CHE302 LECTURE III
ACTUATOR AND CONTROL VALVE SELECTION

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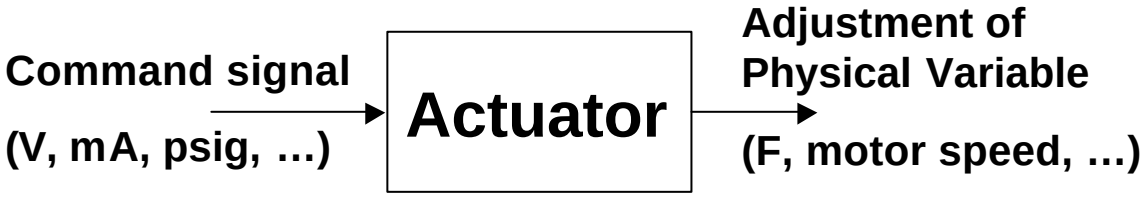
INTRODUCTION TO ACTUATOR

- **What is actuator?**
  - **Actuator converts the command signal from controllers or higher-level components into physical adjustment in adjustable process variable**



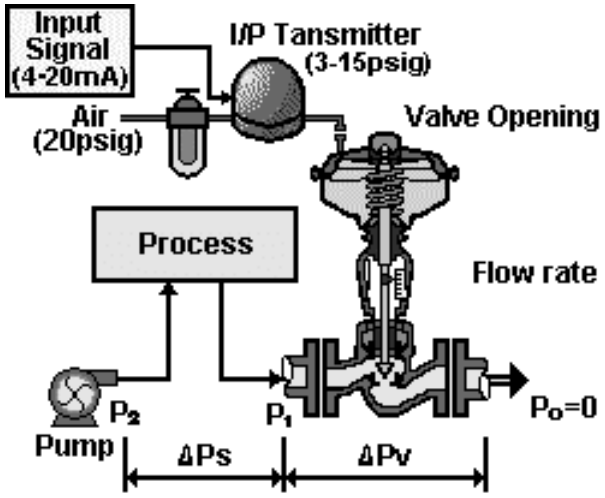
- **Actuator types**
  - **Control valve: pneumatic, electric, hydraulic**
  - **Electric heater output: SCR, thyristor**
  - **Pump/Motor speed: inverter**
  - **Displacement: pneumatic, electric, hydraulic**

