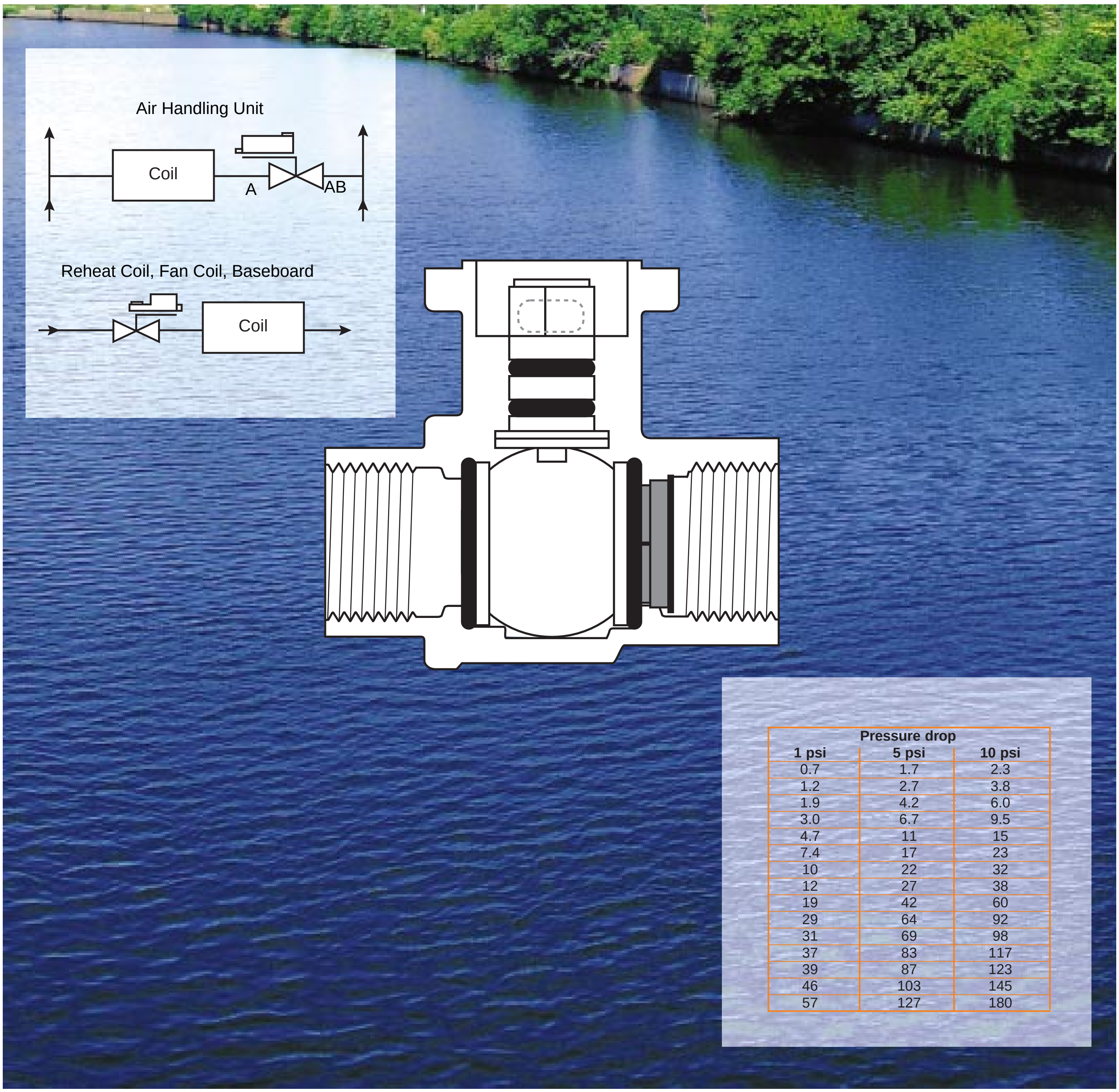
BELIMO

Actuators for heating, ventilation, air-conditioning

ELECTRONIC VALVE SIZING AND SELECTION

V4.1



Pressure drop		
1 psi	5 psi	10 psi
0.7	1.7	2.3
1.2	2.7	3.8
1.9	4.2	6.0
3.0	6.7	9.5
4.7	11	15
7.4	17	23
10	22	32
12	27	38
19	42	60
29	64	92
31	69	98
37	83	117
39	87	123
46	103	145
57	127	180

Tables

Figures

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Introduction

The **common applications** in HVAC valve control, each of which uses slightly different selection and sizing methods, are defined in the section headings in the table of contents.

In addition to sizing, it is necessary to check specifications to ensure correct selection. Special conditions are possible which may make selection more demanding than the common applications.

Glycol or other additives may make the specific gravity necessary to include in calculations. NEMA 3 or higher applications will require a enclosure. A combination of medium or ambient temperatures may make a special valve or protection of the actuator by thermal isolation necessary. Space constraints may dictate choice of valve type. Other special conditions may exist.

The information necessary to properly size a valve is the same in all cases. If full information is not available, there will be cases where the valve will be incorrectly sized or the wrong valve will be selected. The pressure drop through coil and piping at design is usually unknown. Without this information correct sizing and selection cannot be assured. An adequate estimate is usually possible. See **Belimo's Valve Application Guide Doc V4.2** for a detailed discussion of basics of valves, coil characteristics, valve authority, actuator considerations, loop tuning, and heat transfer calculations.

Sizing information:
- Pipe size
- Flow rate in GPM or # of steam
- Density of medium (water = 1)
- Pressure drop through coil and piping at design
- Desired pressure drop through valve in full open position

Selection information:
- 2-way or 3-way
- Allowable leakage
- Temperature of medium and ambient
- Environment (Nema 4 required, ambient temperature, etc.)
- Space constraints
- Actuator selection requires control signal definition and any special needs

I. Two-position control of hot and cold water

Two psi is typically the maximum pressure loss allowed. Ten to 20% of the supply to return differential pressure is also used as a rule of thumb. *Figure 1a* shows common applications for **2-way valves in 2-position control**. *Figure 1b* shows common **3-way valve applications in 2-position applications.**

