Bab 6. Basic Valve Equation

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Basic Valve Equation

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$$q(\ell) = C_v^{\max} f(\ell) \sqrt{\frac{\Delta P_v}{g_s}} \qquad 0 \le \ell \le 1$$

- Valve size: determines $C_v^{\max}$
- Valve trim type:
  - Linear: $f(\ell) = \ell$
  - Square-Root (Quick Opening): $f(\ell) = \sqrt{\ell}$
  - Equal Percentage: $f(\ell) = R^{\ell - 1}$
- Table 2.1 shows $\ell(\%)$ vs $C_v^{\max} R^{\ell - 1}$ for EP valves of diff. Body sizes.

Table 2.1 for EP Valve

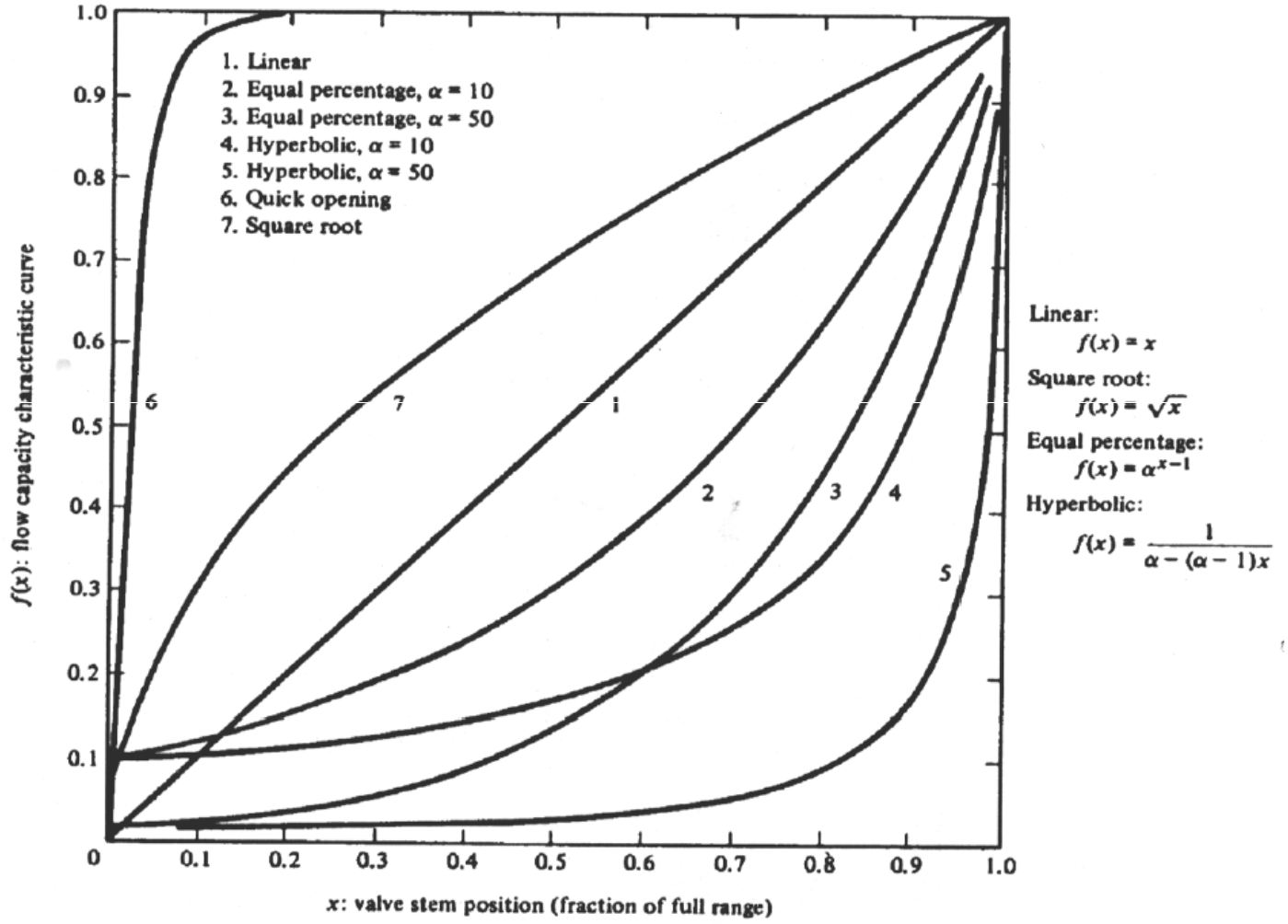
$\ell(\%)$

Table 2.1 Representative C_v's for an Equal Percentage Globe Valve.

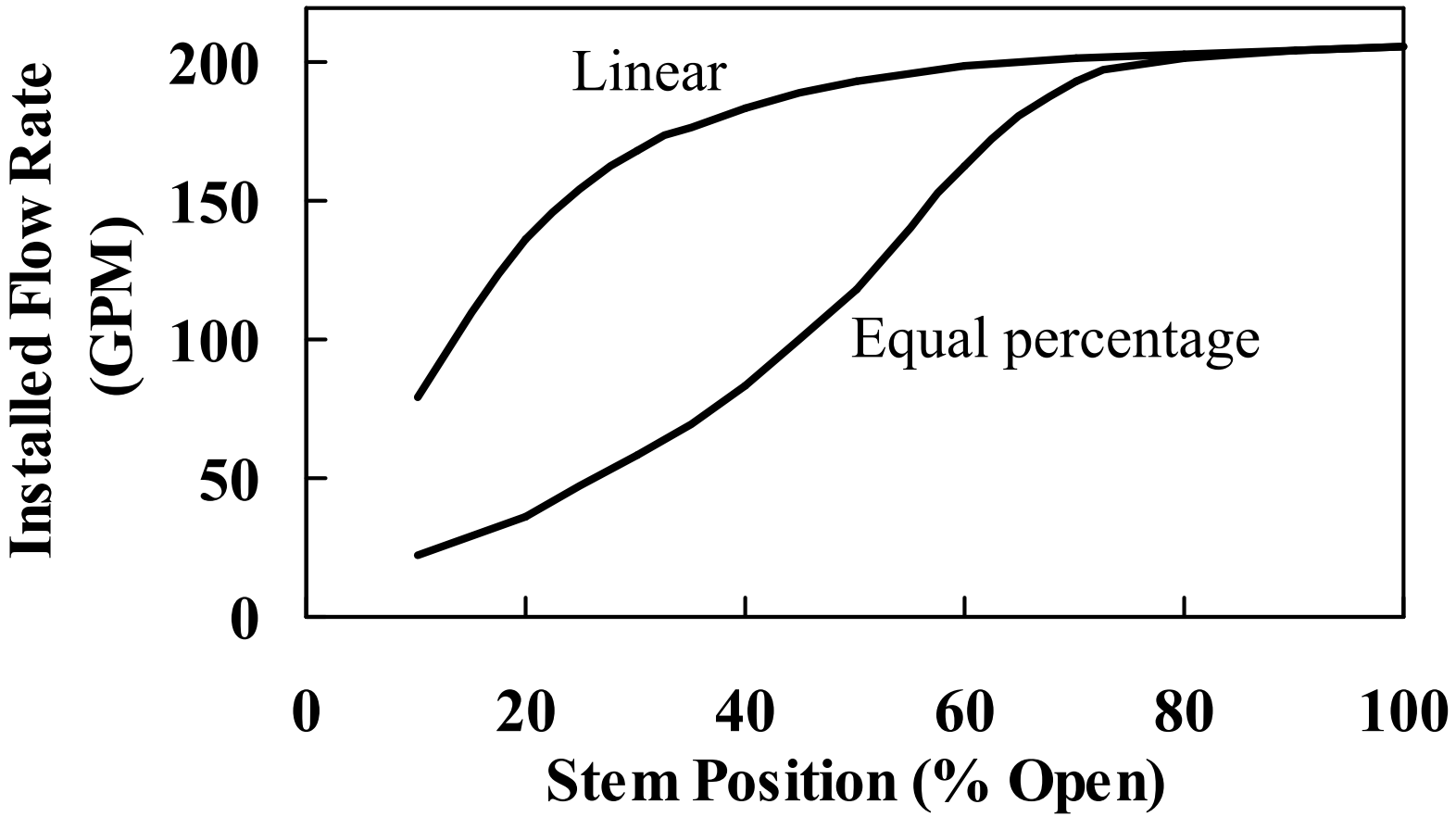
	Body Size (in)	Stem Position as a Percentage of Total Travel									
		10	20	30	40	50	60	70	80	90	100
C_v	1	0.79	1.25	1.80	2.53	3.63	5.28	7.59	10.7	12.7	13.2
	1.5	0.80	1.23	1.91	2.95	4.30	6.46	9.84	16.4	22.2	28.1
	2	1.65	2.61	4.30	6.62	11.1	20.7	32.8	44.7	50.0	53.8
	3	3.11	5.77	9.12	13.7	21.7	36.0	60.4	86.4	104	114
	4	4.90	8.19	13.5	20.1	31.2	52.6	96.7	140	170	190

