Simple Process Control Loop

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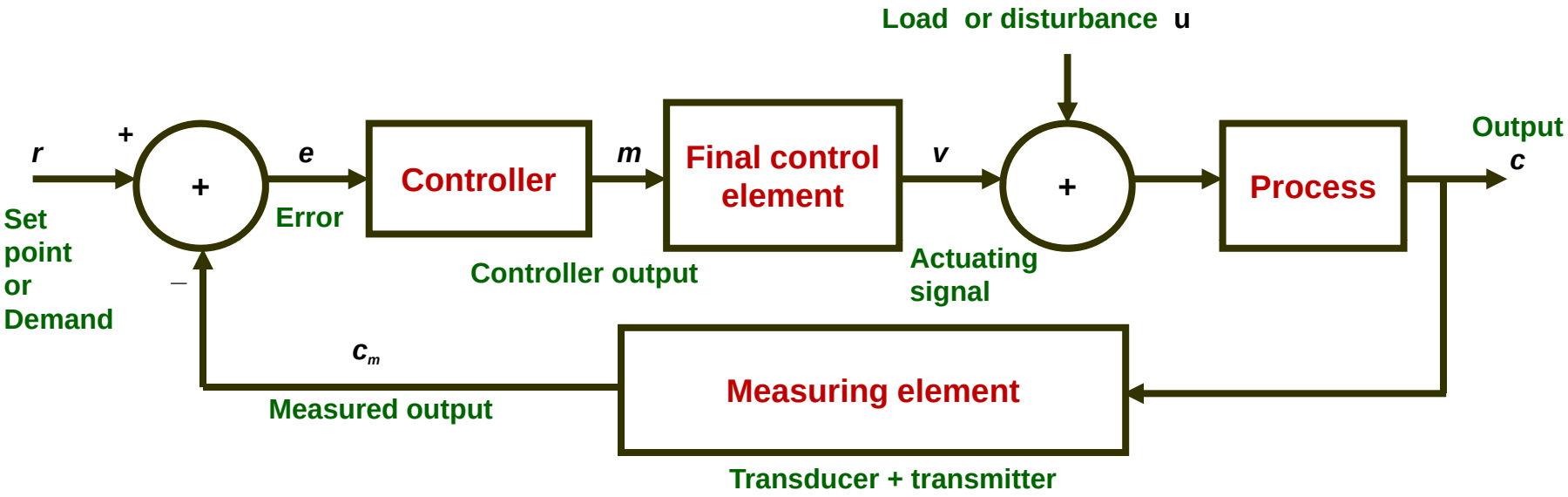
Simple process control loop (with negative feedback)



- Independent variables:
  - set point '*r*'
  - load '*u*'
- Manipulated variable: actuating signal '*v*'
- Controlled variable: output '*c*'
- Feed back variable: measured output '*cm*'

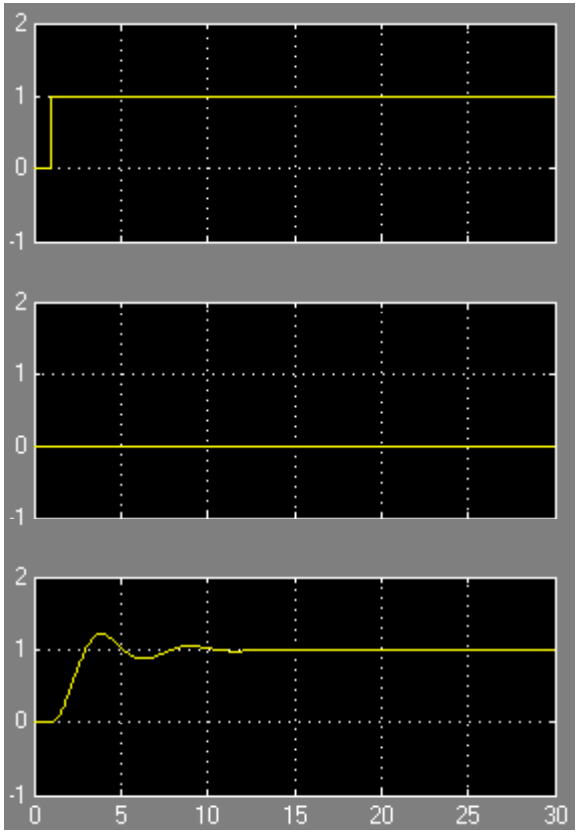
Servo problem

It is the ability of output tracking the given set point changes

Set point

Load or disturbance

Output



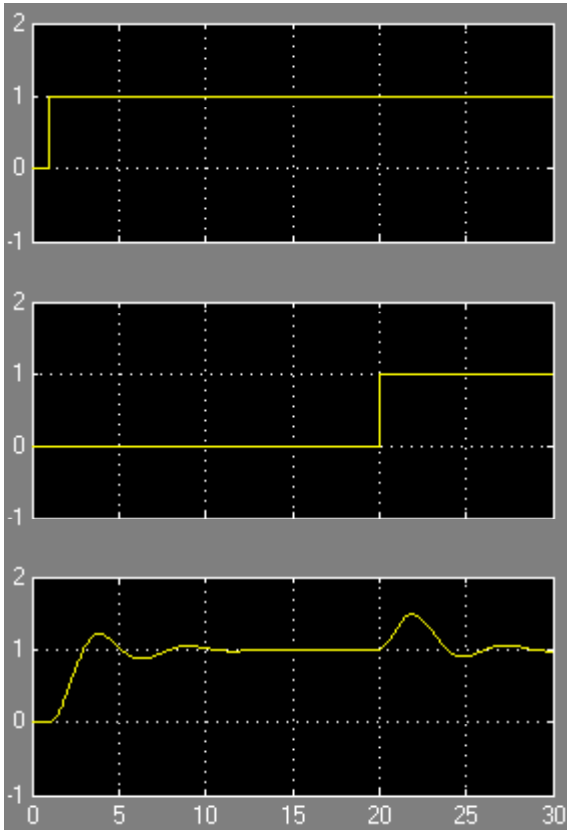
Regulatory problem

It is the ability to control the output at the desired level in the face of disturbances entering the process

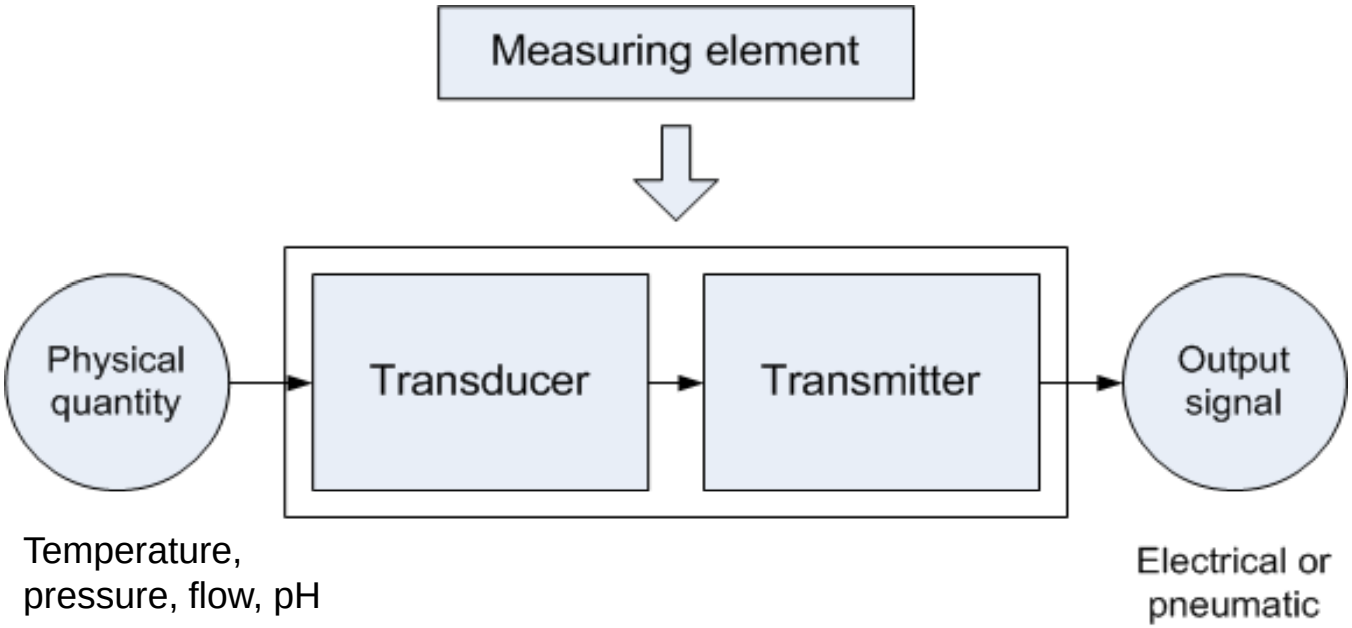
Set point

Load or disturbance

Output



Measuring element



- **Electrical output signal range**:
  - Voltage: 0-1V, 0-5V, 0-10V, 1-5V
  - Current: 0-1mA, 0-5mA, 0-10mA, 0-20mA, 4-20mA
- **Pneumatic output signal range**: 3-15psi

Transmitter gain

$$K_t = \frac{100\%}{\text{span of the transducer}}$$

Example: If a temperature transducer produces a full scale change in output for a change in temperature from 20˚C to 150˚C, the gain of the transmitter is

K_t = 100%/(150˚C -20˚C) = 100%/130˚C = 0.77%/˚C

For a 4-20mA output, 0% means 4 mA and 100% means 20 mA.

