

Chemical Engineering and Materials Science

Syracuse University

Valves, Instrumentation, and Control

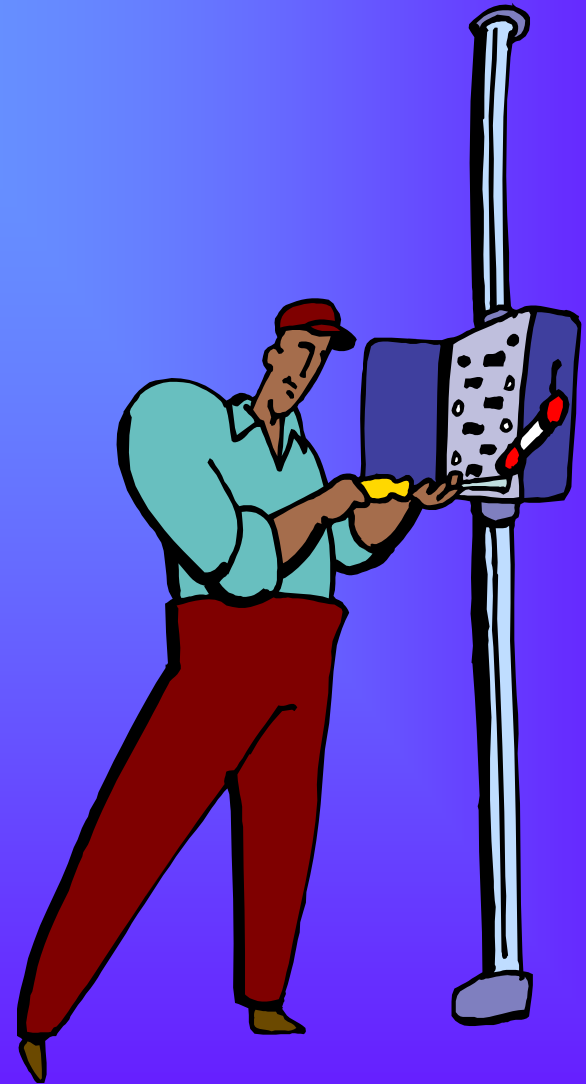
Process Design

CEN 574

Spring 2004

Outline

- Types of valves
- Components of valves
- Instrumentation: on-line meters
- Process control review



Valves, Instrumentation, and Control Learning Objectives

At the end of this section, you should be able to...

- Describe the major types of valves, their operation and characteristics, and draw their standard symbols on a P&ID.
- Select an appropriate valve for a specific application.
- Identify the function of the major components of a valve.
- Select trim and K

- List the four most commonly measured variables and draw the symbols for those meters on a P& ID.
- Describe the principals of measurement.
- Define the variables involved in an PID loop and draw appropriately on a P&ID.
- Define tuning.
- List the common process problems that lead to unstable PID loops.

References

- Chapter 15 in Turton et al., *Analysis, Synthesis, and Design of Chemical Processes*.
- *Process Engineers: Take Control!* Cecil L. Smith. Chemical Engineering Progress. August 2000.

VALVES



Valve Types

- Ball Valve
- Butterfly Valve
- Gate Valve
- Globe Valve
- Check Valve



Parts of a Valve

1. Closure member: part of the valve that closes flow (disk, ball, gate, etc.).
2. Actuator: means of operating the valve – hand, gear, chain wheel, motor, solenoid, pressure and flow of the media, air pressure.

3. End fitting: must be specified when buying the valve - butt weld end, compression flange, pipe thread, quick disconnect
4. Material: closure member, housing, seat – stainless steel
5. Packing/seals: seals stem, replaced
6. Seat: where the closure members seals against the valve housing

Ball Valve

Sphere with a port in a housing, rotate to expose channel.

- Applications: Flow control, pressure control, shutoff, corrosive fluids, liquids, gases, high temp.
- Advantages – low pressure drop, low leakage, small, rapid opening
- Disadvantages – seat can wear if used for throttling, quick open may cause hammer