$C_v^{\max} R^{\ell-1}$

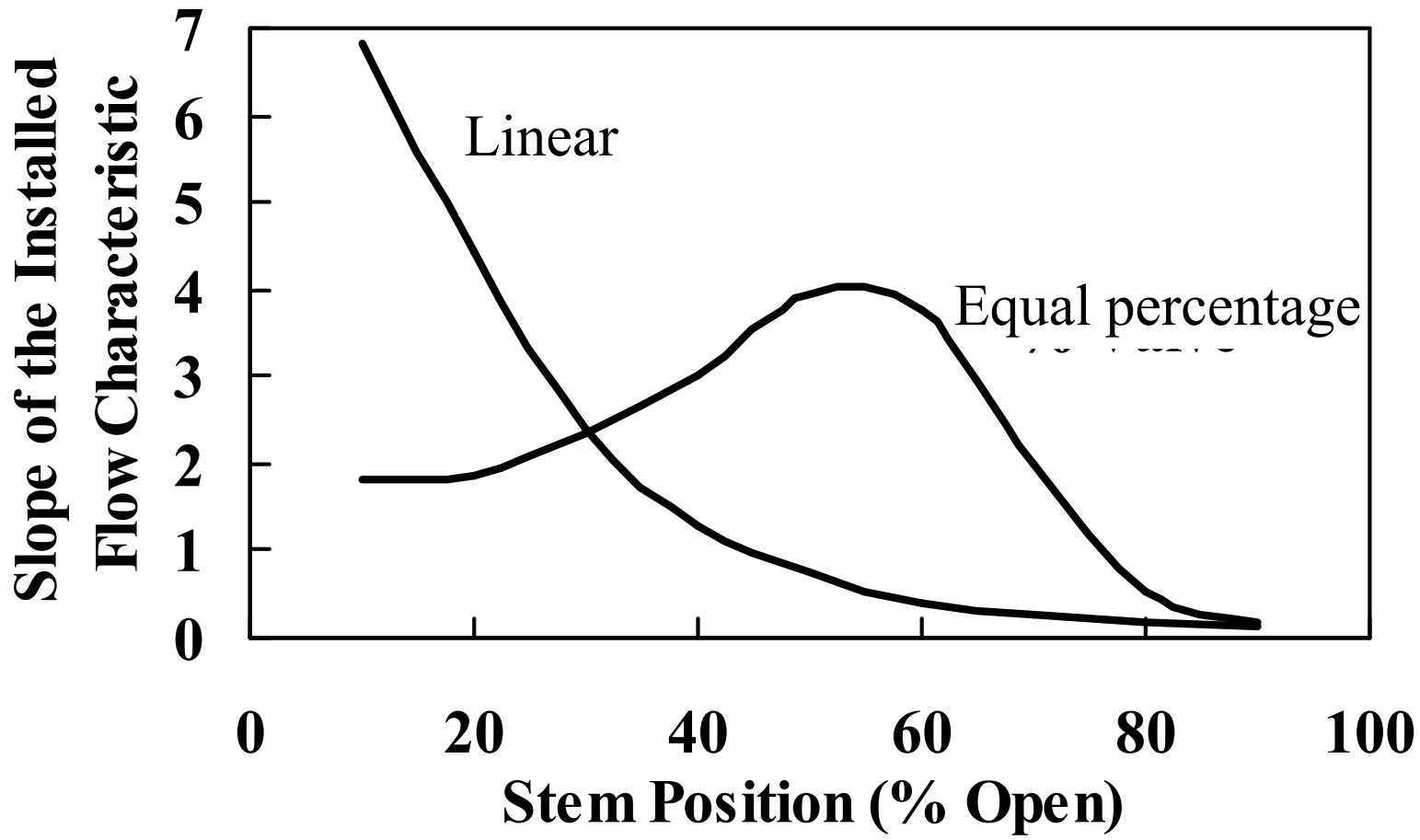
Characteristic Curves for Different Trim Types (Uninstalled –constant ΔP_v)