Temperature transmitters

Non-indicating (blind) transmitters

Indicating transmitter

Controller

Depending on construction controllers may be classified as

- **Electronic**
- **Pneumatic**

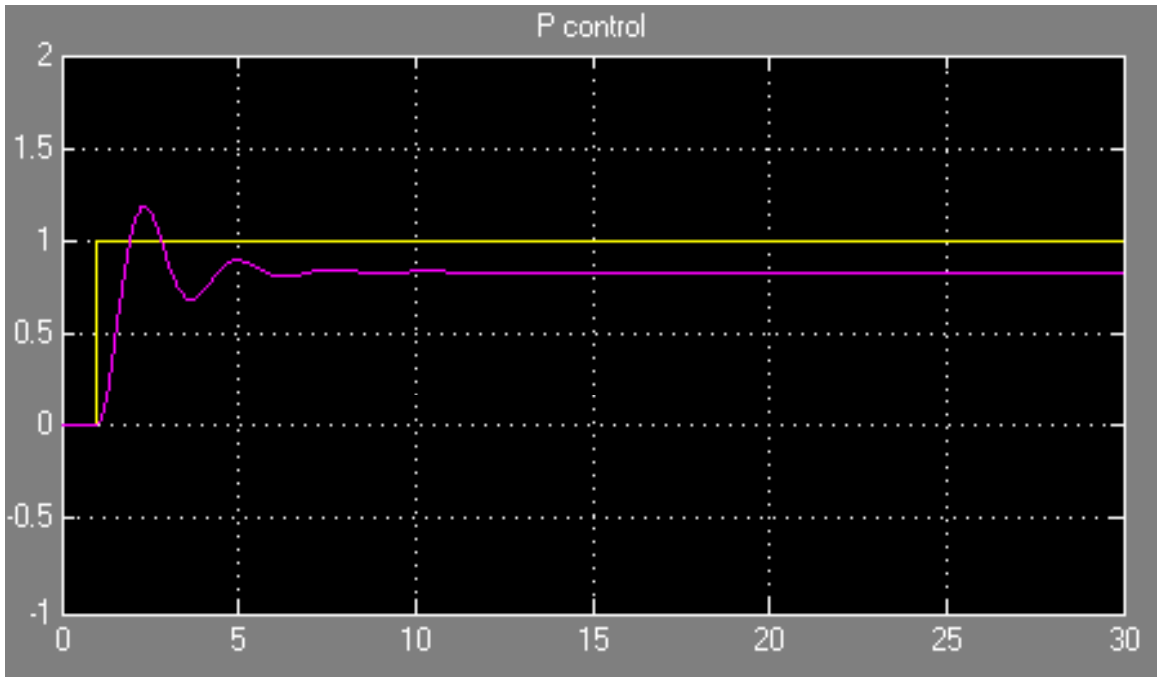
Depending on operation controllers may be classified as

- **Analog**
- **Digital**

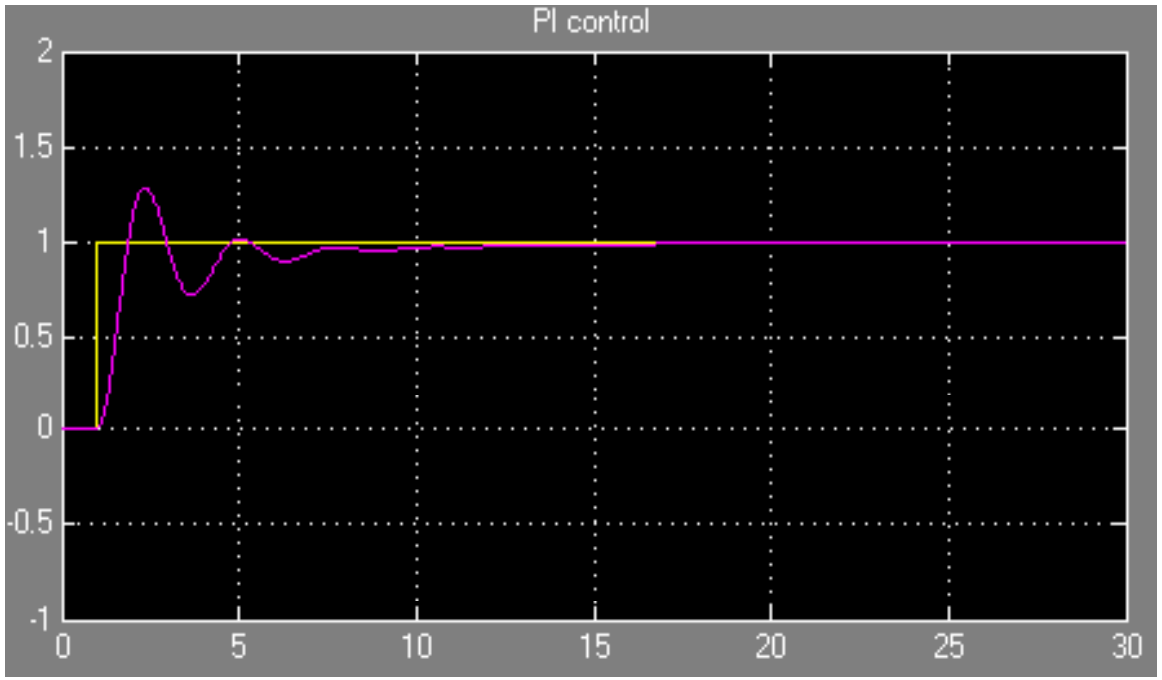
Different types of Controllers

- Proportional (P) controllers
- Proportional-integral (PI) controllers
- Proportional-derivative (PD) controllers
- Proportional-integral-derivative (PID) controllers
- On/Off controllers