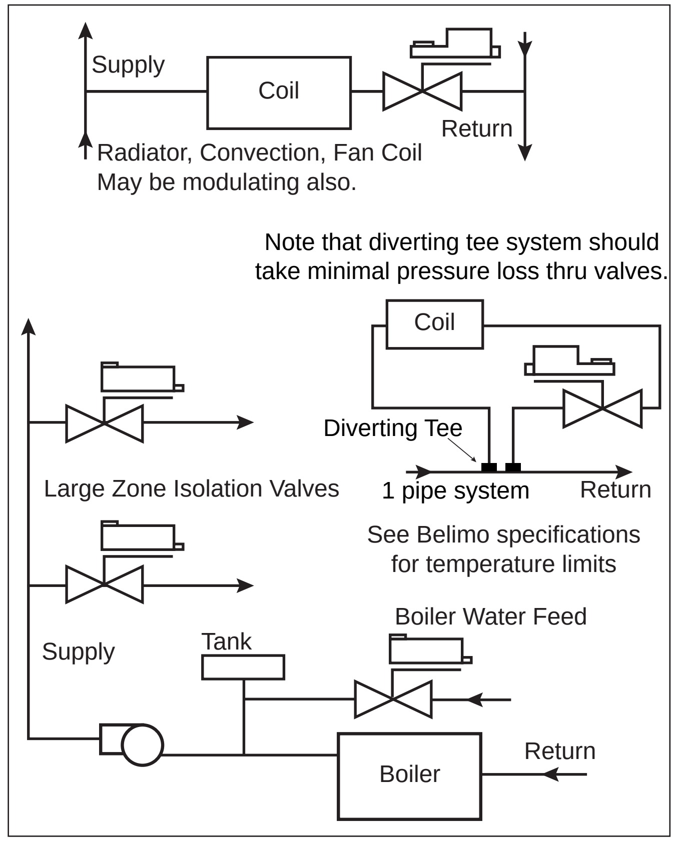

Fig. 1a - Two-way valves in 2-position applications

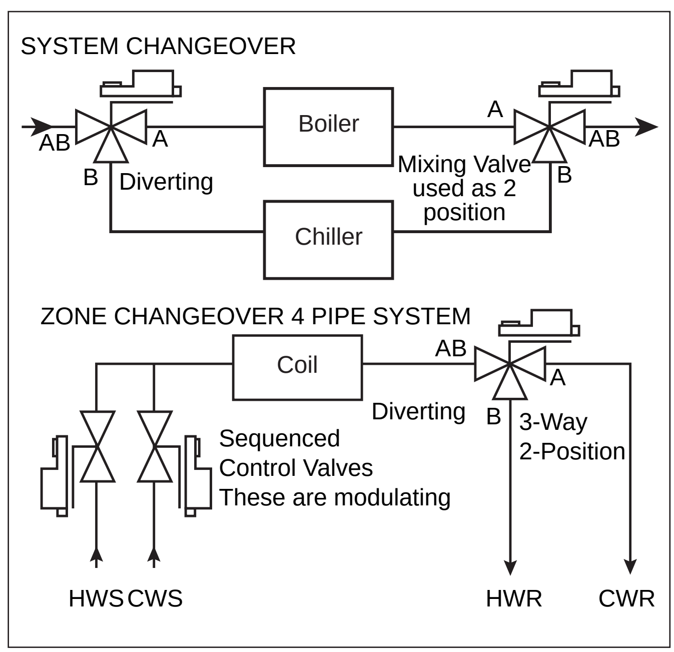

Fig. 1b - Three-way valves in 2-position applications

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Globe, ball, zone, and Belimo Characterized Control Ball Valves will normally be full line size in 2-position applications. There is no reason to use characterized valves for these applications unless planning to go to modulation at a later date. The ball or butterfly valve is less expensive and has a higher capacity – lower pressure loss — for large valves. In some cases, particularly with butterfly valves, the valve can be reduced a pipe size to save money and still produce a low enough pressure loss.

Standard full port and reduced port ball valves and butterfly valves used in 2-position applications can be full line size. They may be reduced if the calculations are performed and show a low enough pressure drop.

C_v is the capacity of water in GPM which flows through a valve with a 1 psi pressure loss.

The formula for calculating the C_v needed is

$C_v = GPM / \sqrt{\Delta P/g}$
(g = 1 for water and therefore $C_v = GPM / \sqrt{\Delta P}$)

It is typical to select a 2-position valve with a C_v = GPM required. Examination of the sizing tables shows that line size valves are usually selected.

Table A gives the C_v's of the Belimo characterized ball valve line. Note that there are full ported versions also available for 2-position use. *Table B* has Belimo globe valve C_v values.

Example 1:

A zone isolation valve must pass 10 GPM. The line size is 1". What size valves are acceptable for a ball valve and a globe valve?
Assume that the pressure drop should be 1 psi at the most. Select a line size valve. From Table 1 a 1" ball valve in a 1" line has a C_v of 23.
Using $C_v = GPM / \sqrt{\Delta P}$ and $\Delta P = 1$ and substituting,
$C_v = 10 / \sqrt{1}$.
$C_v = 10$. This is the minimum C_v required.
Any valve with C_v equal to or greater than 10 will work.

Now find the globe which fits.
From *Table B* there are 1" globe valves with C_v's of 10 and 14. The pressure drop is less for the C_v = 14 and normally it is selected.
Note that the rule of thumb can be that the required C_v is equal to or greater than the GPM required or line size.

There are other reduced pipe size valves that could also be used.

F_p & C_v

The C_v of a high capacity valve diminishes significantly as the pipe size is increased. This is calculated using the piping geometry factor or F_p. C_{vc} is corrected C_v. It is found using $C_{vc} = C_v \times F_p$.

F_p can be estimated for average concentric reducers using a formula shown in Belimo's Control Valve Applications Guide. High capacity valves (standard ball valves and butterfly valves) have a low F_p; the capacity is greatly reduced. Low capacity valves like the globe and characterized ball valve have F_p near 1; there is little reduction in capacity from using reducers.

In *Table A* the full port, high capacity valves are marked. When using them in pipes larger than the valve size the C_{vc} table at the bottom of the page should be used to find the corrected C_v.

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Table A: Valve Flow Rate for Water Applications (Gallons Per Minute, GPM)

C_V Maximum Rating	Valve Inches	Valve DN mm	Two Way Ball Valve	Three Way Ball Valve	Pressure drop across the valve: 1 psi	2psi	3psi	4psi	5psi	6psi	7psi	8 psi	9psi	10psi
0.8	1/2"	15	B209	B309	0.8	1.1	1.4	1.6	1.8	2.0	2.1	2.3	2.4	2.5
1.2	1/2"	15	B210	B310	1.2	1.7	2.1	2.4	2.7	2.9	3.2	3.4	3.6	3.8
1.9	1/2"	15	B211	B311	1.9	2.7	3.3	3.8	4.2	4.7	5.0	5.4	5.7	6.0
3.0	1/2"	15	B212	B312	3.0	4.2	6.2	6.0	6.7	7.3	7.9	8.5	9.0	9.5
4.7	1/2"	15	B213	B313	4.7	6.6	8.1	9.4	11	12	12	13	14	15
7.4	1/2"	15	B214		7.4	10	13	15	17	18	20	21	22	23
10	1/2"	15	B215*	B315	10	14	17	20	22	24	26	28	30	32
4.7	3/4"	20	B217	B317	4.7	6.6	8.1	9.4	11	12	12	13	14	15
7.4	3/4"	20	B218	B318	7.4	10	13	15	17	18	20	21	22	23
10	3/4"	20	B219		10	14	17	20	22	24	26	28	30	32
24	3/4"	20	B220*	B320	24	34	42	48	54	59	63	68	72	76
7.4	1"	25	B222	B322	7.4	10	13	15	17	18	20	21	22	23
10	1"	25	B223	B323	10	14	17	20	22	24	26	28	30	32
19	1"	25	B224		19	27	33	38	42	47	50	54	57	60
30	1"	25	B225*	B325	30	42	52	60	67	73	79	85	90	95
10	1-1/4"	32	B229	B329	10	14	17	20	22	24	26	28	30	32
19	1-1/4"	32	B230*	B330	19	27	33	38	42	47	50	54	57	60
25	1-1/4"	32	B231	B331	25	35	43	50	56	61	66	71	75	79
37	1-1/4"	32	B232*	B332	37	52	64	74	83	91	98	105	111	117
19	1-1/2"	40	B238	B338	19	27	33	38	42	47	50	54	57	60
29	1-1/2"	40	B239	B339	29	41	50	58	65	71	77	82	87	92
37	1-1/2"	40	B240*	B340	37	52	64	74	83	91	98	105	111	117
29	2"	50	B248	B348	29	41	50	58	65	71	77	82	87	92
46	2"	50	B249	B349	46	65	80	92	103	113	122	130	138	145
57	2"	50	B250*	B350	57	81	99	114	127	140	151	161	171	180