Ball Valve



Gate Valve

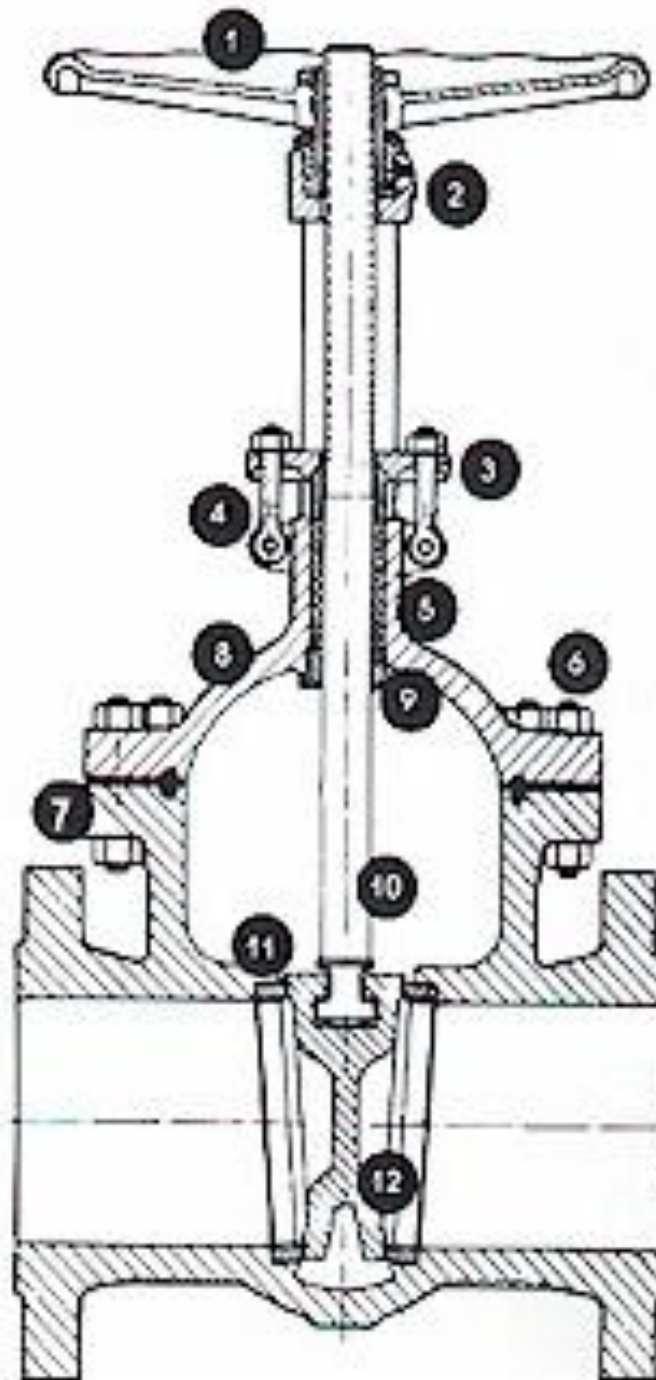
Sliding disk, perpendicular to flow

Applications: Stop valves, (not throttling), high pressure and temp, not for slurries, viscous fluids

Advantages – low pressure drop when fully open, tight seal when closed, free of contamination buildup

Disadvantages – vibration when partially open, slow response and large actuating force

