Application Worksheet

All dimensions are nominal. Dimensions in [ ] are in millimeters.

Service Conditions

Medium Through Valve: ______________________________ Required C_V: __________

Temperature Maximum: __________ Minimum: __________ Normal: __________

Flow Maximum: __________ Minimum: __________ Normal: __________

Inlet Pressure Maximum: __________ Minimum: __________ Normal: __________

Outlet Pressure Maximum: __________ Minimum: __________ Normal: __________

Differential Pressure Service: __________ Close-off: __________

Pipeline

Upstream Material: __________ Size: __________ Schedule: __________

Downstream Material: __________ Size: __________ Schedule: __________

Valve Requirements

Required Fail Position: ______________________________

Body Material: __________ Size: __________ End Connections: __________

Trim ***Check one*** ☐ Modified Linear ☐ Equal Percentage

Material: __________ Close-off Class: __________

Additional Requirements: ______________________________

Actuator Requirements

Check one ☐ Pneumatic On/Off ☐ Pneumatic Throttling ☐ Electric

Power Supply: ______________________ Input Signal: ______________________

Additional Requirements: ______________________________

Positioner Requirements

Check one ☐ Pneumatic ☐ Electropneumatic

Input: ______________________ Output: ______________________

Additional Requirements: ______________________________

Name: ______________________ Company: ______________________

Date: ______________________ P.O. Number: ______________________

Project Name: ______________________ Tag Number: ______________________

VALVE SELECTION

The proper sizing of a valve is one of the most important factors in the ability of a loop to maintain control. A valve that is too small is not able to provide the desired capacity during peak load conditions, while a valve that is too large will tend to overshoot the control point and operate with the valve plug too close to the seat, resulting in undue wear of the plug and seat.

Valve Coefficient (C_V)

The valve coefficient (**C_V**) is mathematically determined through an evaluation of the system service conditions. This factor can be used to select a valve body of the appropriate port size. In almost all cases, the valve should be of a smaller size than the pipeline into which it will be installed. To avoid undue wear, a valve body of the smallest possible port size should be selected; however, the valve should never be less than half the pipeline size, as this will cause extreme mechanical stress to the pipeline.

Service Conditions

The specifier should be knowledgeable of the service conditions of the application in order to properly determine the actuator and valve requirements.

Medium
The composition of the fluid passing through the valve.

Temperature (T)
The temperature of the medium passing through the valve. This measurement is required to properly specify the materials used to manufacture the valve.

Flow (q or W)
The volume of fluid passed through the valve as required by the particular application. Flow is usually expressed as either gallons per minute (**q**), or pounds per hour (**W**). Water and other liquids are usually measured in gallons per minute, while steam and other gases are usually measured in pounds per hour. This measurement is required to correctly determine the valve coefficient (**C_V**).

Inlet Pressure (Upstream Pressure or **P_1**)
The pressure (psia) of the medium flowing into the valve body. This measurement is required to correctly determine the valve coefficient (**C_V**) and valve close-off capability.

Outlet Pressure (Downstream Pressure or **P_2**)
The pressure (psia) of the medium flowing through a fully opened valve to the process. The outlet pressure from the valve is determined by the process or equipment that is being fed by the valve, and is not caused by the valve itself. This measurement is required to correctly determine the valve coefficient (**C_V**) and valve close-off capability.

Differential Pressure (Pressure Drop or **ΔP**)
The difference between the inlet and outlet pressures (**P_1-P_2**). This measurement is required to correctly determine the valve coefficient (**C_V**) and valve close-off capability.

Valve Sizing Differential Pressure:
The differential pressure (psid) for **valve sizing** is determined with the valve **full open**. This pressure drop, along with the required flow rate, is used to determine the required **C_V** to aid in the selection of the proper control valve.

Close-Off Differential Pressure:
The differential pressure (psid) for **valve "close-off"** is determined with the valve **fully closed**. Usually, in most common applications, with the valve closed the outlet pressure will be zero (0) psig and as such the pressure drop will be equal to the Inlet Pressure. In some applications there may be residual back pressure in the downstream system (such as filling a pressurized tank) that will cause the Outlet Pressure to be a value greater than zero, which in turn reduces the value of the expected differential pressure.

Example:
Valve B73 (on page 190) has a maximum "Close-Off Pressure" allowance of 65 psid. If this valve is used to control the flow into an open tank, the closed valve outlet pressure will be zero. As such the maximum inlet pressure that the actuator can close this valve against is 65 psig.
(65 psid rating + zero outlet pressure = 65 psig inlet pressure).