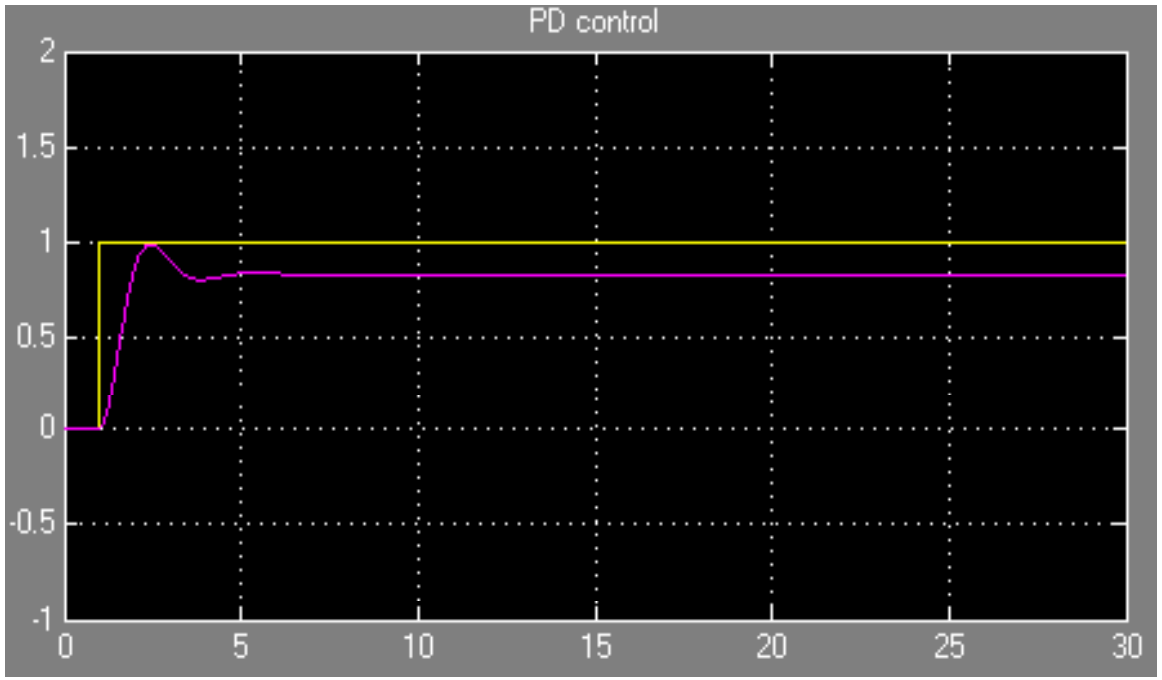
P-control



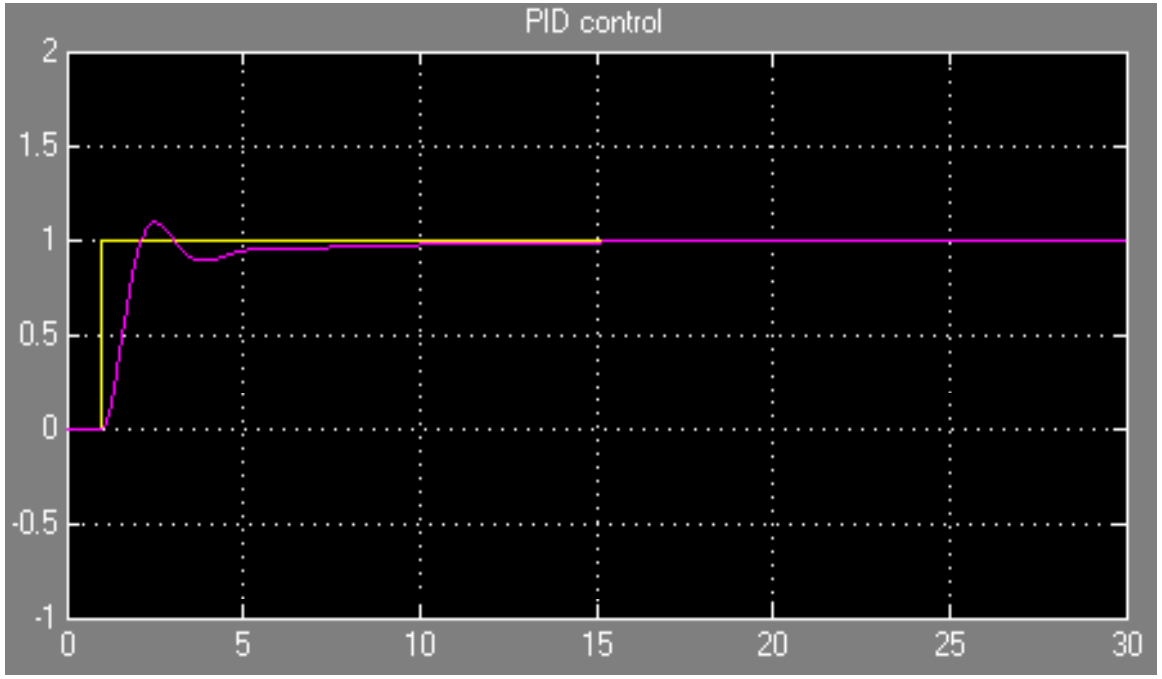
PI-control



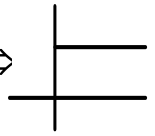
PD-control

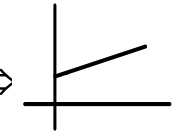


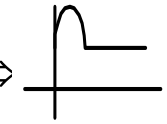
PID-control

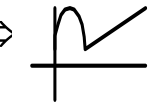


Controller symbol

P – controller – *for a step change in error* ⇒ 

PI – controller – *for a step change in error* ⇒ 

PD – controller – *for a step change in error* ⇒ 

PID – controller – *for a step change in error* ⇒ 

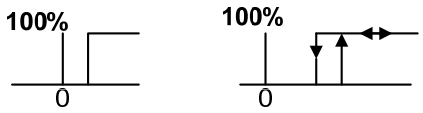
Controller gain

$$K_c = \frac{\text{Change in controller output}}{\text{Error}}$$

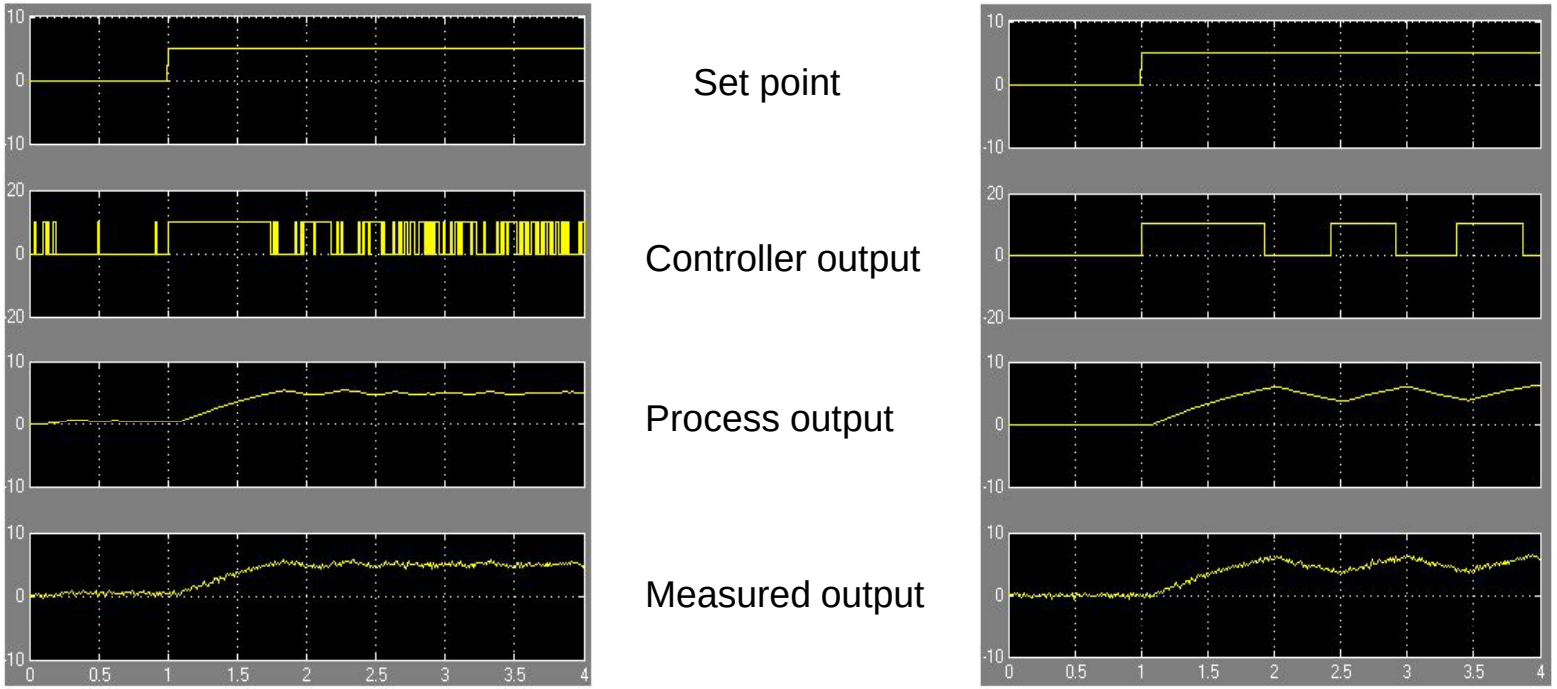
PID temperature controller

On/Off controllers

Two state with or without hysteresis:



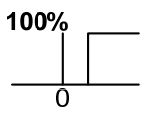
Without hysteresis With hysteresis

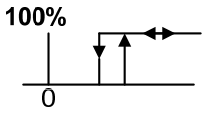


Without hysteresis **With hysteresis**

On/Off controllers

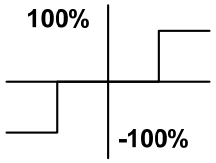
Two state with or without hysteresis:

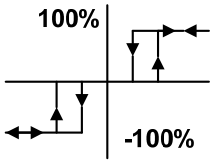




Without hysteresis With hysteresis

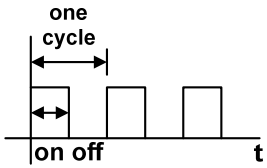
Three state with or without hysteresis:





Without hysteresis With hysteresis

Proportional time using PWM:



Final control element

It is the mechanism which alters the value of the manipulated variable in response to the output signal from the controller

- **Electric actuators**
  - **Motorized – rotary or linear**
  - **Solenoid operated**
- **Pneumatic actuators**
- **Electro-pneumatic actuators**
- **Hydraulic actuators**
  - **Piston**
  - **Diaphragm**
- **Control valves**
- **Heaters**
- **Burners**
- **Pumps**

Motorized rotary actuator

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  - Piston
  - Diaphragm
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- Pumps

