Selecting Valves For Variable Flow Hydronic Systems

By Gil Avery, P.E., Fellow/Life Member ASHRAE

Valves, such as common globe, butterfly, and ball valves, that performed satisfactorily for constant flow or variable flow primary-secondary systems generally are not satisfactory for primary-only variable flow systems because of the great variations in differential pressures across modulating control valves in direct return hydronic systems.

The valve requirements for primary-only systems are more severe than those for primary-secondary systems because the pump head on primary-only systems often is 20% to 100% greater than the pump head of the secondary pump of a primary-secondary system. For example, in *Figure 1* the coil valves must be able to operate properly under all conditions and with a pump head 40 ft (120 kPa) greater than the head required for a secondary pump on a primary-secondary system.

This article reviews the limitations of commonly used control valves for these systems and specifies the requirements necessary for valves to meet the high differential pressures prevalent in primary-only systems.

Two-way modulating valves have four operational ratings that should be considered when selecting the valve for these systems.

- **Close-off:** determined by the power of the actuator and the valve construction.
- **Static:** determined by the strength of the valve body and generally available with ANSI 150 or 300 ratings.
- **Rangeability:** At least 200 to 1. (The ratio of the maximum flow with the valve wide open to the minimum controllable flow.)
- **Dynamic:** the maximum differential the valve's wetted parts will withstand. This rating has not been defined by our industry. Manufacturers sometimes refer to it as the modulating rating. Dynamic rating is more descriptive and will be used in this article. A valve with a close-off rating of 100 psid (690 kPa) and a dynamic (modulating) rating of 25 psid (172 kPa) should not be used on systems where the valve differential pressure is ever greater than 25 psid (172 kPa) even though it will close off against 100 psid (690 kPa). Differential pressures greater than 25 psi (172 kPa)

About the Author
Gil Avery, P.E., is director of systems research with The Kele Companies in Memphis, Tenn.

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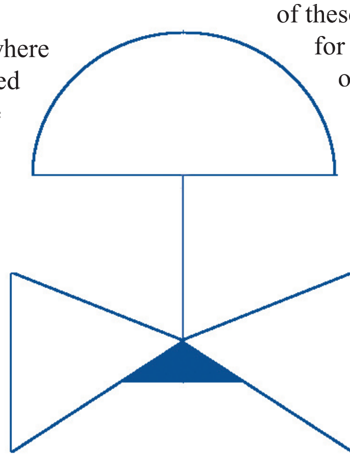
may damage the valve’s wetted parts (erode or wire draw the plug or seat).

Valves with Flow Coefficients (Cv’s) Greater Than 2

These valves are generally used on air handlers to maintain the design leaving air temperature, to isolate the chillers, to maintain the minimum flow through the on-line chiller(s), and to regulate the chilled water flow and pressure to remote buildings and zones, etc.

A typical application is shown in *Figure 1* where the valves on Air Handlers A–F are controlled by a leaving air temperature sensor. When the valves on Air Handler Coils B–F are closed, the differential pressure across the branch serving coil A is only 30 ft (90 kPa), and the valve differential pressure is only 15 ft (45 kPa). Under these operating conditions, there is no flow in the mains serving Coils B–F, and the pressure drop across Branch A is the same as the setting of the differential pressure sensor (DP). Therefore, all branches must be sized for this drop (30 ft [90 kPa]) since this is the minimum drop that can occur across any branch. Setting the differential pressure sensor any higher or locating it closer to Coil A will waste pump energy for the life of the system.



