Flow Coefficients and Computations

The pipe size in the system ordinarily will determine the valve size. However, to assure accurate throttling or positioning, it is advisable to calculate the valve size. Formulas for liquid and gas are as follows:

Liquid Flow Formula*

$$C_V = Q_a \sqrt{\frac{sg}{\triangle P}}$$

$$Q_a = C_V \sqrt{\frac{\triangle P}{sg}}$$

$$\triangle P = sg \left(\frac{Q_a}{C_V}\right)^2$$

Where:

C_V = Flow coefficient (gpm/△P)
sg = Specific gravity
Q_a = Actual flow (gpm)
△P = Actual pressure drop P_1-P_2(psi)

Gas Flow Formula*

$$C_V = \frac{Q}{1360} \sqrt{\frac{sg(T)}{\triangle P}} \sqrt{\frac{2}{P_1 + P_2}}$$

$$Q = 1360\, C_V \sqrt{\frac{\triangle P}{sg(T)}} \sqrt{\frac{P_1 + P_2}{2}}$$

$$\triangle P = P_1 - \sqrt{P_1^2 - (sg \times T)\left(\frac{Q}{963 \times C_V}\right)^2}$$

Where:

Q = Volumetric flow (SCFH)**
sg = Specific gravity
T = Absolute flowing temperature (ºF + 460)
P_1 = Inlet pressure (psia)
P_2 = Outlet pressure (psia)
△P = Pressure drop (P_1-P_2)
C_V = Valve coefficient from tables

* Fluid Controls Institute Inc. Standard FCI 62-1
** SCFH (standard cubic foot per hour) of gas is measured at 60ºF (519.7R) and 14.696 psia. CFH (cubic foot per hour) is measured at any temperature and pressure.

Conversion of CFH to SCFH is as follows:

$$SCFH = \frac{P_{actual}}{14.696} \times \frac{519.7\ ºR}{T_{actual}} \times CFH_{actual}$$

Where:

SCFH = Standard cubic feet per hour
P_{actual} = Pressure of gas in psia
T_{actual} = Temperature of gas (ºF + 460)

Note 1: The design of the Straightway Valves are not conducive to good throttling characteristics.

Important:
In general, any reduction in outlet pressure below one half the absolute inlet pressure will give no further increase in flow. The value of the ratio of pressure at which maximum flow is obtained varies somewhat depending on the actual fluid.

Flow Coefficients and Computations

Examples (Flow Computations)

Weir Valves

Examples:
(flow at pressure drop of 1 psi)

Problem:
To find the rate of flow of water through a 1½" unlined cast iron flanged valve, half open, with a pressure drop of one psi.

Solution:
From the 'Flanged End - Unlined' Weir Cv table the corresponding rate of flow is 42 gpm.

Problem:
To find the valve position of 2½" glass lined valve, with a water flow of 170 gpm and a pressure drop of 1 psi.

Solution:
From the same table as above the corresponding valve position is 70% open.

Problem:
To determine the flow in cubic feet per hour of air through a wide open 2 inch unlined valve. Inlet pressure at 60 psig, outlet pressure at 40 psig, and temperature at 60°F.

$$Q = (1360)(70)\sqrt{\frac{20}{520}}\sqrt{\frac{74.7 + 54.7}{2}}$$

$$Q = 150{,}400 \text{ SCFH}$$

Problem:
To find the rate of flow of water through a 2½" soft rubber lined valve, half open with a pressure drop of 3 psi.

Solution:
From 'Flanged End - Unlined' Weir Cv table

$C_V = 85$ gpm
$Q_a = 85\sqrt{3}$
$Q_a = 147$ gpm

Straightway Valves

Examples
(flow at pressure drop of 1 PSI.)

Problem
To find the rate of flow of water through a 1½" unlined flanged valve, half open, with a pressure drop of 1 PSI.

Solution
From C_V table: the corresponding rate of flow is 72 GPM.

Problem
Find the valve position of a 2½" rubber lined valve, with a water flow of 285 GPM and a pressure drop of 1 PSI.

