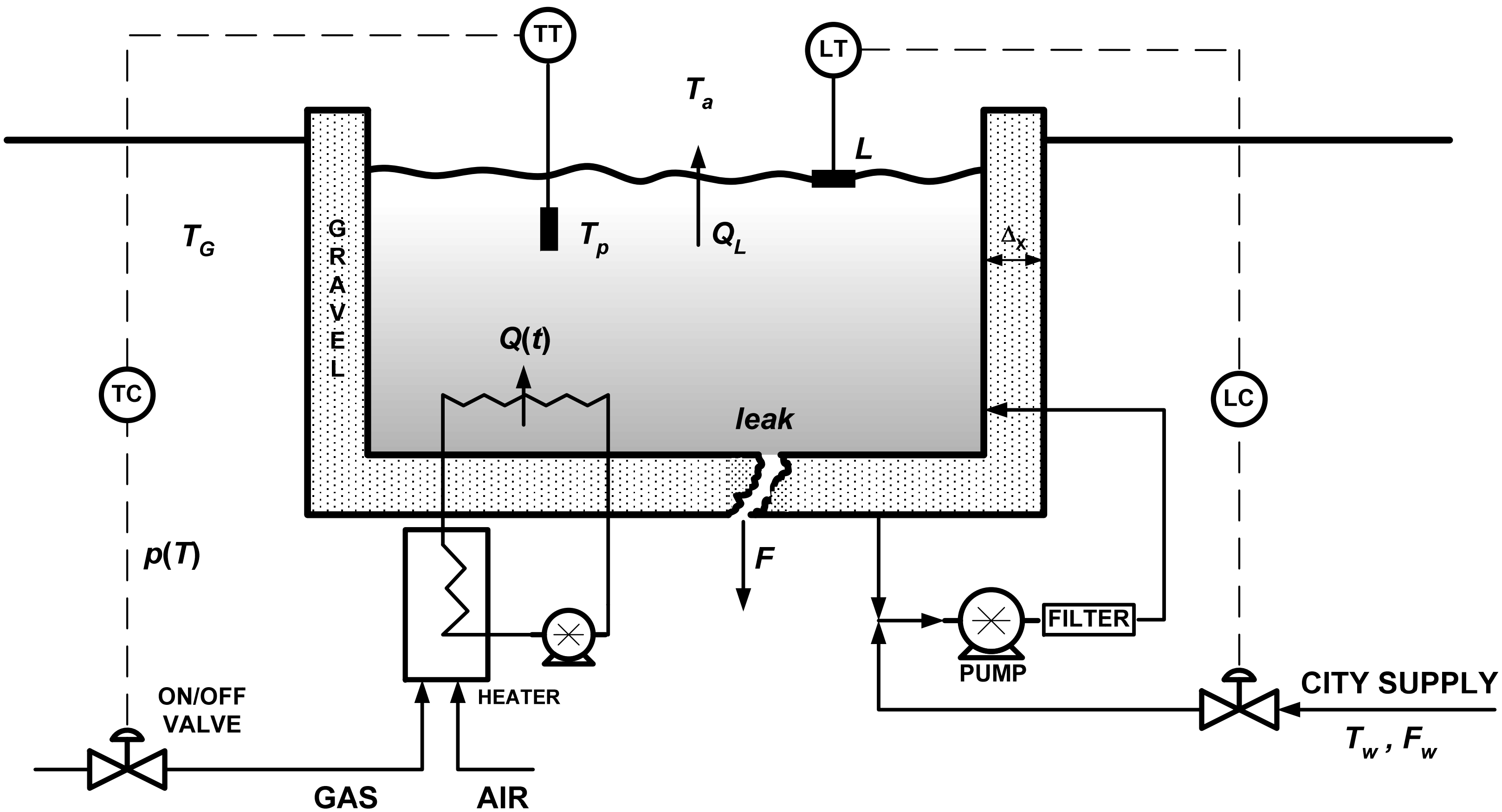
Process Dynamics

Class 3

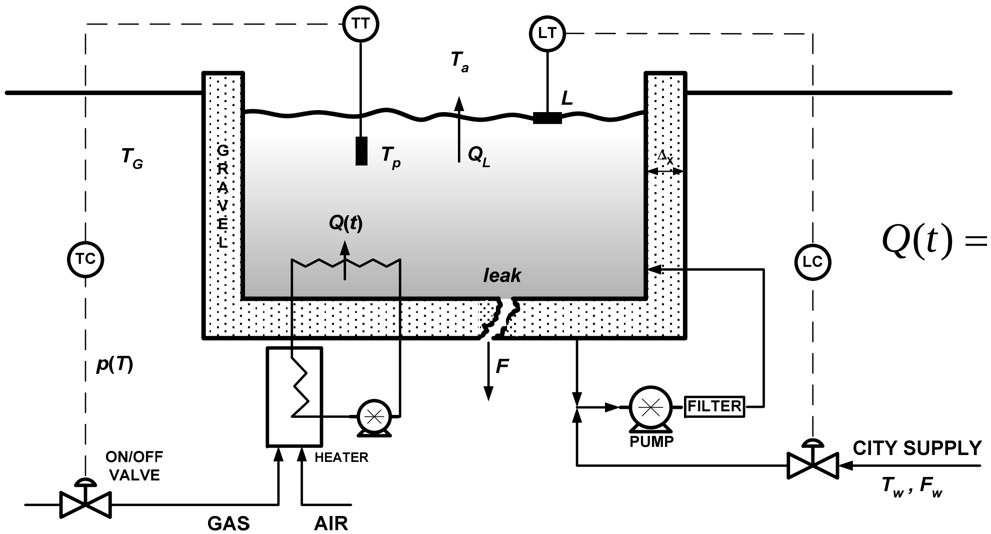
1.8. Homework Review



Outputs: T_p, L(level)
Inputs: $Q(t)$, F_w
Disturbances: T_w, T_a

$$Q(t) = UA(T_p - T_a) + k_G \frac{(T_p - T_G)}{\Delta x} + F_w \rho C(T_p - T_w)$$