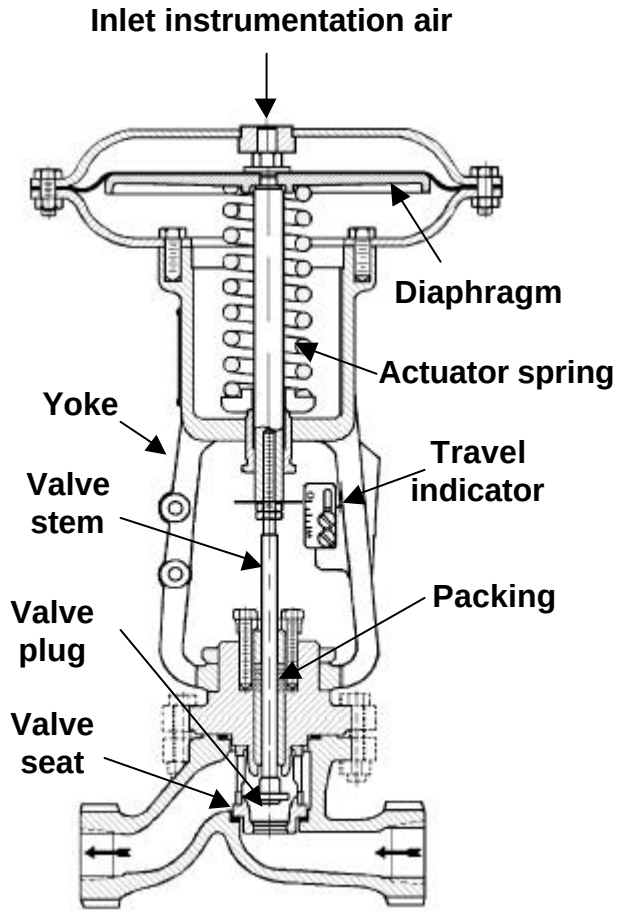
ACTUATOR AND D/A CONVERTER

- **Actuator**
  - **Convert the industrial standard signal to action such as valve opening, power level, displacement, and etc.**
  - **Standard instrumentation signal levels and signal conversion transmitters are used.**
  - **Actuator power**
    - **Pneumatic: simple, low cost, fast, low torque, hysteresis**
    - **Electric: motor and gear box, high torque, slow**
    - **Hydraulic: high torque, fast, expensive**
- **Digital-to-Analog (D/A) converter (+Hold)**
  - **Digital signal is converted to continuous signal and the signal is hold until the signal is changed**
  - **Specification: hold type, resolution (8bit, 12bit, 16bit)**

CONTROL VALVE

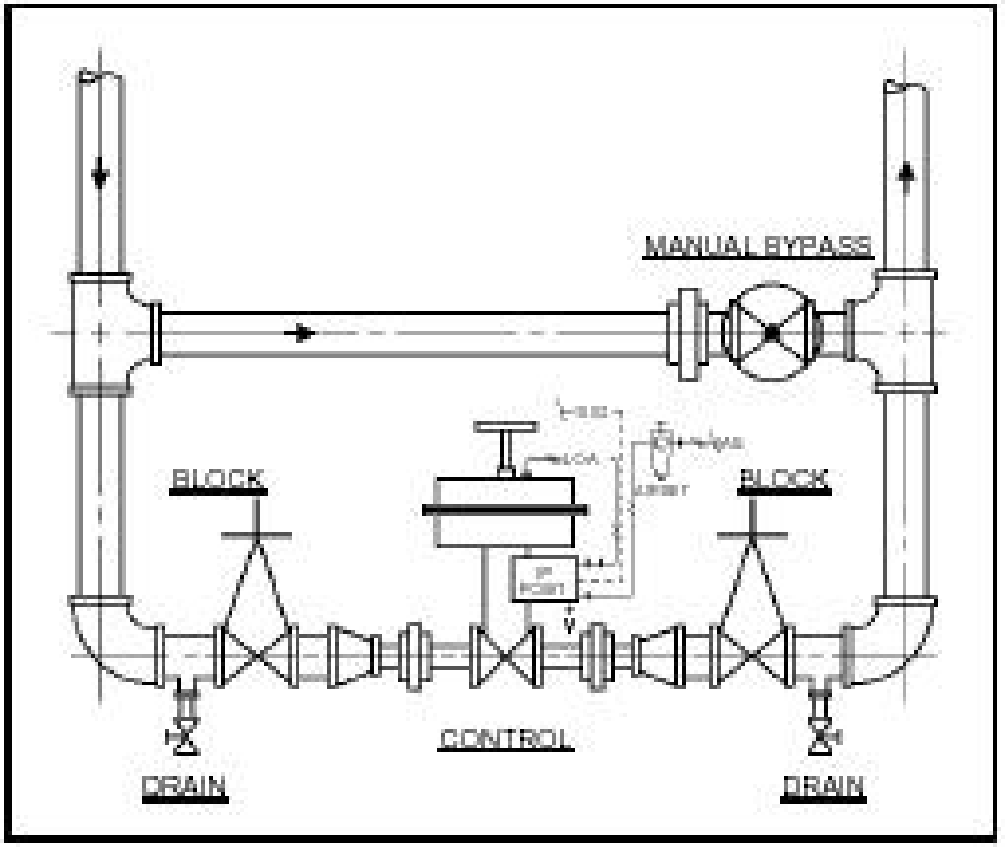
- **Valve+Actuator**
  - **Valve opening is adjusted by an actuator**
- **Pneumatic Control Valve**
  - **Usually 3~15psig signal is provided.**
  - **I/P transmitter converts 4~20mA signal to 3~15psig pneumatic signal via 20psig supply air**





