Masoneilan Control Valve Sizing

OVERVIEW

This valve sizing software program is based on the use of nomenclature and sizing equations from ISA Standard S75.01 and IEC Standard 534-2.

The sizing equations are based on equations for predicting the flow of compressible and incompressible fluids through control valves. The equations are not intended for use when dense slurries, dry solids or non-Newtonian liquids are encountered.

Original equations and methods developed by Masoneilan are included for two-phase flow, multistage flow, and supercritical fluids.

Values of numerical factors are included for commonly encountered systems of units. These are English customary units and metric units for both kilopascal and bar usage.

The principal use of the equations is to aid in the selection of an appropriate valve size for a specific application. In this procedure, the numbers in the equations consist of values for the fluid and flow conditions and known values for the selected valve at rated opening. With these factors in the equation, the unknown (or product of the unknowns, e.g., $F_p C_v$) can be computed. Although these computed numbers are often suitable for selecting a valve from a series of discrete sizes, they do not represent a true operating condition. Some of the factors are for the valve at rated travel, while others relating to the operating conditions are for the partially open valve.

Once a valve size has been selected, the remaining unknowns, such as F_p, can be computed and a judgement can be made as to whether the valve size is adequate.

Flow Coefficient C_v

The use of the flow coefficient, C_v, first introduced by Masoneilan in 1944, quickly became accepted as the universal yardstick of valve capacity. So useful has C_v become, that practically all discussions of valve design and characteristics or flow behavior now employ this coefficient.

By definition, the valve flow coefficient, C_v, is the number of U. S. gallons per minute of water that will pass through a given flow restriction with a pressure drop of one psi. For example, a control valve that has a maximum flow coefficient, C_v, of 12 has an effective port area in the full open position such that it passes 12 gpm of water with one psi pressure drop. Basically, it is a capacity index upon which the engineer can rapidly and accurately estimate the required size of a restriction in any fluid system.

Operating Conditions

The selection of a correct valve size, as determined by formula, is always premised on the assumption of full knowledge of the actual flowing conditions. Frequently, one or more of these conditions is arbitrarily assumed. It is the evaluation of these arbitrary data that really determines the final valve size. **No formulas, only good common sense combined with experience, can solve this problem**.

There is no substitute for good engineering judgement. Most errors in sizing are due to incorrect assumptions as to actual flowing conditions. Generally speaking, the tendency is to make the valve too large to be on the "safe" side (commonly referred to as "oversizing"). A combination of several of these "safety factors" can result in a valve so greatly oversized it tends to be troublesome.

Specific Gravity

In the flow formulas, the specific gravity is a square root function ; therefore, small differences in gravity have a minor effect on valve capacity. If the specific gravity is not know accurately, a reasonable assumption will suffice. The use of .9 specific gravity, for example, instead of .8 would cause an error of less than 5 % in valve capacity.

Pressure Drop Across the Valve

On a simple back pressure or pressure reducing application, the drop across the valve may be calculated quite accurately. This may also be true on a liquid level control installation, where the liquid is passing from one vessel at a constant pressure to another vessel at a lower constant pressure. If the pressure difference is relatively small, some allowance may be necessary for line friction. On the other hand, in a large percentage of control applications, the pressure drop across the valve will be chosen arbitrarily.

Any attempt to state a specific numerical rule for such a choice becomes too complex to be practical. The design drop across the valve is sometimes expressed as a percentage of the friction drop in the system, exclusive of the valve. A good working rule is that 50% of this friction drop should be available as drop across the valve. In other words, one-third of the total system drop, including all heat exchangers, mixing nozzles, piping etc.., is assumed to be absorbed by the control valve. This may sound excessive, but if the control valve were completely eliminated from such a system, the flow increase would only be about 23%. In pump discharge systems, the head characteristic of the pump becomes a major factor. For valves installed in extremely long or high-pressure drop lines, the percentage of drop across the valve may be somewhat lower, but at least 15% (up to 25% where possible) of the system drop should be taken.

Remember one important fact, the pressure differential absorbed by the control valve in actual operation will be the difference between the total available head and that required to maintain the desired flow through the valve. It is determined by the system characteristics rather than by the theoretical assumptions of the engineer. In the interest of economy, the engineer tries to keep the control valve pressure drop as low as possible. However, a valve can only regulate flow by absorbing and giving up pressure drop to the system. As the proportion of the system drop across the valve is reduced, its ability to further increase flow rapidly disappears.