Solution
From C_V table the corresponding valve position is 70% open.

Problem
To find valve size and valve position of an unlined valve, with flow at 200 GPM and an actual pressure drop of 5 PSI for a liquid with a specific gravity of 1.8

Solution

$$C_V = 200\sqrt{\frac{1.8}{5}} = 200\sqrt{.36} = (200)(0.6) = 120$$

From C_V table: a 2" valve has a C_V of 120 at 40% open.

Problem
To determine the flow in cubic feet per hour of air through a wide open 2" unlined valve. Inlet pressure at 60 PSIG, outlet pressure at 40 PSIG, and temperature at 60°F.

Solution
From C_V table: $C_V = 275$

$$\begin{aligned} Q &= 1360\,(275)\sqrt{\frac{20}{(1)(520)}}\sqrt{\frac{74.7 + 54.7}{2}} \\ &= 374{,}000\sqrt{.04}\sqrt{64.7} \\ &= 374{,}000 \times 1.61 \\ Q &= 602{,}140 \text{ standard cubic feet per hour} \end{aligned}$$

Problem
To find the rate of flow of water through a 2½" #5 rubber lined valve, full open, with a pressure drop of 3 PSI.

Solution
From C_V table: $C_V = 365$
$Q_a = 365\sqrt{3}$ or 632 GPM

Problem
Find the pressure drop across a 1½" plastic lined valve 100% open with water flow of 63 GPM

Solution
From C_V table: $C_V = 80$

$$\triangle P = \left(\frac{63}{80}\right)^2$$

$$\triangle P = 0.62 \text{ psi}$$

Flow Coefficients and Computations

Fluid velocity is a very important design consideration when selecting diaphragm valves. As mentioned previously velocity should be limited to 15–20 fps for clean fluids and 8-10 fps for slurries. Velocity through a Dia-Flo® weir type diaphragm valve can be determined by using the following equation:

$$V = \frac{.321Q}{A}$$

Where
V = Velocity in feet per second
Q = Flow in gallons per minute
A = Area in square inches at the point of greatest restriction (from table below)

Area Over the Weir for Standard Weir Valves (Square Inches)

Valve Size	% OPEN 10	20	30	40	50	60	70	80	90	100
1/2	.03	.06	.08	.10	.12	.14	.16	.18	.19	.20
3/4	.06	.11	.16	.20	.24	.28	.31	.34	.37	.39
1*	.09	.18	.26	.33	.40	.46	.52	.57	.62	.65
1 1/4, 1 1/2	.23	.43	.62	.79	.95	1.11	1.24	1.37	1.48	1.56
2	.38	.73	1.05	1.33	1.61	1.87	2.10	2.31	2.50	2.64
2 1/2	.55	1.05	1.51	1.93	2.33	2.71	3.05	3.35	3.62	3.83
3	.84	1.60	2.30	2.93	3.53	4.11	4.62	5.08	5.50	5.81
4	1.37	2.62	3.76	4.81	5.78	6.73	7.57	8.33	9.01	9.51
6	3.0	5.7	8.1	10.4	12.5	14.5	16.3	18.0	19.5	20.5
8	5.8	11.2	16.1	20.5	24.7	28.7	32.3	35.5	38.4	40.6
10	8.4	16.1	23.1	29.5	35.5	41.3	46.5	51.1	55.3	58.4
12	11.8	22.6	32.4	41.4	49.8	58.0	65.2	71.7	77.5	81.9

Area Over the Weir for DualRange® Valves (Square Inches)

Valve Size	% OPEN 10	20	30	40	50	60	70	80	90	100
1"*	.06	.11	.14	.18	.25	.31	.38	.49	.62	.65
1 1/2"	.10	.21	.28	.34	.44	.59	.80	1.00	1.22	1.56
2"	.14	.22	.37	.63	.98	1.26	1.57	1.91	2.11	2.64
2 1/2"	.14	.39	.63	.88	1.31	1.86	2.27	2.67	3.25	3.83
3"	.30	.65	.98	1.29	1.94	2.51	3.35	3.99	4.65	5.81
4"	.60	1.14	1.62	2.63	4.01	4.92	5.95	6.81	7.85	9.51
6"	1.54	2.30	4.01	6.63	9.43	11.68	13.79	15.84	17.90	20.50