Gate Valve



Butterfly Valve

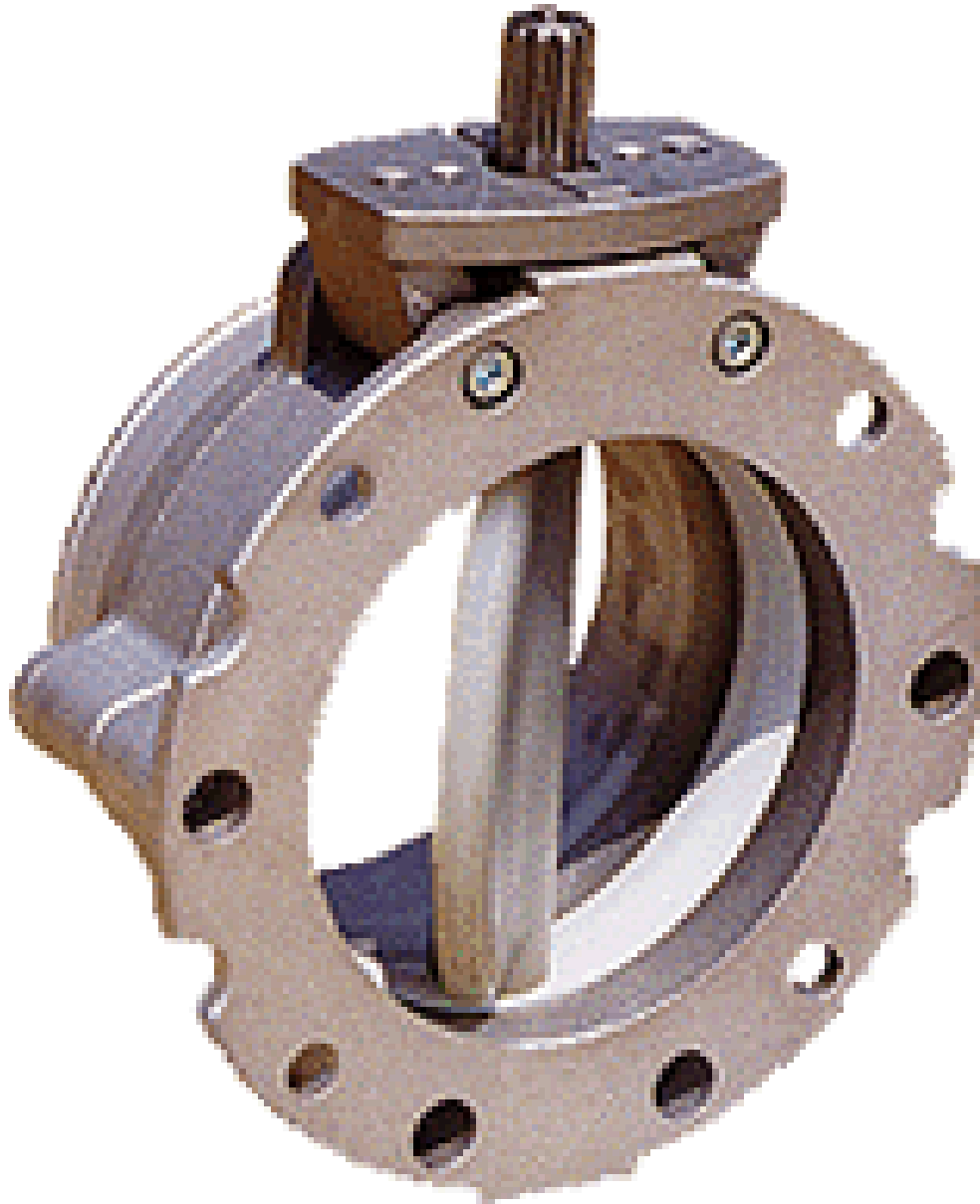
rotating disk on a shaft, in a housing

Low pressure, large diameter lines where leakage is unimportant

Advantages – low pressure drop, small and light weight

Disadvantages – high leakage, high actuation forces so limited to low pressures

Butterfly Valve

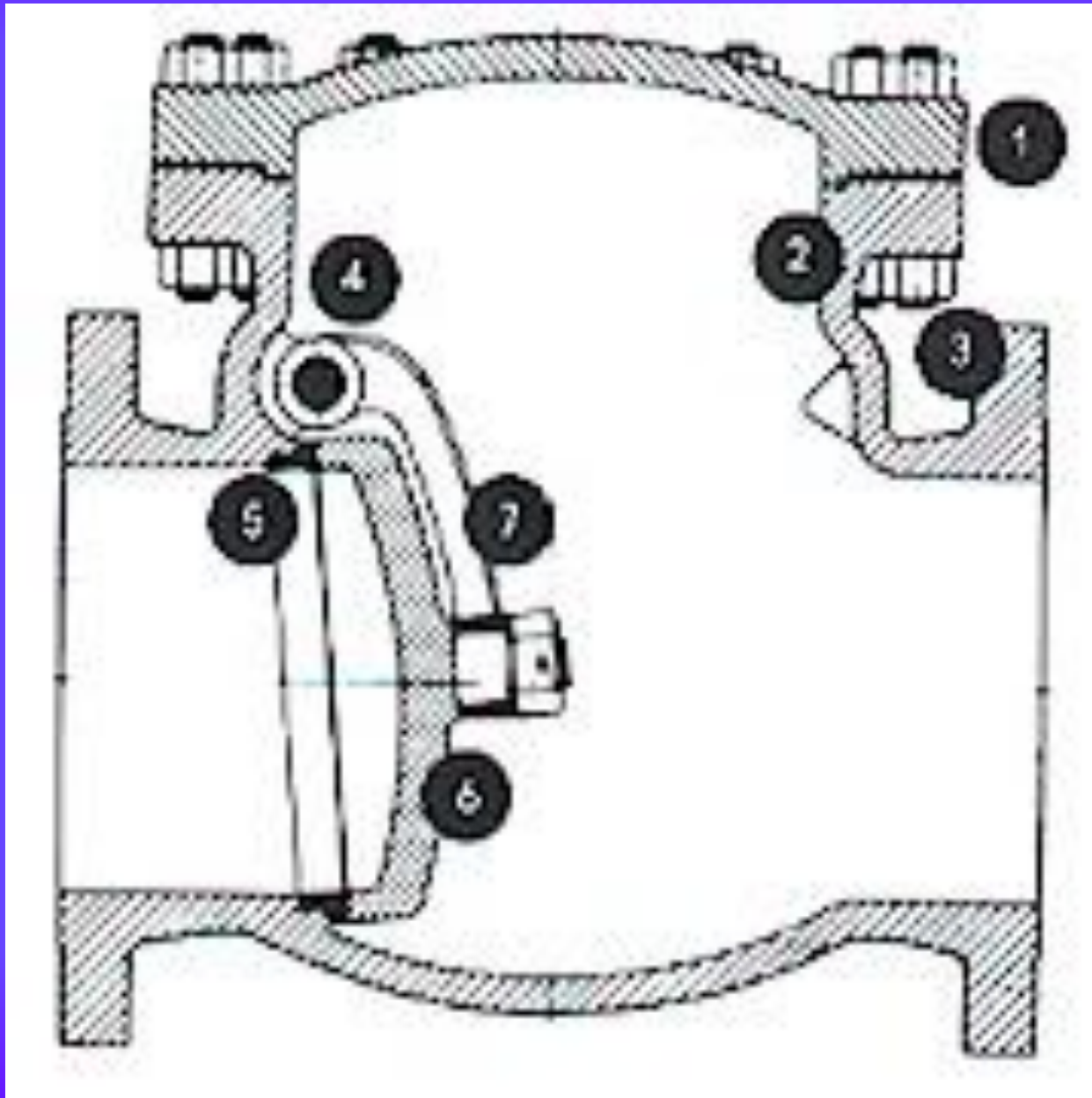


Check Valves

allows flow in only one direction

Swing valve similar to butterfly except hinged along one edge rather than rotate about the diameter, used primarily for check valves.

