

Valve Sizing and Selection

Sizing flow valves is a science with many rules of thumb that few people agree on. In this article I'll try to define a more standard procedure for sizing a valve as well as helping to select the appropriate type of valve.

****Please note that the correlation within this article are for turbulent flow**

STEP #1: Define the system
 The system is pumping water from one tank to another through a piping system with a total pressure drop of 150 psi. The fluid is water at 70 °F. Design (maximum) flowrate of 150 gpm, operating flowrate of 110 gpm, and a minimum flowrate of 25 gpm. The pipe diameter is 3 inches. At 70 °F, water has a specific gravity of 1.0.

Key Variables: Total pressure drop, design flow, operating flow, minimum flow, pipe diameter, specific gravity

STEP #2: Define a maximum allowable pressure drop for the valve
 When defining the allowable pressure drop across the valve, you should first investigate the pump. What is its maximum available head? Remember that the system pressure drop is limited by the pump. Essentially the Net Positive Suction Head Available (NPSHA) minus the Net Positive Suction Head Required (NPSHR) is

the maximum available pressure drop for the valve to use and this must not be exceeded or another pump will be needed. It's important to remember the trade off, larger pressure drops increase the pumping cost (operating) and smaller pressure drops increase the valve cost because a larger valve is required (capital cost). The usual rule of thumb is that a valve should be designed to use 10-15% of the total pressure drop. $C_v = 150 \sqrt{\frac{1}{15}} = 38.7 \approx 39$ whichever is greater.

10% of the total pressure drop is 15 psi which is what we'll use as our allowable pressure drop when the valve is wide open (the pump is our system is easily capable of the additional pressure drop).

STEP #3: Calculate the valve characteristic

$$C_v = Q_1 \sqrt{\frac{G}{\Delta P}}$$

where:

Q_1 = design flowrate (gpm)

G = specific gravity relative to water

ΔP = allowable pressure drop across the valve

For our system,

At this point, some people would be tempted to go to the valve charts or

characteristic curves and select a valve. Don't make this mistake, instead, proceed to Step #4!

STEP #4: Preliminary valve selection
 Don't make the mistake of trying to match a valve with your calculated C_v value. The C_v value should be used as a guide in the valve selection, not a hard and fast rule. Some other considerations are:

- Never use a valve that is less than half the pipe size
- Avoid using the lower 10% and upper 20% of the valve stroke. The valve is much easier to control in the 10-80% stroke range.

Before a valve can be selected, you have to decide what type of valve will be used (See the list of valve types later in this article). For our case, we'll assume we're using an equal percentage, globe valve (equal percentage will be explained later). The valve chart for this type of valve is shown below. This is a typical chart that will be supplied by the manufacturer (as a matter of fact, it was!)

For our case, it appears the 2 inch valve will work well for our C_v value at about 80-85% of the stroke range. Notice that we're not trying to

squeeze our Cv into the 1 1/2 valve which would need to be at 100% stroke to handle our maximum flow. If this valve were used, two consequences would be experienced: the pressure drop would be a little higher than 15 psi at our design (max) flow and the valve would be difficult to control at maximum flow. Also, there would be no room for error with this valve, but the valve we've chosen will allow for flow surges beyond the 150 gpm range with severe headaches!

So we've selected a valve...but are we ready to order? Not yet, there are still some characteristics to consider.

STEP #5: Check the Cv and stroke percentage at the minimum flow

If the stroke percentage falls below 10% at our minimum flow, a smaller valve may have to be used in some cases. Judgements plays role in many cases. For example, is your system more likely to operate closer to the maximum flowrates more often than the minimum flowrates? Or is it more likely to operate near the minimum

flowrate for extended periods of time. It's difficult to find the perfect valve, but you should find one that operates well most of the time. Let's check the valve we've selected for our system:

Referring back to our example, we see that a Cv of 6.5 is required to a stroke percentage of 40% which is certainly acceptable. Notice that we used a pressure drop of 15 psi in our calculation. If we used a lower pressure drop across the valve at smaller flowrates, the maximum value for the "worst case" scenario. If the minimum flow was around 1.5, there would be a problem because the valve has a Cv of 1.66 at 10% stroke and since we use the maximum pressure drop, our estimate is conservative.

Essentially, at lower pressure drops, Cv would only increase which in this case would be advantageous.

STEP #6: Check the gain across applicable flowrates

Gain is defined as:

FLOW CHARACTERISTIC	VALVE SIZE		MAXIMUM TRAVEL	PORT DIA.	DESIGNS E	
					10	30
	DIN	Inches	mm	mm	Cv	
Equal Percentage	DN 25	1, 1-1/4	19	33.3	.783	2.20
	DN 40	1-1/2	19	47.6	1.52	3.87
	DN 50	2	29	58.7	1.66	4.66
	DN 65	2-1/2	38	73.0	3.43	10.8
	DN 80	3	38	87.3	4.32	10.9
	DN 100	4	51	111.1	5.85	18.3
	DN 150	6	51	177.8	12.9	43.3
	DN 200	8	76	203.2	27.0	105
					X	
	DN 25	1, 1-1/4	19	33.3	.766	.587
	DN 40	1-1/2	19	47.6	.780	.716
	DN 50	2	29	58.7	.827	.774
	DN 65	2-1/2	38	73.0	.778	.678
	DN 80	3	38	87.3	.774	.682
	DN 100	4	51	111.1	.731	.643
	DN 150	6	51	177.8	.688	.682
	DN 200	8	76	203.2	.644	.636