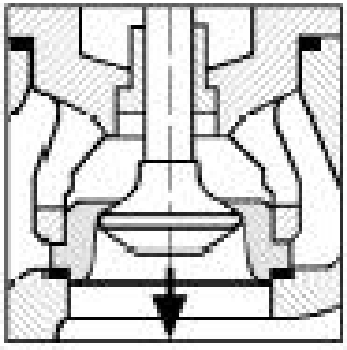
CONTROL VALVE IMPLEMENTATION

- **For the maintenance**
  - **Bypass**
  - **Block valves**
- **Installation**
  - **Horizontal**
  - **Vertical**
  - **Flange type**
  - **Screw type**
  - **Reducer may be required**

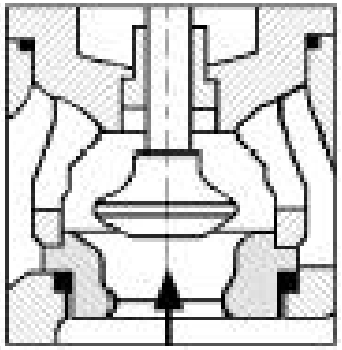


AIR-TO-OPEN OR AIR-TO-CLOSE

- As air pressure increases, the valve opening can becomes larger or smaller
- Air-to-open (normally closed, fail close): as the air P increases, the valve opening gets larger
- Air-to-close (normally open, fail open): as the air P increases, the valve opening gets smaller
- The selection should be made based on the safety consideration
  - Furnace fuel valve should be closed in case of utility failure
  - Coolant valve in exothermic reactor should be open in case of utility failure



Metal Seat-Fail Close,
Air- to- Open



Metal Seat-Fail Open,
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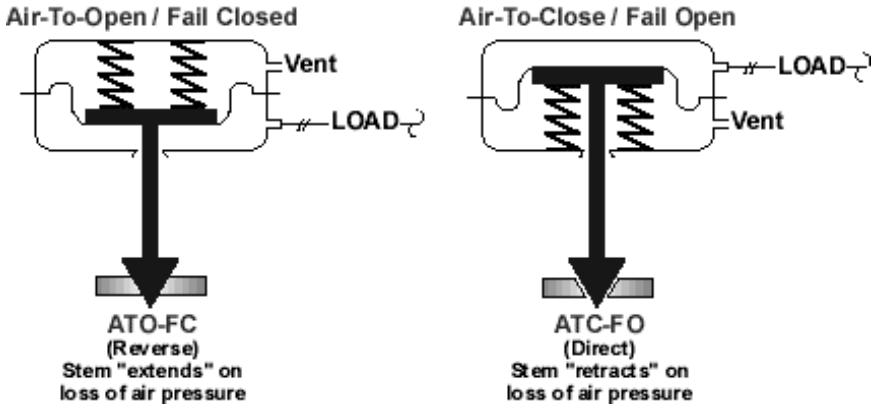
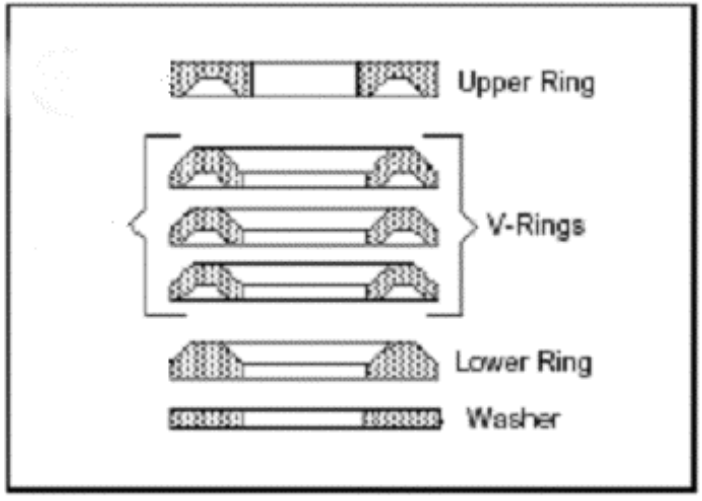