Installed Flow Characteristic



Slope of Installed Characteristic



Valve Nonlinearity

- Valves behave nonlinearly, even in the most ideal situation (without stiction, hysterisis).
- Once installed, linear trim does **NOT** lead to a linear relationship between ℓ and q.
  - ΔP_v does not stay constant but varies with ℓ
  - Ex) Closing a linear valve from full to half reduces the flow by less than half.
- Valve characteristic curve
  - A curve showing ℓ vs. q
  - Desirable to be linear in the range of operation.
- Questions:
  - How do we size a valve?
  - How do we compute the characteristic curve?

Pressure Drop vs. Flow Rate

Table 2.2 Installed Pressure Drop For a Control Valve versus Flow Rate

Q (GPM)	ΔP (psi)	Q (GPM)	ΔP (psi)
50	19.3	74	18.0
54	19.1	78	17.8
58	18.9	82	17.5
62	18.7	86	17.2
66	18.5	90	16.9
70	18.3	94	16.6

Sizing a Valve

- Determine the flow range needed.
- Total pumping requirement:

$$\Delta P_{total} = \Delta P_v + \Delta P_s$$

$$\Delta P_s = kq^2 \quad \Rightarrow \quad \Delta P_{total} = \left(\frac{q_{\max}}{C_v}\right)^2 g_s + kq_{\max}^2$$

ΔP_v at q_{max}

Minimum pumping required

- Note that pumping requirement and choice of valve size are interrelated and involves a trade-off.
  - The larger the valve, the less the pumping (more economical) but less controllability.
- Rule of thumb:

$$\Delta P_v \approx \frac{1}{3} \text{ or } \frac{1}{4} \text{ of } \Delta P_{total}$$ at nominal flowrate.