* Includes all 3/4" flanged valves except solid plastic

Flow Coefficients and Computations

Weir Valve Cv Ratings

% open	Flanged End – Unlined 1/2	3/4-1	1 1/4 & 1 1/2	2	2 1/2	3	4	6	8	10	12
10	0.5	3	11	12	17	30	39	105	200	320	550
20	0.7	7	21	26	41	55	92	210	400	655	950
30	1.0	11	29	39	68	85	145	315	575	1000	1275
40	1.5	14	36	49	90	115	200	415	750	1300	1600
50	2.0	18	42	56	115	135	265	480	900	1450	1875
60	3.0	20	46	62	140	155	285	520	975	1625	2100
70	3.5	21	50	66	150	165	290	550	1050	1725	2250
80	4.0	22	52	69	155	175	300	570	1125	1775	2375
90	5.0	22	54	70	160	185	305	590	1175	1800	2475
100	5.5	22	56	70	160	190	310	600	1200	1800	2550

% open	Flanged End – Plastic Lined (except PFA) 3/4-1	1 1/4 & 1 1/2	2	2 1/2	3	4	6	8
10	3	5	10	17	40	60	105	390
20	5	15	23	40	70	120	265	600
30	7	25	37	61	100	170	400	740
40	8	31	50	82	120	210	505	830
50	9	36	65	94	140	245	585	900
60	10	38	68	98	150	265	630	960
70	11	39	69	99	160	280	670	1000
80	11	40	69	100	170	285	680	1040
90	10	39	69	100	175	290	685	1060
100	10	38	67	100	175	285	690	1070

% open	Flanged End – Hard Rubber Lined 1/2	3/4-1	1 1/4 & 1 1/2	2	2 1/2	3	4	6	8	10	12
10	0.2	2.9	12	15	20	31	46	150	225	320	400
20	0.4	5.4	22	30	35	57	105	275	450	655	750
30	0.7	8.2	26	40	50	75	160	375	650	1000	1125
40	1.2	11	28	45	65	93	210	475	800	1300	1425
50	1.5	13	29	50	80	110	220	550	900	1425	1700
60	2.0	13	29	54	90	130	230	600	975	1550	1900
70	2.4	13	30	60	100	145	245	610	1050	1650	2075
80	2.8	12	30	60	110	155	250	620	1075	1700	2200
90	3.4	11	31	59	115	160	260	625	1125	1750	2300
100	4.0	10	31	55	115	160	260	625	1150	1750	2350

Cv rating

Rate of flow depends upon the pressure drop.

Cv is the amount of flow in gallons per minute through a valve which results in a 1 psi pressure drop. Throttling characteristics are shown in the same manner with Cv's at various openings.

Use formula shown below to compute actual flow at various pressure drops.

Actual flow (g.p.m.) $= C_v\sqrt{\frac{\Delta P}{sg}}$

% open	Flanged End – Soft Rubber Lined 1/2	3/4-1	1 1/4 & 1 1/2	2	2 1/2	3	4	6	8	10	12
10	0.5	2.0	12	16	20	27	55	110	225	320	400
20	0.5	3.1	19	26	40	48	105	225	450	655	750
30	0.7	4.5	23	35	55	66	155	330	650	1000	1125
40	1.0	5.5	25	46	70	83	195	430	800	1300	1425
50	1.0	6.2	26	51	85	100	220	465	900	1425	1700
60	1.5	6.9	26	53	95	117	230	480	975	1550	1900
70	2.0	7.1	26	54	105	133	235	495	1050	1650	2075
80	2.0	7.2	26	54	110	144	240	505	1075	1700	2200
90	2.0	7.1	25	52	110	150	245	510	1125	1750	2300
100	2.0	7.0	25	50	110	155	250	515	1150	1750	2350