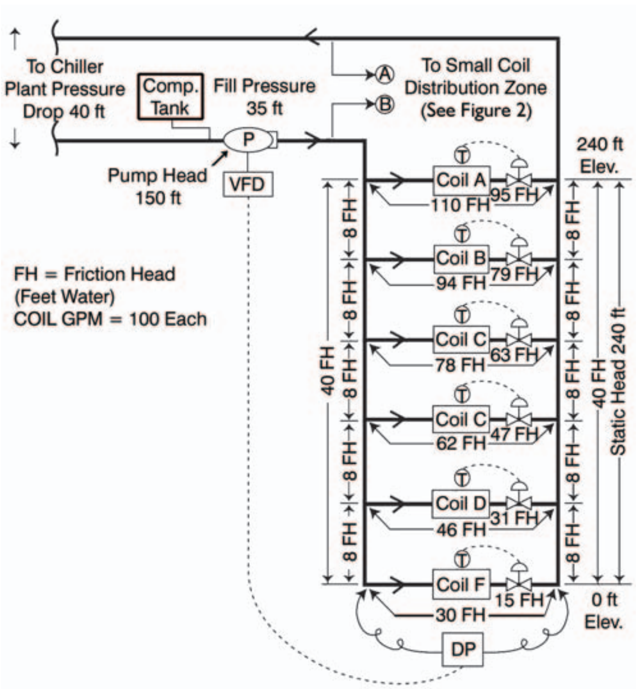
The DP is used to control the speed of pump (P) so that as the valves close off the pump speed is reduced. The control valves on coils A–F are all sized to handle 100 gpm at 15 ft (6.3 L/s at 45 kPa) (half the branch design differential of 30 feet [90 kPa]). Under full load operation the valve on Coil A must be able to modulate with a differential pressure of 95 ft (285 kPa), even though it was selected for only 15 ft (45 kPa).

Commonly used commercial valves have a rangeability of about 20 to 1. The Cv of the branch is 27.8 (100 gpm [6.3 L/s] divided by the square root of the pressure drop of the branch [30/2.31]$^{1/2}$). With 95 ft (285 kPa) of head across Valve A, the maximum flow is 191 gpm (12 L/s). The minimum controllable flow of a valve with a rangeability of 20 to 1 is 9.6 gpm (0.6 L/s). This flow is probably too high to maintain good control. Many systems, especially those serving multiple buildings, may have valve maximum to minimum operating differentials (pressure rise ratios) much higher than the 6.3 to 1 (95 divided by 15) shown in *Figure 1*, often exceeding 10 to 1. Because of these wide variations in differential pressure, valves for variable flow systems must have a rangeability of at least 200 to 1.

With this rangeability, Valve A can control down to 0.96 gpm (0.06 L/s) (191 divided by 200). High rangeability valves also save pump energy because the valves can be selected for lower pressure drops. Selecting the valves for a drop of 7.5 FH, rather than 15 FH as in *Figure 1*, raises the minimum controllable flow to only 1.1 gpm (0.07 L/s) but reduces the pump energy by about 5%. The pump can be selected for 142.5 ft (427.5 kPa) rather than 150 ft (450 kPa). *Table 1* charts the minimum controllable flow for a 100 gpm (6.3 L/s) coil as the pressure rise ratio varies from 1 to 20 and the valve rangeability varies from 10 to 300.

Under emergency or test conditions when the pump is operated on the backup across-the-line starter or if the DP malfunctions, the differential pressure across any valve may approach the cutoff head of the pump. Therefore, all valves should be selected to close off against the cutoff head of the pump if the head is known or 1.5 times the pump design head if the cutoff head is not known. In this example the cutoff head is not known so the valves should be selected for 225 ft (675 kPa) (1.5 × 150) differential.

In an attempt to improve the valve operation on systems with wide ranging differentials and to limit the overdraw on system