GPM = $C_V \times \sqrt{\Delta p}$

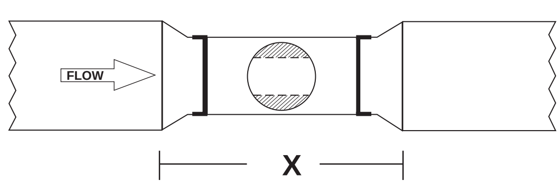
* = Models with no characterizing disc.

The influence of the pipe geometry due to reduced flow is negligible for all valves with characterizing discs.

Table B: C_V for Valves Without Characterizing Discs.

Model #	Valve size Inches	Valve size DN mm	Line size: 1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	4"
B215	1/2"	15	10.0	7.4	6.3	-	-	-	-	-	-
B220	3/4"	20	-	24.0	19.0	16.1	14.6	-	-	-	-
B225	1"	25	-	-	30.0	27.3	24.9	21.9	-	-	-
B230	1-1/4"	32	-	-	-	19.0	18.8	18.2	17.9	-	-
B232	1-1/4"	32	-	-	-	37.0	35.5	31.8	30.0	-	-
B240	1-1/2"	40	-	-	-	-	37.0	35.0	34.0	33.0	-
B250	2"	50	-	-	-	-	-	57.0	56.0	54.0	52.0

Full port valve size smaller than line
(without characterizing disc)



“X” should be as short as possible. Length will influence the resulting C_V value of a full ported ball valve.

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Valve Flow Rate for Water Applications (GPM)

C_V Maximum Rating	Valve Inches	Valve DN mm	Two Way Globe Valve	Three Way Globe Valve	Pressure drop across the valve									
					1 psi	2psi	3psi	4psi	5psi	6psi	7psi	8 psi	9psi	10psi
0.4	1/2”	15	G212		0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.3
1.3	1/2”	15	G213		1.3	1.8	2.3	2.6	2.9	3.2	3.4	3.7	3.9	4.1
2.2	1/2”	15	G214	G314	2.2	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.6	7.0
4.4	1/2”	15	G215	G315	4.4	6.2	7.6	8.8	9.8	10.8	11.6	12.4	13.2	13.9
5.5	3/4”	20	G219		5.5	7.8	9.5	11.0	12.3	13.5	14.5	15.6	16.5	17.4
7.5	3/4”	20	G220	G320	7.5	10.6	13.0	15.0	16.7	18.4	19.8	21.2	22.5	23.7
10	1”	25	G224		10	14	17	20	22	24	26	28	30	32
14	1”	25	G225	G325	14	20	24	28	31	34	37	40	42	44
20	1-1/4”	32	G232	G332	20	28	35	40	45	49	53	57	60	63
28	1-1/2”	40	G240	G340	28	40	48	56	63	69	74	79	84	89
40	2”	50	G250	G350	40	57	69	80	89	98	106	113	120	126

Valve Flow Rate for Low Pressure Steam Applications

/ hr. Steam

C_V Maximum Rating	Valve Inches	Valve DN mm	Two Way Globe Valve	Inlet - psig 2 psi		5 psi		10 psi		15 psi	
				2-position 10% of P1 $\Delta P = .2$ psi	Modulating 80% of P1 $\Delta P = 1.6$ psi	2-position 10% of P1 $\Delta P = .5$ psi	Modulating 80% of P1 $\Delta P = 4$ psi	2-position 10% of P1 $\Delta P = 1$ psi	Modulating 80% of P1 $\Delta P = 8$ psi	2-position 10% of P1 $\Delta P = 1.5$ psi	Modulating 80% of P1 $\Delta P = 12$ psi
0.4	1/2”	15	G212	2.2	5.8	3.7	9.5	5.8	14	7.8	18
1.3	1/2”	15	G213	7	20	12	30	19	45	25	56
2.2	1/2”	15	G214	12	33	21	52	32	76	43	96
4.4	1/2”	15	G215	23	65	41	104	65	153	86	192
5.5	3/4”	20	G219	30	81	51	131	80	191	107	240
7.5	3/4”	20	G220	41	111	70	179	110	260	146	328
10	1”	25	G224	55	148	92	238	146	347	195	437
14	1”	25	G225	77	207	130	333	204	486	273	612
20	1-1/4”	32	G232	109	295	186	475	292	694	390	874
28	1-1/2”	40	G240	153	413	260	666	409	971	546	1224
40	2”	50	G250	218	590	371	951	584	1387	780	1749

Valve Flow Rate for Medium Pressure Steam Applications

/ hr. Steam

C_V Maximum Rating	Valve Inches	Valve DN mm	Two Way Globe Valve	Inlet - psig 20 psi		25 psi		30 psi		35 psi	
				2-position 10% of P1 $\Delta P = 2$ psi	Modulating .42 of P1 $\Delta P = 14$ psi	2-position 10% of P1 $\Delta P = 2.5$ psi	Modulating .42 of P1 $\Delta P = 16$ psi	2-position 10% of P1 $\Delta P = 3$ psi	Modulating .42 of P1 $\Delta P = 18$ psi	2-position 10% of P1 $\Delta P = 3.5$ psi	Modulating .42 of P1 $\Delta P = 20$ psi
0.4	1/2”	15	G212	10	20	12	23	13	26	15	29
1.3	1/2”	15	G213	32	67	38	76	44	86	50	96
2.2	1/2”	15	G214	53	113	64	129	74	146	84	162
4.4	1/2”	15	G215	107	226	127	259	148	291	168	324
5.5	3/4”	20	G219	133	283	159	323	185	364	210	405
7.5	3/4”	20	G220	182	385	217	441	252	496	286	552
10	1”	25	G224	243	514	289	588	336	662	381	736
14	1”	25	G225	340	719	405	823	470	927	534	1030
20	1-1/4”	32	G232	485	1028	579	1176	671	1324	763	1472
28	1-1/2”	40	G240	679	1439	810	1646	940	1853	1068	2060
40	2”	50	G250	970	2056	1157	2351	1342	2648	1526	2944

The influence of the pipe reduction factor on the flow for the Belimo electronic globe valves is negligible.