Motorized linear actuator

Final control element

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- Electro-pneumatic actuators
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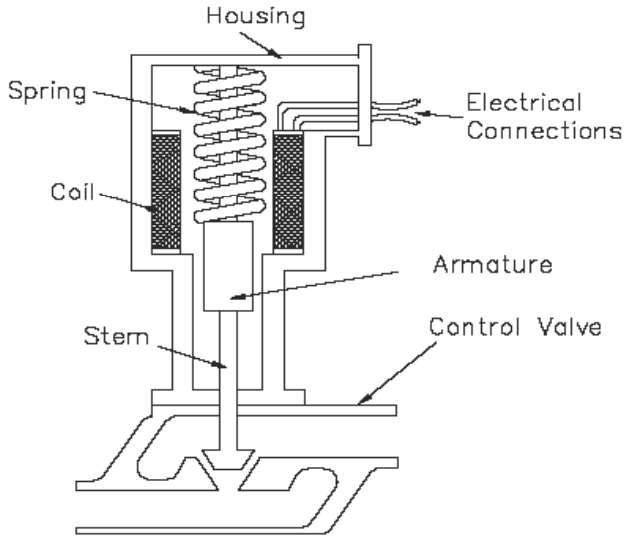
  - Piston
  - Diaphragm
- Control valves
- Heaters
- Burners
- Pumps



Solenoid operated actuator

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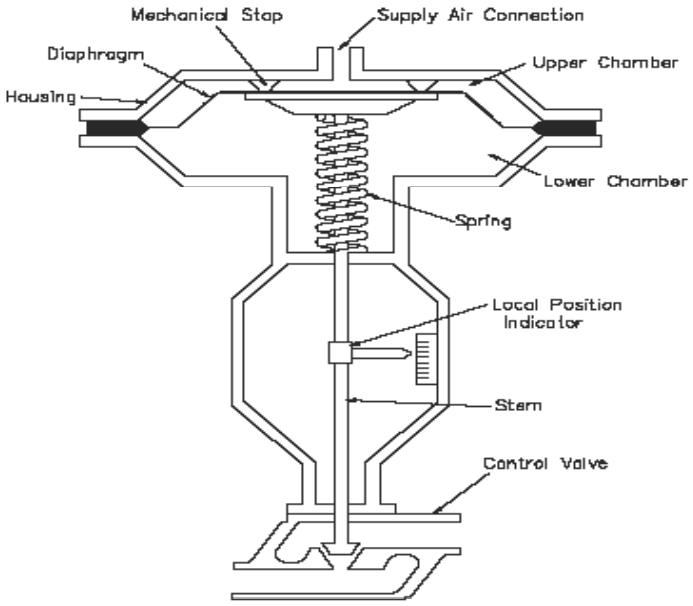
- Control valves
- Heaters
- Burners
- Pumps



Pneumatic actuator

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Pneumatic actuator

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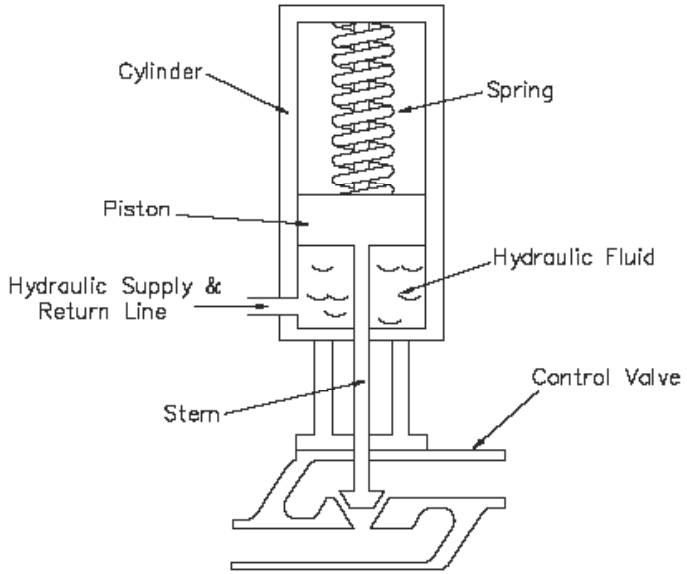

Hydraulic piston actuator

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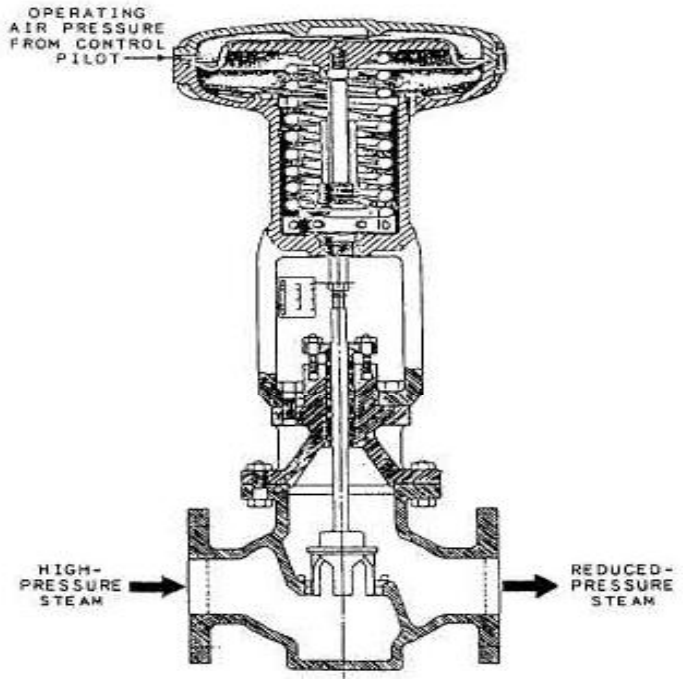
  - Diaphragm
- Control valves
- Heaters
- Burners
- Pumps



Diaphragm control valve

Final control element

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Diaphragm control valve

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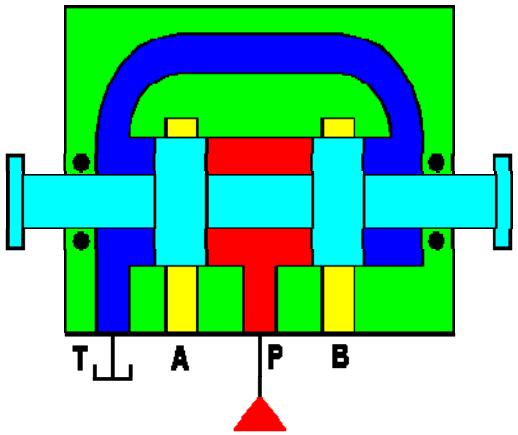

Direction control valve

Final control element

It is the mechanism which alters the value of the manipulated variable in response to the output signal from the controller

- Electric actuators
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  - Piston
  - Diaphragm
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Direction control valve

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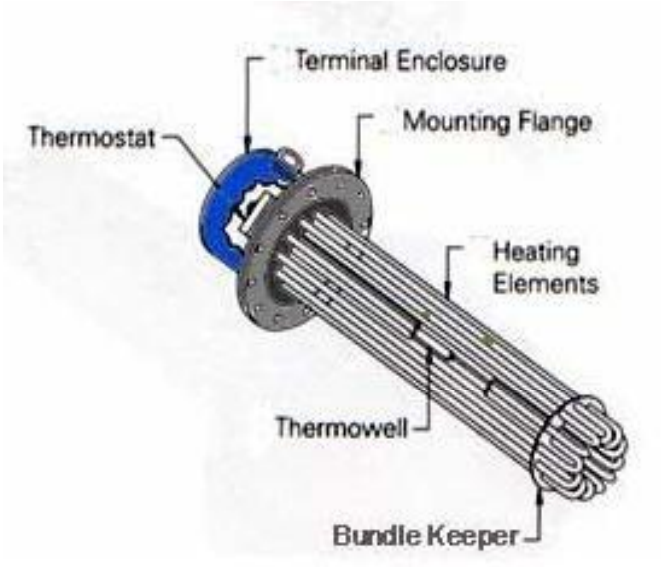

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  - Piston
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- Heaters
- Burners
- Pumps

Oil fired burner

Final control element

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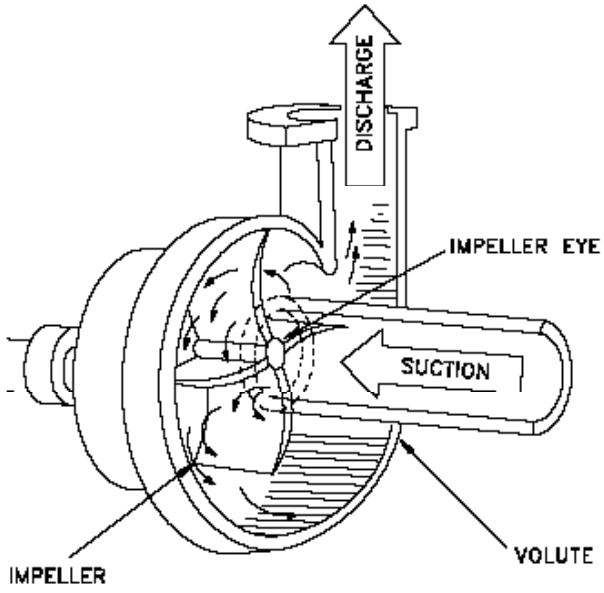