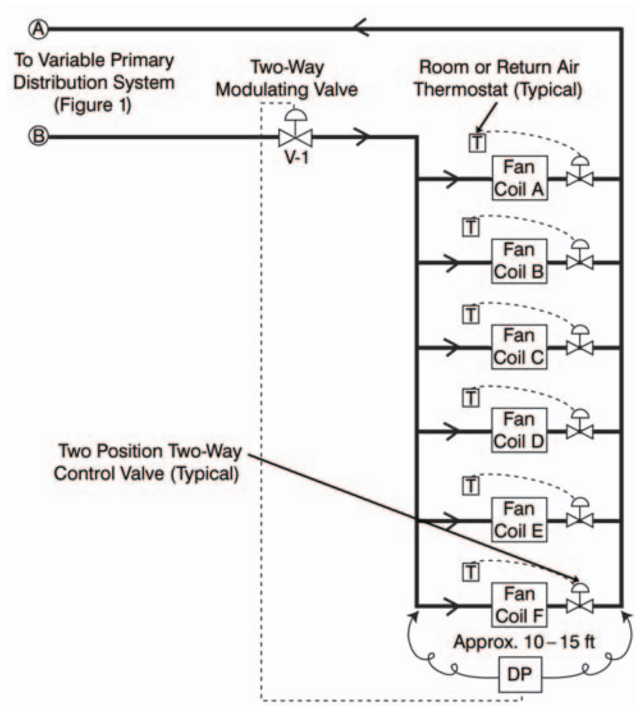


Figure 1 (left): Chilled water variable primary distribution system for a multistory building. Figure 2 (right): Chilled water variable primary distribution system for a typical small coil zone.

start up, valves are available with various devices, including flow limiting regulators, pressure independent actuators, and automatic and manual balancing valves. Each of these devices adds pump head to the system and increases the operating and maintenance costs for the life of the system.

Overdraw is rarely a problem on hydronic systems. The maximum flow on start up, when the valves on Coils A through F in *Figure 1* are fully open, is about 690 gpm (44 L/s); or an overflow of about 90 gpm (5.7 L/s). Any increase in chilled water flow will just decrease the cool-down time.

When overdraw to a coil does occur, the supply air temperature will drop and the temperature sensor will start to close the valve to minimize the overdraw. Most systems that do not operate continuously are started in the morning when the cooling load is less than design. The internal load (lights, people, equipment, etc.) and transmission load are all below design and overdraw is improbable. On some systems, no outside air load exists until the building is occupied.

Valves once considered industrial and deemed too costly for HVAC systems are now available for about the same price per Cv as common globe valves. The valve chart in *Table 2* lists the features and relative prices for six types. The rotary-segmented plug valve and double-seated globe valve have characteristics that negate the need for any flow control accessory. The plug valve also is priced lower than globe or ball valves furnished with flow control devices.

Industrial engineers generally select control valves with the proper characteristics to match valve performance with system operation. Valves with flow accessories are not normally considered. The HVAC industry should follow this approach since many of the valve standards and tests have come from the industrial market.

Pressure Rise Ratio*					
1	2	5	10	20	
Minimum Controllable Flow (gpm)					Valve Rangeability
10	14.1	22.4	31.6	44.7	10
5	7.1	11.2	15.8	22.4	20
2.5	3.5	5.6	7.9	11.2	40
1	1.4	2.2	3.2	4.5	100
0.5	0.71	1.1	1.58	2.24	200
0.3	0.47	0.75	1.05	1.49	300

* The ratio of the maximum to minimum pressure drop across the control valve when handling required flow under varying dynamic conditions.

Table 1: Minimum controllable flow—100 gpm coil.

Modulating valves for variable flow systems should:

- Be selected to operate and close tight at a valve differential pressure as great as the pump cutoff head or 1.5 times the pump design head.
- Have a body rating to withstand the static system head plus the pump cutoff head plus the fill pressure. In *Figure 1*, the body pressure may be as high as 500 ft (216 psi [1500 kPa]).
- Have a rangeability of at least 200 to 1 when tested per ANSI/ISA-75.11.01-2002 standard.
- Meet ANSI 150 or 300 standard body ratings that conform to the ASME B16.34-1996 standard.
- Meet ANSI Class VI leakage rating.
- Have actuators with enough power to close the valve tight