Check valve



Globe Valve

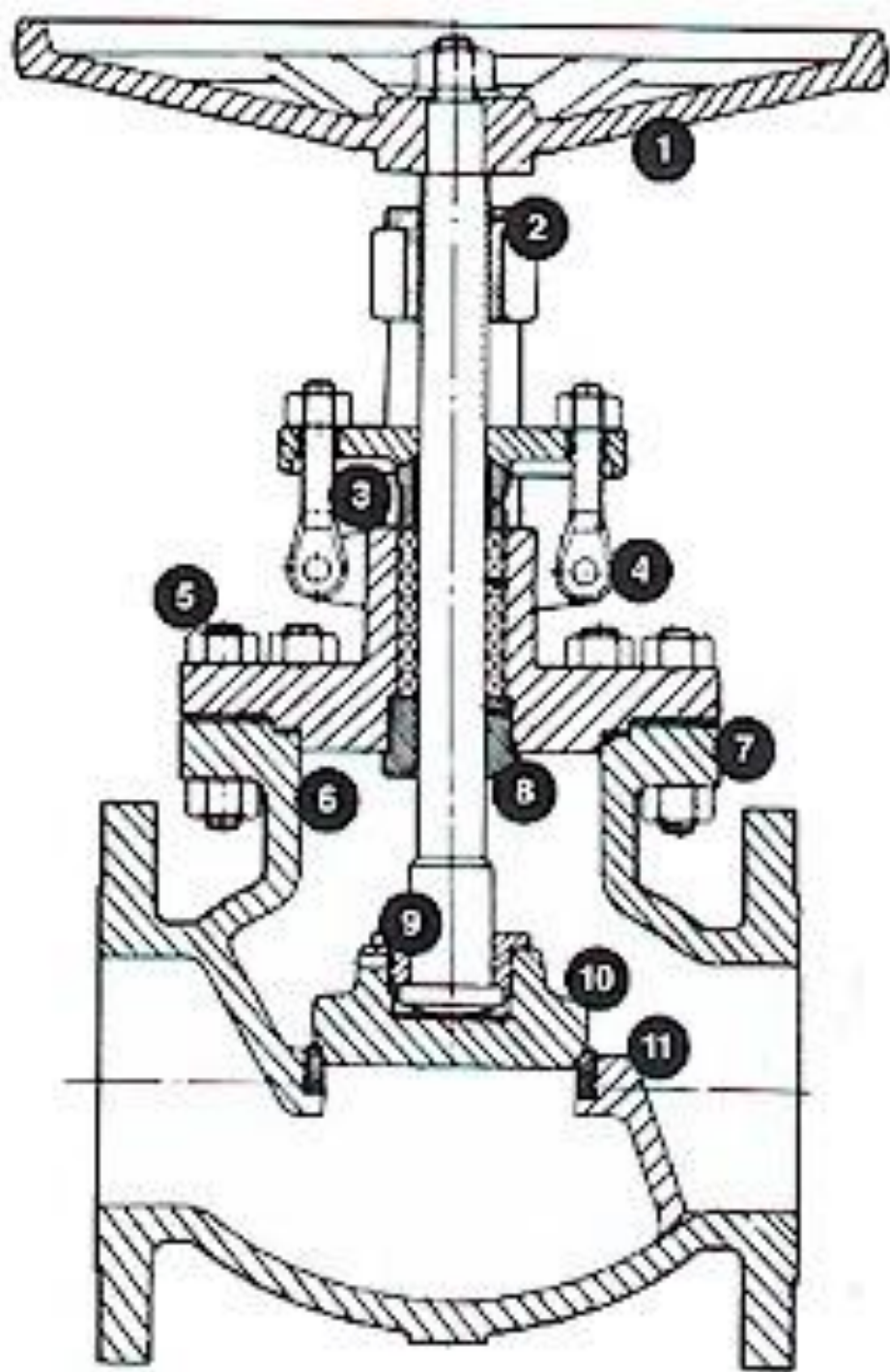
three types (globe, angle and Y), disc or plug moved perpendicular to flow and closes on a ring seat

Throttling, general purpose flow control valve

Advantages – faster than gate, seat less wear and tear, high pressure drop for pressure control

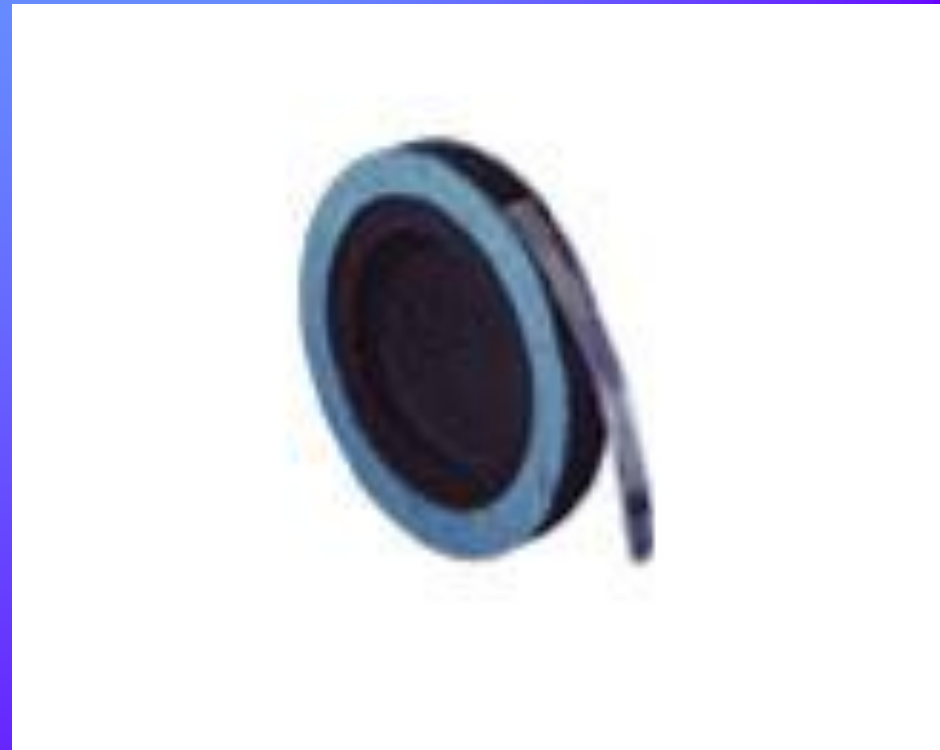
Disadvantage high pressure drop, require considerable power to operate (gears and levers), heavy