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Valve Flow Rate for Water Applications (GPM) Two-Way Globe Valve

C_V Maximum Rating	Valve Inches	Valve DN mm	Model Number	Pressure drop across the valve 1 psi	2psi	3psi	4psi	5psi	6psi	7psi	8 psi	9psi	10psi
65	2-1/2”	65	G665	65	92	113	130	145	159	172	184	195	206
90	3”	80	G680	90	127	156	180	201	220	238	255	270	285
170	4”	100	G6100	170	240	294	340	380	416	450	481	510	538
263	5”	125	G6125	263	372	456	526	588	644	696	744	789	832
344	6”	150	G6150	344	486	596	688	769	843	910	973	1032	1088

Valve Flow Rate for Water Applications (GPM) Three-Way Mixing Globe Valve

C_V Maximum Rating	Valve Inches	Valve DN mm	Model Number	Pressure drop across the valve 1 psi	2psi	3psi	4psi	5psi	6psi	7psi	8 psi	9psi	10psi
68	2-1/2”	65	G765	68	96	118	136	152	167	180	192	204	215
91	3”	80	G780	91	129	158	182	203	223	241	257	273	288
190	4”	100	G7100	190	269	329	380	425	465	503	537	570	601
280	5”	125	G7125	280	396	485	560	626	686	741	792	840	885
340	6”	150	G7150	340	481	589	680	760	833	900	962	1020	1075

Valve Flow Rate for Water Applications (GPM) Three-Way Diverting Globe Valve

C_V Maximum Rating	Valve Inches	Valve DN mm	Model Number	Pressure drop across the valve 1 psi	2psi	3psi	4psi	5psi	6psi	7psi	8 psi	9psi	10psi
68	2-1/2”	65	G765D	68	96	118	136	152	167	180	192	204	215
85	3”	80	G780D	85	120	147	170	190	208	225	240	255	269
154	4”	100	G7100D	154	218	267	308	344	377	407	436	462	487
195	5”	125	G7125D	195	276	338	390	436	478	516	552	585	617
248	6”	150	G7150D	248	351	430	496	555	607	656	701	744	784

The influence of the pipe reduction factor on the flow for the Belimo electronic globe valves is negligible.

Valve Flow Rate for Low Pressure Steam Applications

lbs. / hr. Steam

C_V	Valve		Two Way Globe Valve	Inlet - psig							
				2 psi		5 psi		10 psi		15 psi	
Maximum Rating	Inches	DN mm		2-position 10% of P1 ∆P = .2 psi	Modulating 80% of P1 ∆P = 1.6 psi	2-position 10% of P1 ∆P = .5 psi	Modulating 80% of P1 ∆P = 4 psi	2-position 10% of P1 ∆P = 1 psi	Modulating 80% of P1 ∆P = 8 psi	2-position 10% of P1 ∆P = 1.5 psi	Modulating 80% of P1 ∆P = 12 psi
65	2-1/2”	65	G665	354	958	604	1545	949	2254	1268	2842
90	3”	80	G680	490	1327	836	2139	1314	3120	1756	3935
170	4”	100	G6100	926	2507	1580	4042	2483	5895	3317	7433
263	5”	125	G6125	1433	3878	2445	6253	3841	9120	5132	11499
344	6”	150	G6150	1875	5073	3198	8178	5024	11928	6712	15040

Valve Flow Rate for High Pressure Steam Applications

lbs. / hr. Steam

C_V	Valve		Two Way Globe Valve	Inlet - psig							
				20 psi		25 psi		30 psi		35 psi	
Maximum Rating	Inches	DN mm		2-position 10% of P1 ∆P = 2 psi	Modulating .42 of P1 ∆P = 14 psi	2-position 10% of P1 ∆P = 2.5 psi	Modulating .42 of P1 ∆P = 16 psi	2-position 10% of P1 ∆P = 3 psi	Modulating .42 of P1 ∆P = 18 psi	2-position 10% of P1 ∆P = 3.5 psi	Modulating .42 of P1 ∆P = 20 psi
65	2-1/2”	65	G665	1577	3320	1881	3797	2181	4275	2480	4753
90	3”	80	G680	2183	4596	2604	5258	3020	5919	3433	6580
170	4”	100	G6100	4124	8682	4918	9931	5704	11181	6485	12430
263	5”	125	G6125	6381	13432	7609	15364	8825	17297	10033	19230
344	6”	150	G6150	8346	17568	9952	20098	11543	22624	13123	25152

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Table C is a butterfly valve table with C_V shown for various valve and pipe sizes.

For example, 600 GPM must flow through a 4" pipe and valve with a pressure drop of no more than 1 psi.

Since the table shows that a 4" valve in a 4" pipe passes 660 GPM with a 1 psi loss, it is selected for the application which will require only 600 GPM.

Table C
Butterfly Valves

Valve Size	Pipe Size	C_{VC} at degrees open 60°	70°	90°		Full Open — 90 Flow in GPM at pressure drop of: 1 psi	2 psi	3 psi	4 psi	5 psi	6 psi
2"	2"	66	93	166		166	235	288	332	371	407
2"	2.5"	57	95	141		141	199	244	282	315	345
2"	3"	52	85	121		121	171	210	242	271	296
2.5"	2.5"	99	138	247		247	349	428	494	552	605
2.5"	3"	98	124	222		222	314	385	444	496	544
2.5"	4"	93	98	175		175	247	303	350	391	429
3"	3"	136	190	340		340	481	589	680	760	833
3"	4"	124	158	282		282	399	488	564	631	691
3"	5"	127	135	241		241	341	417	482	539	590
4"	4"	264	370	660		660	933	1143	1320	1476	1617
4"	5"	247	315	561		561	793	972	1122	1254	1374
4"	6"	255	270	482		482	682	835	964	1078	1181
5"	5"	432	605	1080		1080	1527	1871	2160	2415	2645
5"	6"	418	532	950		950	1344	1645	1900	2124	2327
5"	8"	388	411	734		734	1038	1271	1468	1641	1798
6"	6"	645	903	1613		1613	2281	2794	3226	3607	3951
6"	8"	553	704	1258		1258	1779	2179	2516	2813	3081
6"	10"	553	587	1048		1048	1482	1815	2096	2343	2567

Not rated for steam.
Note: Values for C_V in pipes larger than valve in table above are calculated for average reducers.

