherwise indicated.

Close-off Pressures

Close-off Pressure – 599 Series Ball

2-Way Valve Body Part No.	Valve Size in.	Flow Rate Cv	Close Off psi
599-10300 / 599-10300S	1/2	0.4	200
599-10301 / 599-10301S		0.63	200
599-10302 / 599-10302S		1.0	200
599-10303 / 599-10303S		1.6	200
599-10304 / 599-10304S		2.5	200
599-10305 / 599-10305S		4.0	200
599-10306 / 599-10306S		6.3	200
599-10307* / 599-10307S*		10	200
599-10308 / 599-10308S	3/4	6.3	200
599-10309 / 599-10309S		10	200
599-10310 / 599-10310S		16	200
599-10311* / 599-10311S*		25	200
599-10312 / 599-10312S	1	10	200
599-10313 / 599-10313S		16	200
599-10314 / 599-10314S		25	200
599-10315 / 599-10315S		40	200
599-10316* / 599-10316S*		63	200
599-10317 / 599-10317S	1-1/4	16	200
599-10318 / 599-10318S		25	200
599-10319 / 599-10319S		40	200
599-10320 / 599-10320S		63	200
599-10321* / 599-10321S*		100	200
599-10322 / 599-10322S	1-1/2	25	200
599-10323 / 599-10323S		40	200
599-10324 / 599-10324S		63	200
599-10325 / 599-10325S		100	200
599-10326* / 599-10326S*		160	200
599-10327 / 599-10327S	2	40	200
599-10328 / 599-10328S		63	200
599-10329* / 599-10329S*		100	200
599-10330* / 599-10330S*		160	200

** Denotes a full-port valve with no flow optimizer insert.*
S suffix denotes Stainless Steel Ball and Stem

Close-off Pressure – 599 Series Ball

3-Way Valve Body Part No.	Valve Size in.	Flow Rate Cv	Close Off psi
599-10350 / 599-10350S	1/2	0.4	200
599-10351 / 599-10351S		0.63	200
599-10352 / 599-10352S		1.0	200
599-10353 / 599-10353S		1.6	200
599-10354 / 599-10354S		2.5	200
599-10355 / 599-10355S		4	200
599-10356 / 599-10356S		6.3	200
599-10357* / 599-10357S*		10	200
599-10358 / 599-10358S	3/4	6.3	200
599-10359 / 599-10359S		10	200
599-10360* / 599-10360S*		16	200
599-10361 / 599-10361S	1	10	200
599-10362 / 599-10362S		16	200
599-10363* / 599-10363S*		25	200
599-10364 / 599-10364S	1-1/4	16	200
599-10365 / 599-10365S		25	200
599-10366* / 599-10366S*		40	200
599-10367 / 599-10367S	1-1/2	25	200
599-10368 / 599-10368S		40	200
599-10369* / 599-10369S*		63	200
599-10370 / 599-10370S	2	40	200
599-10371 / 599-10371S		63	200
599-10372* / 599-10372S*		100	200

** Denotes a full-port valve with no flow optimizer insert.*
S suffix denotes Stainless Steel Ball and Stem

Flow Coeffiecients

2-Way, Full-Port (no flow optimizer) Ball Valve Part Nos. and Flow Coefficients

Valve Size in.	(mm)	Valve Part No.	Effective (Installed) Cv (Kvs) — Supply Line Size in Inches (mm): 1/2 (15)	3/4 (20)	1 (25)	1-1/4 (32)	1-1/2 (40)	2 (50)	2-1/2 (65)	3 (80)
1/2	(15)	**599-10307 or 599-10307S**	10.0 (8.62)	6.94 (5.93)	6.19 (5.29)					
3/4	(20)	**599-10311 or 599-10311S**		25.00 (21.55)	18.66 (15.99)	15.35 (13.12)				
1	(25)	**599-10316 or 599-10316S**			63.00 (54.31)	39.78 (34.00)	33.56 (28.69)			
1-1/4	(32)	**599-10321 or 599-10321S**				100.00 (86.21)	69.19 (5.13)	51.45 (43.98)		
1-1/2	(40)	**599-10326 or 599-10326S**					160.00 (137.93)	93.80 (80.17)	76.34 (65.25)	
2	(50)	**599-10329 or 599-10329S**						100.00 (86.21)	94.30 (80.60)	86.12 (73.61)

3-Way, Full-Port (no flow optimizer) Ball Valve Part Nos. and Flow Coefficients

Valve Size in.	(mm)	Valve Part No.	Effective (Installed) Cv (Kvs) — Supply Line Size in Inches (mm): 1/2 (15)	3/4 (20)	1 (25)	1-1/4 (32)	1-1/2 (40)	2 (50)	2-1/2 (65)	3 (80)
1/2	(15)	**599-10357 or 599-10357S**	10.0 (8.62)	6.94 (5.93)	6.19 (5.29)					
3/4	(20)	**599-10360 or 599-10360S**		16.00 (13.79)	13.9 (11.98)	12.4 (10.69)				
1	(25)	**599-10363 or 599-10363S**			25.00 (21.55)	22.5 (19.4)	21.2 (18.27)			
1-1/4	(32)	**599-10366 or 599-10366S**				40.00 (34.48)	36.9 (31.81)	33.3 (28.70)		
1-1/2	(40)	**599-10369 or 599-10369S**					63.00 (54.31)	55.3 (47.67)	51.00 (43.96)	
2	(50)	**599-10372 or 599-10372S**						100 (86.21)	94.3 (81.29)	86.1 (74.23)

Key Valve may be oversized (dark green: first value in each row) | Optimal valve size (white) | Valve may be undersized (light green: last value in each row)

Steam Saturation Pressure

Gauge/Temperature

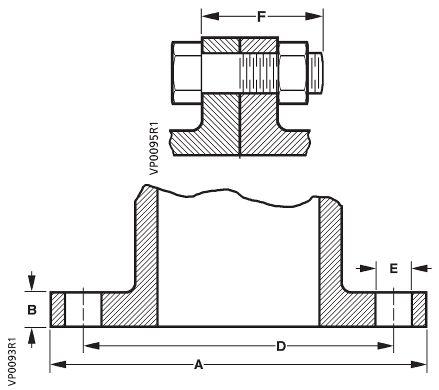
Gauge Pressure psi	Absolute Pressure psi	Temperature Degrees Fahrenheit
0.0	14.70	212.0
0.3	15	213.0
1.3	16	216.3
2.3	17	219.4
3.3	18	222.4
4.3	19	225.2
5.3	20	228.0
6.3	21	230.6
7.3	22	233.1
8.3	23	235.5
9.3	24	237.8
10.3	25	240.1
11.3	26	242.2
12.3	27	244.4
13.3	28	246.4
14.3	29	248.4
15.3	30	250.3
16.3	31	252.2
17.3	32	254.1
18.3	33	255.8
19.3	34	257.6
20.3	35	259.3
21.3	36	261.0
22.3	37	262.6
23.3	38	264.2
24.3	39	265.8
25.3	40	267.3
26.3	41	268.7
27.3	42	270.2
28.3	43	271.7
29.3	44	273.1
30.3	45	274.5
31.3	46	275.8
32.3	47	277.2
33.3	48	278.5
34.3	49	279.8
35.3	50	281.0
36.3	51	282.3
37.3	52	283.5
38.3	53	284.7
39.3	54	285.9
40.3	55	287.1
41.3	56	288.2
42.3	57	289.4
43.3	58	290.5
44.3	59	291.6
45.3	60	292.7
46.3	61	293.8
47.3	62	294.9
48.3	63	295.9
49.3	64	297.0
50.3	65	298.0
51.3	66	299.0
52.3	67	300.0
53.3	68	301.0
54.3	69	302.0
55.3	70	302.9
56.3	71	303.9
57.3	72	304.8
58.3	73	305.8
59.3	74	306.7
60.3	75	307.6
61.3	76	308.5
62.3	77	309.4
63.3	78	310.3
64.3	79	311.2
65.3	80	312.0
66.3	81	312.9
67.3	82	313.8
68.3	83	314.6
69.3	84	315.4
70.3	85	316.3
71.6	86	317.1
72.3	87	317.9
73.3	88	318.7
74.3	89	319.5
75.3	90	320.3
76.3	91	321.1
77.3	92	321.8
78.3	93	322.6
79.3	94	323.4
80.3	95	324.1
81.3	96	324.9
82.3	97	325.6
83.3	98	326.4
84.3	99	327.1
85.3	100	327.8
87.3	102	329.3
89.3	104	330.7
91.3	106	332.0
93.3	108	333.4
95.3	110	334.8
97.3	112	336.1
99.3	114	337.4
101.3	116	338.7
103.3	118	340.0
105.3	120	341.3
107.3	122	342.5
109.3	124	343.8
111.3	126	345.0
113.3	128	346.2
115.3	130	347.4
117.3	132	348.5
119.3	134	349.7
121.3	136	350.8
123.3	138	352.0
125.3	140	353.1
127.3	142	354.2
129.3	144	355.3
131.3	146	356.3
133.3	148	357.4
135.3	150	358.5
137.3	152	359.5
139.3	154	360.5
141.3	156	361.6
143.3	158	362.6
145.3	160	363.6
147.3	162	364.6
149.3	164	365.6
151.3	166	366.5
153.3	168	367.5
155.3	170	368.5
157.3	172	369.4
159.3	174	370.4
161.3	175	371.3
163.3	178	372.2
165.3	180	373.1
167.3	182	374.0
169.3	184	374.9
171.3	186	375.8
173.3	188	376.7
175.3	190	377.6
177.3	192	378.5
179.3	194	379.3
181.3	196	380.2
183.3	198	381.0
185.3	200	381.9
190.3	205	384.0
195.3	210	386.0
200.3	215	388.0
205.3	220	389.9
210.3	225	391.9
215.3	230	393.8
220.3	235	395.6
225.3	240	397.4
230.3	245	399.3
235.3	250	401.1
245.3	260	404.5
255.3	270	407.9
265.3	280	411.2
275.3	290	414.4
285.3	300	417.5

Vacuum/Temperature

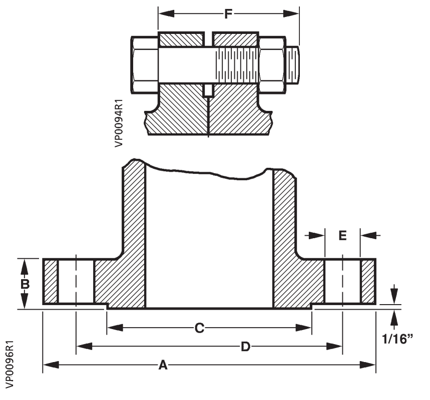
Vacuum Inches Hg	Absolute Pressure psi	Temperature Degrees Fahrenheit
29.74	0.0886	32
29.67	0.1217	40
29.56	0.1780	50
29.40	0.2562	60
29.18	0.3626	70
28.89	0.505	80
28.50	0.696	90
28.00	0.946	100.00
27.88	1	101.83
25.85	2	126.15
23.81	3	141.52
21.78	4	153.01
19.74	5	162.28
17.70	6	170.06
15.67	7	176.85
13.63	8	182.86
11.60	9	188.27
9.56	10	193.22
7.52	11	197.75
5.49	12	201.96
3.45	13	205.87
1.42	14	209.55

Flanged Cast Iron Dimensions

2-1/2 to 6-inch Cast Iron Flange Dimensions (as defined by ANSI standard B16.1)



ANSI Class 125.