Globe Valve



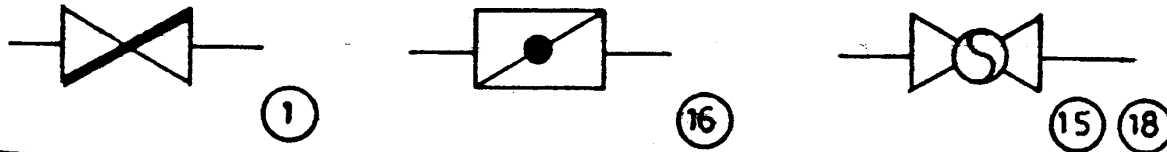
Rupture Disk

(not a valve – ruptures at a set pressure)

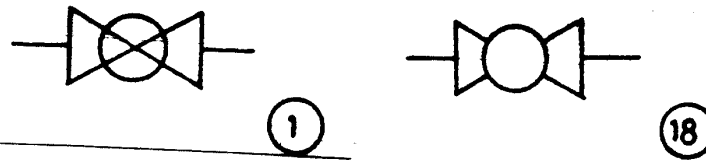


Valve Symbols

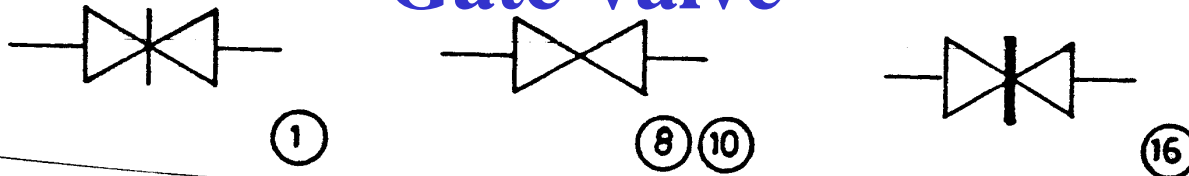
Butterfly Valve



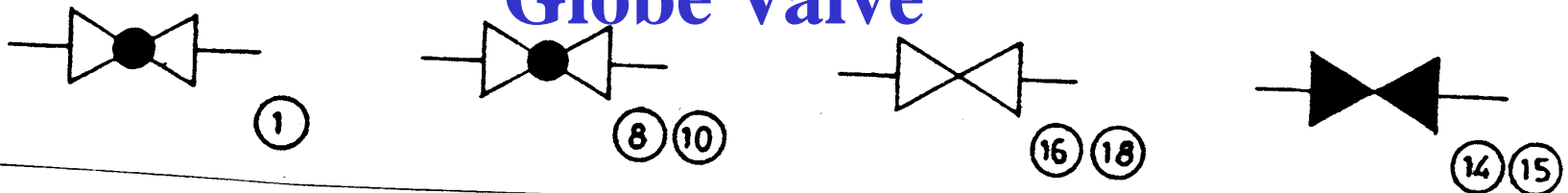
Ball Valve



Gate Valve



Globe Valve



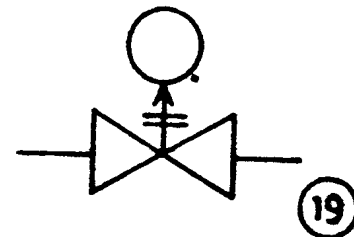
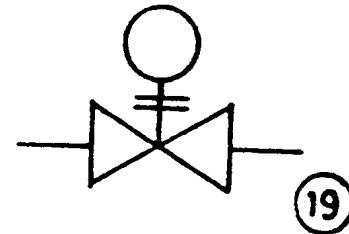
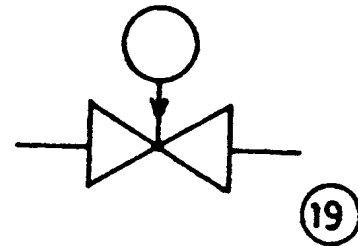
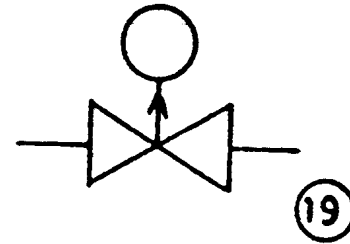
Motor element operation

Control valve opens on failure of operating medium.

Control valve closes on failure of operating medium.

Control valve retains position on failure of operating medium.

Combination of above symbols is used to indicate safe and permitted direction of drift.



Instrumentation

- Form groups of two.
- List as many process conditions that can be measured on-line as you can.
- List the four most common.

Instrumentation

Most commonly measured process conditions: temperature, level, pressure, flow rate, pH.