Characteristic Curve (Installed)

- Once pump and valve are sized,

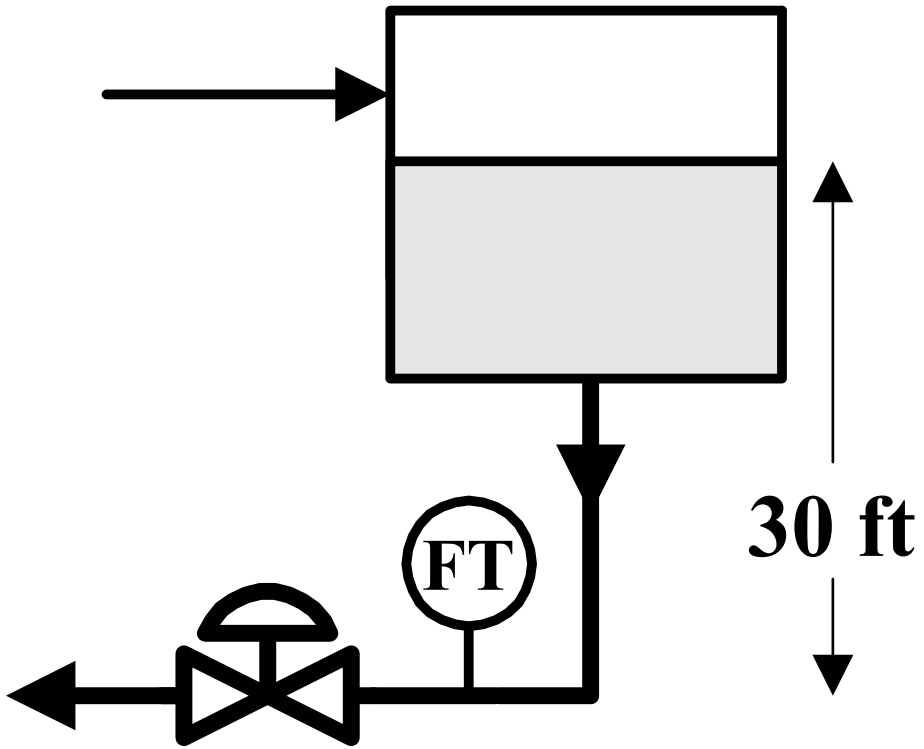
$$\Delta P_v = \Delta P_{total} - \Delta P_s = \left(\frac{q_{\max}}{C_v}\right)^2 g_s + kq_{\max}^2 - kq^2$$

