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

Amplifier

Process (Tank)

Disturbances

Set Point

Error

(SP - M)

Manipulated
Variable

Output

(Controlled
Variable - Level)

Measurement
Signal

Process Sensor
Feedback vs. Feedforward

- Feedback
  - Control action after an error exists
- Feedforward
  - Reacting to the disturbance before the error occurs
Typical ON/OFF Control System

Inflow

Electrically Operated Solenoid valve

Solenoid Power Supply

P1 closes @ L1
P1 opens @ L2
Typical ON/OFF Response

Periodic Time

L1

L2

SP

time

Periodic Time
Proportional Control
Level Control of Open Tank

- Qin: Inflow
- Qout: Outflow
- SP: Set Point
- LT: Level Transmitter
- V1: Valve
- A/C: Air/Compressed Air
- Pressure range: 20 - 100 kPa
Simple Proportional System

Inflow

Valve

Pivot

Float

Outflow
Open Tank Control

- SP
- Q_{in}
- Q_{out}
- LIC
- LT
- A/O
- 20 - 100 kPa
Proportional Control

\[ m = k(\text{SP}-\text{M}) + \text{bias} \]
Proportional Band – the input change required to change the output 100%.

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

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

Wide PB – Low Gain

Narrow PB – High Gain

In

Out
Proportional Control Response Curve

Level originally at setpoint

Inflow

Outflow

Loss in Volume

New mass balance occurs here

New level below setpoint

Input/Output

Level

$\text{Offset}$

$t_0$

$t_1$

$t$

$\text{time}$

$\text{time}$

$t_0$

$t_1$
Proportional Response with Narrower PB

Level originally at setpoint

Loss in Volume occurs here

New mass balance occurs here

Input/Output

Outflow

Inflow

Level

New level below setpoint

Offset

Inflow

Outflow

Loss in Volume

New mass balance

Level originally at setpoint

Input/Output
Response Versus PB, Proportional Control Only

- **Load Change**
  - Step Disturbance

- **System Response**
  - "Wide" PB
  - "Moderate" PB
  - "Narrow" PB

- **SP**
  - 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

time

Offset
Additional Control Signal Restores Process to Setpoint

- Initial mass balance
- Outflow
- Inflow
- 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

Control Signal vs. Time

Error vs. Proportional Response

- Fast Reset
- Normal Reset
- Slow Reset
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 = \( ke = 2 \times 5 = 10\% \)
Integral Action- in 4 minutes the control will go through 2 repeats.
Integral action \( = 2 \times 10 = 20\% \)
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

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

Proportional action
\[ A - B \]
Rate action
\[ A - B \]
Rate action due to cessation of increase in \( e \)
\[ B - C \]
Control signal at end of excursion
\[ \% \]
Proportional action
\[ B - C \]
Rate action due to cessation of increase in \( e \)
\[ B - C \]
Large System Under Proportional and Proportional Plus Derivative Control

Control Signal

Load Disturbance Applied

Prop. + Derivative

Prop. Only

Setpoint

Level

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
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