ANSI Class 250.

ANSI Class 125

Nominal Pipe Size	Flanges		Drilling		Bolting		Length of Machine Bolts
	Flange Diameter	Flange Thickness	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	
	A	B	D	E			F
2-1/2"	7"	11/16"	5-1/2"	3/4"	4	5/8"	2-1/2"
3"	7-1/2"	3/4"	6"	3/4"	4	5/8"	2-1/2"
4"	9"	15/16"	7-1/2"	3/4"	8	5/8"	3"
5"	10"	15/16"	8-1/2"	7/8"	8	3/4"	3"
6"	11"	1"	9-1/2"	7/8"	8	3/4"	3-1/4"

ANSI Class 250

Nominal Pipe Size	Flanges			Drilling		Bolting		Length of Machine Bolts
	Flange Diameter	Flange Thickness	Diameter of Raised Face	Diameter of Bolt Circle	Diameter of Bolt Holes	Number of Bolts	Diameter of Bolts	
	A	B	C	D	E			F
2-1/2"	7-1/2"	1"	4-15/16"	5-7/8"	7/8"	8	3/4"	3-1/4"
3"	8-1/4"	1-1/8"	5-11/16"	6-5/8"	7/8"	8	3/4"	3-1/5"
4"	10"	1-1/4"	6-15/16"	7-7/8"	7/8"	8	3/4"	3-3/4"
5"	11"	1-3/8"	8-5/16"	9-1/4"	7/8"	8	3/4"	4"
6"	12-1/2"	1-7/16"	9-11/16"	10-5/8"	7/8"	12	3/4"	4"

Sizing and Selecting Pressure Independent Control Valves (PICV)

Just two pieces of information are needed to size a PICV:

1. Line size where the valve will be installed
2. Design flow, in gpm, of the coil being controlled

Then find the valve size of the PICV, closest to the line size, which has a preset maximum flow setting greater than or equal to the design flow of the coil being controlled. It is that easy!

Because the valves are pressure independent, within a certain differential pressure range, the differential pressure is not required for "sizing calculations."

In order for the valve to function as a pressure independent valve, you must ensure that the minimum differential pressure across the valve will always be greater than the start pressure of the pressure regulator in the PICV, or Δp_{min} of the pressure independence range of the PICV.

Please refer to the start pressures listed below and refer to the product data sheets for more information.

Part Number	Line Size Inches (mm)	ANSI Pressure Class	Maximum Flow Range (GPM)	Normally Open/ Closed	Close-off Pressure (psi)	ANSI Leakage Class	Pressure Independence Range (psi)	
							Δp min	Δp max
Threaded								
599-04300-X	1/2 (15)	250	0.3 to 2.7	NC	45	Class IV (0.01%)	2.3	58
599-04301-X			1.0 to 7.5				2.6	
599-04302-X	3/4 (20)		0.5 to 4.5				2.3	
599-04303-X			1.0 to 8.9				3.2	
599-04304-X	1 (25)		1.0 to 8.9				3.2	
599-04305-X	1-1/4 (32)		2.5 to 13.2				2.6	
599-04306-X	1-1/2 (40)		10 to 31		50	Class III (0.1%)	3.8	
599-04307-X	2 (50)		11 to 37				4.6	
599-04310-X	1/2 (15)		0.2 to 0.9	NO	200	Class IV (0.01%)	2.5	
599-04311-X			0.5 to 2.5				3	
599-04312-X	3/4 (20)		1 to 5.8				3.5	
Flanged								
599-07310	2-1/2 (65)	125	19 to 110	NO*	100	Class IV (0.01%)	3.6	90
599-07311	3 (80)		24 to 150					
599-07315	2-1/2 (65)		26 to 154				8	
599-07316	3 (80)		31 to 190					
599-07320	2-1/2 (65)	250	19 to 110				3.6	
599-07321	3 (80)		24 to 150					
599-07325	2-1/2 (65)		26 to 154				8	
599-07326	3 (80)		31 to 190					

Table Notes:

X suffix on threaded valves represents the various factory preset maximum flow GPM settings that are orderable

* Flanged valves are normally open but SQV spring return actuators fail open (SQV91P30U, 238 actuator prefix code) or fail closed (SQV91P40U, actuator prefix code 239)

Butterfly Valves

Introduction

When selecting a butterfly valve for water applications you must first determine the requirements of the valve assembly. The first question to ask is, “Will the valve be used for “Isolation” or “Proportional Control” of the fluid?” and “Does the application require a 2-way or 3-way assembly?”

2-way and 3-way Isolation Valves

When selecting a valve for isolation purposes, it is seldom necessary to calculate flow requirements beyond the published Cvs (flow coefficients)* of the valve. These valves are typically line size and require the lowest pressure drop available in the full open position. It may be possible to supply a valve smaller than the actual line size and still obtain a low-pressure drop. However, the cost of reducing flanges will typically offset any savings incurred by reducing the valve size. The 2- and 3-way Flow Coefficient charts, below and on G-16, provide Cv values for Siemens butterfly valves.

2-way and 3-way Proportional Control Valves

Control Valves are the most important element of a fluid handling system and proper selection of these valves is crucial for efficient operation of the process. When sizing butterfly valves for control, it is imperative to have certain requirements of the system.

You must have:

- **Maximum flow requirement**: This would be equivalent to the design flow and provided or converted to gallons per minute.
- **Maximum pressure drop allowed**: The Consulting Engineer usually provides this factor and are typically 3 to 5 psi max. However, the pressure drop should never exceed one half of the inlet pressure.

Without these two factors, selection of a control valve would be simply a guess.

2-way Flow Coefficients (Cvs)

Size	Degrees Open								
	10°	20°	30°	40°	50°	60°	70°	80°	90°
2"	0	1.3	5	14	26	40	52	59	60
2-1/2"	0	1.4	6	21	44	74	107	138	151
3"	0.7	1.5	8	29	67	115	175	234	262
4"	1.7	15	48	107	196	318	463	589	647
5"	3	32	99	206	362	579	832	1045	1141
6"	4	47	145	295	510	810	1160	1450	1580
8"	6	84	239	450	751	1190	1754	2385	2892
10"	9	133	360	652	1064	1683	2524	3596	4593
12"	12	192	509	899	1449	2288	3470	5085	6682
14"	75	340	770	1400	2200	3400	5600	7900	10000
16"	100	440	1000	1800	2800	4500	7400	10800	13000
18"	130	570	1300	2300	3600	5800	9600	15000	18000
20"	150	710	1600	2900	4600	7200	12000	18400	22000

Table Note

Flow Coefficients (Cv) = The amount of water in gallons per minute, at 60°F that will pass through a given orifice with a one pound pressure drop.

Butterfly Valves

3- way Flow Coefficients (Cvs)

Size	Degrees Open									
Run	**0°**	**10°**	**20°**	**30°**	**40°**	**50°**	**60°**	**70°**	**80°**	**90°**
Branch	**90°**	**80°**	**70°**	**60°**	**50°**	**40°**	**30°**	**20°**	**10°**	**0°**
2"	54	53	49	43	38	40	44	52	57	58
2-1/2"	114	108	93	74	52	64	78	102	126	135
3"	188	178	148	114	55	95	120	165	210	229
4"	385	374	348	313	150	295	345	419	482	511
5"	642	627	600	563	270	549	630	740	829	870
6"	935	909	867	809	483	780	895	1051	1180	1242
8"	1688	1573	1424	1271	796	1175	1367	1661	1994	2254
10"	2667	2430	2132	1856	1142	1685	1971	2439	3046	3570
12"	3938	3531	3019	2579	1629	2312	2715	3401	4368	5240
14"	5109	4825	4416	3719	2433	3514	3992	5259	6342	7173
16"	6735	6462	5832	4904	3213	4498	5265	6943	8567	9410
18"	9060	8724	7650	6372	4433	5778	6815	9056	11695	12785
20"	11229	10799	9545	7901	5619	7339	8449	11309	14423	15770

Table Notes

Three-way valve assemblies Cvs are corrected from published two-way Cvs to account for line losses generated by the tee, and are calculated values only. The pipe friction losses are a function of fluid velocity through the pipe and the three-way Cvs listed are apparent for full flow through the pipe. Operation at less than full capacity (lower velocity) will increase the actual Cvs

Sizing Example

With this information and assuming the media is water or a similar media (glycol/water mix), a control valve can be properly sized for the application by following these steps:

1. **Calculate the required Cv**: Using the following formula and the information required above, you could calculate the flow coefficient (Cv) of the control valve.

$$Cv = \frac{GPM}{\sqrt{\Delta P}}$$

Whereas: GPM = The maximum flow requirement
P = The max. pressure drop (5 psi)

Example

The line size is 6" and the required flow is 600 GPM with a maximum pressure drop of 5 psi. The square root of 5 is equal to 2.236. When divided into 600, the required Cv for this application is: 268.336.

2. **Select your valve size**: Using the Flow Coefficients (Cvs), select the appropriate valve size. If your required Cv is in between valve sizes, choose the larger size valve. When selecting a 3–way assembly, the Cv of the run should be selected.

Example

The line size is 6" and the calculated required Cv is 268.336. The valve selected is a 4" with a rated Cv of 647.

Butterfly valves are high capacity valves and require very little pressure drop to control flow, which allows for reduction from the line size when sizing valves. This pipe reduction affects the flow characteristics and will reduce the effective Cv of the valve. This phenomenon is known as the piping geometry factor (Fp), which brings us to the final step in valves sizing.

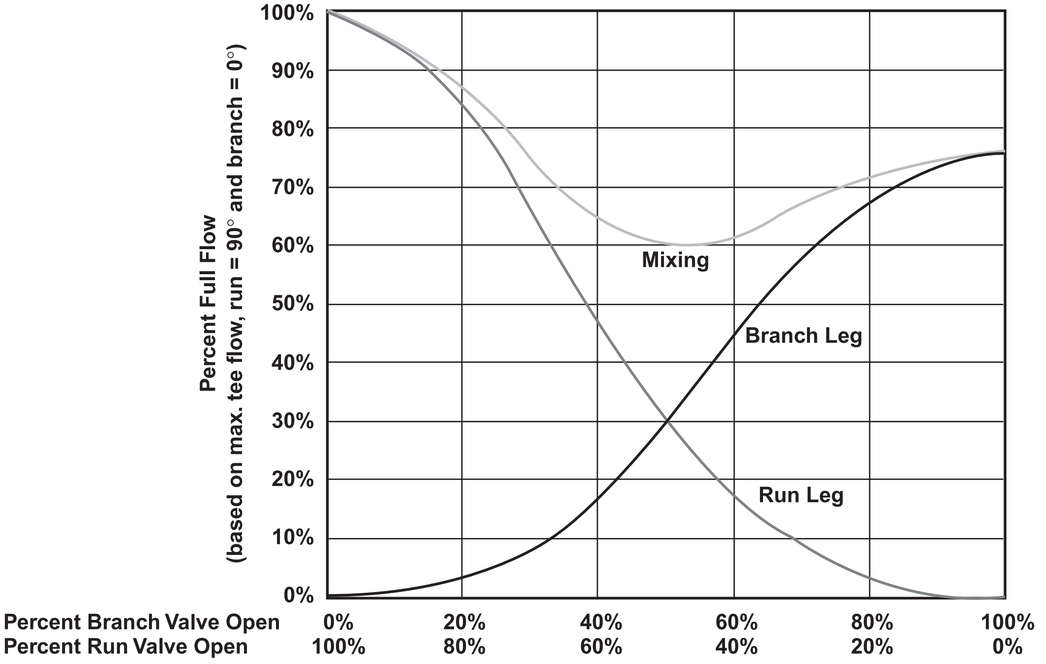
Butterfly Valves

3. **Piping Geometry Factor**: Reducing pipe sizes for installation of a smaller than pipe size valves will reduce the effective Cv of the valve. The greater the pipe reduction, the greater loss of Cv. Using the Adjusted Cvs for Piping Geometry Factors chart, verify that the corrected Cv, for the valve size selected, meets or exceeds the required Cv calculated in step 2.
   Note: 3-way Cvs have already been adjusted.