ΔP_{total}

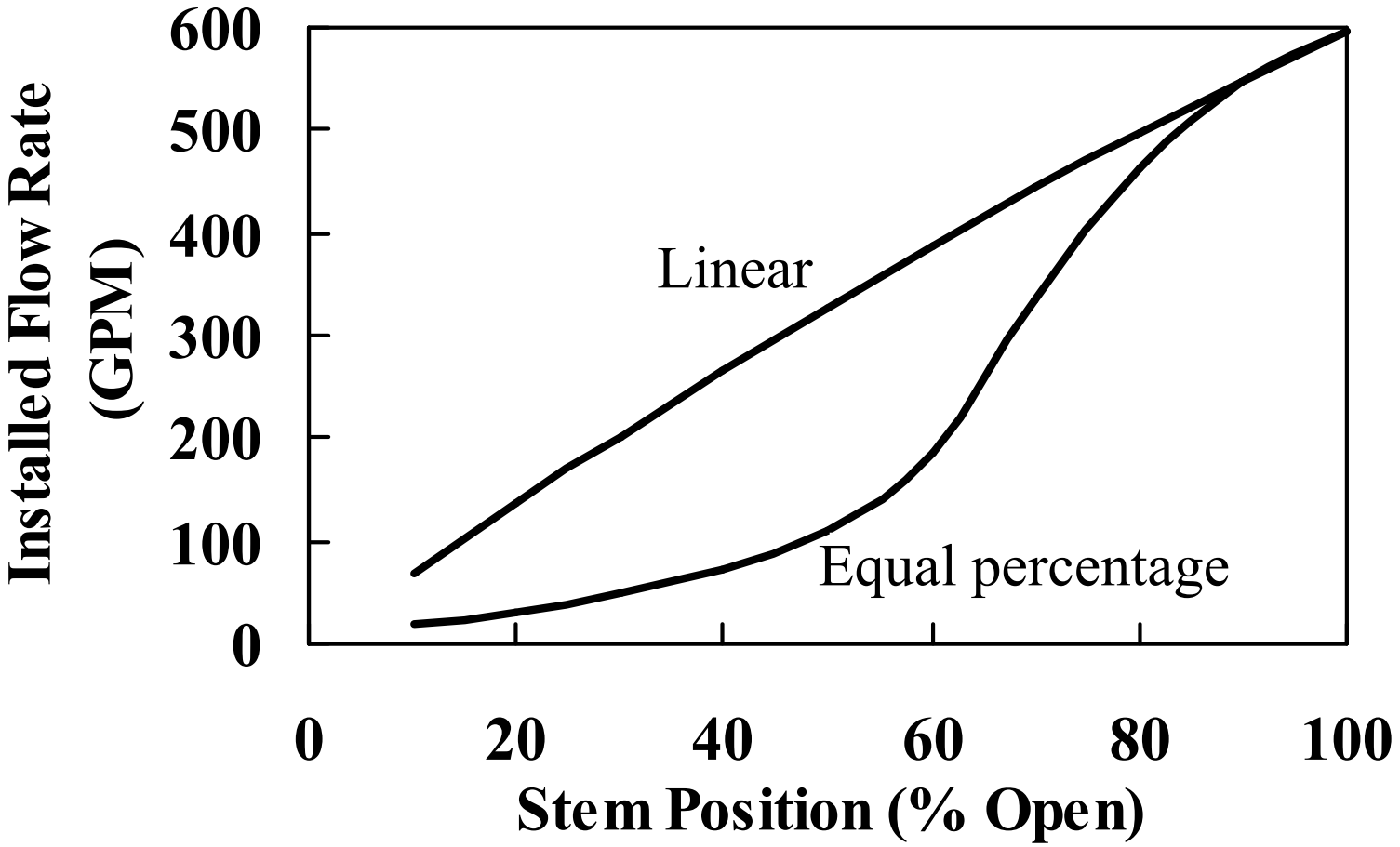
$$q(\ell) = C_v f(\ell)\sqrt{\frac{\Delta P_v}{g_s}} \qquad 0 \le \ell \le 1$$

- Plot ℓ vs. q.
- Play with Module 3

Flow System with Relatively Constant Valve Pressure Drop



Installed Valve Characteristics



Analysis of These Examples

- Note the linear installed valve characteristics over a wide range of stem positions
- If the ratio of pressure drop across the control valve for the lowest flow rate to the value for the highest flow rate is greater than 5, an equal percentage control valve is recommended

Control Valve Design Procedure

- Choose a control valve so that the average flow rate results when the valve is 2/3 open
- After the valve has been sized, check to ensure that the maximum and minimum flow rates will be accurately metered

Additional Information Required to Size a Control Valve

- C_V versus % open for different valve sizes
- Available pressure drop across the valve versus flow rate for each valve. Note that the effect of flow on the upstream and downstream pressure must be known

C_v versus % Valve Travel for Different Sized Valves

	Body Size (inch)	% Valve Opening		
		50	60	70
C_v	1	3.63	5.28	7.59
	1.5	4.3	6.46	9.84
	2	11.1	20.7	32.8
	3	21.7	36.0	60.4
	4	31.2	52.6	36.7