Valve Type (Construction)	Pipe Size, Connection	Cv	Typ. Max DP (psid)	Typ. Max Temp. (°F)	$/Cv	Typical Rangeability
Rotary Segmented Plug Valve (Stainless Trim, Graphite Seat, Teflon™ Gaskets)	1 in. NPT	24	200	400	$$	300:1
	1.5 in. NPT	55	200	400	$$	
	2 in. NPT	77	200	400	$$	
	3 in. Flanged	207	200	400	$$	
	4 in. Flanged	350	200	400	$$	
	6 in. Flanged	507	200	400	$$	
Standard Globe Valve (Stainless Trim, Metal Seat, Teflon Gaskets)	1 in. NPT	12	100	340	$$	Approx. 20:1 to 50:1
	1.5 in. NPT	30	100	340	$$	
	2 in. NPT	47	100	340	$$	
	2.5 in. NPT	63	60	340	$$	
	3 in. Flanged	100	45	340	$$	
	4 in. Flanged	160	25	340	$$	
	6 in. Flanged	400	12	340	$$	
HVAC Ball Valves (Chrome Ball)	1 in. NPT	19	50	212	$	?
	1.25 in. NPT	25	50	212	$	
	1.5 in. NPT	37	50	212	$	
	2 in. NPT	46	50	212	$	
Pressure Independent Ball Valves (Chrome Ball)	1 in. NPT	N/A	50	212	$$$	?
	1.25 in. NPT	N/A	50	212	$$$	
	1.5 in. NPT	N/A	50	212	$$$	
	2 in. NPT	N/A	50	212	$$$	
Butterfly Valve (Stainless Disc, EPDM Seat)	2 in. Flanged	44	75	275	$	Approx. 10:1 (Not Recommended For Modulating Service at High DP)
	2.5 in. Flanged	75	75	275	$	
	3 in. Flanged	116	75	275	$	
	4 in. Flanged	230	75	275	$	
	6 in. Flanged	605	75	275	$	
Double Seated Globe Valve (Stainless Trim, Metal Seat, Teflon Gaskets)	2.5 in. Flanged	75	150	300	$$$$	Approx. 50:1 to 200:1
	3 in. Flanged	116	150	300	$$$$	
	4 in. Flanged	178	150	300	$$$$	
	5 in. Flanged	318	150	300	$$$$	
	6 in. Flanged	390	150	300	$$$$	

Table 2: Rangeability and $/Cv comparisons. (More dollar signs equals more expensive.)

and positively position the valve plug at the highest differential pressure.

- Include a pressure recovery chamber to minimize noise.

Valves With Flow Coefficients (Cv's) Less Than 2

Small valves with a flow coefficient (Cv) of less than 2 are generally used on fan-coil units and small zone heating coils. Most are two-position, two-way valves controlled by room temperature sensors. They are used because:

- Modulating valves with flow coefficients less than 2 may have ports that are so small they are susceptible to getting clogged by debris in the hydronic system.
- On recirculating fan coil units with no outdoor air connection, the space humidity will be less when a two-position, rather than a modulating, valve is used on a cooling coil. The modulating valve does less dehumidification in the partially open position.
- Actuators on two-position valves are generally smaller and fit better in the small end compartment of fan coil enclosures.
- The units are often located near or in occupied areas where noise is a consideration. It may be necessary to connect these units to a separate piping circuit, as shown in *Figure 2*, to reduce the noise and differential pressure across the valves. The DP sensor controls the modulating two-way supply valve V-1. On direct return systems the supply and return mains should be liberally sized to minimize the difference in pressure across the branches.
- The branch differential pressures are less. Therefore, the port sizes are larger.
- The comfort achieved by on-off room temperature sensors will be as good or better than from the temperature sensors found in most residences where the sensor controls a two-position heating valve and direct expansion cooling unit.

Summary

Now cost effective valves are available for variable flow systems that don't penalize the owner with higher operating and maintenance costs for the life of their system. All control valves must be tested and rated for the severe service that exists in these systems. Specifying high performance valves with high rangeabilities will reduce the initial system cost by using a lower head pump and eliminating all the branch balancing and/or flow control devices.