% open	Flanged End – PFA Lined 1"	1.5"	2"	3"	4"	6"
10	1.0	3.1	9	19	32	68
20	1.4	11	25	53	77	193
30	2.7	20	47	91	125	318
40	4.7	28	47	125	178	479
50	7.3	27	52	113	231	571
60	10	29	56	124	288	644
70	11	30	60	134	315	684
80	11	32	60	141	330	698
90	11	33	60	147	356	728
100	12	34	61	150	365	738

Flow Coefficients and Computations

Weir Valve Cv Ratings (Continued)

%	Glass Lined								
open	½	¾-1	1¼ & 1½	2	2½	3	4	6	8
10	0.5	1.4	10	11	17	24	32	160	280
20	0.7	4.4	19	25	41	60	63	315	560
30	1.0	8.0	27	42	72	100	130	455	840
40	1.5	12	36	56	96	140	200	590	1125
50	2.0	15	45	72	120	180	265	685	1350
60	3.0	19	51	80	150	215	320	760	1525
70	3.0	22	54	83	170	235	365	805	1625
80	3.5	22	55	83	175	240	400	835	1675
90	4.5	22	54	82	180	245	415	845	1700
100	5.5	22	53	78	180	250	420	850	1700

%	Screwed End Metal						
open	½	¾	1	1¼ & 1½	2	2½	3
10	0.4	2	3	9	12	20	78
20	0.6	3	6	16	26	37	110
30	1.0	5	8	24	39	52	128
40	1.4	6	10	30	49	65	140
50	1.6	7	12	36	56	75	146
60	2.0	8	14	40	62	83	150
70	2.6	8	16	44	66	89	156
80	3.0	10	17	47	69	94	161
90	3.8	10	18	48	70	96	166
100	4.4	10	19	48	70	95	172

%	Solid Plastic							
open	½	¾	1	1¼	1½	2	3"	4"
10	0.20	0.60	0.80	1.20	1.80	6.0	19	34
20	0.50	2.20	3.40	4.00	9.20	12.20	43	60
30	0.90	4.00	6.20	9.80	16.00	24.50	68	82
40	1.80	5.60	8.20	16.00	21.80	38.50	92	103
50	2.50	7.00	10.50	20.90	27.20	49.50	106	124
60	2.90	7.70	12.80	25.30	31.50	57.00	118	144
70	3.20	8.20	14.30	26.40	31.50	60.00	122	160
80	3.40	8.40	15.20	27.10	31.50	62.60	124	172
90	3.60	8.70	15.80	27.70	31.50	64.00	125	179
100	3.60	8.70	15.80	28.40	31.50	65.50	125	185

Cv ratings applying to screwed end metals and flanged unlined valves are based on use of cast iron bodies. For socket weld metal bodies, ues Buttweld Cv Table.

%	Butt Weld									
open	½"	¾"	1"	1½"	2"	2½"	3"	4"	6*	8*
10	0.2	2.0	3.0	9	12	20	30	32	105	200
20	0.4	3.1	6.0	16	26	37	55	70	210	400
30	0.7	4.5	8.0	24	39	52	85	130	315	575
40	1.2	5.5	10.0	30	49	65	115	200	415	750
50	1.5	6.0	13.0	36	56	75	135	265	480	900
60	2.0	6.4	14.0	40	62	83	155	290	520	975
70	2.4	6.8	16.0	44	66	89	165	320	550	1050
80	2.8	7.0	17.0	47	69	94	170	360	570	1125
90	3.0	7.2	18.0	48	70	95	175	385	590	1175
100	3.5	7.5	18.6	48	70	95	180	400	600	1200

*Data is based on estimates.