In some cases, it may be necessary to make an arbitrary choice of the pressure drop across the valve because meager process data are available. For instance, if the valve is in a pump discharge line, having a discharge pressure of 7 bar (100 psi), a drop of 0.7 to 1.7 bar (10 to 25 psi) may be assumed sufficient. This is true if the pump discharge line is not extremely long or complicated by large drops through heat exchangers or other equipment. The tendency should be to use the higher figure.

On more complicated systems, consideration should be given to both maximum and minimum operating conditions. Masoneilan Engineering assistance is available for analysis of such applications.

Flowing Quantity

The selection of a control valve is based on the required flowing quantity of the process. The control valve must be selected to operate under several different conditions. The maximum quantity that a valve should be required to pass is 10 to 15 % above the specified maximum flow. The normal flow and maximum flow used in size calculations should be based on actual operating conditions, whenever possible, without any factors having been applied.

On many systems, a reduction in flow means an increase in pressure drop, and the C_v ratio may be much greater than would be suspected. If, for example, the maximum operating conditions for a valve are 200 gpm at 25 psi drop, and the minimum conditions are 25 gpm at 100 psi drop, the C_v ratio is 16 to 1, not 8 to 1 as it would first seem. The required change in valve C_v is the product of the ratio of maximum to minimum flow and the square root of the ratio of maximum to minimum pressure drop, e.g.,

$$\frac{200 \times \sqrt{100}}{25 \times \sqrt{25}} = \frac{16}{1}$$

There are many systems where the increase in pressure drop for this same change in flow is proportionally much greater than in this case.

Temperature Conversion Table

°C		°F	°C		°F
-273	-459.4		43.3	110	230
-268	-450		46.1	115	239
-240	-400		48.9	120	248
-212	-350		54.4	130	266
-184	-300		60.0	140	284
-157	-250	-418	65.6	150	302
-129	-200	-328	71.1	160	320
-101	-150	-238	76.7	170	338
-73	-100	-148	82.2	180	356
-45.6	-50	-58	87.8	190	374
-42.8	-45	-49	93.3	200	392
-40	-40	-40	98.9	210	410
-37.2	-35	-31	104.4	220	428
-34.4	-30	-22	110	230	446
-31.7	-25	-13	115.6	240	464
-28.9	-20	-4	121	250	482
-26.1	-15	5	149	300	572
-23.2	-10	14	177	350	662
-20.6	-5	23	204	400	752
-17.8	0	32	232	450	842
-15	5	41	260	500	932
-12.2	10	50	288	550	1022
-9.4	15	59	316	600	1112
-6.7	20	68	343	650	1202
-3.9	25	77	371	700	1292
-1.1	30	86	399	750	1382
0	32	89.6	427	800	1472
1.7	35	95	454	850	1562
4.4	40	104	482	900	1652
7.2	45	113	510	950	1742
10	50	122	538	1000	1832
12.8	55	131	566	1050	1922
15.6	60	140	593	1100	2012
18.3	65	149	621	1150	2102
21.1	70	158	649	1200	2192
23.9	75	167	677	1250	2282
26.7	80	176	704	1300	2372
29.4	85	185	732	1350	2462
32.2	90	194	762	1400	2552
35	95	203	788	1450	2642
37.8	100	212	816	1500	2732
40.6	105	221			

Note : The temperature to be converted is the figure in the red column. To obtain a reading in ˚C use the left column ; for conversion to ˚F use the right column.

Table 1

Metric Conversion Tables

Length

Multiply	By	To Obtain
millimeters	0.10	centimeters
millimeters	0.001	meters
millimeters	0.039	inches
millimeters	0.00328	feet
centimeters	10.0	millimeters
centimeters	0.010	meters
centimeters	0.394	inches
centimeters	0.0328	feet
inches	25.40	millimeters
inches	2.54	centimeters
inches	0.0254	meters
inches	0.0833	feet
feet	304.8	millimeters
feet	30.48	centimeters
feet	0.304	meters
feet	12.0	inches