Adjusted Cvs for Piping Geometry Factors

Size	Pipe Size													
	2-1/2"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	22"	24"
2"	47	38												
2-1/2"		125	79											
3"			189	149										
4"				505	408									
5"					947	685								
6"						1138	916							
8"							2256	1822						
10"								3812	3123					
12"									5747	4811				
14"										8900	7600			
16"											11830	10140		
18"												16560	14580	
20"													20460	18260

6-inch 3-way Assembly at Constant Valve Differential Pressure (corrected for tee loss)



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- Choose the medium being controlled
- Determine the correct Cv or required flow (gpm)
- Calculate pressure drop and quantity of steam

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Terminology

Absolute Pressure — Absolute pressure is referenced to a theoretical perfect vacuum. At standard atmospheric pressure, absolute pressure may be calculated by adding 14.7 psi to the observed gauge pressure.

Ambient Temperature Rating — Ambient temperature refers to the temperature of the air surrounding the device.

Angled Body — A two way valve body that has connection points at right angles to each other**.**

Booster Pump — A pump used in secondary loops of hydronic systems to provide additional flow for that section of the system.

Butterfly Valve — A valve utilizing a disk rotating on a shaft to provide control and close off. Alternately, a check valve utilizing two semi-circular hinged plates to permit flow in one direction only.

Cavitation — The forming and imploding of cavities in a liquid due to rapid pressure changes, producing shock waves and cyclic stresses that can lead to undesirable noise and/or surface fatigue damage.

Close-off Rating — The maximum differential pressure, inlet to outlet, that a valve will close off against while fluid is flowing to a given leakage rate (tightness) criteria. In a stroke valve, the primary determinants are the force available from the actuator, the diameter of the plug, and the valve design. In a rotary valve, such as a ball valve, the primary determinant is typically the seal design as the torque of the actuator has little effect.

Close-off Rating of Three Way Valves — The maximum pressure difference between either of the two inlet ports and the outlet port for mixing valves, or the pressure difference between the inlet port and either of the two outlet ports for diverting valves.

Contoured Plug — In a globe valve, a contoured plug uses its peripheral shape to affect a desired flow characteristic. This is typically linear, equal percentage, or a modification of these. These are differentiated from V-plugs, basket plugs, cage plugs, and the like by the fact that the media flows around the plug and not through it.

Controlled Medium — The controlled medium is the material that is being conveyed and controlled though the device. In typical HVAC systems this includes air, water, and/or steam. It may also include fuel oil, natural gas, refrigerants, etc.

Critical Pressure Drop — The maximum pressure drop across a valve at which gasses and vapors will follow standard flow calculations. Pressure drops greater than this produced what is known as "choked flow" and sizing criteria will no longer accurately predict the volumetric flow.

Design Conditions — The assumed environmental variables that define the performance limits required of a HVAC system. This may include maximum and minimum outside air temperatures, expected solar and other thermal loads, occupancy levels, etc.

Differential Pressure Regulator — A differential pressure regulator is a device used to maintain consistent flow regardless of differential pressure changes. A differential pressure regulator can be an independent device, but is part of a Pressure Independent Control Valve (PICV) resulting in consistent flow corresponding to the given position of the control valve portion of the device and a pressure independent maximum flow corresponding to the flow limiter setting of the device.

Direction of Flow — The flow of a controlled fluid through the valve is usually represented by an arrow on the valve body. If the flow of the fluid goes against the indicated direction, the disk can slam into the seat as it approaches the closed position. The result is excessive wear, hammering, and oscillations. Additionally the actuator must work harder to reopen the closed valve since it must overcome the pressure exerted by the fluid on top of the disc, rather than have the fluid assist in opening the valve by exerting pressure under the disc.

Diverting Valve — A three way valve that has one inlet and two outlets. Water entering the inlet port is diverted to either of the two outlet ports in any proportion desired by moving the valve stem. These valves are not commonly use in modern control loops.

End Fitting — The part of the valve body that connects to the piping. Union, screwed, flared, sweat and flanged are typical examples of end fittings.

Equalinear Flow — Valve Cv vs travel position is approximately mid-way between that of linear and equal percentage.

Equal Percentage Flow Characteristic — An equal percentage flow characteristic is one in which a flow rate change is proportional to the flow rate just prior to the change in valve position. Equal increments of valve travel result in equal percentage changes to the existing flow rate. Flow capacity increases exponentially with valve stem travel.

Flanged End Connections — A valve that connects to a pipe by bolting a flange on the valve to a flange on the pipe. Flanged connections are often used on larger valves, typically over 2".

Flashing — In the context of control valves, flashing is related to cavitation, but the mechanics are slightly different. Flashing occurs when a liquid's environment causes a rapid phase change from liquid to gaseous phases. With flashing, the volume of vapor is much greater than the volume of liquid, and rapidly accelerates the remaining liquid droplets, which forcefully impact the mechanical components of the valve and pipes, causing damage. This situation can be calculated by knowing the pressures and temperatures involved, as well as the vapor pressure of the liquid at those temperatures. Cavitation often occurs in environments that have not yet reached the point of flashing, due to fluid flow dynamics and velocities.

Flow Characteristic — The relation between volumetric flow and valve position.

Flow Coefficient — The flow coefficient is the constant that relates volumetric flow, differential pressure, and specific gravity of a fluid through a metering device. Cv is the flow coefficient in imperial units. For liquids through a standard orifice it is calculated to be equal to the volumetric flow in gallons per minute times the square root of the specific gravity divided by the square root of the differential pressure in psi. For water systems the specific gravity can be assumed to be 1, therefore it is often simplified to GPM divided by the square root of ΔP. For HVAC applications, a control valve closely follows this orifice model.

Flow Limiter — A flow limiter is a device used for limiting the maximum flow. This can be accomplished using a manual balancing valve or with the field adjustable flow limiter integrated in the Siemens Pressure Independent Control Valves (PICV).

Flow Rate — The volume of media conveyed per unit of time. Typical US units are gallons per minute (GPM) for water and pounds per hour (#/hr) for steam.

FPM — Feet per minute.

Full Port — Maximum flow capacity possible for a particular ball valve orifice. In a ball valve, this typically refers to a valve with no flow characterizer or restrictor.

Gauge Pressure — Pounds per square inch (PSI) as read on a gauge face. This differs from Absolute Pressure in that it is relative to the current ambient pressure, not a fixed reference such as absolute vacuum. Gauge pressure, therefore, uses the local ambient pressure as its zero point (14.7 psia at sea level and standard conditions).

GPM — Gallons per minute.

Incompressible — Description of liquids, because their change in volume due to pressure is negligible.

Laminar Flow — Also known as viscous or streamlined flow. A non-turbulent flow regime in which the stream filaments glide along the pipe axially with essentially no transverse mixing. This is usually associated with viscous liquids. The area inside a valve is typically turbulent — the opposite of laminar.

Linear Flow Characteristic — A flow characteristic in which the percentage of maximum flow is equal to the percentage of maximum stroke of the valve. For example, 50% stroke would provide 50% of the maximum flow of the valve. In other words, "Linear valves produce equal flow increments per equal stem travel throughout the travel range of the stem." (2012 ASHRAE Handbook, 13.14)

Load — A demand on the mechanical equipment in an HVAC system.

Load Change — A change in the building cooling or heating requirements as a result of air temperature variations, caused by wind, occupants, lights, machinery, solar effect, etc.

Mixing Valve — A three way valve having two inlets and one outlet. The proportion of fluid entering each of the two inlets can be varied by moving the valve stem. These valves are typically not suitable for diverting applications.

Normally Closed (N.C.) — Condition of the valve upon loss of power or control signal to the actuator. Also as relates to a stroke valve body that has been manufactured as a N.C. valve body. In stroke valves, this is typically the valve's state when the stem is in the "up" position.

Normally Open (N.O.) — Condition of the valve upon loss of power or control signal to the actuator. Also as relates to a stroke valve body that has been manufactured as a N.O. valve body. In stroke valves, this is typically the valve's state when the stem is in the "up" position.

Terminology

NPT — A pipe thread standard describing tapered pipe threads, common in North America (National Pipe thread – Tapered).

Packing — Seals used around the valve stem so that the controlled medium will not leak outside the valve.

PICV — A Pressure Independent Control Valve is a control valve and automatic differential pressure regulator in a single device. The differential pressure regulator automatically adjusts to changes in differential pressure in the system to maintain a consistent flow corresponding to the given position of the control valve portion of the device.

Port — Opening (inlet or outlet) that allows flow through a valve body.

Positive Positioner — A device that eliminates the actuator shaft positioning error due to load on the valve body. This device is closed loop, and applies the necessary force required to positively position the valve stem to a referenced (commanded) position.

Presetting — Presetting is the part of the adjustable flow limiter in Siemens Pressure Independent Control Valves used to set the maximum flow of the valve. It can also refer to the setting of the flow limiter that the valve was set to at the factory.

Pressure Drop — The difference in pressure between the inlet and outlet ports of the control valve, commonly refered to as ΔP (delta P).

PSI — Pounds per square inch.

PSIA — Pounds per square inch absolute. (Also see Absolute Pressure.)

PSIG — Pounds per square inch gauge. (Also see Gauge Pressure.)

Rangeability — The ratio of the maximum controllable flow to the minimum controllable flow. As an example, a valve with a rangeability of 50 to 1 having a total flow capacity of 100 GPM, fully open, will be able to control flow accurately down to 2 GPM.

Reduced port — A smaller flow capacity that is possible for the particular end fitting.

Reducer — A pipe fitting that is used to couple a pipe of one size to a pipe of a different size. An increaser may be used when the pipe sizes are reversed.

Resolution — Resolution applies to the valve actuator. The resolution of an actuator defines the smallest discrete increment the actuator can position to relative to the total control signal range. For example, with a modulating actuator that controls to a tenth of a volt, and has a 0 to 10 Volt control signal, can control to within 1/100th of the entire control range, therefore a resolution of 100:1.

Saturated Steam — Steam which is at its lowest possible temperature at a given pressure without a phase change to liquid.