Centrifugal pump

Final control element

It is the mechanism which alters the value of the manipulated variable in response to the output signal from the controller

- Electric actuators
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- Pumps

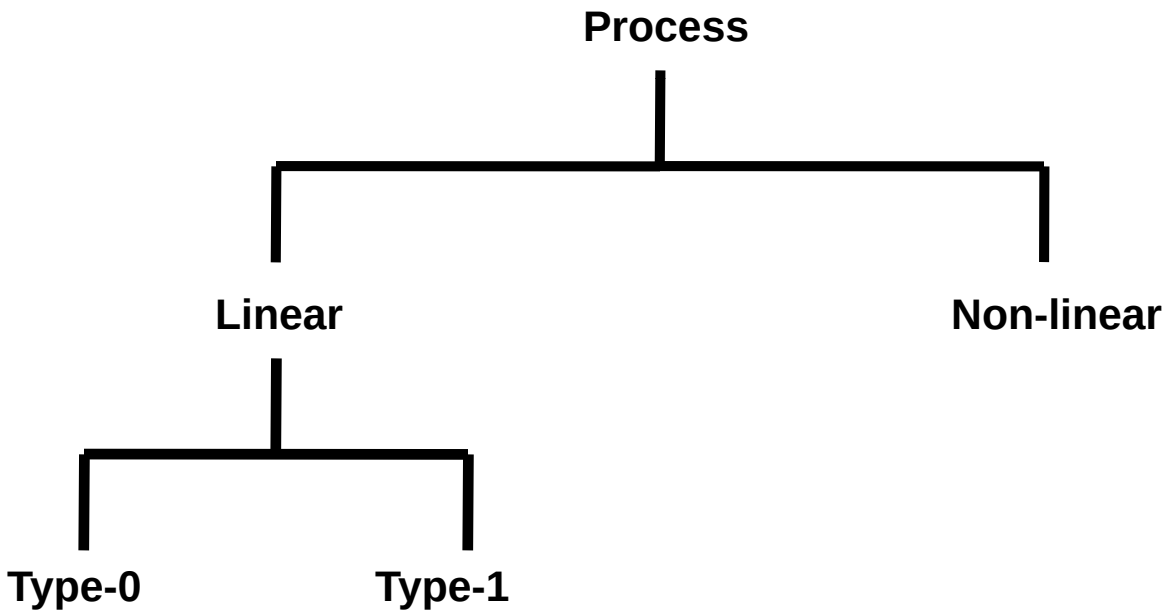
Centrifugal pump

Gain of the final control element

$$K_v = \frac{\text{span of the final control element}}{100\%}$$

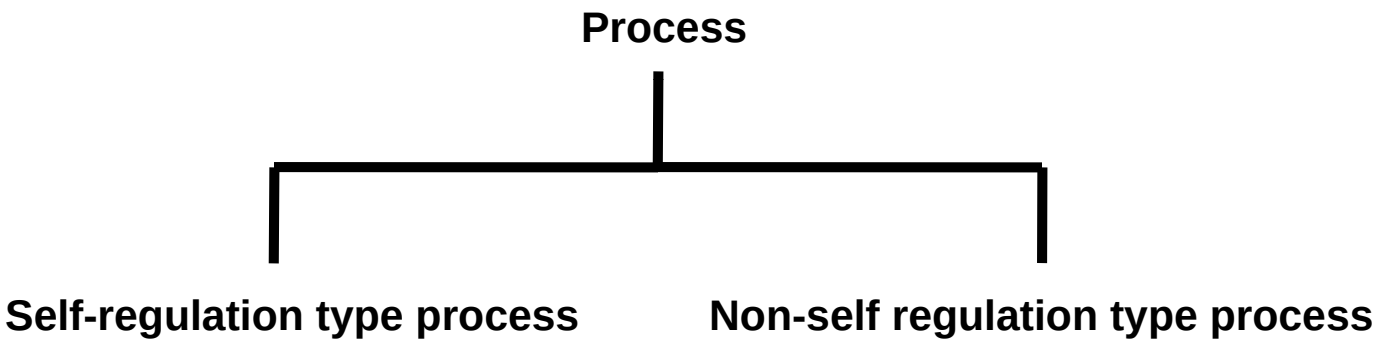
Process

A process may be characterized by its input-output relationship



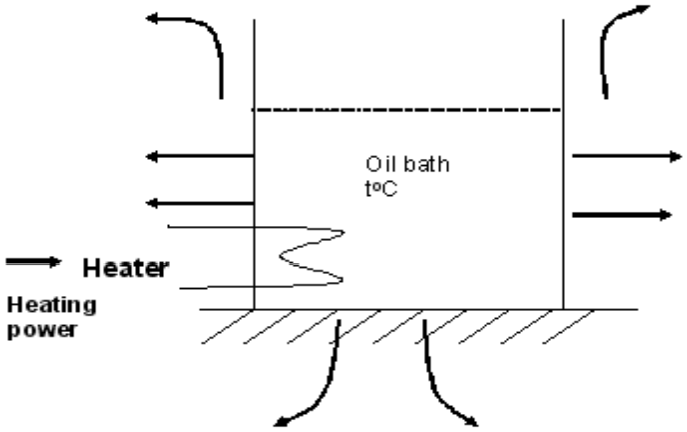
Process

A process may be characterized by its natural form of feedback

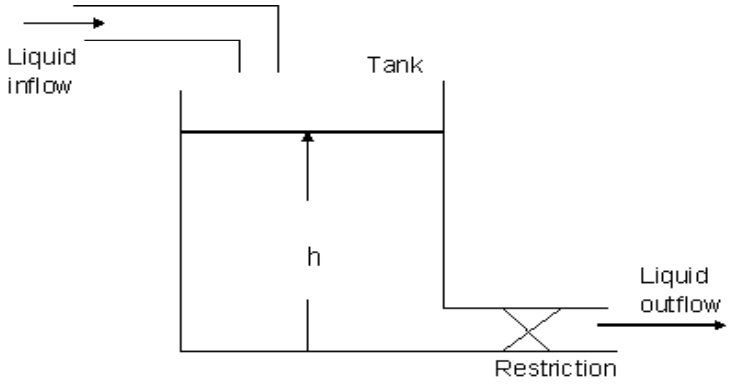


Self-regulation type processes

Heated oil bath



Liquid level in a tank



Self-regulation type processes

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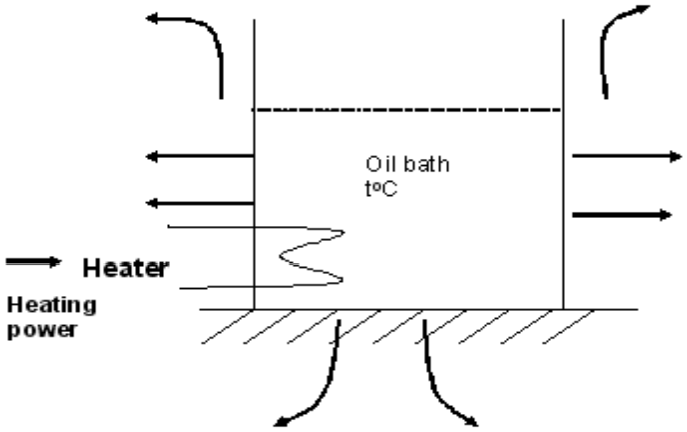
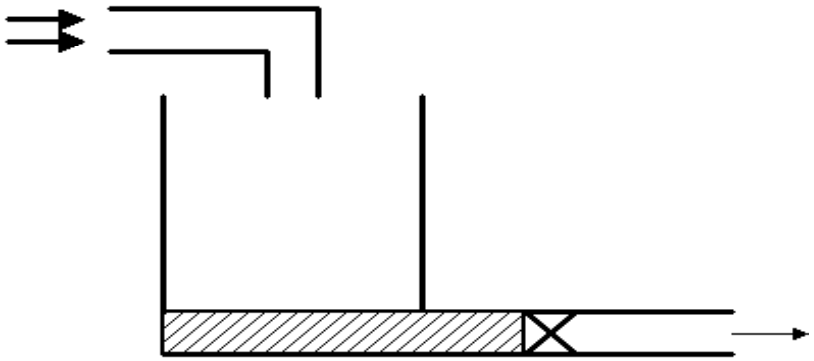
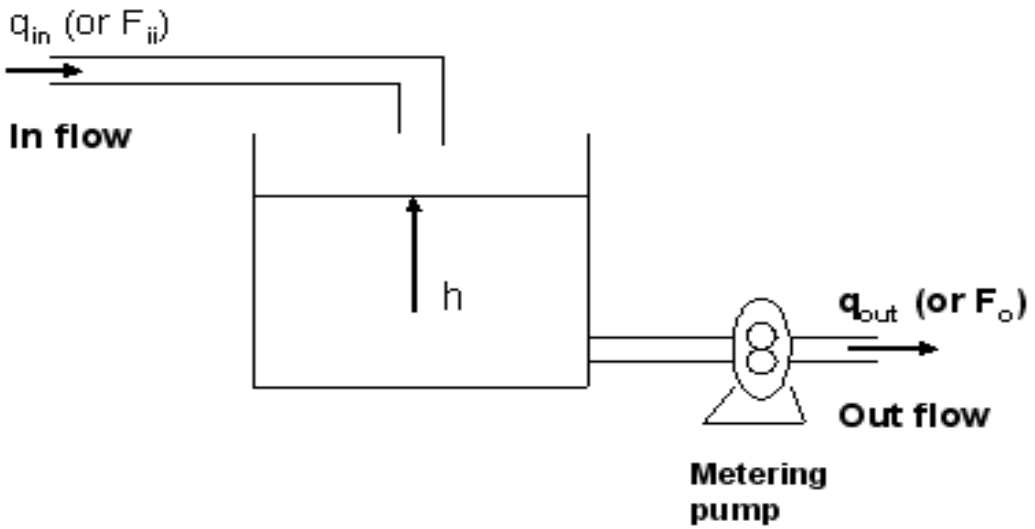