Area

Multiply	By	To Obtain
sq. millimeters	0.010	sq. centimeters
sq. millimeters	$10.^{-6}$	sq. meters
sq. millimeters	0.00155	sq. inches
sq. millimeters	1.076×10^{-5}	sq. feet
sq. centimeters	100	sq. millimeters
sq. centimeters	0.0001	sq. meters
sq. centimeters	0.155	sq. inches
sq. centimeters	0.001076	sq. feet
sq. inches	645.2	sq. millimeters
sq. inches	6.452	sq. centimeters
sq. inches	0.000645	sq. meters
sq. inches	0.00694	sq. feet
sq. feet	9.29×10^{4}	sqs. millimeters
sq. feet	929	sq. centimeters
sq. feet	0.0929	sq. meters
sq. feet	144	sq. inches

Flow Rates

Multiply	By	To Obtain
gallons US/minute GPM	3.785	liters/min
gallons US/minute	0.133	ft^3/min
gallons US/minute	8.021	ft^3/hr
gallons US/minute	0.227	m^3/hr
gallons US/minute	34.29	Barrels/day (42 US gal)
cubic feet/minute	7.481	GPM
cubic feet/minute	28.32	liters/minute

Flow Rates

Multiply	By	To Obtain
cubic feet/minute	60.0	ft^3/hr
cubic feet/minute	1.699	m^3/hr
cubic feet/minute	256.5	Barrels/day
cubic feet/hr	0.1247	GPM
cubic feet/hr	0.472	liters/min
cubic feet/hr	0.01667	ft^3/min
cubic feet/hr	0.0283	m^3/hr
cubic meters/hr	4.403	GPM
cubic meters/hr	16.67	liters/min
cubic meters/hr	0.5886	ft^3/min
cubic meters/hr	35.31	ft^3/hr
cubic meters/hr	150.9	Barrels/day

Velocity

Multiply	By	To Obtain
feet per second	60	ft/min
feet per second	0.3048	meters/second
feet per second	1.097	km/hr
feet per second	0.6818	miles/hr
meters per second	3.280	ft/sec
meters per second	196.9	ft/min
meters per second	3.600	km/hr
meters per second	2.237	miles/hr

Weight (Mass)

Multiply	By	To Obtain
pounds	0.0005	short ton
pounds	0.000446	long ton
pounds	0.453	kilogram
pounds	0.000453	metric ton
short ton	2000.0	pounds
short ton	0.8929	long ton
short ton	907.2	kilogram
short ton	0.9072	metric ton
long ton	2240	pounds
long ton	1.120	short ton
long ton	1016	kilogram
long ton	1.016	metric ton
kilogram	2.205	pounds
kilogram	0.0011	short ton
kilogram	0.00098	long ton
kilogram	0.001	metric ton
metric ton	2205	pounds
metric ton	1.102	short ton
metric ton	0.984	long ton
metric ton	1000	kilogram

Some units shown on this page are not recommended by SI, e.g., kilogram/sq. cm should be read as kilogram (force) / sq. cm