If however this same valve B73 is used to control the flow into a closed pressurized tank (pressurized to 25 psig) then the maximum inlet pressure that the actuator can close this valve against is 90 psig.
(65 psid rating + 25 psig back pressure = 90 psig inlet pressure).

Since this 90 psig is less than the body rating of 125 psig this valve would be acceptable for this service.

Other Considerations

- **Specific Gravity —** The ratio between the weight of the flow medium at the flow temperature and that of a defined standard substance (water or air). The specific gravity may be required to correctly determine the valve coefficient (C_v).

  Liquids (G_f) water = 1.0 @ 39°F (4°C)
  Gases (G_g) air = 1.0 @ 60°F (18°C) and 14.7 psia

- **Viscosity —** The degree of thickness of a liquid. Extremely thick process media can create high friction as it passes through the valve. In most instances a sizing correction factor is not required. Please consult the factory when the flow medium is of a viscosity of 40 centistokes or greater.

- **Steam Superheat —** The number of degrees Fahrenheit (T_{sh}) above the saturation temperature of steam at a given pressure. Superheated steam is created when saturated steam is further heated from another source after leaving the water from which it is formed. This measurement is required to correctly determine the valve coefficient (C_v).

Valve Sizing Equations

The following formulas can be used to determine the C_v requirement for a specific set of service conditions,

where:

C_v = valve coefficient
G_f = liquid specific gravity at flow temperature (water = 1.0)
G_g = gas specific gravity (air = 1.0)
P_1 = inlet pressure (psia)
P_2 = outlet pressure (psia)
ΔP = inlet pressure minus outlet pressure (psi)
q = liquid flow in gallons per minute (gpm)
T_{sh} = steam superheat (°F)
W = gas flow in pounds per hour (pph)

Cavitation

Water and Other Liquids

Cavitation takes place when the pressure through a valve drops to or below the vapor pressure of a liquid, causing it to vaporize and rapidly expand in gas form. Vapor bubbles flow downstream where the fluid velocity decreases and the surrounding pressure increases. The vapor bubbles then collapse or implode, causing sudden condensation and producing shock waves that may result in excessive noise, vibration, erosion or mechanical damage to valve and/or piping. In most liquid applications, the outlet pressure (psia) should be no less than one-third the inlet pressure (psia). Where extremely large differential pressures are required, the use of multiple valves in series will reduce the possibility of cavitation.

Water

where:

q = liquid flow in gallons per minute (gpm)
ΔP = inlet pressure minus outlet pressure (psi)

$$C_v = \frac{q}{\sqrt{\Delta P}}$$

example:

medium = water
q = 160 U.S. gallons per minute
ΔP = 25 [100 psia inlet – 75 psia outlet]

$$C_v = \frac{160}{\sqrt{25}} \quad \text{or} \quad C_v = \frac{160}{5} \quad \text{or} \quad C_v = 32$$

Saturated Steam

where:

- **W** = gas flow in pounds per hour (pph)
- P_1 = inlet pressure (psia)
- P_2 = outlet pressure (psia)
- ΔP = inlet pressure minus outlet pressure (psi)

$$C_V = \frac{W}{2.1\sqrt{\Delta P(P_1 + P_2)}}$$

example:

medium = saturated steam
W = 4000 pph
P_1 = 100 psia
P_2 = 75 psia
ΔP = 25 [100 psia inlet – 75 psia outlet]

$$C_V = \frac{4000}{2.1\sqrt{25(100 + 75)}}$$

$$C_V = \frac{4000}{138.9}$$

$$C_V = 28.8$$

Choked Flow (Critical Drop)

Steam and Other Gases

When P_2 is less than 1/2 P_1, set P_2 equal to 1/2 P_1 in the appropriate sizing equation for steam or gases.

Steam, as are all gases, is a compressible fluid. The maximum velocity of the steam or gas through the valve is limited to the speed of sound. When the outlet pressure (psia) is equal to one-half (or less) of the inlet pressure (psia), the fluid velocity through the valve reaches the speed of sound, and flow cannot be further increased by a reduced outlet pressure. This is known as a choked flow condition. The pressure drop under these conditions is known as critical drop.

example:

medium = saturated steam
W = 4000 pph
P_1 = 100 psia
P_2 = 35 psia (actual)
ΔP = 65 psia

Since the outlet pressure is less than 1/2 of the inlet pressure, choked flow will occur. Set P_2 to equal 1/2 of P_1. Use this revised P_2 in the normal sizing formulae.