Other variables include composition, moisture, specific gravity, viscosity, dissolved oxygen.

Temperature

Thermocouple

- Two wires of different metals welded together at the end
- When the junction is heated a small electric current proportional to the junction temperature is generated
- Types of thermocouple refer to the types of metal – common J,H, K
- Thermowell is a sleeve that the thermocouple sits in
- Issues – low current, fouling of thermowell

Thermister/Resistive thermal detectors (RTD)

- Consists of a resistor that have a high coefficient of resistance
- Resistance = $f(\text{temperature})$

Flow Rate

- Historically the most common method to measure flow rate is the orifice plate.
- However, more sophisticated methods are becoming more common because they have less pressure drop.

Orifice Meter

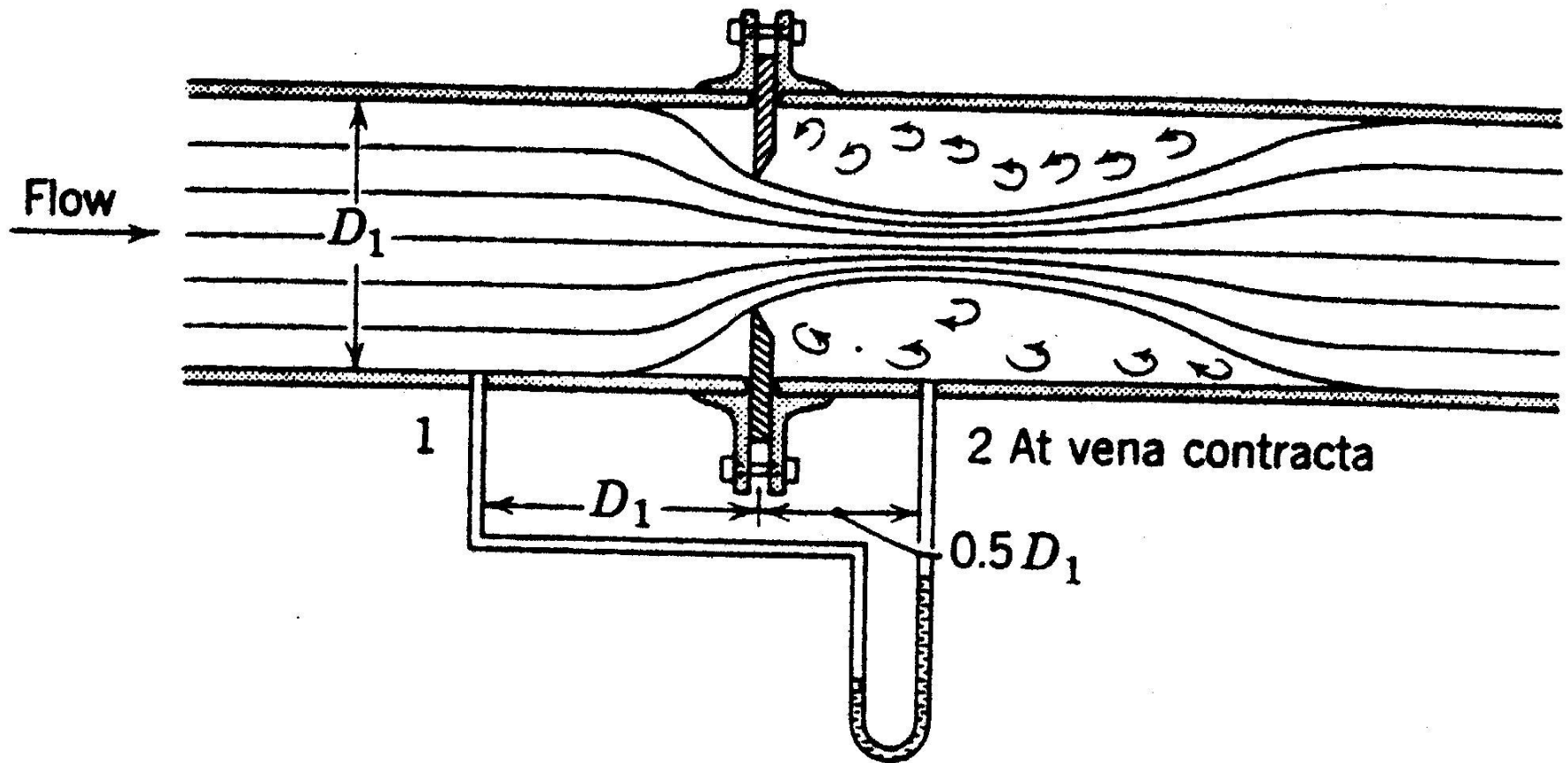
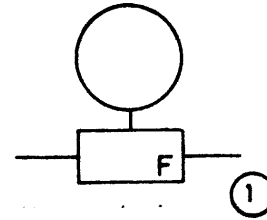


Figure 20.10. Sharp-edged orifice meter.