Screwed- end connection — A valve body with a threaded pipe connection, usually female NPT threads, in valve bodies through 2".

Seat — The stationary portion of the valve which seals the valve, thus prevents flow, when in full contact with the movable ball, plug or disc.

Static Pressure rating — The maximum pressure that the valve body will tolerate per a defined standard. The standards may define the pressure at temperatures other than that observed, so one must understand the standard to understand the actual pressure rating for the given application. Common pressure standards for HVAC valves in North America include ANSI (125, 250) and WOG (300, 600), but others such as CWP are sometimes used.

Stem — The cylindrical shaft of a control valve moved by an actuator, to which the throttling plug, ball or wafer disc is attached.

Stroke — The total distance that a linear valve stem travels or moves. It is also known as lift.

Superheated Steam — Steam at a temperature higher than saturation temperature at the given pressure.

System Pressure Drop — The sum of all pressure drops in a Hydronic system.

Three Way Valve — A valve body with one inlet and two outlets or two inlets and one outlet.

Tight Shut-off — A valve body with no flow or leakage in a closed position. This is relative to the defined tightness of the seal, usually defined by a measurement standard. The most common standard is ANSI/FCI 70 -2, which classifies "tightness" from Class I to Class VI. Class I is non-defined leakage, Class II through Class IV are descriptive based on leakage as a percent of total capacity, and Class V and Class VI are descriptive based on leakage as a finite rate per inch of orifice diameter. Since the criteria and testing method for Class II – IV are significantly different than Class V – VI, these groups cannot be directly compared.

Trim — All parts of the valve which are in contact with the flowing media, but are not part of the valve shell or casting. Ball, stem, disc, plug, and seat are all considered trim components.

Turndown — Ratio between the maximum usable flow and the minimum controllable flow. Turndown is usually less than Rangeability, and cannot be applied to a valve exclusive of the specific application it is placed in, It is a function of the valve, actuator, piping, coil, and all other system parameters that determine the maximum usable flow. Since the valve only has reasonable control over one part of the ratio, the minimum controllable flow, this is not a good criteria for evaluating valve quality.

Two-way Valve — A valve body with a single flow path — one inlet and one outlet.

Valve — A control device which will vary the rate of flow of a medium such as water or steam.

Valve Actuator — A device that uses a source of power to position or operate a valve, sometimes also called a valve operator. The source of power may be anything, examples include manual (via a hand wheel), pneumatic, or electronic.

Valve Authority — Valve authority is measured as the percentage of the differential pressure across the valve divided by the differential pressure of the entire loop or branch controlled by the valve, multiplied by 100. As a rule of thumb, valve authority should be between 25% and 50% for good control of the loop/branch. Alternatively, from the 2012 ASHRAE Handbook, "Using flow coefficient analysis, however, results in a slightly modified definition for authority, comparing the flow coefficient of the valve (Cv) to the coefficient of the remaining system components (Cs)." (2012 ASHRAE Handbook, 13.14) Valve authority using this definition would ideally have the flow coefficient of the valve matching the flow coefficient of the rest of the system, resulting in an ideal value of 1. It is therefore important when discussing valve authority to be clear on which definition is being used.

Valve Body — The portion of the valve casting through which a controlled medium flows**.**

Valve Disc — The movable part of a butterfly valve which makes contact with the seat when the valve is closed.

Valve Flow Characteristic — The relationship between the stem travel, expressed in percent of travel, and the flow of the fluid through the valve, expressed in percent of full flow or gallons per minute.

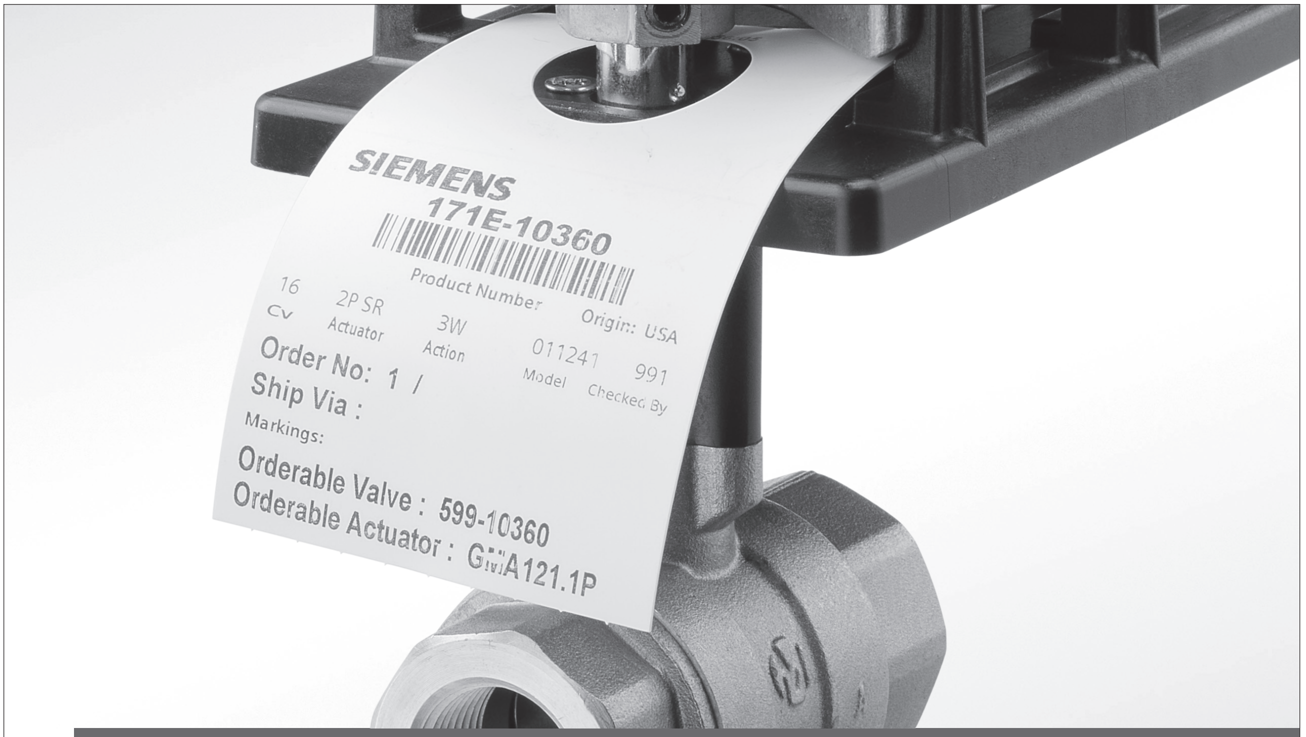
Valve Guide — The part of a globe valve throttling plug that keeps the disc aligned with the valve seat.

Velocity — The rate of movement for air or water, distance per unit time.

Viscous — Having a relatively high resistance to flow.

Volumetric Air Flow — Area x Velocity.

Wire Draw — The process where high velocity media erodes a path across the mechanical components of a valve. This typically occurs in a stroke valve when the valve is operated primarily with the plug very close to the seat , causing very high velocities of media across the plug and seat. The damage appears as if a wire has been drawn across the components. This differs from the other typical valve mechanical damage modes – cavitation and flashing – where the surface appears to have been pulled away as or struck by very small particles, respectively.



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Damper Actuators Selection and Sizing

Introduction

The size and quantity of actuators required depends on several damper torque factors:

- Type of damper seals (Standard, low or very low leakage)
- Quality of damper installation
- Number of damper sections
- Approach air velocity
- Static pressure

The following procedures can be used to determine the damper torque, actuator size and quantity of actuators required to operate a damper.

Determing Damper Torque

1. From the damper manufacturer get the Damper Torque Rating (DTR) for the damper at the most severe operating conditions.

   If the damper torque rating is not available, **Table 1** can be used for estimating purposes only on an interim basis. However, it is very important to get the damper torque rating from the manufacturer as soon as possible to assure accurate torque calculations.
2. Calculate the damper area (DA) in square feet from the damper dimensions.
3. Calculate the Total Damper Torque (TDT) in lb-in using the following formula:

   TDT = DTR X DA
4. If the damper torque rating is not available, use a torque wrench on the damper shaft while air is moving through the duct to measure the TDT.

Actuator Size

1. From the actuator literature select the actuator type and size whose actuator torque rating (ATR) in lb-in is most appropriate for the application.
2. The ATR is normally based on 90° rotation of the damper. For torque ratings of other than 90°f rotation, use the following formula:

   $$\text{ATR @ X° rotation} = \text{ATR @ 90° rotation} \times \left(\frac{\text{Crank Radius @ X°}}{\text{Crank Radius @ 90°}}\right)$$
3. If the actuator is rated in pounds of thrust, it can be converted to torque using the following formula:

   Torque = (*Crank arm length x 0.707) x Thrust

   *The crank arm length is for 90° shaft rotation at nominal actuator stroke.

Quantity of Actuators

1. Calculate the number of actuators required using the following formula:

   $$\text{Number of actuators} = \frac{\text{Total Damper Torque}}{\text{SF x Actuator Torque Rating}}$$

   SF = Safety Factor: When calculating the number of actuators required, a safety factor should be included for unaccountable variables such as slight misalignments, aging of the damper, etc. A suggested factor is 0.8 or 80% of the rated torque.
2. If the number of actuators calculated is too large to be practical, select a more powerful actuator or consider using a positioning relay if it is a pneumatic actuator.

Table 1

Damper Type	Damper Leakage at 1" H_2O Static Pressure Drop	Damper Torque for Approach Air Velocities of 1200 ft./min. or less
Standard leakage	More than 10 CFM/ft.²	2.5 lb.-in./ft.²
Low leakage	5 to 10 CFM/ft.²	5.0 lb.-in./ft.²
Very low leakage	Less than 5 CFM/ft.²	7.0 lb.-in./ft.²

Contact your local customer service representative for additional application assistance when specific damper factors are known.