II. Two-way valve modulating control of coil water flow

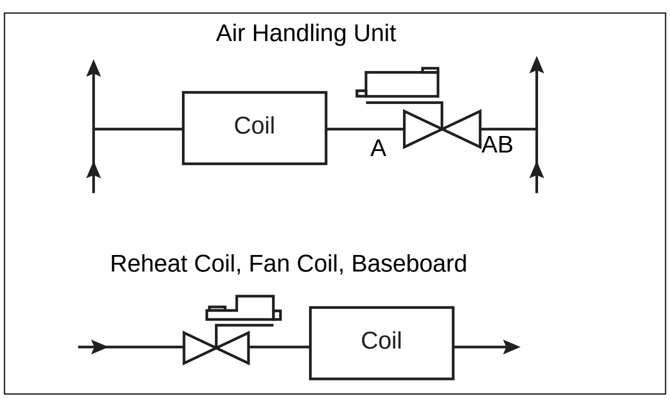

Figure 2a - Two-Way Valves in Modulating Applications

Figure 2a shows the primary applications which use 2-way valves in modulating applications. These applications are the most common in commercial HVAC control. The valves should be equal percentage.

The use of tables is an accurate and fast method for sizing. The Belimo characterized control ball valve is similar to the globe in C_V. Unlike the standard ball valve it also has a true equal percentage modulating response curve similar to the globe. It will not normally require multiple reducers to adjust the C_V for pipe variations. *Tables A to C* give C_V and Cvc for Control Ball, Globe, and Butterfly valves.

In *Figure 2b* example pressure losses are shown for the pipe elements. The valve is 50% of the circuit's loss. This gives it a 50% authority which produces an adequate response curve. In 2 way valve applications, the authority should be as high as possible. Better than 50% as shown here would be 75% if possible. See Belimo's Control Valve Application Guide for a full description.

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Two way valves should be sized for Cv based on the supply to return differential, not the coil loss. Equal percent valves are necessary. As much pressure loss as possible should be taken across the valve to achieve the deep equal percentage curve.

Since differentials are typically unknown, the 5 psi rule of thumb has evolved. Size the valve for 4 to 9 psi drop at design flow.

Cooling coils are more sensitive to undersizing than heating coils. Size appropriately.

Figure 2c shows a system with 2 valves. If the valves were sized for 5 psi drop, then V1 would be OK. It has pressure losses similar to those given in *2b*. However, valve V2 would be grossly oversized at a 5 psi drop. The balancing valve would be set to take a high loss. This would give the valve a low authority and it would resemble a quick opening valve. Control would hunt and accuracy would be hard to maintain. **As the valve closed it would take higher and higher pressure losses. This would lead to increased flow well beyond that which the inherent curve indicates. It has a low authority, over the linear curve.**

Typically the control engineer does not have full pressure and loss data. In this case the valve is sized using rules of thumb which ignore the fuller hydraulic analysis recommended.

When the coil drop is unknown, it is assumed to be about 4 psi. Actual drops range from 1 psi to 10 psi according to coil manufacturer tables.

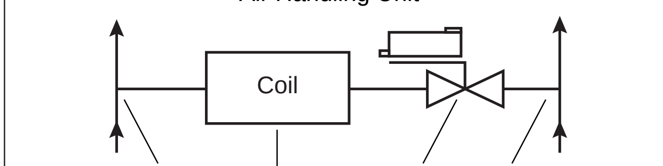

Figure 2b - Pressure loss for modulating control

Three methods are commonly used to size valves in modulating applications:

1. One quick method is to size the valve for 3 to 5 psi or **nominally 4 psi** pressure drop when full open.

   $\mathbf{C_V = GPM / 2}$ or $\mathbf{GPM = 2\,C_V}$ (since $\sqrt{4} = 2$)

   This formula is very easy to use and is as accurate as any other method. Size the valve for a C_V = 1/2 the GPM it must pass in modulating applications. When the valves fall between C_V required, size for the smaller valve in heating applications. Note that a 9 psi drop gives GPM = 3 C_V which would be an upper limit for heating pressure drops. When the valves fall between C_V required for cooling valves, select for the larger.

2. Another method is to size the valve to be **from 1/2 to 3/4 the supply to return** drop. This will give good control. However the pressure drop is often unknown.

3. A similar method is to size the valve to be **no less pressure loss than the coil.** Again it is rare that the pressure drop is known. The consultant has the data but it is not put on drawings. Low bid adherence may lead to a different coil than specified being used.

These rule of thumb methods are not as accurate as full hydraulic analysis as shown in Fig. 2c.

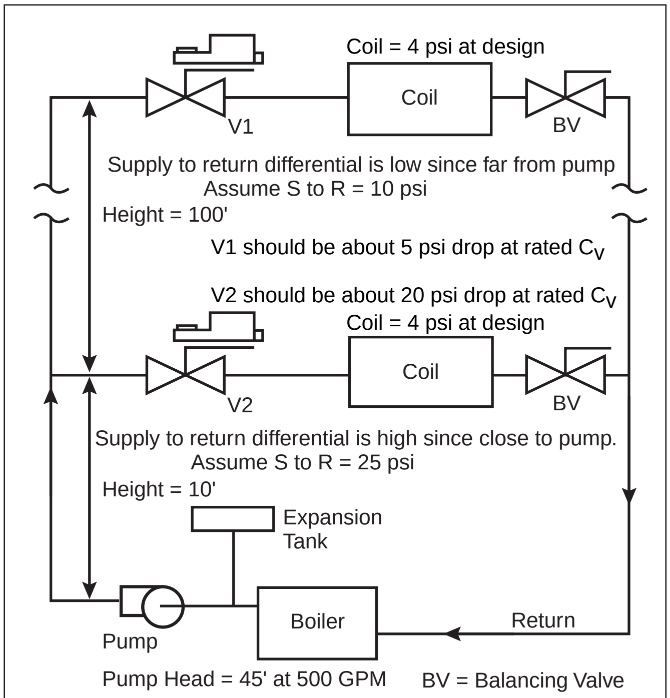

Fig. 2c - Authority

Example 2.
Given a heating coil with a 60 GPM modulating requirement and pipe size of 2" with no other information.
Assume ΔP = 4 psi and required C_V = GPM / 2. Required C_V = 60 / 2 = 30.
Go to *Table A* and select valve: the C_V = 31 of the 2" characterized valve is correct, as is C_V = 29 of the 1-1/2" valve. Alternately the valve may be selected by going to the 4 psi pressure drop column and reading down comparing pipe sizes to the C_V. One arrives at the same valve.

Butterfly valves must be frequently limited in amount of rotation. It is common practice to consider the modulating range of a butterfly to be between 15° and 70°. A smaller valve is used for fine control below useful range of the butterfly.

III. Two-way valve modulating control of system pressure

Figure 3 is another example of a 2-way valve application, but rather than controlling flow to gain temperature control, the flow is controlled to keep the system pressures from rising.

This application can be designed using a number of different methods. One is to decide on a limit in pressure differential between the supply and return and use this as the setpoint of a controller. The pump curve must be examined by the design engineer to find what setpoint to use. When it reaches the

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setpoint, the bypass valve starts to open. It passes water through to keep the pump at a pressure limit. At maximum, the valve will have the same supply to return pressure difference, but the flow will have increased to a maximum.