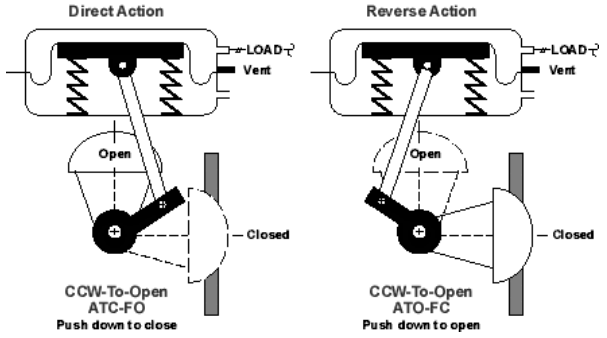
CONTROL VALVE PACKING

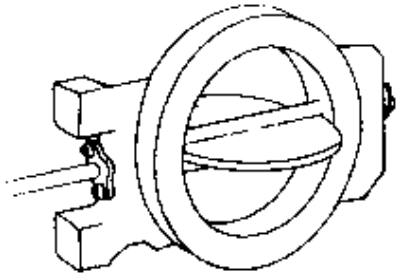
- **Packing is essential to maintain the sealing**
- **Packing has to be replaced periodically**
- **Excessive usage may shorten the lifetime of the packing**
- **Control action should not be to vigorous in order to prevent the excessive wear**



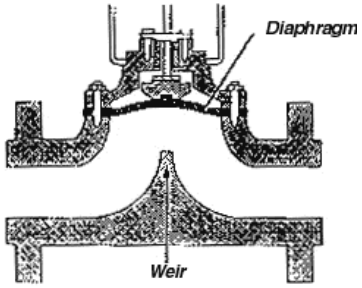
CONTROL VALVE CLASSIFICATION

- Control Valve
  - Linear motion
    - Globe
      - 2 way
        - Single seated
        - Double seated
      - angle
      - 3 way
        - Split bodied
    - Diaphragm
    - Pinch or clamp
    - Gate
  - Rotary motion
    - Eccentric plug
    - Butterfly
    - Ball

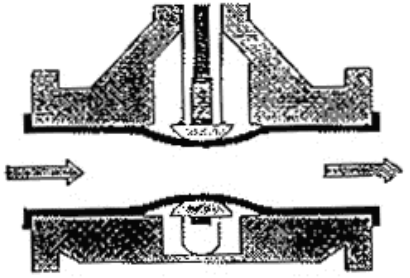




Butterfly



Diaphragm



Pinch

Gate

VALVE TYPES

- **Globe valve**
  - **rugged, usually the most expensive, particularly in the larger sizes, accurate and repeatable control, high pressure drop**
- **Gate Valve**
  - **sliding disc (gate), ideal for high pressure drop and high temperature applications where operation is infrequent, multi-turn or long stroke pneumatic and electro-hydraulic actuators are needed, poor control**
- **Ball Valve**
  - **tight shutoff, high capacity with just a quarter-turn to operate**
- **Butterfly Valve**
  - **damper valve , most economical valves, high torque required**
- **Diaphragm Valve**
  - **simplest, tight shutoff, isolated, ideal for corrosive, slurry and sanitary services.**

VALVE EQUATION

- **Basic Equation**

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

where ℓ is the valve stem position.