NEMA Ratings

Type	Intended Use and Description	Requirements or Qualification Tests, Paragraph or Section Numbers
1	Indoor use primarily to provide a degree of protection against limited amounts of falling dirt	Corrosion Protection 5.3; Rust Resistance Section 38
2	Indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.	Corrosion Protection 5.3; Rust Resistance Section 38; Drip Section 31; Gaskets Section 14; Gasket Tests Section 43
3	Outdoor use primarily to provide a degree of protection against rain, sleet, wind blown dust and damage from external ice formation.	Rain Section 30; Outdoor Dust or Hose Section 32 or 35; Icing Section 34; Protective Coating Section 15; Gaskets Section 14; Gasket Tests Section 43
3R	Outdoor use primarily to provide a degree of protection against rain, sleet, and damage from external ice formation.	Rain Section 30; Icing Section 34; Protective Coating Section 15; Gaskets Section 14; Gasket Tests Section 43
3S	Outdoor use primarily to provide a degree of protection against rain, sleet, windblown dust and to provide for operation of external mechanisms when ice laden.	Rain Section 30; Outdoor Dust or Hose Section 32 or 35; Icing Section 34; Protective Coating Section 15; Gaskets Section 14; Gasket Tests Section 43
4	Indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, hose-directed water and damage from external ice formation.	Hosedown Section 35; Protective Coating Section 15; Icing Section 34; Gaskets Section 34; Gasket Tests Section 43
4X	Indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, hose-directed water, and damage from	Hosedown Section 35; Protective Coating Section 15; Corrosion Resistance Section 39; Icing Section 34; Gaskets Section 14; Gasket Tests Section 43
5	Indoor use primarily to provide a degree of protection against setting airborne dust, falling dirt, and dripping noncorrosive liquids.	Corrosion Protection Section 5.3; Rust Resistance Section 38; Drip Section 31; Indoor Setting Airborne Dust or Atomized Water Method B Section 32 or 33; Gaskets Section 14; Gasket Tests Section 43
6	Indoor or outdoor use primarily to provide a degree of protection against hose-directed water, and the entry of water during occasional temporary submersion at a limited depth	Hosedown Section 35; Icing Section 34; Submersion Section 36; Protective Coating Section 15; Gaskets Sections 14; Gasket Tests Section 43
6P	Indoor or outdoor use primarily to provide a degree of protection against hose-directed water, the entry of water during prolonged submersion at a limited depth and damage from external ice formation.	Hosedown Section 35; Icing Section 34; Protective Coating Section 15; Air Pressure Section 40; Gaskets Section 14; Gasket Tests Section 43
12, 12K	Indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping noncorrosive liquids.	Corrosion Protection Section 5.3; Rust Resistance Section 38; Protective Coating Section 15; Drip Section 31; Indoor Setting Airborne Dust or Atomized Water Method B Section 32 or 33; Gaskets Sectios 14; Gasket Tests Section 43
13	Indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and noncorrosive coolant.	Corrosion Protection Section 5.3; Rust Resistance Section 38; Oil Section 37; Gaskets Section 14; Gasket Tests Section 43

Table Notes

Refer to specific sections in the UL Standard *UL50 Enclosures for Electrical Equipment*.

NEMA Ratings can be applied by the manufacturer through a "self-certification" process or through an independent testing house, such as UL. The term, *Type*, indicates to an inspector that the certification was performed independently.

Multi-purpose, Balance-retard and Analog Relays

Relay Piping

Application Index

In the list below, locate the application and type of relay required to locate the appropriate connections diagram.

Application	Type of Relay	Figure
Reverse Acting	Multi-purpose	1
Reverse Acting	Analog	2
Minimum Pressure	Multi-purpose	3
Minimum Pressure with Characterized Output	Multi-purpose	4
Minimum Pressure with Characterized Output	Analog	5
Characterized Minimum Pressure	Analog	6
Minimum Pressure with Hesitation	Balance-retard	7
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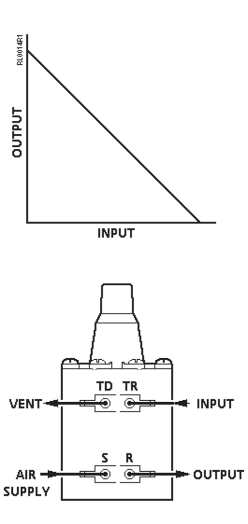


Figure 1.

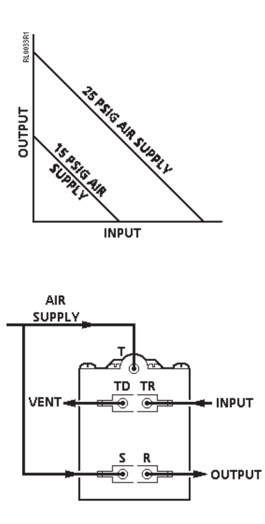
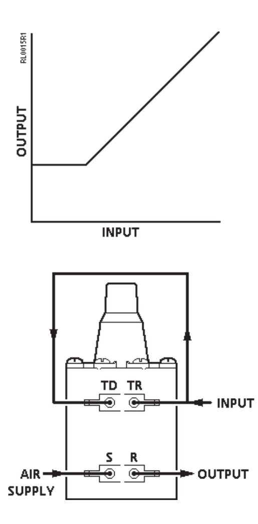


Figure 2.



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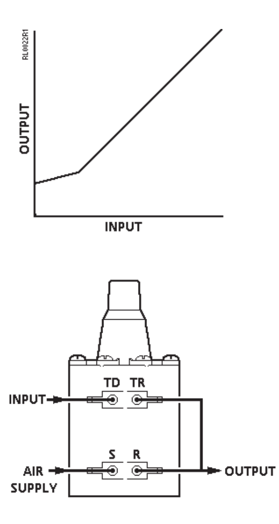


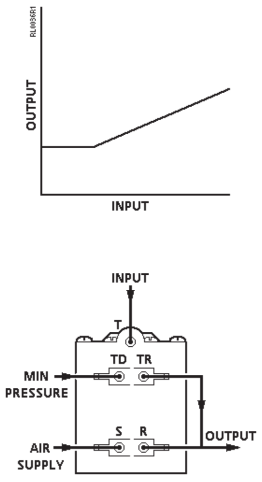
Figure 4.

Key

R Output signal port
TD Direct acting input signal port
TR Reverse acting input port
S Air supply port
SP Setting of the adjustable screw
T Direct acting input port

(Continued on next page)

Relay Piping *(Continued — Refer to chart on G-27)*



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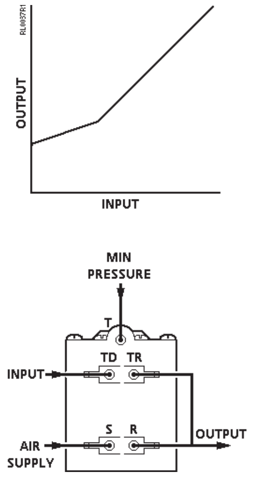

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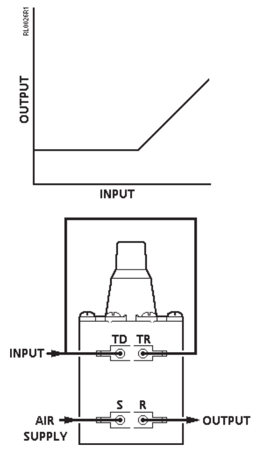

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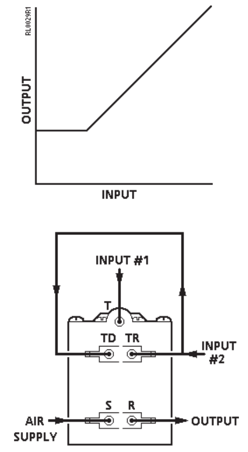

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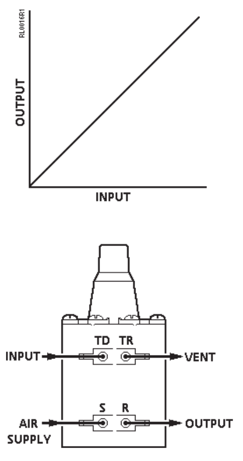

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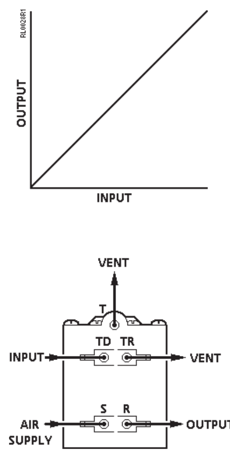
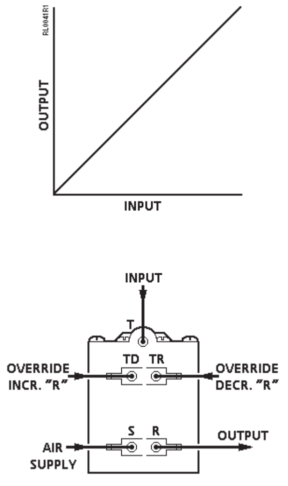


Figure 10.



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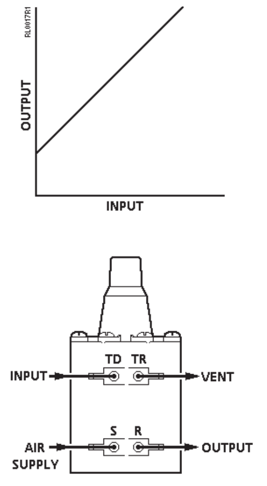

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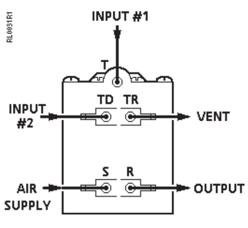

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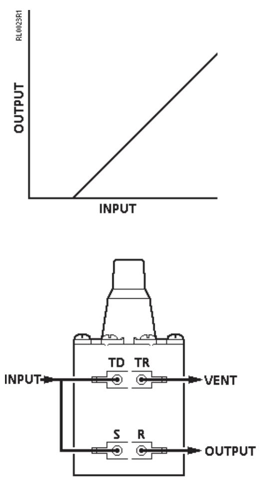

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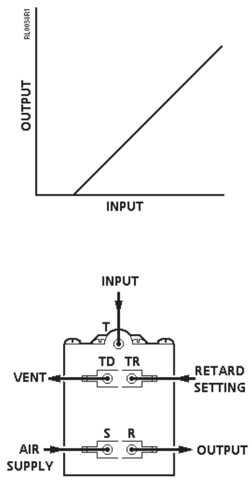

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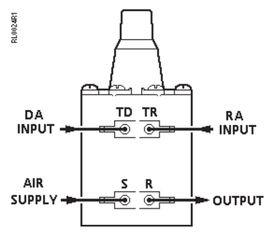
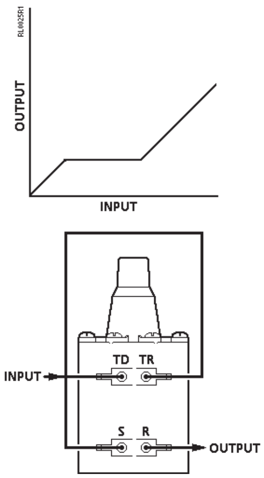


Figure 16.

Relay Piping *(Continued — Refer to chart on G-27)*



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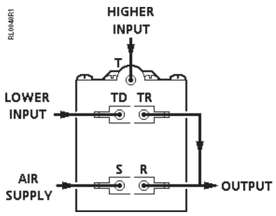

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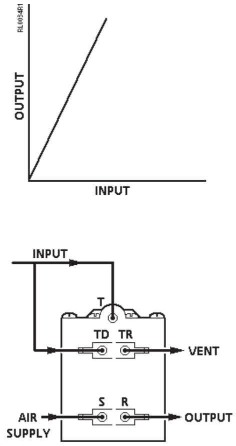

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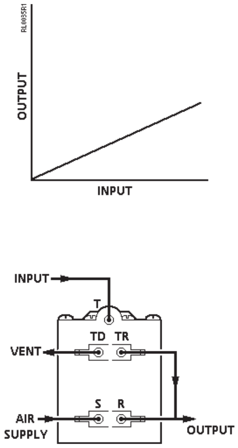

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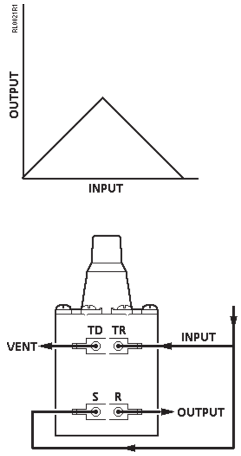

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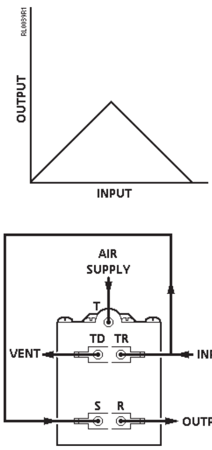


Figure 22.