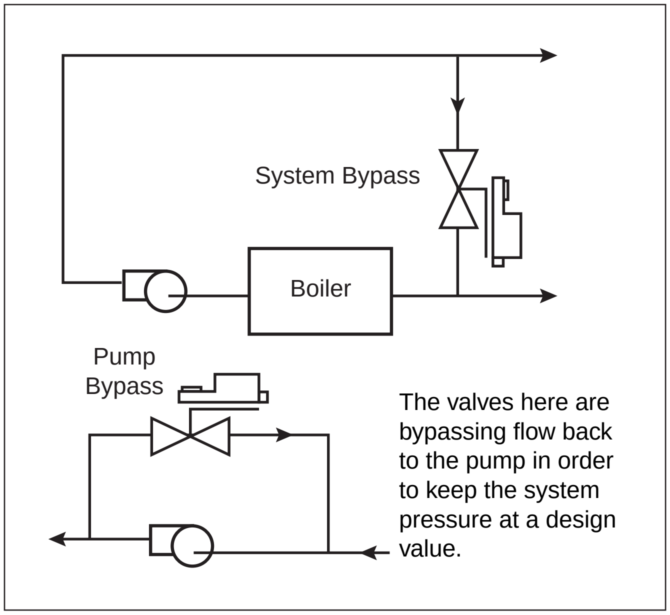

Fig. 3 - Two way modulating valves controlling pressure

Example 3.
System bypass line is 2". Given that the differential will be 9 psi and the valve must pass 100 GPM.

$$C_V = GPM / \sqrt{\Delta P}$$
$$Cv = 100 / \sqrt{9} = 33$$

From *Table A*, a 2" valve with a C_V of 46 will be correct.

Note that this application uses different pressures and capacities than temperature control applications. A pump bypass is similar.

Example 4.
System bypass line is 4". Given that the differential will be 16 psi and the valve must pass 400 GPM. A butterfly valve is specified.

$$C_V = GPM / \sqrt{\Delta P}$$
$$C_V = 400 / \sqrt{16} = 400 / 4 = 100$$

Look at *Table C* for a butterfly valve. The 2.5" in the 4" line has a C_V of 98 when 70° open and C_V of 93 when 60° open. Thus is will be open about 75° at the maximum — a good amount for modulation.

See Belimo's Valve Applications Guide Doc V4.2 for discussion.

IV. Three-way valve modulating control of flow

When controlling flow the valve is sized to take a high pressure drop. Normally the higher of 3 to 5 psi or the coil pressure drop is the goal. **Thus 4 psi drop is the nominal goal.**

Figures 4 shows the common 3-way valve application which controls flow.

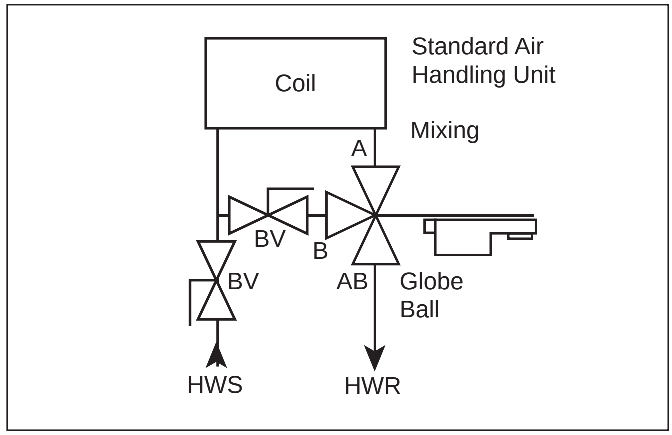

Fig. 4 - Three way valves in high pressure drop applications

The formula used for sizing is
GPM = $C_V \sqrt{\Delta P}$, the same as for 2-way valves.

Since ΔP = about 4, $\sqrt{\Delta P} = 2$ and the required C_V = GPM/ 2.

This valve is normally sized to be the same pressure loss as the coil. These valves should have equal percentage characteristics.

Sizing methods are similar to those for two way valves. The A port, control, should be equal percent. The B port, bypass, is best linear to maintain constant flow in the primary system, but can be equal percentage. The valve should take a high percentage of the supply to return pressure difference. No less than the coil or 4 to 9 psi is used as the rule of thumb when the actual pressures are unknown.

V. Three-way valve modulating control of temperature with constant flow

Coil pump
Figure 5a shows the common 3-way valve application with a coil pump. This application controls temperature, not flow, as the other control methods do. **Sizing techniques are different in this application.**

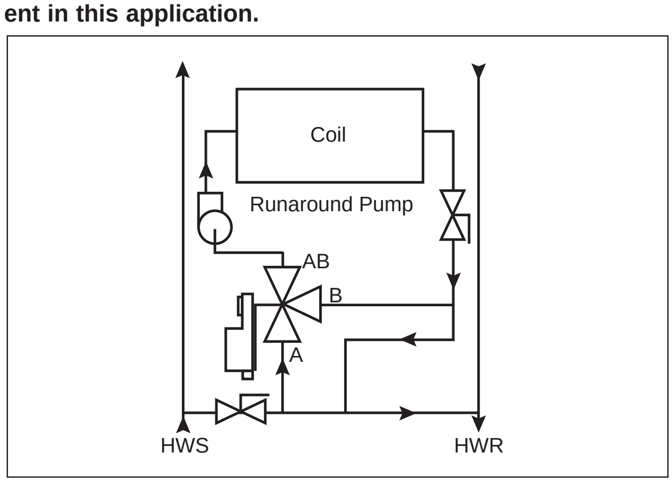

Fig. 5a - Three-way valve in constant flow application

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In the previous application the valve is controlling temperature, not flow. The flow is constant but the temperature is varied by mixing return with supply water.

It is not sized for a high pressure drop. It can be sized line size or about the same pressure drop as the coil at the maximum. Equal percent recommended.

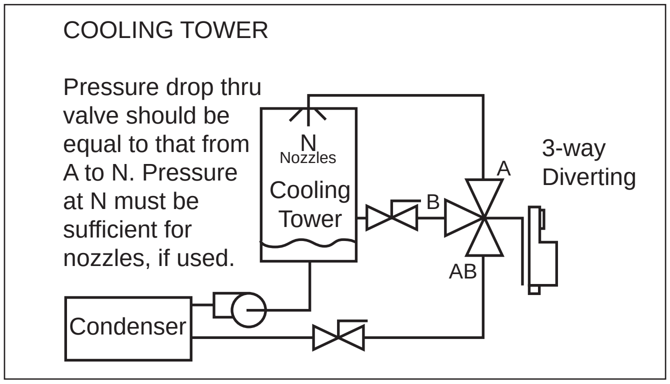

Fig. 5b - Three-way valves in low pressure drop application — Control of Temperature

Cooling tower
In *Figure 5b*, a 3-way diverting valve is installed for a cooling tower bypass.

This valve may not be sized without a known required pressure drop. Failure to verify the allowable drop will lead to problems.