– **Valve coeff. (C_v) is decided by valve size**

– **Valve trim type for different plug**

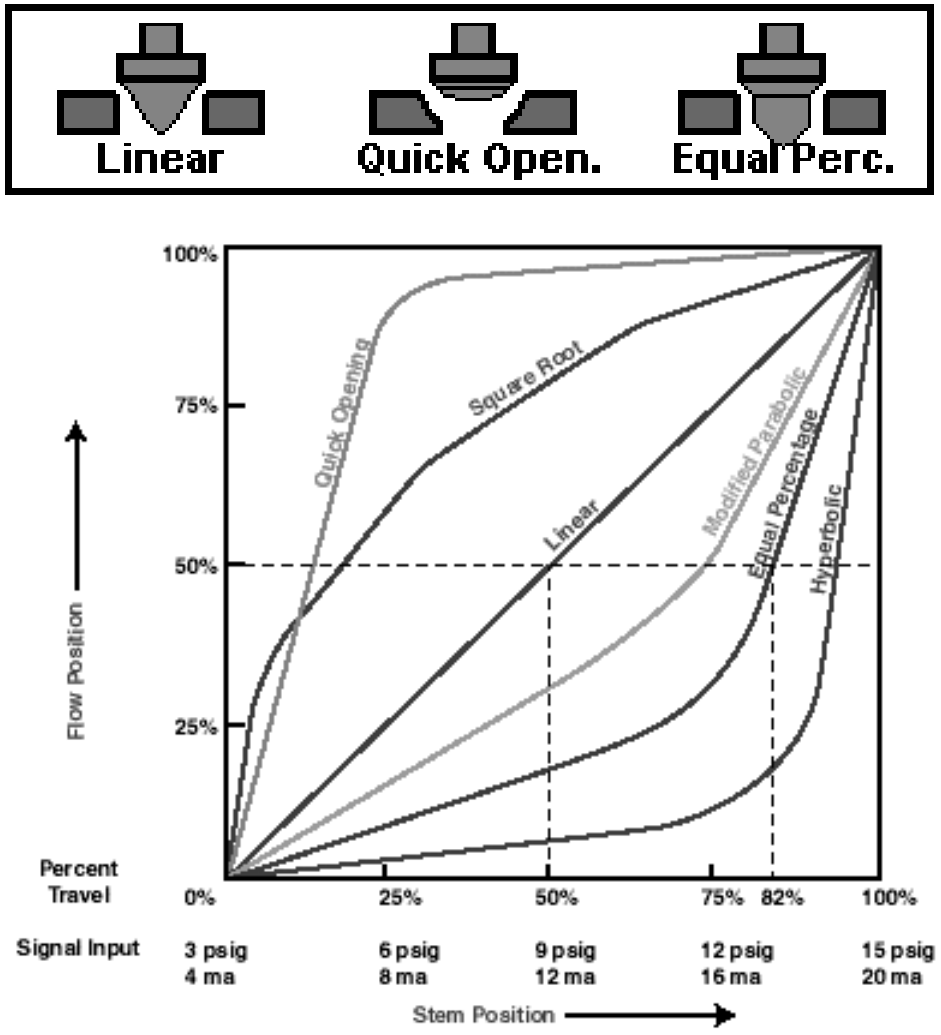
- **Linear:** $f(\ell) = \ell$
- **Square-Root (Quick Opening):** $f(\ell) = \sqrt{\ell}$
- **Equal Percentage:** $f(\ell) = R^{\ell-1}$

- ***R*: rangeability (ratio between minimum flow and maximum flow)**

  Þ **the bigger R is, the more accurate**

VALVE TRIM(PLUG) TYPE

- **Equal Percentage**
  - **Most commonly used**
  - **Used where large pressure drop is expected**
- **Linear**
  - **Used where fairly constant press. drop is expected**
  - **Used for liquid level or flow loop**
- **Quick Opening**
  - **Used for frequently on-off service**
  - **Used where instantly large flow is needed**