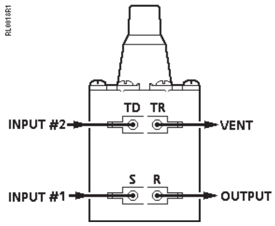


Figure 23.

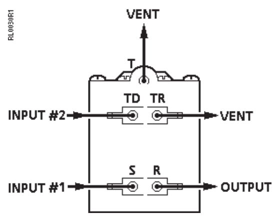


Figure 24.

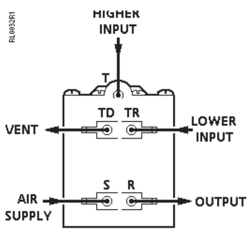


Figure 25.

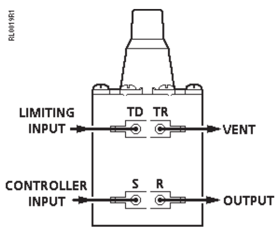


Figure 26.

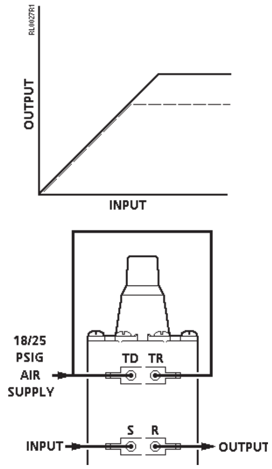


Figure 27.

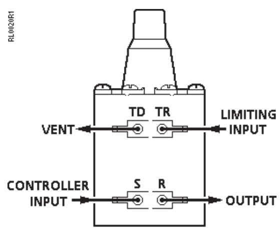
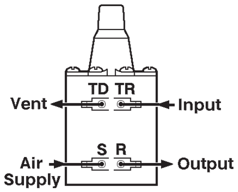
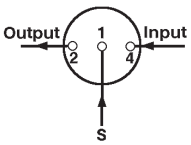
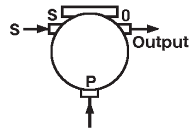
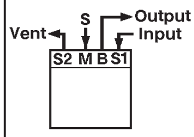
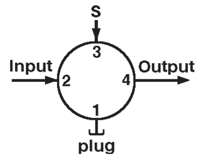
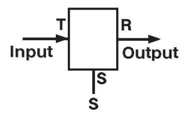
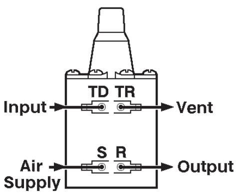
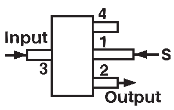
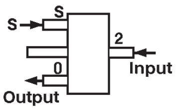
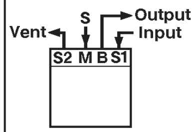
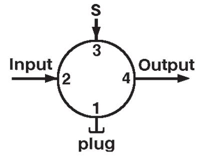
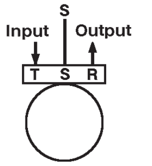
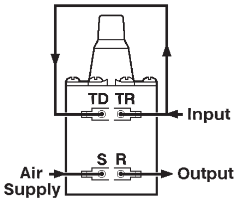
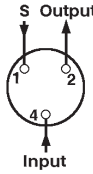
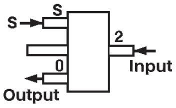
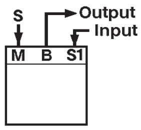
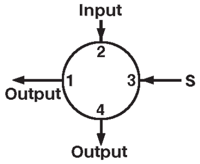
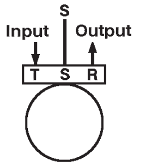
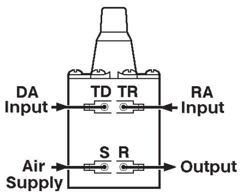
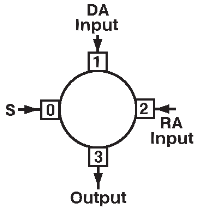
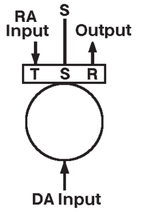
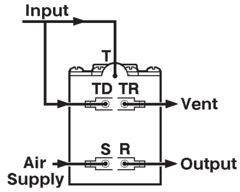
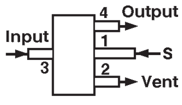
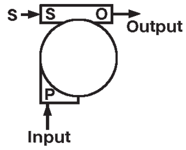
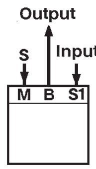
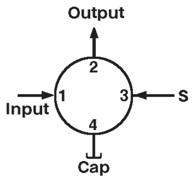
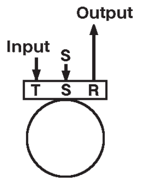


Figure 28.

Retrofit Cross Reference

Siemens	Honeywell	Johnson	Robertshaw	Barber-Colman	Discontinued Siemens (Powers)
 243 – 0009 243 – 0046 Reverse Acting	 RP 972 A Reverse Acting	 C – 208 Reverse Acting	 R 516 Reverse Acting	 AK 50613 Reverse Acting	 TYPE 783 Reverse Acting
 243 – 0009 243 – 0046 Direct Acting	 RP 970 A Direct Acting	 C 5230 Direct Acting	 R 532-L Direct Acting	 AK - 50603 Direct Acting	 Type 782 Direct Acting
 243 – 0009 243 – 0046 Minimum Pressure	 SP 970 A Minimum Pressure	 C 5230 Minimum Pressure	 S 511 – 5 Minimum Pressure	 AK - 50605 Minimum Pressure	 Type 782 Minimum Pressure
 243 – 0010 243 – 0047 Balancing Relay	NONE	 C 130 – 1 Balancing Relay	NONE	NONE	 310 – 0010 Balancing Relay
 243 – 0011 243 – 0048 Ratio Relay 1 In = 2 Out	 RP 971 A 1007 Sequencing Relay (Setpoint + 3 psig)	 C 202 – 1 1 In = 2 Out	 R 539 1 In = 2 Out	 AK – 50703 1 In = 2 Out	 Type 782 – 0070 1 In = 2 Out

RL0042R1

General Conversions

To Convert From	Into	Multiply By
atmospheres	feet of water (at 4°C)	**33.90**
atmospheres	inch of mercury (at 0°C)	**29.92**
atmospheres	pounds/square inch	**14.70**
Btu	foot-pounds	**778.3**
Btu	horsepower-hours	**3.931 x 10^{-4}**
Btu	kilowatt-hours	**2.928 x 10^{-4}**
Btu/hour	foot-pounds/second	**0.2162**
Btu/hour	horsepower-hours	**3.929 x 10^{-4}**
Btu/hour	watts	**0.2929**
Btu/minute	foot-pounds/second	**12.96**
Btu/minute	horsepower	**0.02356**
Btu/minute	kilowatts	**0.01757**
Btu/minute	watts	**17.57**
Btu/minute	tons of refrigeration	**1/200**
Btu/hour	tons of refrigeration	**1/12,000**
Btu/ft.^{2}/minute	Watts/square inch	**0.1221**
Btu/pound air	Kilojoules/kilogram	**2.33**
Candle/in.^{2}	Laberts	**0.4870**
Candle/ft.^{2}	Candle meters	**0.0929**
cubic feet	cubic inches	**1,728.0**
cubic feet	cubic yards	**0.03704**
cubic feet	gallons (U.S. liquid)	**7.48052**
cubic feet	pints (U.S. liquid)	**59.84**
cubic feet	quarts (U.S. liquid)	**29.92**
cubic feet/min.	gallons/second	**0.1247**
cubic feet/min.	pounds of water/minute	**62.43**
cubic feet/min.	liters per second	**0.4719**
cubic feet/sec.	millions gallons/day	**0.646317**
cubic feet/sec.	gallons/minute	**448.831**
cubic inches	cubic feet	**5.787 x 10^{-4}**
cubic inches	cubic yards	**2.143 x 10^{-5}**
cubic inches	gallons	**4.329 x 10^{-3}**
cubic yards	cubic feet	**27.0**
cubic yards	cubic inches	**46,656.0**
cubic yards	gallons (U.S. liquid)	**202.0**
cubic yards	pints (U.S. liquid)	**1,615.9**
cubic yards	quarts (U.S. liquid)	**807.9**
cubic yards/min.	cubic feet/second	**0.45**
cubic yards/min.	gallons/second	**3.367**
degrees (angle)	seconds	**3,600.0**
degrees/second	revolutions/minute	**0.1667**

To Convert From	Into	Multiply By
feet of water	atmospheres	**0.02950**
feet of water	inch of mercury	**0.8826**
feet of water	pounds/square foot	**62.43**
feet of water	pounds/square inch	**0.4335**
feet/min.	feet/second	**0.01667**
feet/min.	miles/hour	**0.01136**
feet/sec.	miles/hour	**0.6818**
feet/sec.	miles/min.	**0.01136**
Foot-candle	Lumen/square meter	**10.764**
foot-pounds	Btu	**1.286 x 10^{-3}**
foot-pounds	horsepower-hour	**5.050 x 10^{-7}**
foot-pounds	kilowatt-hour	**3.766 x 10^{-7}**
foot-pounds/min.	Btu/min.	**1.286 x 10^{-3}**
foot-pounds/min.	foot-pounds/second	**0.01667**
foot-pounds/min.	horsepower	**3.030 x 10^{-5}**
foot-pounds/min.	kilowatts	**2.260 x 10^{-5}**
foot-pounds/sec.	Btu/hour	**4.6263**
foot-pounds/sec.	Btu/min.	**0.07717**
foot-pounds/sec.	horsepower	**1.818 x 10^{-3}**
foot-pounds/sec.	kilowatts	**1.356 x 10^{-3}**
gallons	cubic feet	**0.1337**
gallons	cubic inches	**231.0**
gallons	cubic yards	**4.951 x 10**
gallons	liters	**3.785**
gallons (liq. Br. Imp.)	gallons (U.S. liquid)	**1.20095**
gallons (U.S.)	gallons	**0.83267**
gallons of water	pounds of water	**8.3453**
gallons/min.	cubic feet/sec.	**2.228 x 10^{-3}**
gallons/min.	cubic feet/hour	**8.0208**
US gallons/min.	liters per second	**0.06309**
US gallons/min.	liters per second	**3.7854**
gallons/hour	cubic meters/hour	**1.434 x 10^{-3}**
horsepower	Btu/minute	**42.44**
horsepower	foot-pounds/min.	**33,000.0**
horsepower	foot-pounds/sec.	**550.0**
horsepower	kilowatts	**0.7457**
horsepower	Watts	**745.7**
horsepower (boiler)	Btu/hour	**33.479**
horsepower (boiler)	kilowatts	**9.803**
horsepower-hours	Btu	**2,547.0**
horsepower-hours	foot-pounds	**1.98 x 10^{6}**
horsepower-hours	kilowatt-hours	**0.7457**