Sizing and selection are performed in the same way as other modulating valves, but the pressure drop is based on the requirement of the system. There must be enough pressure on the valve outlet port, A, to the spray nozzles to push the water through. The pressure at the B port is typically too high, and overflow would occur without a balancing valve.

Perimeter Loop Reset
See *Figure 5c.* This valve is normally line size. It controls the mixture of water to set the perimeter temperature. It does not need to take a high pressure loss. A balancing valve may be installed in the bypass port to return pipe to equal the boiler pressure drop. The valve is normally line size; linear characteristic is recommended.

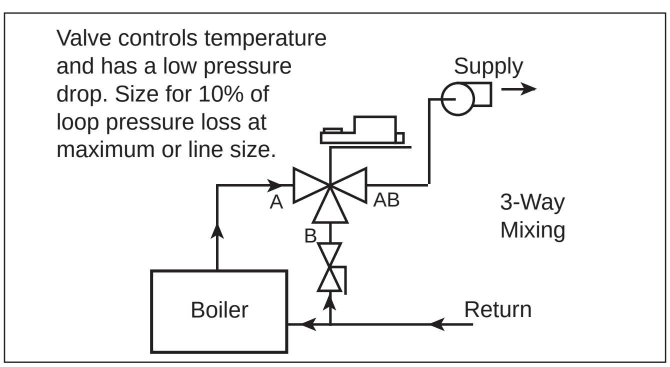

Fig. 5c — Perimeter Loop Reset

VI. Other considerations

Glycol does not have a strong effect on the valve sizing because g, the specific gravity, is relatively small. Rarely will a valve need to be increased in size due to change in specific gravity. However, the heat capacity of the mixture is lower than water and does affect the GPM requirement. The design engineer will include this in his coil and GPM requirements and specify the mixture required.

Table D

Ethylene Glycol		Specific Gravity	Freezing Point	
% by weight	% by volume		°F	°C
10	9	1.01	26	-3
20	18	1.03	17	-8
30	27	1.04	8	-15
40	37	1.06	-14	-25

Propylene Glycol		Specific Gravity	Freezing Point	
% by weight	% by volume		°F	°C
7	10	1.01	28	-2
17	20	1.02	9	-13
26	30	1.02	9	-13
37	40	1.04	-5	-21
46	50	1.04	-18	-28

Cavitation
Cavitation does not occur with steam valves. It can be predicted for water valves by solving this equation:

Maximum allowable $\Delta P = F_L^2 (P1 - VP)$

F_L is the liquid pressure recovery factor.
P1 is the inlet pressure psia.
VP is the vapor pressure in psia at inlet temperature.

Table E

F_L	Type Valve	Amount Open
1	Globes	All positions
1	Control Ball	All positions
.65	Butterflies	70° open
.5	Butterflies	90° open
.5	Standard Ball	90° open

Table F

VP = Vapor pressure of water	
°F	psia
40	.12
50	.18
100	.95
150	3.7
175	6.7
190	9.3
200	11.5
212	14.7

See **Belimo's Valves Control Applications Guide Doc V4.2** for more detail on this subject.

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Determining the required valve pressure ratings
Valves have a number of pressure conditions which must be considered. They have 2 ratings — body and stem static rating and disc and seat close-off rating. Static rating is the amount of total pressure which the body and stem seal must hold against without leaking. Close off is the differential across the disc against which the valve can hold without leaking.

Steam valves should be selected for the boiler rating. For example, if an 18 psi boiler pressure is maintained, then the valve must hold against 18 psi (and 255°F).
Water valves require a bit more consideration.

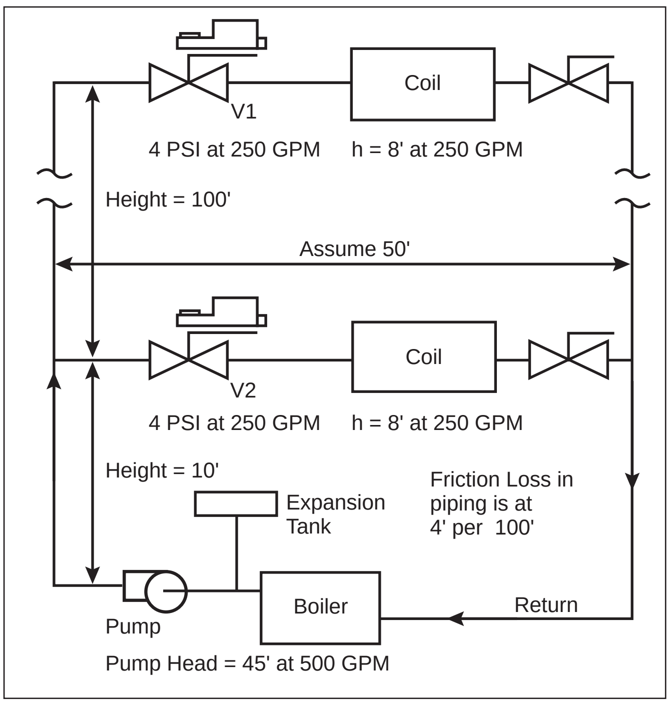

Fig. 6 - Boiler, pump and piping system

In *Figure 6* there are several conditions which must be evaluated to determine the pressure ratings required of the valve.

Static head or pressure
The pressure on the valve when the system is off is the weight of the column of water above it.

V1 has almost no pressure on it. It is on the top floor, and there is no piping above it. V2 has 100' of water pressure on it. We know that there is 2.3' per psi. Thus static pressure is 100/2.3 = 44 psi.

Fill pressure
By applying a fill pressure that is 20 psi higher than the static pressure, a sufficient pressurization is achieved. This gives 44 + 20 = 64 psi for V2 in the example above. V1 would have only the fill pressure of 20 psi.

Pump pressure
When the pump is running, it pushes water against the valve body. There is about 130' of pipe on the way to V1, and the piping loss typical average is 4' per 100' of run. The loss is about 5'.

V1 has the pressure of the pump or 45' less the piping losses of 5' on the way to the valve or 40'. This is 40/2.3 = 17 psi of pump pressure.

V2 has about 25' of pipe between it and the pump for 1' of friction loss. 45 - 1 = 44' of pump head or 44/2.3 = 19 psi of pump pressure.

Total pressure
When the pump is running and the valves are full open, then the head at the valve inlet is the sum of the various heads.

Total pressure = pump pressure + fill pressure + static head pressure

The total for V1 will be 17 psi pump + 20 psi fill gives 37 psi.

The total for V2 will be 44 psi column height + 19 psi pump + fill pressure of 20 psi = 83 psi.

Dead head pressure
Many systems do not have supply to return bypass pressure control. Both valves could be near closed and take full pump pressure.

When V1 and V2 are both closed, the whole pump pressure appears at the inlet of V1 and V2. In this system there is no pressure control, and it would be possible for the pump to dead head. The operating point moves up the curve to a high pressure at no or very low flow.