Flow (gpm)	Stroke (%)	Change in flow (gpm)	Change in Stroke (%)
25	35	110-25 = 85	73-35 = 38
110	73	110-25 = 85	73-35 = 38
150	85	150-110 = 40	85-73 = 12

Gain #1 = $85/38 = 2.2$

Gain #2 = $40-12 = 3.3$

The difference between these values should be less than 50% of the higher value.

$0.5 (3.3) = 1.65$

and $3.3 - 1.65 = 1.65$. Since 2.2 is closer than 50%, there should be problem with controlling the valve.

Also note that the gain should never be less than 0.50. So for our case, I believe our selected valve will do nicely!

OTHER NOTES:

Another valve characteristic that can be examined is called the choked flow. The relation uses the F_L value found on the valve chart. I

recommend checking the choked flow for vastly different maximum and minimum flowrates. For example if the difference between the maximum and minimum flows is above 90% of the maximum flow, you may want to check the choked flow.

Usually, the rule of thumb for determining the maximum pressure drop across the valve also helps to avoid choking flow.

SELECTING A VALVE TYPE

When speaking of valves, it's easy to get lost in the terminology. Valve types are used to describe the mechanical characteristics and geometry (Ex/ gate, ball, globe valves). We'll use valve control to refer to how the valve travel or stroke

(openness) relates to the flow:

1. Equal Percentage: equal increments of valve travel produce an equal percentage in flow change
2. Linear: valve travel is directly proportional to the valve stroke
3. Quick opening: large increase in flow with a small change in valve stroke

So how do you decide which valve control to use? Here are some rules of thumb for each one:

1. Equal Percentage (most commonly used valve control)
 - a. Used in processes where large changes in pressure drop are expected
 - b. Used in processes where a small percentage of the total pressure drop is permitted by the valve

- c. Used in temperature and pressure control loops.
- 2. Linear
 - a. Used in liquid level or flow loops
 - b. Used in systems where the pressure drop across the valve is expected to remain fairly constant (ie. steady state systems)
- 3. Quick Opening
 - a. Used for frequent on-off service
 - b. Used for processes where “instantly” large flow is needed (ie. safety systems or cooling water systems)

Now that we’ve covered the various types of valve control, we’ll take a look at the most common valve types.

Gate Valves Best Suited Control:

**Q u i c k
Opening**

Recommended
Uses:

- 1. Fully open/closed, non-throttling
- 2. Infrequent operation
- 3. Minimal fluid trapping in line

Applications:
Oil, gas, air,
s l u r r i e s ,

heavy liquids, steam, noncondensing gases, and corrosive liquids

Advantages:

- 1. High capacity
- 2. Tight shutoff
- 3. Low cost
- 4. Little resistance to flow

Disadvantages:

- 1. Poor control
- 2. Cavitate at low pressure drops
- 3. Cannot be used for throttling

Globe Valves Best Suited Control:
Linear and Equal percentage

Recommended Uses:

- 1. Throttling service/flow regulation

- 2. Frequent operation

Applications: Liquids, vapors, gases, corrosive substances, slurries

Advantages:

- 1. Efficient throttling
- 2. Accurate flow control
- 3. Available in multiple ports

Disadvantages:

- 1. High pressure drop
- 2. More expensive than other valves

Ball Valves

Best Suited Control: Quick opening, linear

Recommended Uses:

- 1. Fully open/closed, limited throttling
- 2. Higher temperature fluids

Applications: Most liquids, high temperatures, slurries

Advantages:

- 1. Low cost
- 2. High capacity
- 3. Low leakage and maint.
- 4. Tight sealing with low torque

Disadvantages:

- 1. Poor throttling characteristics
- 2. Prone to cavitation

Butterfly Valves Best Suited Control: Linear, Equal percentage

Recommended Uses:

- 1. Fully open/closed or throttling services
- 2. Frequent operation
- 3. Minimal fluid trapping in line

Applications: Liquids, gases, slurries, liquids with suspended solids

Advantages :

- 1. Low cost and maint.
- 2. High capacity
- 3. Good flow control
- 4. Low pressure drop

Disadvantages:

- 1. High torque required for control

- 2. Prone to cavitation at lower flows

Other Valves

Another type of valve commonly used in conjunction with other valves is called a check valve. Check valves are designed to restrict the flow to one direction. If the flow reverses direction, the check valve closes.

Relief valves are used to regulate the operating pressure of incompressible flow. Safety valves are used to release excess pressure in gases or compressible fluids.

References:

Rosaler, Robert C., Standard Handbook of Plant Engineering, McGraw-Hill, New York, 1995, pages 10-110 through 10-122
Purcell, Michael K., “Easily Select and Size Control Valves”, Chemical Engineering Progress, March 1999, pages 45-50