$P_2 = P_1 / 2$		$P_2 = 100 / 2$	$P_2 = 50$
$\Delta P = P_1 - P_2$	$\Delta P = P_1 - P_1/2$	$\Delta P = 100 - 50$	$\Delta P = 50$

$$C_V = \frac{W}{2.1\sqrt{\Delta P(P_1 + P_2)}}$$

$$C_V = \frac{4000}{2.1\sqrt{50(100 + 50)}}$$

$$C_V = \frac{4000}{181.9}$$

$$C_V = 22$$

Technical Information

STEAM PROPERTIES

Steam is perfectly transparent, colorless, dry and invisible. When it comes in contact with air, it partially condenses and forms a visible mist, or wet steam. Wet steam has the same temperature as dry steam contained under the same pressure.

Steam in its most common state is known as saturated steam. Its temperature is the same as that of the water from which it is formed and is dependent on the pressure under which it is contained. Superheated steam is created when saturated steam is further heated from another source after leaving the water from which it is formed.

Saturated Steam Pressure and Temperature

Vacuum	Temperature	Vacuum	Temperature	Latent Heat
in Hg	°F	kPag	°C	BTU/lb
9.74	32	-100.7	0	1075.5
25	133	-85	56	1018
20	161	-68	72	1002
15	179	-51	82	991
10	192	-34	89	983
5	203	-17	95	976

Pressure	Temperature	Pressure	Temperature	Latent Heat
psig	°F	kPag	°C	BTU/lb
0	212	0	100	970
5	227	34	108	961
10	239	69	115	953
15	250	103	121	946
20	259	138	126	939
25	267	172	130	934
30	274	207	134	929
35	281	241	138	924
40	287	276	142	920
45	292	310	145	916
50	298	345	148	912
60	307	414	153	905
70	316	483	158	898
80	324	552	162	892
90	331	621	166	886
100	338	689	170	881
110	344	758	173	875
120	350	827	177	871
130	356	896	180	866
140	361	965	183	861
150	366	1034	185	857
175	377	1207	192	847
200	388	1379	198	837
225	397	1551	203	828
250	406	1724	208	820

Adjusted to Sea Level — 14.696 psia (760 mm Hg)

STEAM PROPERTIES

- One cubic foot of water will become 1646 cubic feet of steam when evaporated at zero psi gauge pressure and a temperature of 212°F.
- One cubic foot of steam weighs 0.03732 pounds, and one pound of steam occupies 26.796 cubic feet at zero psi gauge pressure and a temperature of 212°F.
- One cubic foot of dry air weighs 0.08073 pounds, and one pound of dry air occupies 12.387 cubic feet at zero psi gauge pressure and a temperature of 0°F.
- The latent heat created from the vaporization of water to steam is:

  970 BTU per pound @ 14.7 psia
  889 BTU per pound @ 100 psia
- One British Thermal Unit (BTU) is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit, usually from 39.2°F to 40.2°F.

1 Gal. (U.S.) = 0.1337 ft^3

1 Gal. (U.S.) water = 8.337 lbs

1 ft^3 water = 62.364 lbs

Steam Required to Heat Water
According to Temperature Rise and Gallons per Hour

	U.S. Gallons of Water Heated per Hour (for fuel oil — multiply pounds per hour listed by 0.5)																	
	25	50	75	100	150	200	300	400	500	750	1000	1500	2000	3000	4000	5000	7500	10000
Temperature Rise (°F)	Pounds of Steam per Hour Required																	
10	—	—	—	—	—	17	25	33	42	63	83	120	167	250	330	420	620	830
20	—	—	—	—	25	33	50	67	83	125	167	250	330	500	670	830	1250	1670
30	—	—	—	25	37	50	75	100	125	190	250	370	500	750	1000	1250	1900	2500
40	—	—	25	33	50	66	100	130	170	250	330	500	660	1000	1330	1700	2500	3300
50	—	21	31	42	63	84	125	170	210	310	420	630	840	1250	1680	2100	3100	4200
60	12	25	37	50	75	100	150	200	250	370	500	750	1000	1500	2000	2500	3700	5000
80	16	33	50	67	100	130	200	270	330	500	670	1000	1340	2000	2700	3300	5000	6700
100	21	42	63	83	120	170	250	330	420	630	830	1250	1700	2500	3300	4200	6300	8300
120	25	50	75	100	150	200	300	400	500	750	1000	1500	2000	3000	4000	5000	7500	10000
140	29	58	88	117	175	230	350	470	580	880	1170	1750	2340	3500	4700	5800	8800	11700
160	33	66	100	133	200	270	400	530	660	1000	1330	2000	2700	4000	5300	6600	10000	13300
180	37	75	113	150	225	300	450	600	750	1125	1500	2200	3050	4500	5950	7500	11300	14950
200	42	84	126	165	250	330	500	660	840	1260	1660	2500	3400	5000	6600	8300	12600	16600