1.8. Dynamic Energy Balance



$$Q(t) = UA(T_p - T_a) + k_G \frac{(T_p - T_G)}{\Delta x} + F_w \rho C(T_p - T_w)$$

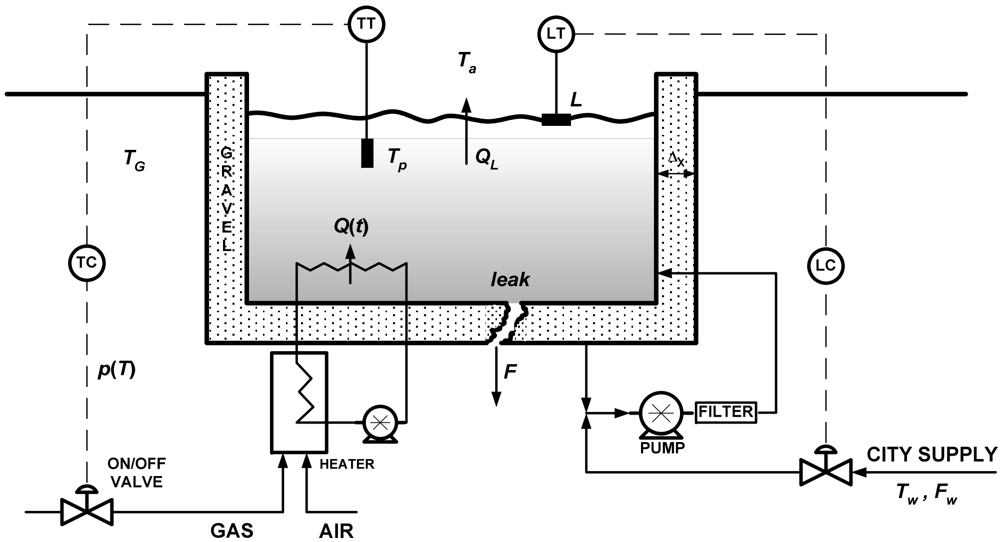
Accumulation = In – Out + Gen - Cons

$$\frac{\partial h}{\partial t} = Q(t) - UA(T_p - T_a) - k_G \frac{(T_p - T_G)}{\Delta x} - F_w \rho C(T_p - T_w)$$