Liquid level in a tank

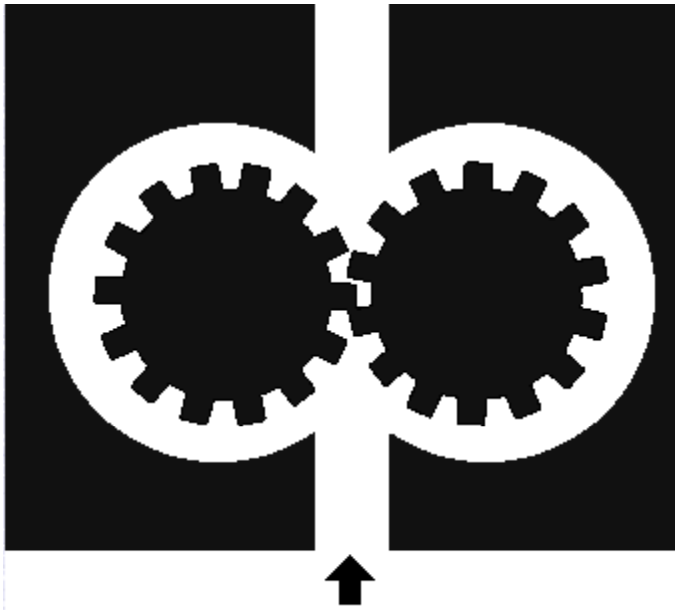


Non-self regulation type processes



Metering Pump

Out



In

Different types of processes

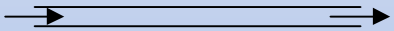
- Electrical
- Mechanical
- Thermal
- Liquid
- Gas
- In combination of above types

Process parameters

- Resistance or restriction

- Capacitance or capacity

- Dead time or transportation lag



- Lag – due to combination of resistance and capacitance
- Inductance – due to mass of fluid or liquid

Steady state gain of a process

$$K_p = \frac{\text{Change in output}}{\text{Change in actuating signal}} = \frac{\Delta c}{\Delta v}$$

Loop gain

The product ($K_t.K_v.K_p$) is a dimension less parameter. It is related to the gain of the controller which is again dimensionless.

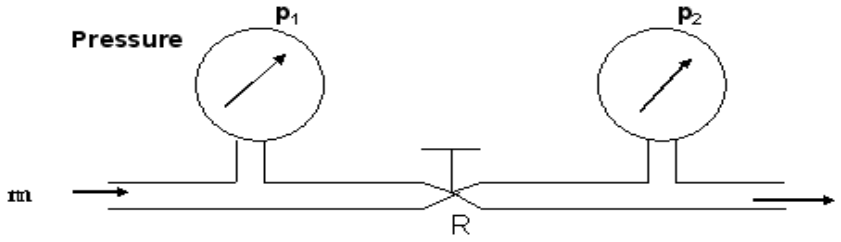
In a temperature control system (0-100°C), 10 KW:

$$K_t = \frac{100\%}{100^o C} \rightarrow \text{dimension } \frac{\%}{^o C}$$

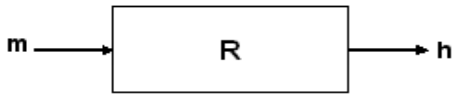
$$K_v = \frac{10KW}{100\%} \rightarrow \frac{W}{\%}$$

$$K_p = \frac{\Delta C}{\Delta V} = \frac{100^o C}{10KW} \rightarrow \frac{^o C}{W}$$