Conversion Factors

To Convert From	Into	Multiply By
inch	Pa	**248.84**
inches	yards	**2.778×10^{-2}**
inches of mercury	atmospheres	**0.03342**
inches of mercury	feet of water	**1.133**
inches of mercury	pounds/square feet	**70.73**
inches of mercury	pounds/square feet	**0.4912**
inches of water	atmospheres	**2.458×10^{-3}**
inches of water	inches of mercury	**0.07355**
in. of water (at 4°C)	ounces/square inches	**0.5781**
inches of water	pounds/square feet	**5.204**
inches of water	pounds/square inches	**0.03613**
kilometers	miles	**0.6214**
kilometers	yards	**1,094.0**
kilowatts	Btu/minutes	**56.92**
kilowatts	foot-pounds/minutes	**4.426×10^{4}**
kilowatts	foot-pounds/second	**737.6**
kilowatts	horsepower	**1.341**
kilowatts	Watt	**1,000.0**
kilowatts	Btu	**3,413.0**
kilowatts-hour	foot-pounds	**2.655×10^{6}**
kilowatts-hour	horsepower-hour	**1.341**
kilowatts-hour	pounds of water evaporated from and at 212°F	**3.53**
liters per sec.	US gal/min.	**15.85**
lumens/square feet	foot-candles	**1.0**
Lumen	Spherical candle power	**0.07958**
Lumen	Watt	**0.001496**
Lumen/square feet	Lumen/square meters	**10.76**
lux	foot-candles	**0.0929**
lux	btu/hr.	**1000**
meter	inches	**39.372**
meters	feet	**3.281**
meters	yards	**1.094**
miles/hour	feet/minute	**88.0**
miles/hour	feet/second	**1.467**
miles/hour	miles/minute	**0.1667**
miles/minute	feet/second	**88.0**
miles/minute	miles/hour	**60.0**

To Convert From	Into	Multiply By
OHM (international)	OHM (absolute)	**1.0005**
ounces	pounds	**0.0625**
pounds	ounces	**16.0**
pounds of water	cubic feet/second	**0.01602**
pounds of water	cubic inches	**27.68**
pounds of water	gallons	**0.1198**
pounds of water/min.	cubic feet/second	**2.670×10^{-4}**
pounds/cubic feet	pounds/cubic inches	**5.787×10^{-4}**
pounds/cubic inches	pounds/cubic feet	**1,728.0**
pounds/square feet	atmospheres	**4.725×10^{-4}**
pounds/square feet	feet of water	**0.01602**
pounds/square feet	inches of mercury	**0.01414**
pounds/square feet	pounds/square inches	**6.944×10^{-3}**
pounds/square inch	atmospheres	**0.06804**
pounds/square inch	feet of water	**2.307**
pounds/square inch	inches of mercury	**2.036**
pounds/square inch	pounds/square feet	**144.0**
revolutions	degrees	**360.0**
square feet	square inches	**144.0**
Watts	Btu/hour	**3.4129**
Watts	Btu/minute	**0.05688**
Watts	foot-pounds/minute	**44.27**
Watts	foot-pounds/second	**0.7378**
Watts	horsepower	**1.341×10^{-3}**
Watts	kilowatts	**0.001**
Watt-hours	Btu	**3,413.0**
Watt-hours	foot-pounds	**2,656.0**
Watt-hours	horsepower-hour	**1.341×10^{-3}**
Watt-hours	kilowatt-hour	**0.001**

English to Metric Conversion Guide

Quantity	To Convert From	Into	Multiply By
Area	Square Inches (in.^{2})	Square Centimeters (cm^2)	**6.4516**
	Square Feet (ft.^{2})	Square Meters (m^2)	**9.2903 x 10^{-2}**
Enthalpy/Heat	BTU Per Pound-Mass—°F (BTU/lb. x °F)	Kilojoule Per Kilogram—Kelvin (kJ/kg.K)	**4.1840**
Flow[1]	Cubic Inches Per Minute (in.^{3}/min.)	Cubic Centimeters Per Second (cm^3/s)	**0.2731**
	Cubic Feet Per Minute (ft.^{3}/min.)	Cubic Centimeters Per Second (cm^3/s)	**471.9474**
	Cubic Feet Per Minute (ft.^{3}/min.)	Cubic Decimeters Per Second (dm^3/s)=ls)[3]	**0.4719**
	Cubic Feet Per Minute (ft.^{3}/min.)	Cubic Meters Per Second (m^3/s)	**0.4719 x 10^{-3}**
	Cubic Feet Per Minute (ft.^{3}/min.)	Cubic Meters Per Hour (m^3/h)	**1.6990**
	Standard Cubic Feet Per Minute SCFM 60°F, 14.7 psia	Cubic Meters Per Hour (m^3/h 0°C, 1.01325 bar)	**1.695** **1.607**
	Standard Cubic Feet Per Minute SCFM 60°F, 14.7 psia	Cubic Meters Per Hour (m^3/h 15°C, 1.01325 bar)	**1.695**
	Gallons Per Minute (U.S. liquid) (GPM)	Cubic Decimeters Per Seconds (dm^3/s)=l/s)	**0.0631**
Force	Pound (Force) (lb.)	Newtons (N)	**4.4482**
Length	Inches (in.)	Millimeters (mm)	**25.4000**
	Inches (in.)	Centimeters (cm)	**2.5400**
	Feet (ft.)	Centimeters (cm)	**30.4800**
	Feet (ft.)	Meters (m)	**0.3048**
Mass (Weight)[2]	Pound (lb.)	Kilogram (kg)	**0.4536**
Power	BTU Per Hour (BTU/hr.)	Watts (W)	**0.2929**
	Horsepower (hp)	Watts (W)	**746.0000**
Pressure (Stress)	Pounds Per Square Inch (psi)	Kilopascals (kPa)	**6.8947**
	Kilograms Per Square Centimeters (Kg/cm^2)	Kilopascals (kPa)	**98.0665**
	Inches of Water (“ W.G.) @ 60°F	Pascals (Pa)	**248.84**
	Inches of Mercury (“ H.G.) @ 60°F	Pascals (Pa)	**3376.85**
Toruqe (Bending)	Degrees Fahrenheit (°F)	Degrees Celcius (t°C)	$t°C = \frac{(t°F-32)}{1.8}$
	Degrees Fahrenheit (°F)	Kelvin (tK)	$tK = \frac{(t°F+459.67)}{1.8}$
Torque	Pound Force-Inch (lb.-in.)	Newton-Meter (Nm)	**0.1129**
	Pound Force-Foot (lb.-ft.)	Newton-Meter (Nm)	**1.3558**
Velocity	Feet Per Second (ft./sec.)	Meters Per Second (m/s)	**0.3048**
	Feet Per Minute (ft./min.)	Meters Per Second (m/s)	**5.0800 x 10^{-3}**
	Miles Per Hour (MPH)	Meters Per Seond (m/s)	**0.4470**
Volume	Cubic Inches (in.^{3})	Cubic Centimeters (cm^3)	**16.3871**
	Cubic Feet (ft.^{3})	Cubic Meters (m^3) = Stere	**2,8317 x 10^{-2}**
	Gallons U.S. (gal.)	Cubic Meters (m^3) = Stere	**3.7854 x 10^{-3}**
	Ounce (oz.)	Cubic Meters (m^3) = Stere	**2.9573 x 10^{-5}**
Work (Energy)	BTU (BTU)	Kilojoule (kJ)	**1.0551**
	Foot Pound (ft.-lb.)	Joule (J)	**1.3558**
	Watthour (W-hr.)	Kilojoule (kJ)	**3.6000**

Chart Notes

1. Since standard and normal cubic meters (STD m^3 and Nm^3) do not have a universally accepted definition, their reference pressure and temperature should always be spelled out.
2. In commercial and everyday use, the term weight almost always means mass.
3. Air consumption for pneumatic control devices should be expressed in milliliters per second (ml/s).
   Allowable leakage rates for pneumatic control devices should be expressed in milliliter per second (ml/s) or microliters per second (ul/s).

Pressure Conversion Table

Instructions

The index numbers in **bold face** refer to the pressure either in **psi** or **kilopascals** (kPa) which it is desired to convert into the other scale. If converting from psi to kPa the equivalent pressure will be found in the left column, while if converting from kPa to psi, the equivalent pressure will be found in the column on the right.

Example: Index 15 15 psi = 103.421 kPa. 15 kPa = 2.176 psi

By manipulation of the decimal point, this table may be extended to values below or above 100.

kPa	Index	psi
0.000	**0**	0.000
6.895	**1**	0.145
16.789	**2**	0.290
20.684	**3**	0.435
27.579	**4**	0.580
34.474	**5**	0.725
41.368	**6**	0.870
48.263	**7**	1.015
55.158	**8**	1.160
62.053	**9**	1.305
68.948	**10**	1.450
75.842	**11**	1.595
82.737	**12**	1.740
89.632	**13**	1.885
96.527	**14**	2.030
103.421	**15**	2.176
110.316	**16**	2.321
177.211	**17**	2.466
124.106	**18**	2.611
131.000	**19**	2.756
137.895	**20**	2.901
144.790	**21**	3.046
151.685	**22**	3.191
158.579	**23**	3.336
165.474	**24**	3.481
172.369	**25**	3.626

kPa	Index	psi
179.264	**26**	3.771
186.058	**27**	3.916
193.053	**28**	4.061
199.948	**29**	4.206
206.843	**30**	4.351
213.737	**31**	4.496
220.632	**32**	4.641
227.527	**33**	4.786
234.422	**34**	4.931
241.316	**35**	5.076
248.211	**36**	5.221
255.106	**37**	5.366
262.001	**38**	5.511
268.895	**39**	5.656
275.790	**40**	5.801
282.685	**41**	5.946
289.580	**42**	6.092
296.475	**43**	6.237
303.369	**44**	6.382
310.264	**45**	6.527
317.459	**46**	6.672
324.054	**47**	5.617
330.948	**48**	6.962
337.843	**49**	7.107
344.729	**50**	7.252

kPa	Index	psi
531.633	**51**	7.397
358.527	**52**	7.542
365.422	**53**	7.687
372.317	**54**	7.832
379.212	**55**	7.977
386.106	**56**	8.122
393.001	**57**	8.267
399.896	**58**	8.412
406.791	**59**	8.557
413.685	**60**	8.702
420.580	**61**	8.847
427.475	**62**	8.992
434.370	**63**	9.137
441.264	**64**	9.282
448.159	**65**	9.427
455.054	**66**	9.572
431.949	**67**	9.717
468.843	**68**	9.862
475.738	**69**	10.008
482.633	**70**	10.153
489.528	**71**	10.298
496.422	**42**	10.443
503.317	**73**	10.588
510.212	**74**	10.733
517.107	**75**	10.878

kPa	Index	psi
524.001	**76**	11.023
530.896	**77**	11.168
537.791	**78**	11.313
544.686	**79**	11.458
551.581	**80**	11.603
558.475	**81**	11.748
565.370	**82**	11.893
572.265	**83**	12.038
579.160	**84**	12.183
586.054	**85**	12.328
592.949	**86**	12.473
599.844	**87**	12.618
606.739	**88**	12.763
613.633	**89**	12.908
621.528	**90**	13.053
627.423	**91**	13.198
634.318	**92**	13.343
641.212	**93**	13.488
648.107	**94**	13.633
655.002	**95**	13.778
661.897	**96**	13.924
668.791	**97**	14.069
675.686	**98**	14.214
682.581	**99**	14.359
689.476	**100**	14.504

All values rounded to 0.001.