$$\frac{\partial mC\left(T_p - T_{ref}\right)}{\partial t} = Q(t) - UA(T_p - T_a) - k_G \frac{(T_p - T_G)}{\Delta x} - F_w \rho C(T_p - T_w)$$

$$mC\frac{\partial T_p}{\partial t} + C\left(T_p - T_{ref}\right)\underbrace{\frac{\partial m}{\partial t}}_{0} = Q(t) - UA(T_p - T_a) - k_G \frac{(T_p - T_G)}{\Delta x} - F_w \rho C(T_p - T_w)$$

1.8. FOPDT Model



$$\tau \frac{\partial x}{\partial t} = -x + Ku(t-\theta)$$

$$\tau = \text{Time constant}$$

$$K = \text{Gain}$$

$$\theta = \text{Dead-time}$$

Assume Ta = Tp and Tg = Tp

$$mC\frac{\partial T_p}{\partial t} = Q(t) - F_w \rho C(T_p - T_w)$$

$$\frac{mC}{F_w \rho C}\frac{\partial T_p}{\partial t} = -T_p + \frac{Q(t)}{F_w \rho C} + T_w$$

$$\tau \frac{\partial x}{\partial t} = -x + K_u u + K_d d$$

$$\tau = \text{Time constant}$$

$$K_u = \text{Manipulated Variable Gain}$$

$$K_d = \text{Disturbance Gain}$$

Lab Project

- Objective: Hands on control experiment
  - Collect data and develop model
  - Reinforce the concepts taught in class about:
    - process time constants
    - controller tuning constants
  - Write executive summary (2 pages max) & present (5 min)
- 5 Lab Options
  - Gravity Drained Tank
  - Shell and Tube Heat Exchanger
  - Flow Control on Pipes and Fittings
  - Finned Tube Heat Exchanger
  - NEW Your Choice of System