Calculating pressure drop across and orifice meter

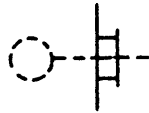
- ΔP (psi) = $K * (\rho / 1726) (\text{velocity}^2)$
- K = orifice coefficient usually 0.6-0.8
- ρ = density (lb/ft³)
- velocity = velocity through the orifice ft/s
- for estimation use orifice $\frac{1}{2}$ of the pipe diameter
- Example: assume 4 inch line, 200 gpm, orifice diameter = 2 in, orifice radius = 1 in = 0.083 ft
- $\text{velocity} = (200 \text{ gal/min}) (\text{ft}^3 / 7.48 \text{ gal}) (\text{min} / 60 \text{ sec}) (1 / \pi (0.083^2 \text{ ft}^2)) = 20.6 \text{ f/s}$
- ΔP (psi) = $0.7 * (62.4) (20.6^2) / 1726 = 10.7 \text{ psi}$

Meter (any type)
Letter F indicates flow measurement.



Level Meters

internal ball float type



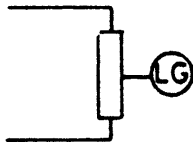
internal displacement type



level gauge/ external liquid level (differential pressure type)



gauge glass

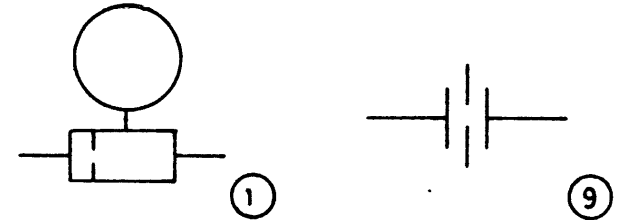


sight glass

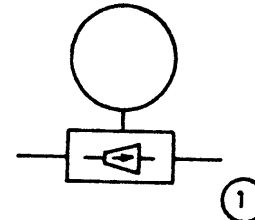


Flow Meters

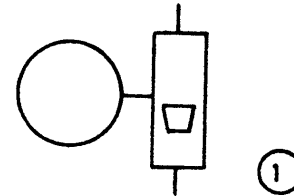
orifice plate



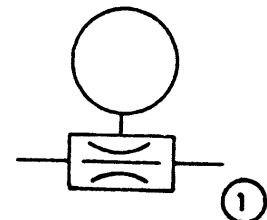
turbine meter



variable area meter (Rotameter)



venturi meter



Process Control: A Review

Assignment: Read the Smith article and Turton's chapter 15 about process control.

Process Upsets

T, F, reaction rate, P etc. may change and effect product quality. These variables may change due to equipment failure, intentional production rate changes, cooling water changes, etc. These changes are called process upsets.

Controlled Variables

Controlled variables are variables that we want to maintain at constant or specified values (T, P, flow rate, level, etc.).

Manipulated Variables

Manipulated variables are variables that we intentionally change to maintain our controlled variable at a constant value. We often manipulate the values by opening or closing a valve.

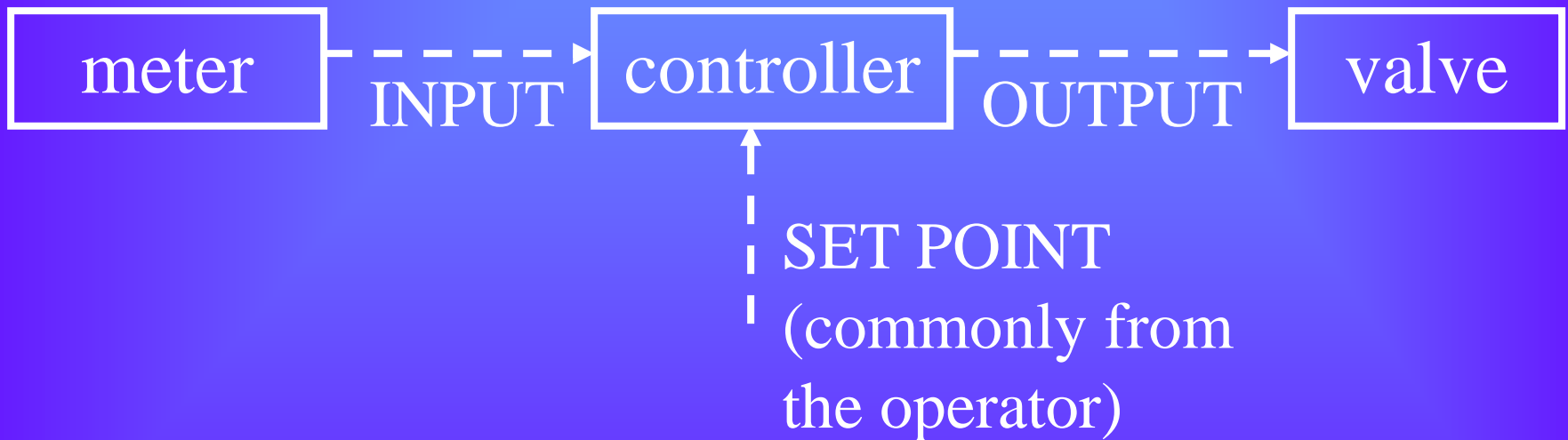
Measured Variables

Measured variables are variables that we measure with a meter (often often the controlled variable or a variable that we use to calculate the controller variable).

Controller

- A unit that reads an INPUT signal and a SET POINT, compares the two, performs a calculation on the difference, and sends out an OUTPUT signal.
- Common type of controller: PID = proportional, integral, derivative

Controller



(Electrical or pneumatic signal indicated by dashed line.)

Controller Operation

- If the INPUT is different than the SET POINT, the OUTPUT signal is changed.
- If the INPUT signal is the same as the SET POINT, the OUTPUT signal remains the same.