Check Max and Min Flows

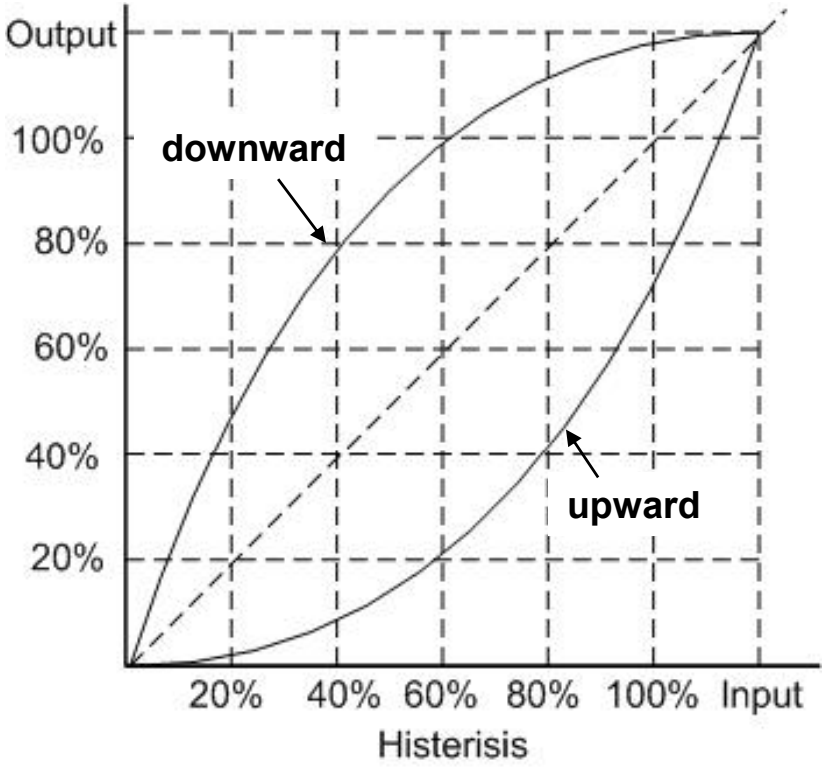
- Ensure that the flow rate will be accurately controlled at the maximum and minimum flow rates
- At minimum flow rate valve should be at least 10-15% open
- At maximum flow rate the valve should be at most 85-90% open

Valve Deadband

- It is the maximum change in instrument air pressure to a valve that does not cause a change in the flow rate through the valve
- Deadband determines the degree of precision that a control valve or flow controller can provide
- Deadband is primarily affected by the friction between the valve stem and the packing

Valve Hysteresis

- When the command signal (pneumatic signal) is going up and down, the flow rate will not be same even though the command signal is same depending on the direction of signal change
  - Due to friction between the stem and packing, loose linkage, pressure drop, stiction
  - Remedy
    - Change the command signal with the same direction by lowering or increasing it momentarily
    - Use valve positioner



Optional Equipment

- Valve positioner
  - A controller that adjusts the instrument air in order to maintain the stem position at the specified position
  - By use of valve positioner, hysteresis can be overcome

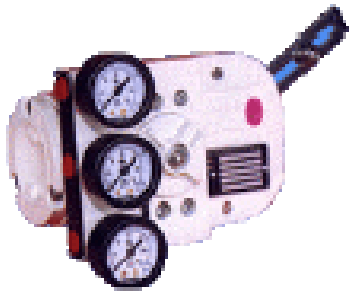


Fig. Positioner

- Booster relay
  - Provides high capacity air flow to the actuator of a valve. Can significantly increase the speed of large valves

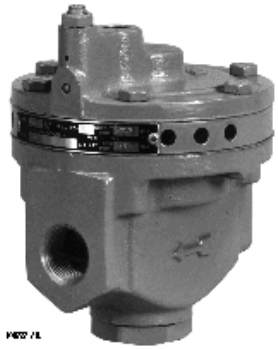


Fig. Booster relay

Control Relevant Aspects of Actuator Systems

- The key factors are the deadband of the actuator and the dynamic response as indicated by the time constant of the valve
- Control valve by itself - deadband 10 – 25% and a time constant of 3 – 15 seconds
- Control valve with a valve positioner or in a flow control loop- deadband 0.1 – 0.5% and a time constant of 0.5 – 2 seconds

Session Summary

- There are various actuators found in process control depending on its application objectives
- Control valve is the most common actuator found in process control
- The actuators must be in good condition to achieve a good control performances