Flow Coefficients and Computations

Dualrange® Control Valves Cv Ratings

% open	Flanged – Unlined ¾-1	1½	2	2½	3	4	6
10	1.0	2.0	4.0	8.0	14	24	65
20	3.2	8.0	9.0	18	27	47	125
30	5.2	14	14	28	42	70	255
40	7.4	21	19	52	68	130	365
50	9.4	33	33	78	97	185	445
60	13	43	50	105	120	245	515
70	18	50	62	130	145	275	550
80	21	52	69	150	160	295	570
90	22	54	70	160	175	305	590
100	22	56	70	160	190	310	600

% open	Flanged – Plastic Lined (except PFA) ¾-1	1½	2	2½	3	4	6
10	1.0	3.0	4.5	7.0	16	20	70
20	2.8	8.0	11	17	34	55	145
30	4.7	13	16	28	52	80	280
40	6.6	21	27	50	84	125	430
50	8.2	32	43	75	125	190	540
60	9.5	37	60	88	150	240	610
70	10	38	68	97	160	270	655
80	11	39	69	100	170	285	680
90	10	38	69	100	175	290	690
100	10	38	67	100	175	285	690

% open	Flanged – Soft Rubber Lined ¾-1	1½	2	2½	3	4	6
10	0.5	3.0	3.5	6.0	12	22	65
20	1.6	8.0	10	15	26	41	125
30	3.2	14	17	25	39	60	250
40	5.5	20	23	47	55	105	350
50	6.2	29	33	76	77	155	405
60	6.9	28	47	95	99	195	450
70	7.1	26	54	105	120	220	485
80	7.2	26	54	110	135	240	505
90	7.1	25	52	110	145	245	510
100	7.0	25	50	110	155	250	515

% open	Flanged – Hd. Rubber Lined ¾-1	1½	2	2½	3	4	6
10	0.5	3.5	6.0	10	12	25	65
20	3.0	10	12	20	26	50	130
30	5.9	16	17	30	40	71	275
40	8.3	26	22	49	57	130	430
50	10	29	37	65	84	190	530
60	11	29	51	84	110	230	570
70	11	30	60	96	125	245	590
80	11	30	60	105	145	250	620
90	10	31	59	110	155	260	625
100	10	31	55	115	160	260	625

% open	Flanged – Glass Lined ¾-1	1½	2	2½	3	4	6
10	1.4	3.0	3.0	8.0	12	24	98
20	3.8	9.0	9.0	18	32	50	190
30	6.2	16	17	28	48	77	370
40	8.6	26	25	56	84	145	520
50	12	40	40	85	135	210	640
60	18	51	62	115	185	270	750
70	22	54	75	140	220	335	805
80	22	55	82	155	240	395	835
90	22	54	82	180	245	415	845
100	22	53	78	180	250	420	850

% open	Flanged End – PFA Lined 1"	1.5"	2"	3"	4"	6"
10	0.3	2	4	8	11	45
20	1	6	12	26	32	106
30	1.8	10	20	47	59	215
40	3.9	19	25	88	107	407
50	6.6	24	34	101	181	525
60	9.5	28	49	124	262	625
70	10	29	59	134	302	670
80	11	31	60	141	330	698
90	11	32	60	147	356	728
100	12	34	61	150	365	738

Flow Coefficients and Computations

Straightway Valve Cv Ratings

% open	Flanged Plastic Lined						
	1	1½	2	3	4	6	8**
10	0.6	5	9.3	40	80	162	227
20	5.6	21	38	97	167	398	619
30	14	42	76	158	252	587	864
40	17	48	96	200	322	733	1080
50	18	54	116	215	334	818	1245
60	20	58	123	236	372	862	1262
70	23	65	137	270	424	963	1372
80	24	73	156	292	474	1052	1535
90	24	80	180	320	525	1191	1917
100	24	80	209	370	569	1400	2644

% open	FLG – #5*		
	1	1½	2
10	15	16	22
20	24	26	40
30	28	36	90
40	32	48	135
50	34	59	150
60	36	64	150
70	38	66	155
80	40	69	165
90	41	73	190
100	42	79	220

% open	FLG – #10*		
	1	1½	2
10	6.5	15	36
20	15	30	72
30	23	48	130
40	30	62	140
50	35	72	160
60	40	80	180
70	44	90	200
80	47	100	220
90	50	115	240
100	55	130	260