Types of Control: Feed Back

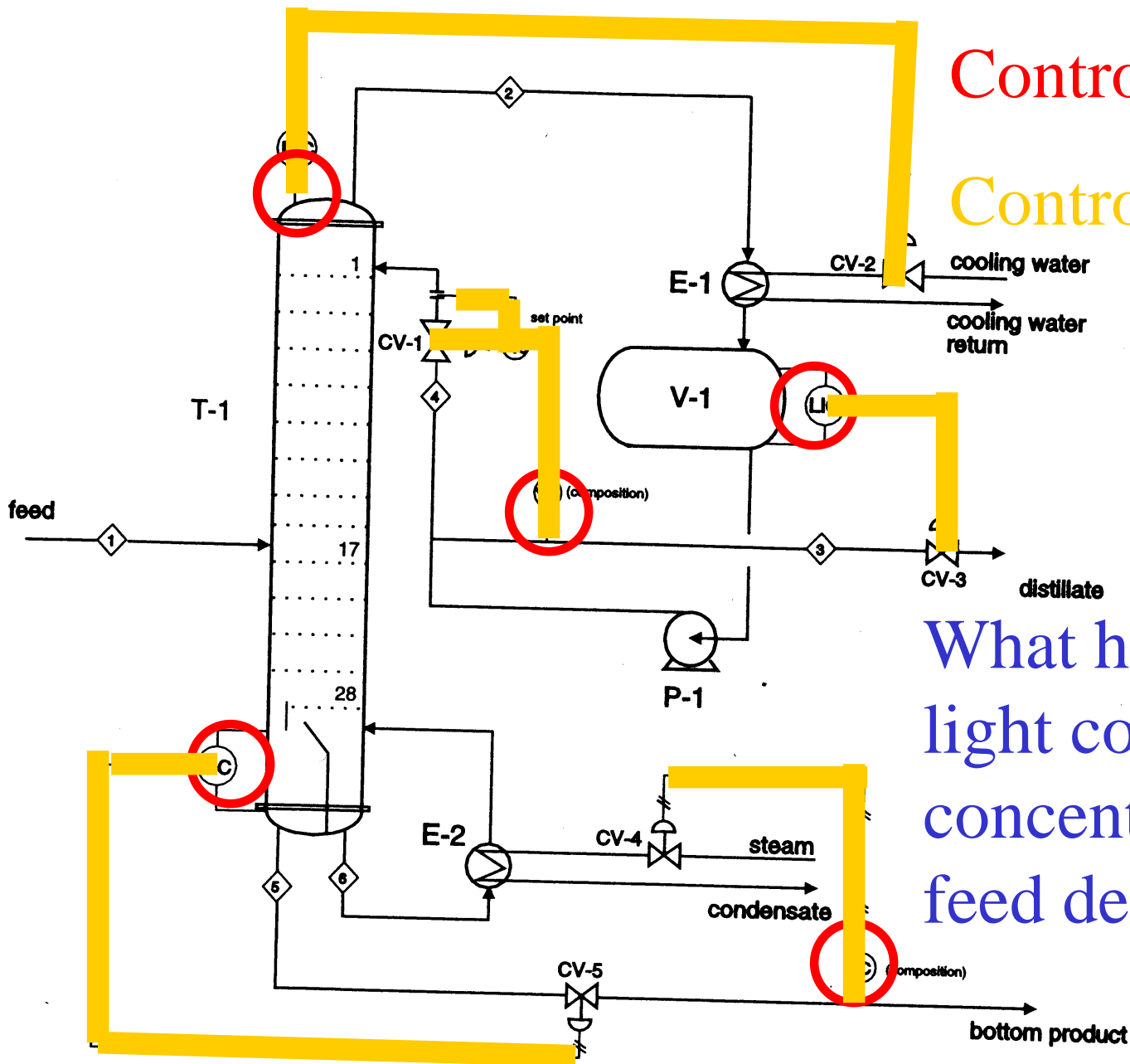
- When the controlled variable changes or is different than the set point, the controller adjusts the manipulated variable to bring the controlled variable back to the set point value.
- The controlled variable must change (be different than the set point) for control action to be taken.

Feed Forward

- The measured variables are used to change manipulated variables before changes in the controlled variable takes place. Especially useful when there are long lag times in the process.
- All factors likely to cause a change in the controlled variable must be taken into account.
- Some type of model of process behavior/dynamics must be known, and the accuracy of control is directly linked to the accuracy of control.

Cascade

- Uses controllers in series. The first controller's output is the set point to the second controller.
- Reduces lags and allows finer controls, but is more complicated than single loops.



Controlled variables?

Control loops?

What happens if the light component concentration in the feed decreases?

Figure 15.9 Typical Basic Control Scheme for a Binary Distillation Column

Distillation Control

- Purity of distillate will decrease and amount in overhead will decrease.
- Valve CV-1 will open to increase reflux rate in response to concentration change.
- Level in reflux drum will drop, so CV-3 will close to reduce overhead flow rate.
- Pressure will decrease causing CV-2 to close and cooling water flow rate to decrease.
- Level and purity in the bottoms will increase causing CV-5 to open increasing bottoms flow, and CV-4 will close reducing steam

Control Exercise

- Form groups of two students
- Develop a feedback control loops.
- Draw your PFD with control loop on the board.