The pump curve becomes important in this case. Assume the valves would have to withstand pump pressure of possibly double the normal operating pressure or 40 psi. The pump curve must be examined. The design engineer has the data necessary to specify this pressure.

The fill pressure and any column heights must be added to the pump pressure. Both valves could have 40 psi pump pressure + 20 psi fill pressure. V2 would have the column height also. The body and stem seals must be able to hold against this pressure.

If 3-way valves were used, or if there were enough valves and a load situation to provide diversity, the pump pressure would never rise to this point because it would be relieved by the bypass or other valves. See *Figure 4.* The valve must hold against the difference between port A and port B, which is quite small. The full pump pressure is relieved through the valve to the AB port.

Close-off pressure
Close off is the maximum differential which will appear across the valve disc and seat. It is necessary to choose the worst condition from those discussed above.

The **system off** condition has no differential across the valve. The weight of the water on each size balances; the fill pressure appears on both sides.

In **normal operation** with both valves full open, the pressures do not include the height of the columns of water; the supply and return cancel out. The fill pressure is seen on both sides

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of the valve also. The only pressure is the pump differential head less the friction loss on the way to the valve. Both valves have a given 4 psi drop when full open.

If one valve were closed and the other open, the pump pressure would rise as flow volume went down. (This affects the flow quantity of the partially open valve.) The pressure rise can only be found by examination of the pump curve.

If pressure control exists, then the pressure may not increase or will increase to a specified level. That level is the differential or close off pressure in this case. As **both valves close** against full pump pressure, the worst close off condition exists. As assumed above, this could be near 40 psi pump pressure.

This is the differential or close off pressure in this case.

Typically the ANSI 125 class is sufficient since the typical pressures met in HVAC systems are in the order of 30 psi. Tall buildings have the same close off as low rises, but the static pressures could be high.

VII. Steam Systems and 2-Position Control

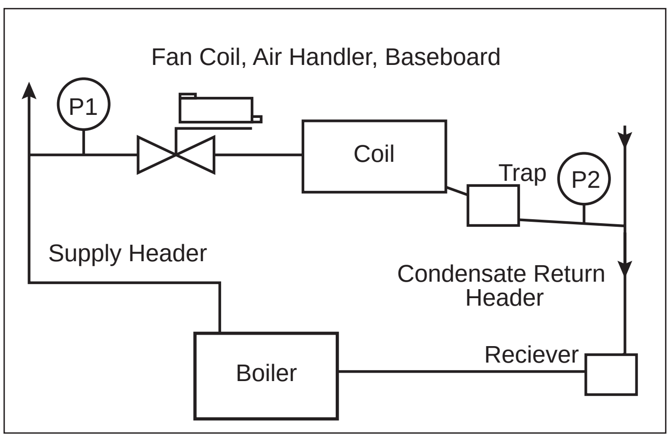

Fig. 7 - Steam valve applications

Figure 7 shows the typical steam system used in commercial applications.

For 2-position control, the steam valve is sized for as low a pressure drop as possible. A line-sized valve is used in most cases. A maximum of 10% of P1 is also a valid method for both high and low pressure systems.

P1 = Inlet Pressure.
This is assumed to be equal to the boiler pressure.
P2 = Outlet Pressure.
This is the return header pressure after the trap. It is assumed to be at atmospheric or zero gauge pressure.

There are some systems with vacuum in the return which require slightly different calculations.
P1 – P2 is the differential pressure across the valve, coil, and trap.
"h" = P1 – P2

It is the valve pressure drop and is used to size the valve.

Low pressure systems, less than 15 psi, are sized using gauge pressure or psig – pounds per square inch gauge. High pressure systems are sized using absolute pressure or psia -- sometimes called atmospheric pressure. Inside the pipes the gauge pressure is less than it would be if exposed to atmosphere. Absolute pressure adds the pressure of the atmosphere to the gauge pressure.

psia = psig + 14.7 psi.

High pressure systems require valves with stainless steel trim. Low pressure valves should use stainless steel trim. Erosion of the seat and disc due to high velocity steam when the valve is near closed is always a possibility.

It is important to distinguish between low and high pressure applications in order to size correctly.
This formula is used to size valves:

$$C_v = (W * \sqrt{V}) / (63.3 * \sqrt{h})*Y$$

W = #/hr
Sometimes written as Q
V = specific volume using psig
h = pressure drop. This is P1, inlet pressure - P2, outlet pressure.
Y = expansion factor. It is typically .75 for steam valves.

Superheat
For correction with superheated steam, increase the required C_v by (1 + superheat x .0007) for each degree F of superheat. That is

New C_v required = C_v calculated x (1 + .0007 x °F superheat)

Table G

	Specific Volume	
psig	**psia**	**V^.5**
0	14.7	5.2
10	25	4
20	35	3.4
30	45	3.1
40	55	2.8
50	65	2.6
60	75	2.4
70	85	2.3
80	95	2.1
100	115	2
120	135	1.8
140	155	1.7
160	175	1.6
200	215	1.5
300	315	1.2
400	415	1.1

VIII. Modulating control of low and high pressure steam

LOW PRESSURE < 15 psi
For modulation 80% of the difference between the inlet and outlet pressures is used as the valve pressure drop. Assuming atmospheric pressure at the outlet, this means 80% of the inlet pressure can be used as the drop. (Some vacuum

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systems may use more than this drop.) Use

h = 80% (P1 - P2)

to size the valve.

HIGH PRESSURE > 15 psi

The maximum flow through a valve occurs when the drop is about 42% of the absolute inlet pressure. After this there is no increase in flow. psia = psig +14.7 or pounds per square inch absolute = pounds per square inch gauge + 14.7 psi which is the weight of the atmosphere. Use

h = .42 psia

to size valves. Note that the outlet pressure is not used in the calculation.

After deciding what pressure drop, h, to use, it is then necessary to find the correct C_V by using a Table. Use of the formula is possible, but difficult.

In all the aforementioned situations, if using ball or butterfly valves, after finding C_V the C_{VC} must be found for the final selection. Belimo Characterized Control Ball Valves may not be used for steam.

Example 1

10 psig boiler pressure. 2-position valve. 400 #/hr of steam needed. Using *Table B*, go to the 10 psi column and 10% of P1 column. Go down the table and find the 400# capacity at C_V = 28.
Any valve with C_V equal to or greater than 28 will work.

The valve selected is usually the same in both cases since the sizes increase in discrete steps. Typically, use line size.

Example 2

5 psig supply. 500 # of steam per hour required for a modulating valve.
Use h = 80% (P1 - P2) = .8 x (5 - 0) = 4
Go to *Table B*. Using 5 psig inlet and the 80% column, go down and find C_V = 28 provides 620# /hr. Select a valve as close as possible.

Example 3

What C_V is required for 30 psig, 4000#/hr, modulating valve? It is unnecessary to use h = .42 psia = .42 (30 + 14.7) = 18.8 psia drop through the valve. *Table B* has already taken this into account. Go to 30 psig and the .42 column. Read down 30 psig 42% column to find 4275# /hr at a C_V = 65.

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