Table 2

Multiply	By	To Obtain	Multiply	By	To Obtain
Volume & Capacity			**Pressure & Head**		
cubic cm	0.06102	cubic inches	atmosphere	14.69	psi
cubic cm	3.531×10^{-5}	cubic feet	atmosphere	1.013	bar
cubic cm	$10.^{-6}$	cubic meters	atmosphere	1.033	Kg/cm^2
cubic cm	0.0001	liters	atmosphere	101.3	kPa
cubic cm	2.642×10^{-4}	gallons (US)	atmosphere	33.9	ft of H_2O
cubic meters	$10.^{6}$	cubic cm	atmosphere	10.33	m of H_2O
cubic meters	61,023.0	cubic inches	atmosphere	76.00	cm of Hg
cubic meters	35.31	cubic feet	atmosphere	760.0	torr (mm of Hg)
cubic meters	1000.0	liters	atmosphere	29.92	in of Hg
cubic meters	264.2	gallons	bar	14.50	psi
cubic feet	28,320.0	cubic cm	bar	0.9869	atmosphere
cubic feet	1728.0	cubic inches	bar	1.020	Kg/cm^2
cubic feet	0.0283	cubic meters	bar	100.0	kPa
cubic feet	28.32	liters	bar	33.45	ft of H_2O
cubic feet	7.4805	gallons	bar	10.20	m of H_2O
liters	1000.0	cubic cm	bar	75.01	cm of Hg
liters	61.02	cubic inches	bar	750.1	torr (mm of Hg)
liters	0.03531	cubic feet	bar	29.53	in of Hg
liters	0.001	cubic meters	kilogram/sq. cm	14.22	psi
liters	0.264	gallons	kilogram/sq. cm	0.9807	bar
gallons	3785.0	cubic cm	kilogram/sq. cm	0.9678	atmosphere
gallons	231.0	cubic inches	kilogram/sq. cm	98.07	kPa
gallons	0.1337	cubic feet	kilogram/sq. cm	32.81	ft of H_2O (4 DEG C)
gallons	3.785×10^{-3}	cubic meters	kilogram/sq. cm	10.00	m of H_2O (4 DEG C)
gallons	3.785	liters	kilogram/sq. cm	73.56	cm of Hg
			kilogram/sq. cm	735.6	torr (mm of Hg)
Pressure & Head			kilogram/sq. cm	28.96	in of Hg
			kiloPascal	0.145	psi
pounds/sq. inch	0.06895	bar	kiloPascal	0.01	bar
pounds/sq. inch	0.06804	atmosphere	kiloPascal	0.00986	atmosphere
pounds/sq. inch	0.0703	kg/cm^2	kiloPascal	0.0102	kg/cm^2
pounds/sq. inch	6.895	kPa	kiloPascal	0.334	ft of H_2O
pounds/sq. inch	2.307	ft of H_2O (4 DEG C)	kiloPascal	0.102	m of H_2O
pounds/sq. inch	0.703	m of H_2O (4 DEG C)	kiloPascal	0.7501	cm of Hg
pounds/sq. inch	5.171	cm of Hg (0 DEG C)	kiloPascal	7.501	torr (mm of Hg)
pounds/sq. inch	51.71	torr (mm of Hg) (0 DEG C)	kiloPascal	0.295	in of Hg
pounds/sq. inch	2.036	in of Hg (0 DEG C)	millibar	0.001	bar

Some units shown on this page are not recommended by SI, e.g., kilogram/sq. cm should be read as kilogram (force) / sq. cm

Table 2 cont.

Useful List of Equivalents (U. S. Customary Units)

1 U.S. gallon of water = 8.33 lbs @ std cond.
1 cubic foot of water = 62.34 lbs @ std cond. (= density)
1 cubic foot of water = 7.48 gallons
1 cubic foot of air = 0.076 lbs @ std cond. (= air density)
Air specific volume = 1/density = 13.1 cubic feet /lb
Air molecular weight M = 29
Specific gravity of air G = 1 (reference for gases)
Specific gravity of water = 1 (reference for liquids)
Standard conditions (US Customary) are at
14.69 psia & 60 DEG F*
G of any gas = density of gas/0.076
G of any gas = molecular wt of gas/29

G of gas at flowing temp = $\frac{G \times 520}{T + 460}$

Flow conversion of gas

$$scfh = \frac{lbs/hr}{density}$$

$$scfh = \frac{lbs/hr \times 379}{M}$$

$$scfh = \frac{lbs/hr \times 13.1}{G}$$

Flow conversion of liquid

$$GPM = \frac{lbs/hr}{500 \times G}$$

*Normal conditions (metric) are at 1.013 bar and 0 DEG. C & 4 DEG. C water

Note : Within this control valve handbook, the metric factors are at 1.013 bar and 15.6˚C.

Universal gas equation

Pv = mRTZ

Where			Metric		
P	=	press lbs/sq ft	P	=	Pascal
v	=	volume in ft^3	v	=	m^3
m	=	mass in lbs	m	=	kg
R	=	gas constant	R	=	gas constant
	=	$\frac{1545}{M}$		=	$\frac{8314}{M}$
T	=	temp Rankine	T	=	temp Kelvin
Z	=	gas compressibility factor = Z			

Gas expansion (perfect gas)

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Velocity of sound C (ft/sec)

$$C = 223 \sqrt{\frac{k\ (T + 460)}{M}}$$

where T = temp DEG F
M = mol. wt
k = specific heat ratio Cp/Cv

Velocity of Sound C (m/sec)

$$C = 91.2 \sqrt{\frac{k\ (T + 273)}{M}}$$

where T = temp DEG C
M = mol. wt
k = specific heat ratio Cp/Cv