% open	Flanged Rubber Lined						
	2½	3	4	6	8	10	12
10	60	65	90	100	350	550	550
20	110	125	185	275	700	1150	1150
30	155	190	255	550	1050	1700	1700
40	190	235	310	825	1400	2250	2250
50	215	270	350	950	1750	2800	2800
60	235	290	415	1000	2150	3100	3100
70	245	315	525	1050	2500	3200	3200
80	260	350	645	1100	2875	3300	3300
90	285	390	685	1300	3200	3650	3650
100	365	460	700	1800	3500	4850	4850

% open	Flanged End Unlined									
	1	1½	2	2½	3	4	6	8	10	12
10	10	15	30	60	75	85	250	350	450	450
20	19	30	60	115	135	165	450	700	1050	1050
30	26	45	90	160	185	240	700	1030	2000	2000
40	32	60	120	205	230	320	950	1400	2800	2800
50	38	72	150	240	270	400	1150	1750	3350	3350
60	44	80	180	265	295	480	1400	2050	3550	3550
70	48	84	210	285	310	560	1650	2350	3650	3650
80	52	87	235	300	335	625	1850	2700	3900	3900
90	56	97	260	350	390	670	2050	3300	4300	4300
100	60	115	275	450	525	700	2250	4250	5000	5000

* Flanged #10 = hard natural rubber lining. Flanged #5 = soft natural rubber, neoprene, hypalon and butyl linings.
** Data is based on estimates.

Flow Coefficients and Computations

Specific Gravitys of Gases Related to Free Air

(Free air = Air at 1 atmosphere and 60° F)

Gas	Specific Gravity s (Air = 1)	Gas	Specific Gravity s (Air = 1)
Acetylene	0.899	Hydrogen Sulphide	1.190
Air	1.000	Methane	0.544
Ammonia	0.590	Methyl Chloride	1.744
Argon	1.378	Natural Gas	0.57—0.71
Blast-Furnace Gas	1.000	Neon	0.696
Blue Water Gas	0.530	Nitric Oxide	1.038
Carbon Dioxide	1.530	Nitrogen	0.970
Carbon Monoxide	0.967	Nitrous Oxide	1.522
Carbureted Water Gas	0.640	Oil Gas	0.480
Chlorine	2.486	Oxygen	1.105
Coal – Retort Gas	0.420	Pintsch Gas	0.840
Coke – Oven Gas	0.380	Producer Gas, Coal	0.870
Dichlorodifloromethane F-12	4.250	Propane	1.560
Ethylene	0.969	Refinery Gas:	
Ethyl Chloride	2.260	Dubbs	0.960
Helium	0.138	Houdrie	1.510
Hydrochloric Acid	1.260	Sulphur Dioxide	2.213
Hydrogen	0.0696		

Strength % by Weight	Specific Gravities					Strength % by Weight
	HCI. Hydrochloric Acid	HNO_3 Nitric Acid	H_2SO_4 Sulphuric Acid	KOH Caustic Potash	NaOH Caustic Soda	
5	1.0251	1.0270	1.0332	1.041	1.058	5
10	1.0503	1.0561	1.0681	1.083	1.115	10
15	1.0754	1.0865	1.1045	1.128	1.170	15
20	1.1005	1.1178	1.1424	1.177	1.225	20
25	1.1257	1.1503	1.1816	1.230	1.279	25
30	1.1508	1.1838	1.2220	1.288	1.332	30
35	1.1759	1.2183	1.2636	1.349	1.384	35
40	1.2000	1.2511	1.3065	1.411	1.437	40
45	–	1.2836	1.3515	1.472	1.488	45
50	–	1.3157	1.3990	1.539	1.540	50
60	–	1.3734	1.5024	–	–	60
70	–	1.4210	1.6151	–	–	70
80	–	1.4601	1.7323	–	–	80
90	–	1.4941	1.8198	–	–	90