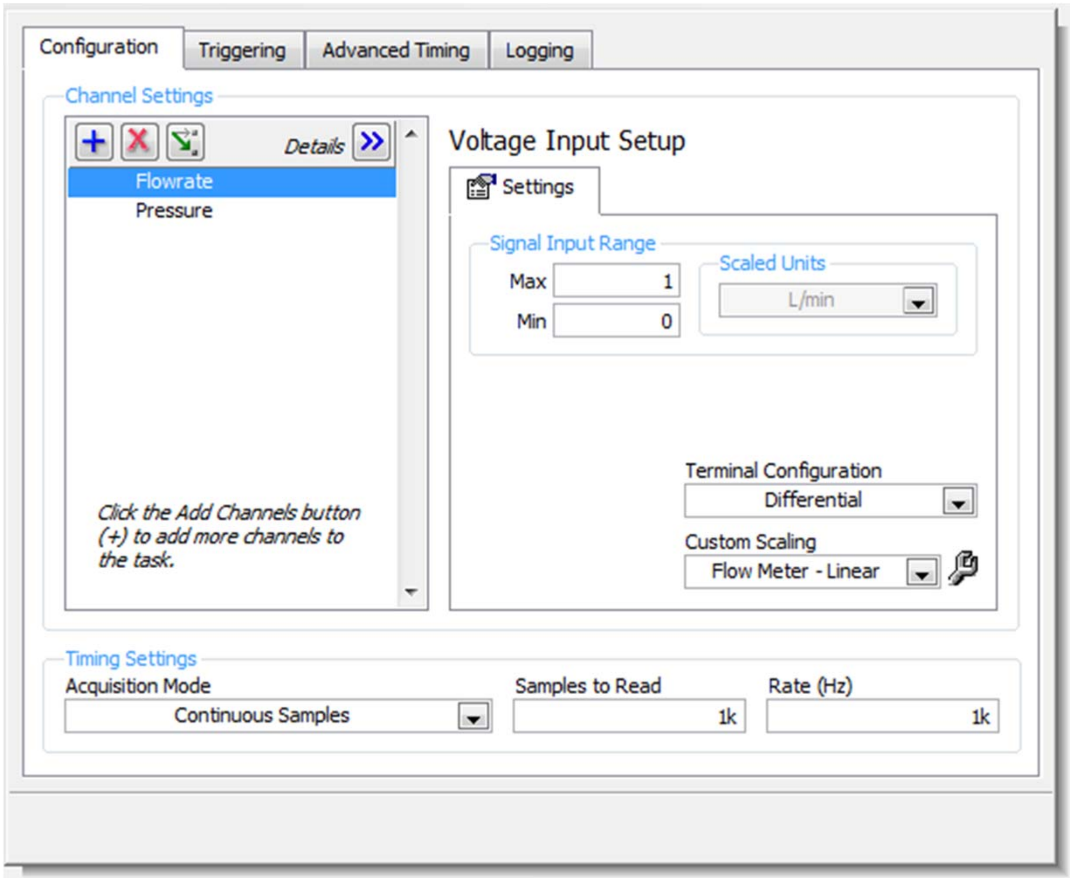
Lab Project Ideas

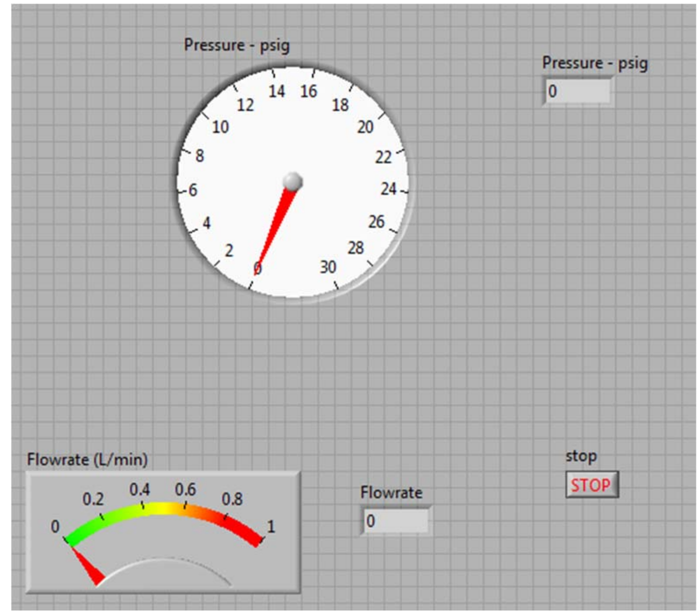
- Hot Chocolate Temperature Control
  - Actuator: Resistor
  - Measurement: Thermocouple
  - Controller: LabView

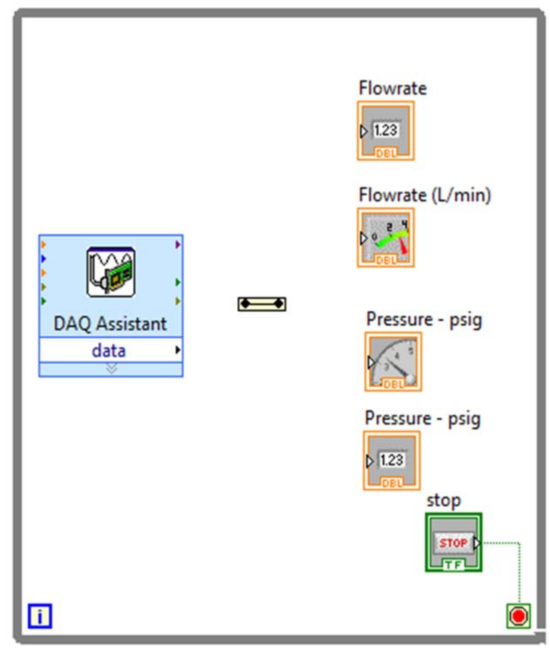
Temperature	Flow	Pressure	Level
Thermocouple Thermister Resistance Temperature Detector (RTD)	Orifice Venturi Rotameter Turbine Vortex-shedding Thermal mass	Bourdon tube Diaphragm Bellows Strain gauge Piezoelectric Piezoresistive	Fload Head device Electrical conductivity

- Your Own Project:
  - Actuator: ______________________
  - Measurement: ______________________
  - Controller: ______________________

LabView Example (ChE 475)