Temperature Conversion Table

Instructions

The numbers in **bold face** refer to the temperature either in degrees Celsius (°C) or Fahrenheit (°F) to convert into the other scale. If converting from °F to °C, the equivalent temperature will be found in the left column. If converting from degrees °C to degrees °F, the answer will be found in the column to the right.

°C	50 to 45	°F
-45.6	**-50**	-58
-40.0	**-40**	-40
-34.4	**-30**	-22
-28.9	**-20**	-4
-23.3	**-10**	14
-17.8	**0**	32
-17.2	**1**	33.8
-16.7	**2**	35.6
-16.1	**3**	37.4
-15.6	**4**	39.2
-15.0	**5**	41.0
-14.4	**6**	42.8
-13.9	**7**	44.6
-13.3	**8**	46.4
-12.8	**9**	48.2
-12.2	**10**	50.0
-11.7	**11**	51.8
-11.1	**12**	53.6
-10.6	**13**	55.4
-10.0	**14**	57.2
-9.44	**15**	59.0
-8.89	**16**	60.8
-8.33	**17**	62.6
-7.78	**18**	64.4
-7.22	**19**	66.2
-6.67	**20**	68.0
-6.11	**21**	69.8
-5.56	**22**	71.6
-5.00	**23**	73.4
-4.44	**24**	75.2
-3.89	**25**	77.0
-3.33	**26**	78.8
-2.78	**27**	80.6
-1.67	**28**	82.4
-1.67	**29**	84.2
-1.11	**30**	86.0
-0.56	**31**	87.8
0	**32**	89.6
0.56	**33**	91.4
1.11	**34**	93.2
1.67	**35**	95.0
2.22	**36**	96.8
2.78	**37**	98.6
3.33	**38**	100.4
3.89	**39**	102.2
4.44	**40**	104.0
5.00	**41**	105.8
5.56	**42**	107.6
6.11	**43**	109.4
6.67	**44**	111.2
7.22	**45**	113.0

°C	46 to 96	°F
7.78	**46**	114.8
8.33	**47**	116.6
8.89	**48**	118.4
9.44	**49**	120.2
10.0	**50**	122.0
10.6	**51**	123.8
11.1	**52**	125.6
11.7	**53**	127.4
12.2	**54**	129.2
12.8	**55**	131.0
13.3	**56**	132.8
13.9	**57**	134.6
14.4	**58**	136.4
15.0	**59**	138.2
15.6	**60**	140.0
16.1	**61**	141.8
16.7	**62**	143.6
17.2	**63**	145.4
17.8	**64**	147.2
18.3	**65**	149.0
18.9	**66**	150.8
19.4	**67**	152.6
20.0	**68**	154.4
20.6	**69**	156.2
21.1	**70**	158.0
21.7	**71**	159.8
22.2	**72**	161.6
23.8	**73**	163.4
23.3	**74**	165.2
23.9	**75**	167.0
21.1	**76**	168.8
25.0	**77**	170.6
25.6	**78**	172.4
26.1	**79**	174.2
26.7	**80**	176.0
27.2	**81**	177.8
27.8	**82**	179.6
28.3	**83**	181.4
28.9	**84**	183.2
29.4	**85**	185.0
30.0	**86**	186.8
30.6	**87**	188.6
31.1	**88**	190.4
31.7	**89**	192.2
32.2	**90**	194.0
32.8	**91**	195.8
33.3	**92**	197.6
33.9	**93**	199.4
34.4	**94**	201.2
35.0	**95**	203.0
35.6	**96**	204.8

°C	97 to 1000	°F
36.1	**97**	206.6
36.7	**98**	208.4
37.2	**99**	210.2
37.8	**100**	212.0
43	**110**	230
49	**120**	248
54	**130**	266
60	**140**	284
66	**150**	302
71	**160**	320
77	**170**	338
82	**180**	356
88	**190**	374
93	**200**	392
99	**210**	410
100	**212**	413
104	**220**	426
110	**230**	443
116	**240**	464
121	**250**	482
127	**260**	500
132	**270**	518
138	**280**	536
143	**290**	554
149	**300**	572
154	**310**	590
160	**320**	608
166	**330**	626
171	**340**	644
177	**350**	662
182	**360**	680
188	**370**	698
193	**380**	716
199	**390**	734
204	**400**	752
210	**410**	770
216	**420**	788
221	**430**	806
227	**440**	824
232	**450**	842
238	**460**	860
243	**470**	878
249	**480**	896
254	**490**	914
260	**500**	932
316	**600**	1112
371	**700**	1292
427	**800**	1472
482	**900**	1652
538	**1000**	1832

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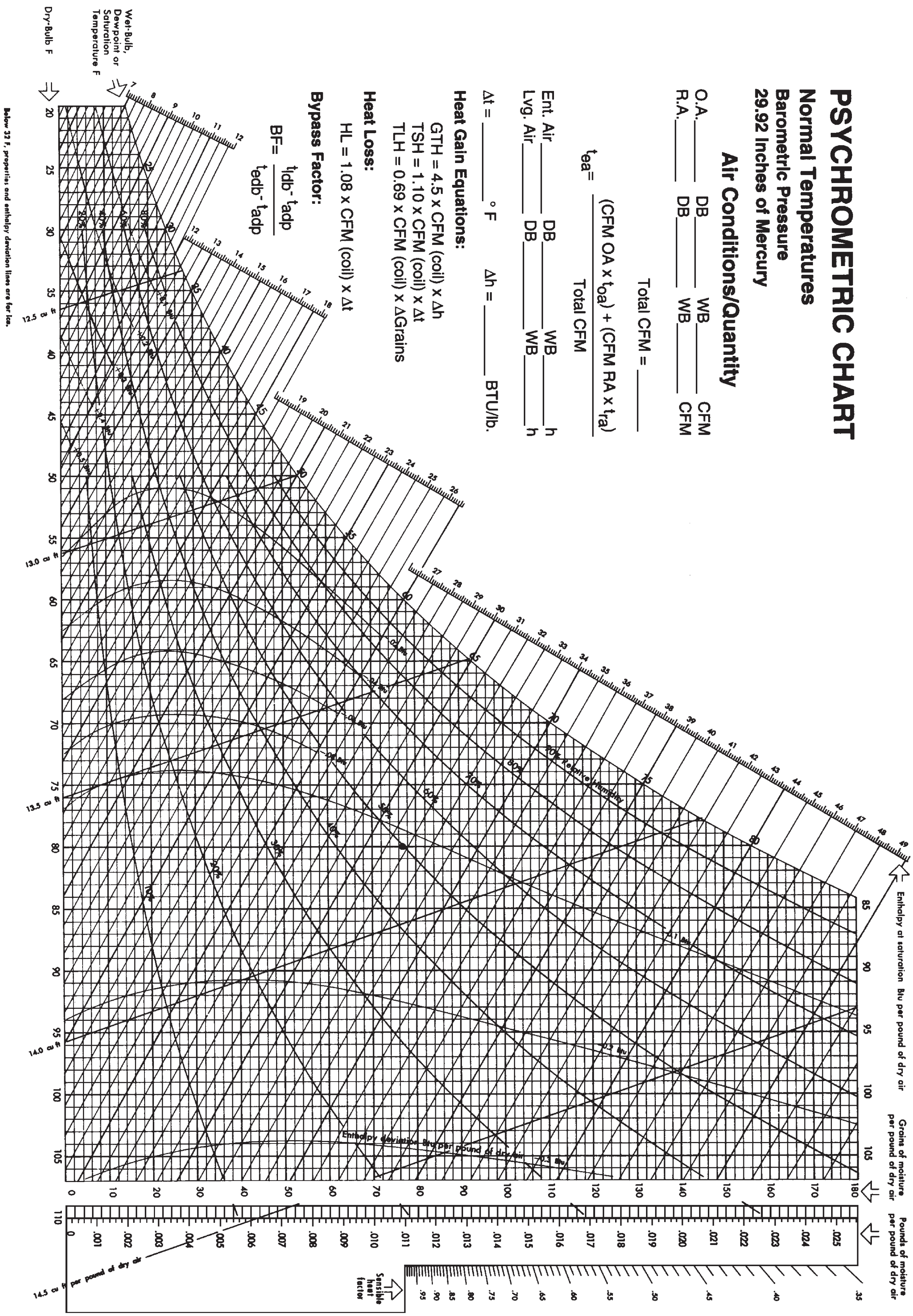

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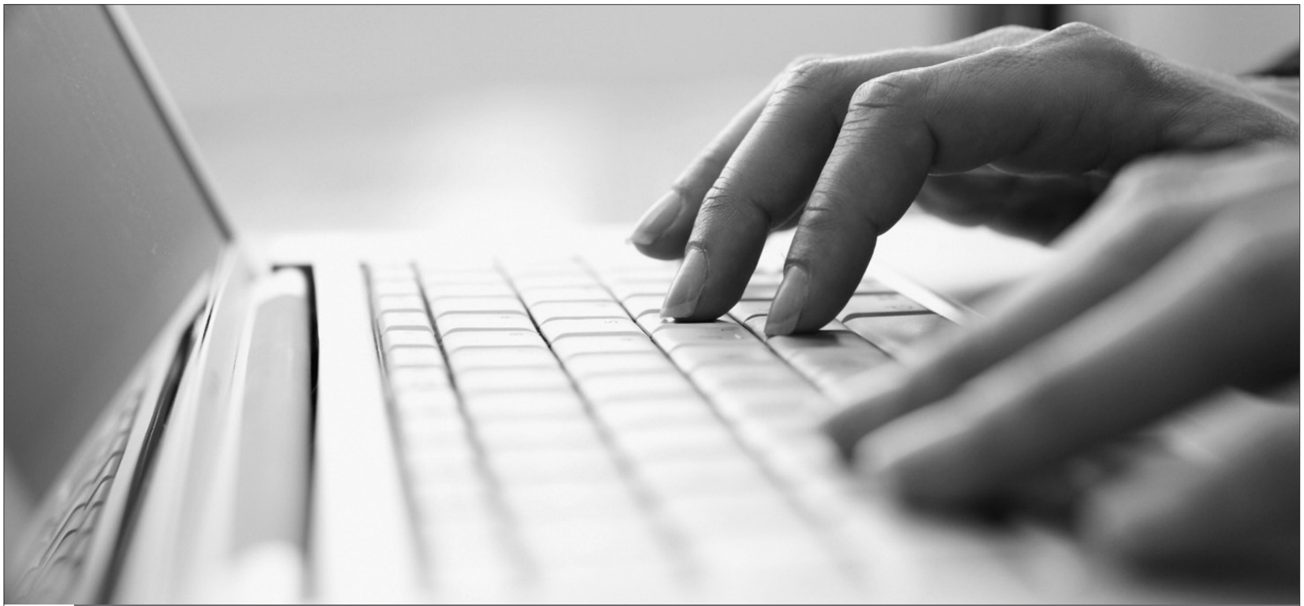

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