Process Examples

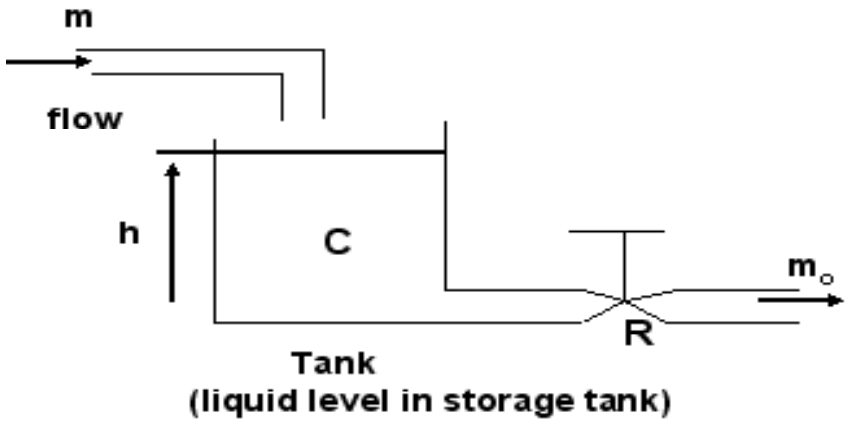


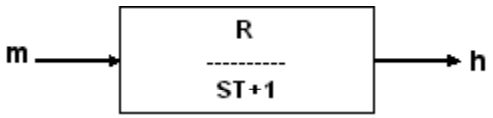
$h = p_1 - p_2$



Block diagram

$h = R\,m$



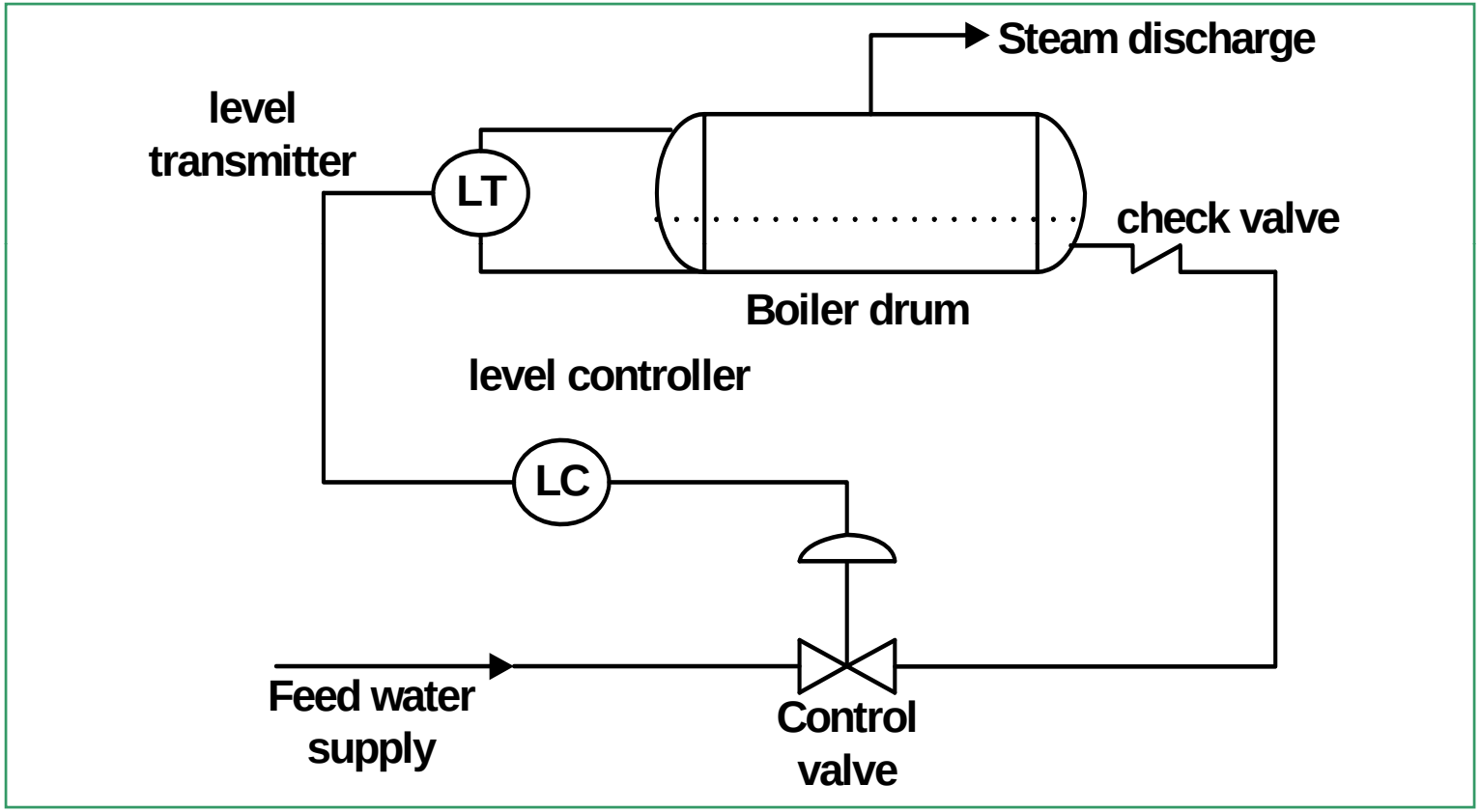


Block diagram

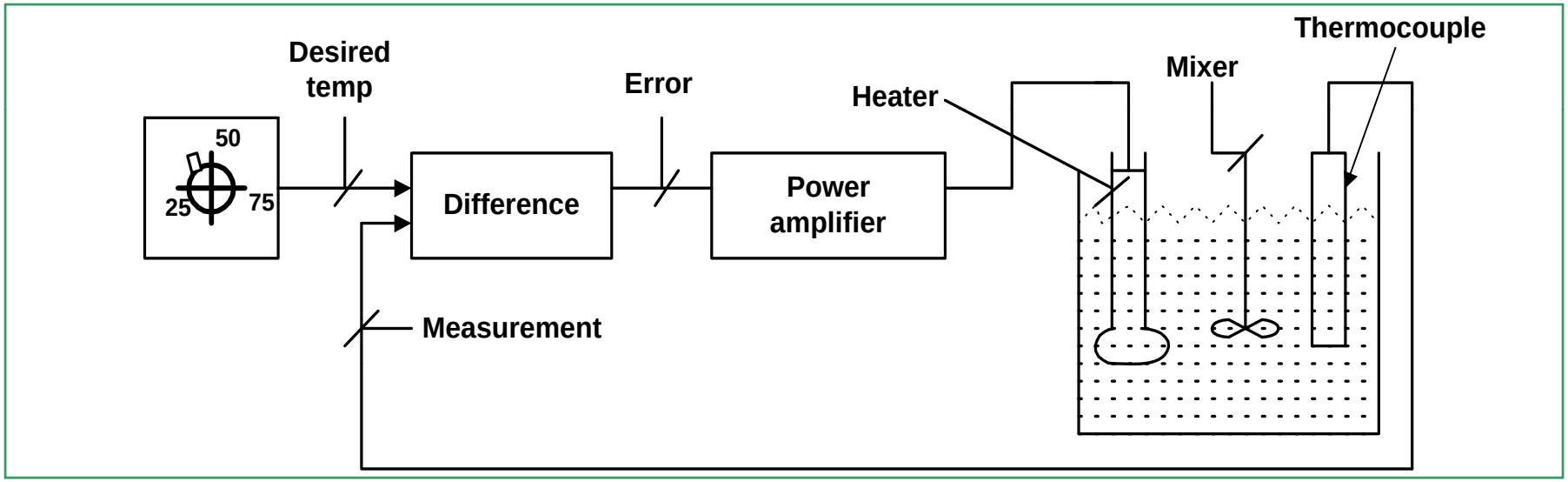
$$h = \left(\frac{R}{sT + 1} \right) m$$

$$T = RC$$

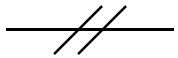
Boiler drum level control (inverse response)



Thermostat for water heating



Common Symbols



Pneumatic control signal

Capillary control signal

Electrical control signal

Gas / liquid pipeline

Restriction

Manual valve

Control valve

On-Off or solenoid type valve

Common Symbols

Locally mounted controller
X: pH
X: S - speed
X: T - temperature
X: L - level
X: P - pressure
X: F - flow