Using the Table

1. Find the units you wish to convert FROM in the left hand column. 2. Find the units you wish to convert TO in the top row.
3. Insert the multiplier shown at the intersection into the following formula: FROM units x MULTIPLIER = TO units

Example: 100 psi x 6.894757 = 689.475 kPa

FROM \ TO	PSI	in H2O	mm H2O	cm H2O	oz/in2	mbar	bar	mm Hg	cm Hg	in Hg	kg/cm2	kPa	MPa	ft H2O	m H2O	atm
psi	1	27.68068	703.1	70.308927	16	68.95	0.06894757	51.71486	5.171486	2.03602	0.070306958	6.894757	0.0069	2.306723	0.70308927	0.0680460
in H_2O	0.03612628	1	25.4	2.54	0.578020	2.488	0.00249	0.0735539	0.187	0.0735539	0.00254219	0.2490819	0.00025	0.08333	0.0254	0.00245825
mm H_2O	0.001422	0.0394	1	0.1	0.0227	0.098	0.000098	0.0735	0.00735	0.00289	0.0001	0.0098	0.00001	0.00328084	0.001	0.000097
cm H_2O	0.0142229	0.3937	10	1	0.227566	0.98	0.000980634	0.7355372	0.0735	0.0289581	0.00099997	0.980634	0.0001	0.032808	0.01	0.000967814
oz/in^2	0.0625	1.73004	43.943	4.394308	1	4.31	0.004309223	3.23218	0.323	0.12725125	0.04394308	0.4309223	0.00043	0.14417	0.04394308	0.004252875
mbar	0.0145	0.4012	10.20	1.020	0.2321	1	0.001	0.75	0.075	0.0295	0.00102	0.1	0.0001	0.03345622	0.00101975	0.000987
bar	14.5038	401.8596	10,197	1019.7466	232.0608	1000	1	750.0626	75	29.53	1.019716	100	0.1	33.4833	10.197466	0.986923
mm Hg	0.0193368	0.535255	13.60	1.359554	0.3093888	1.333	0.001333225	1	0.1	0.039370079	0.00135951	0.1333225	0.000133	0.0446046	0.01359554	0.0013157895
cm Hg	0.1934	5.358	136.0	13.60	3.10	13.33	0.01333	10	1	0.394	0.0136	1.333	0.00133	0.44604625	0.13595509	0.01316
in Hg	0.4911542	13.595484	345.3	34.53253	7.85847	33.86	0.03386389	25.4	2.54	1	0.0345316	3.386389	0.00339	1.132957	0.3453253	0.0334211
kg/cm^2	14.223343	393.711806	10,000.3	1000.028	227.57349	980.7	0.98066494	735.5588	73.56	28.95901	1	98.066494	0.0981	32.809312	10.00028	0.967841598
kPa	0.1450377	4.014742	101.97	10.19745	2.320603	10	0.01	7.500610	0.75	0.2952997	0.01019716	1	0.001	0.3345618	0.1019745	0.009869235
MPa	145.04	4019	101,975	10,197	2321	10,000	10	7500	750	295.3	10.2	1000	1	334.56218	101.9748043	9.869
ft H_2O	0.433515	12	304.80	30.48	6.93624	29.88981	0.02988981	22.4192	2.24192	0.882646	0.03047912	2.988981	0.002988981	1	0.3048	0.02949896
m H_2O	1.42229	39.370079	1000	100	22.7566	980.66494	0.98066494	73.55372	7.35537	2.89581	0.099997	9.8063439	0.0098063439	3.2808399	1	0.0967814
atm	14.696	406.794	10,333	1033.2633	235.136	1013	1.0132535	760	76	29.9213	1.033231	101.32535	0.1013	33.8995	10.332633	1

All units of H_2O at 39.2°F(4°C), all units of Hg at 32°F(0°C)

Hydraulic Ram Conversion

Use the formulas below to convert tons on a given diameter ram to PSI.

(Tons on ram x 2000) / (0.7854 x $dia.^2$) = PSI

($Dia.^2$ x 0.7854 x PSI) / 2000 = Tons on ram

Temperature Conversion

°F = Degrees Fahrenheit	°C = Degrees Celsius	°R = Degrees Reaumur
°F = (°C x 1.8) + 32	°C = (°F – 32) x 0.5555	°R = (°F – 32) x 0.4444
°F = (°R x 2.25) + 32	°C = (°R x 1.25)	°R = (°C x 0.80)

At sea level:

Water boils at 212°F, 100°C and 80°R

Water freezes at 32°F, 0°C and 0°R