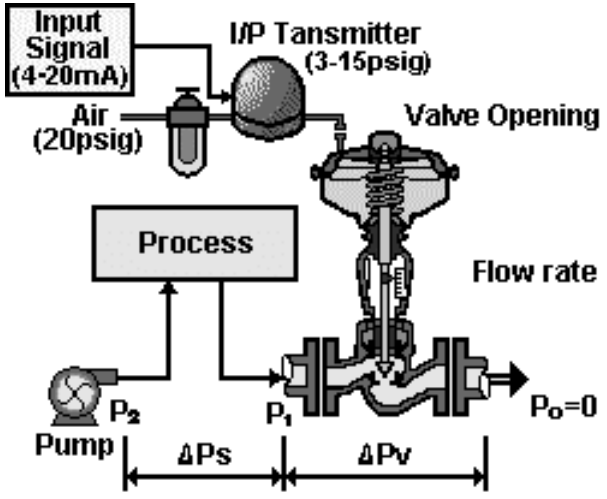
VALVE FLOW CHARACTERISTICS

- **Inherent characteristics**
  - **All ΔP is in valve: no ΔP in process**
- **Installed characteristics**
  - **Total ΔP in a system is provided by a pump or compressor**
  - **Change in valve opening Þ flow change in process Þ change in ΔP across the valve**
  - **Linear plug does not lead to linear behavior when installed**

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

$$\Delta P_s = kq^2$$

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



NONLINEAR BEHAVIOR

- **Flow vs. valve trim (installed)**

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

where

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

Þ **implicit nonlinear equation of flow and valve trim**

- **The pumping requirement (ΔP_{total}) is determined by the ΔP in both process and control valve at the max. flow**

VALVE SIZING

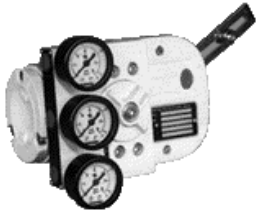
- **Step1**
  - **Decide max. and min. flow of a fluid (rangeability for equal percentage valve) and ΔP_{total}**
- **Step2**
  - **Define a max. allowable ΔP_v when the valve is wide open**
  - **It should be 10~15% of ΔP_{total} or about 10psi whichever is greater**
- **Step3**
  - **Calculate the installed valve characteristic**
  - **It should be linear around the region you want**
- **Step4**
  - **Adjust the pumping requirement (ΔP_{total}) and valve size (C_v) so that the max. flow can be achieved and the curve is linear around the operating region**
  - **Make sure that the ΔP_v when the valve is wide open is not over the limit in Step2**

OTHER CONSIDERTIONS

- **If pump characteristic curve is available**
  - **For many pumps, as flow increases, the pump discharge pressure is decreased.**
  - **Then the pump discharge P (ΔP_{total}) will change with flow rate.**
- **Sonic flow and Choke flow**
  - **When the ΔP across the valve is large, sonic flow can occur.**
  - **When ΔP gets larger, then choked flow occurs, and the downstream pressure does not influence the flow rate.**
  - **These two happen when the valve has excessive pressure drop.**
  - **Also, if the ΔP is too high, flashing may occur.**
- **If lager valve is used, there will be less ΔP_v and less pumping requirement (ΔP_{total}) is needed. However, the controllability of the flow is sacrificed. (trade-off)**
- **As a rule of thumb, the ΔP_v should be around 1/3~1/4 of ΔP_{total} at nominal flow rate.**

HYSTERESIS AND VALVE POSITIONER

- **Hysteresis**
  - **Due to friction between the stem and packing, loose linkage, pressure drop, stiction or etc.**
  - **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.**
  - **Remedy**
    - **Change the command signal with the same direction by lowering or increasing it momentarily**
    - **Use valve positioner**



- **Valve positioner**
  - **The valve positioner is a controller which can synchronize the command signal and its corresponding valve step position.**
  - **By use of valve positioner, hysteresis can be overcome.**