Board mounted controller, X: pH, S, T, L, P, F

Transmitter, X: pH, T, L, P, F, S

Switch, X: pH, T, L, P, F, S

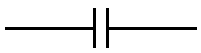
Differential pressure transmitter

Recorder controller, X: pH, T, L, P, F, S

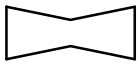
Common Symbols

Check valve

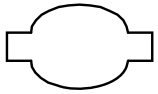
Relief valve



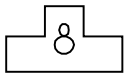
Orifice



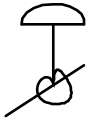
Nozzle or venturi



Magnetic flow meter

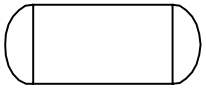


Turbine type flow meter

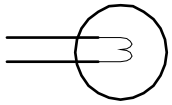


Controlled damper

Common Symbols

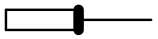


Vessel / reactor

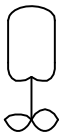


Heat exchanger

Oil-burner



Sensor / transducer



Motor stirrer

Pump

Common Symbols

Summer

Multiplier

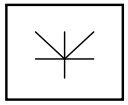
Square-root extractor

Low selector

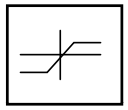
High selector

Divider

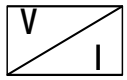
Common Symbols



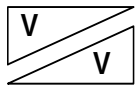
Absolute value



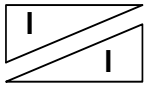
Saturation



Voltage-to-current or current-to-voltage converters



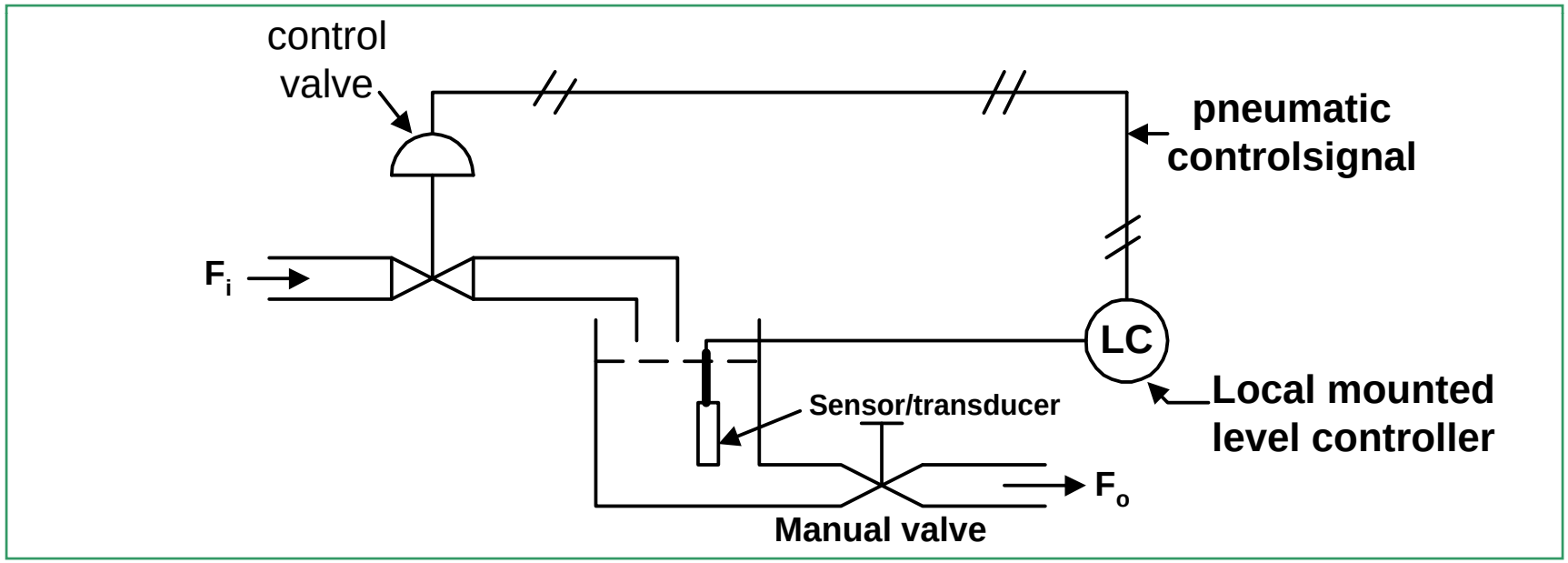
Voltage isolator



Current isolator

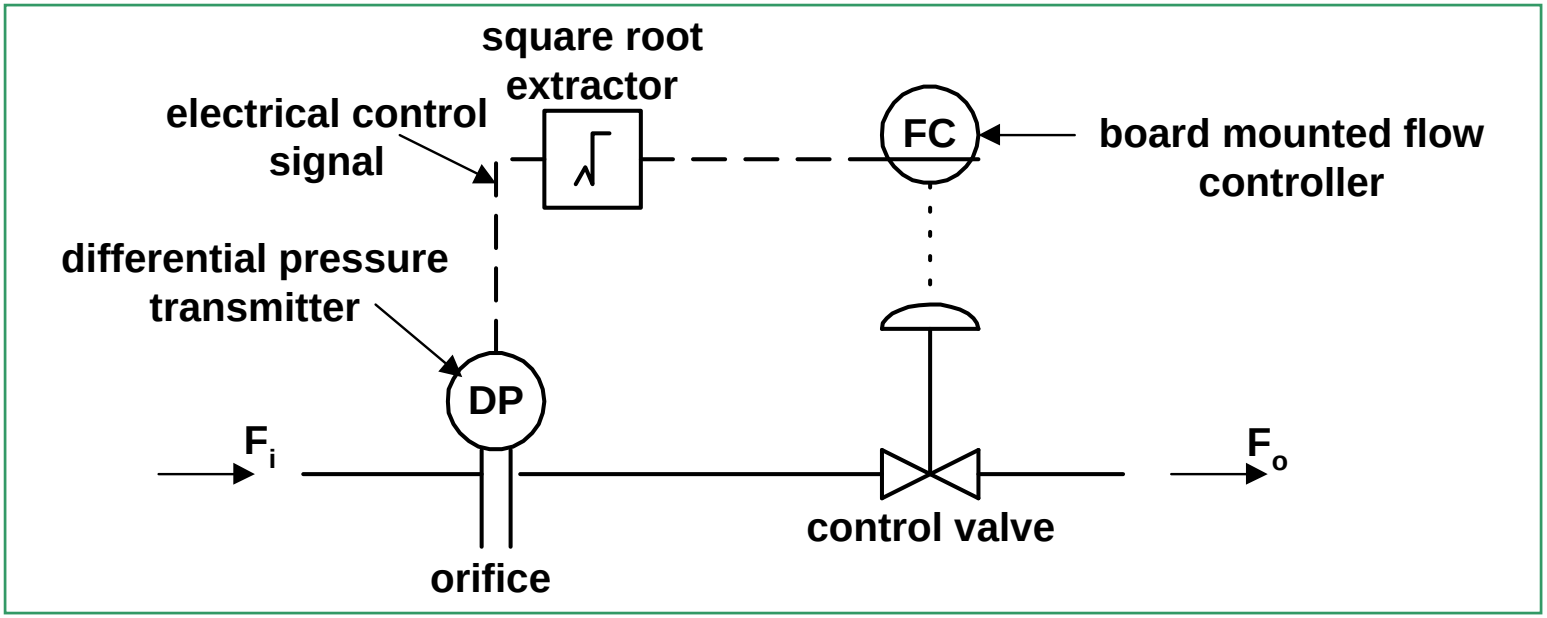
Process instrumentation diagrams

Liquid level control with a local pneumatic level controller



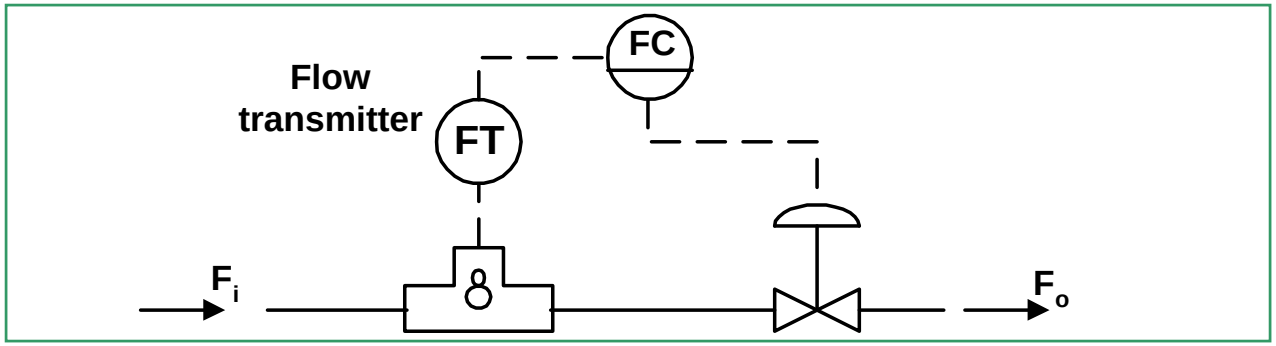
Process instrumentation diagrams

Flow control system with electronic flow controller



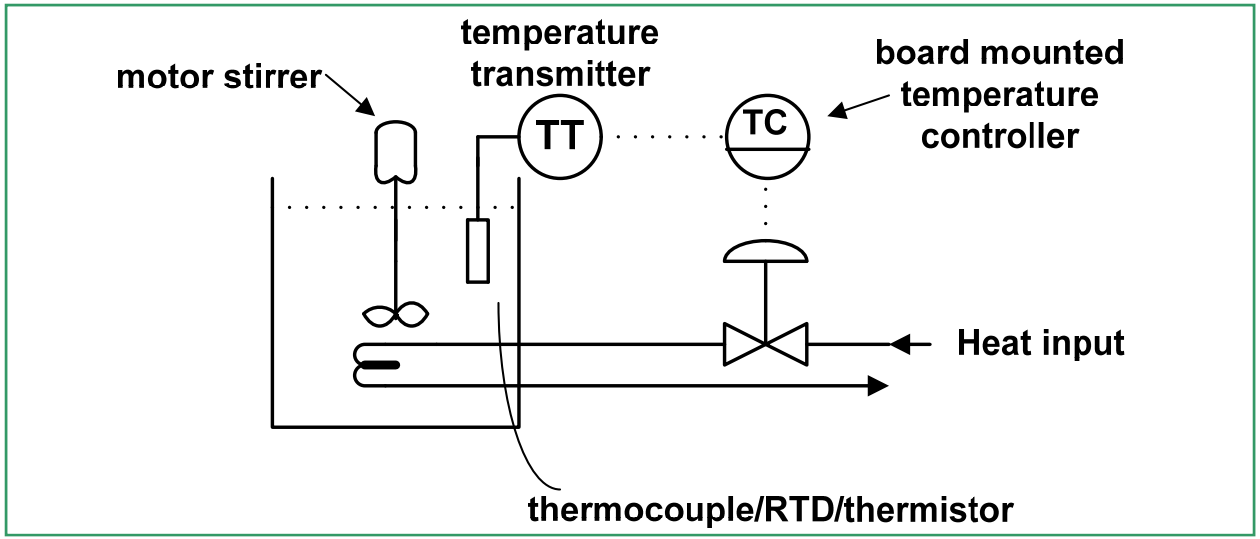
Process instrumentation diagrams

Flow control with a turbine flow meter



Process instrumentation diagrams

Temperature controlled stirred tank



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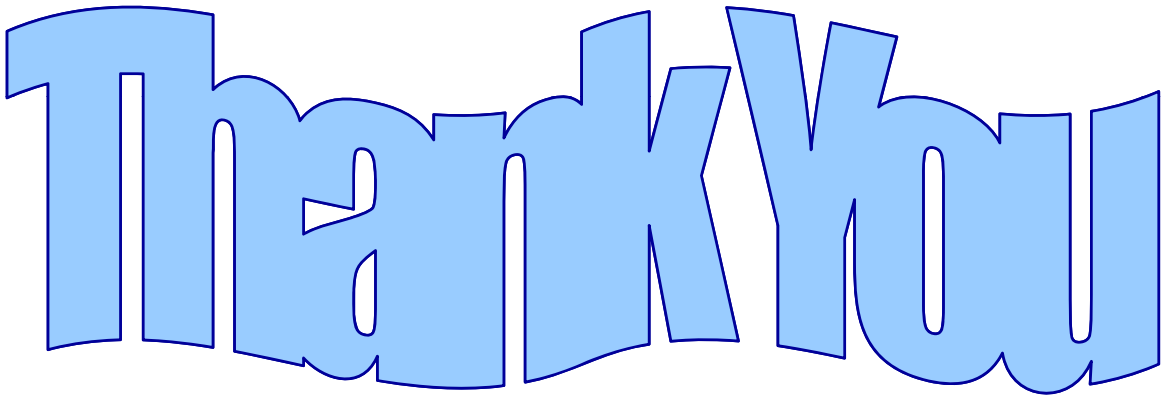
2. **Automatic Process Control** *by* Eckman
3. **Principles of Process Control** *by* Patranabis
4. **Process Control** *by* Harriott
5. **Process Systems Analysis and Control** *by* Coughanowr and Koppel
6. **Process Control** *by* Pollard
7. **Chemical Process Control** *by* Stephanopoulos
8. **Modern Control Engineering** *by* Ogata
9. **Applied Process Control** *by* Chidambaram


ThankYou