Basic Process Control
Basic Control Principles

Inflow
Supply

Level
(Controlled Variable)

Pump

Overflow
Open vs Closed Loop

- **Closed loop**
  - Automatic control

- **Open Loop**
  - Manual control
  - Person takes the place of the controller
Feedback Control

Controller

- Comparator
  - Error (SP - M)

- Amplifier
  - Manipulated Variable

- Process (Tank)
  - Disturbances
  - Output (Controlled Variable - Level)

- Sensor
  - Measurement Signal

Set Point
Feedback vs. Feedforward

- Feedback
  - Control action after an error exists

- Feedforward
  - Reacting to the disturbance before the error occurs
Typical ON/OFF Control System

- SP: Power Supply
- Qin: Inflow
- L1, L2: Lines
- P1: Solenoid valve
  - P1 closes @ L1
  - P1 opens @ L2
- V1: Electrically Operated Solenoid valve
- Qout: Outflow

Inflow

Solenoid Power Supply
Typical ON/OFF Response
Proportional Control
Level Control of Open Tank

SP
Qin

V_1
A/C

20 - 100 kPa

LT
Qout
Simple Proportional System
Open Tank Control

- SP
- Qin
- Qout
- LT
- A/O
- 20 - 100 kPa
- LIC
Controller Action

Direct

Reverse

SP → Qin → LT → LIC

A/C

20 - 100 kPa

SP → Qin → LT → LIC

A/O

20 - 100 kPa
Proportional Control

\[ m = k(\text{SP}-\text{M}) + \text{bias} \]
Proportional Band and Gain

Proportional Band – the input change required to change the output 100%

\[ \text{gain} = \frac{\Delta \text{output}}{\Delta \text{input}} \]

\[ \text{gain} = \frac{100\%}{PB} \]
Narrow, Wide, High & Low

Wide PB – Low Gain

Narrow PB – High Gain
Proportional Control Response Curve

- Input/Output
- Level originally at setpoint
- Level
- Outflow
- Inflow
- Loss in Volume
- New mass balance occurs here
- New level below setpoint
- Offset
- t₀
- t₁
- t
- time
Proportional Response with Narrower PB

Level originally at setpoint

Input/Output

Loss in Volume

New mass balance occurs here

Outflow

Inflow

t₀ t₁

New level below setpoint

Level

time
Response Versus PB, Proportional Control Only

- Step Disturbance
- Load Change
- System Response
- "Wide" PB
- "Moderate" PB
- "Narrow" PB

Offset
$\frac{1}{4}$ Decay Response Curve
For You To Do

- Read pp. 89-105
- Answer Questions pp. 121-122, #1-19
Reset or Integral
Response Curve: Proportional Control Only

System Response

Step Disturbance

SP

time

Offset
Additional Control Signal Restores Process to Setpoint

- Initial mass balance
- Inflow
- Outflow
- Reset Action
- Final mass balance
- Offset Removed
- Time

Setpoint
Integral Action

\[ m = ke \left( + \frac{1}{TR} \int edt \right) + bias \]
Units

- **Minutes per repeat**
  - **MPR**
  - The length of time that it will take the integrator to add an amount equal to the proportional response

- **Repeats per minute**
  - **RPM**
  - The number of times the proportional response is repeated in one minute
Proportional Plus Reset, Open Loop Response
A problem

Output initially 50%, Gain = 2, reset = 2 minutes per repeat

A direct acting controller control is subjected to a sustained error of 5%

What is the output after 4 minutes?

Proportional Response = ke = 2x5=10%
Integral Action- in 4 minutes the control will go through 2 repeats.
Integral action = 2 x 10 = 20%
Total output change is proportional + integral = 30%
A Couple More Things

- Reset Windup
- Instability because of lag
For You to Do

- Read over text pp. 89 –110
- Answer questions pp. 121-122, 1-24
Rate or Derivative
Proportional and Derivative – Open Loop Pressure

Derivative ceases as error stops changing
Derivative Control

\[ m = ke \left( + \frac{1}{T_R} \int edt \right) + kT_D \frac{de}{dt} + bias \]
Simple Flow Control System
The open Loop Response of Proportional Plus Derivative (PD) Action to Rapidly Changing Error Signals
Large System Under Proportional and Proportional Plus Derivative Control

- Control Signal
- Load Disturbance Applied
- Setpoint
- Level
- Prop. + Derivative
- Prop. Only

(time)
Multiple Control Modes

- Virtually all controls have a proportional response
- Integral and derivative are added to improve performance
- Majority have proportional and integral
- Some, typically heat exchangers have derivative added
Open Tank Level Control With Valve In Inflow
Typical Flow Control Loop
Pressure Control – Constant Bleed
Split Ranged Feed and Bleed Pressure Control
Representative Hot Bleed/Cold Service
Water Heat Exchanger
For You To Do

- Read pp. 106-120
- Answer Questions pp. 122-123, #20-38