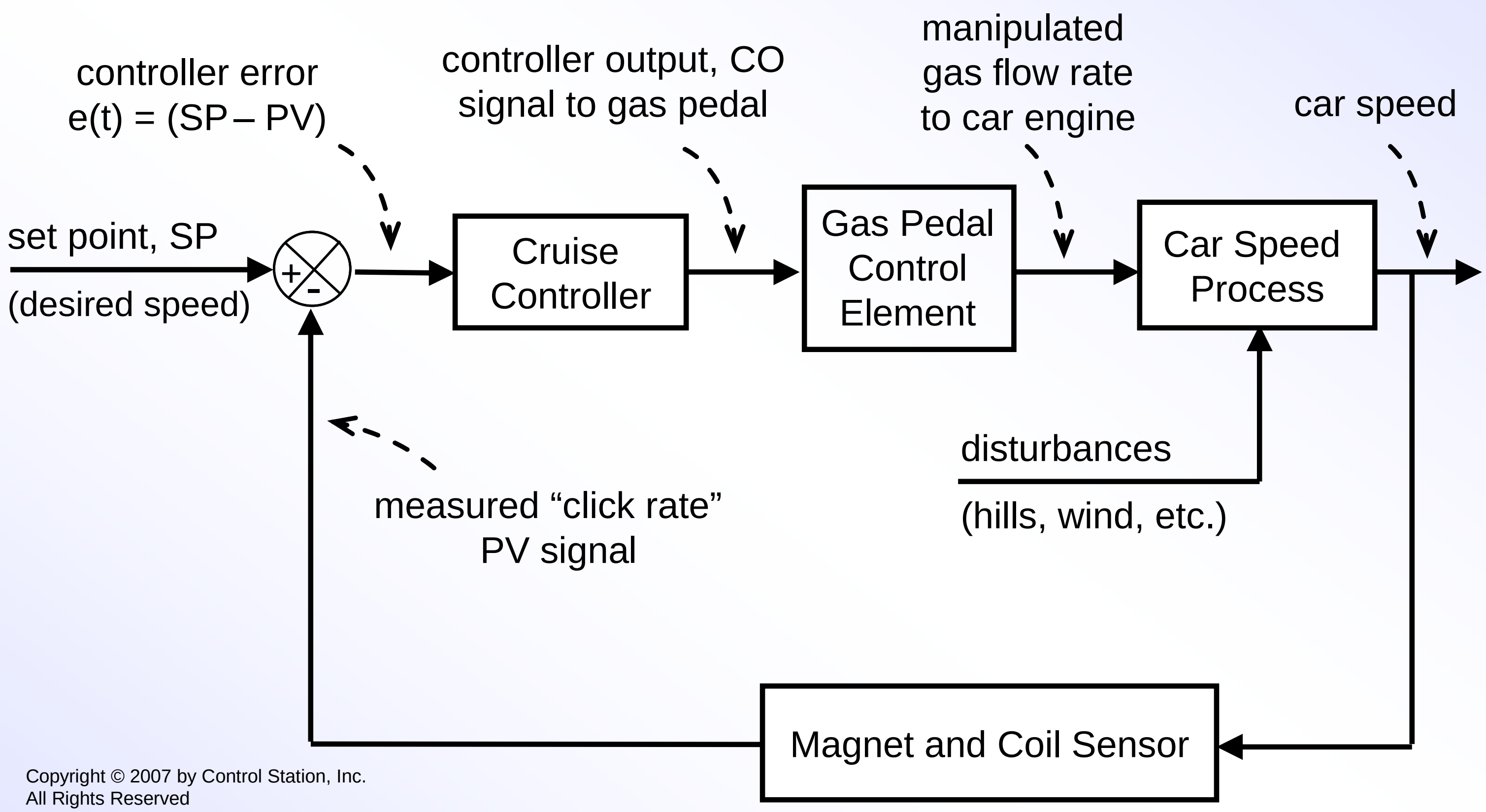


Thought Experiment: Cruise Control in a Car

- Control Objective:
  - maintain car velocity
- Measured Process Variable (PV):
  - car velocity ("click rate" from transmission rotation)
- Manipulated Variable:
  - pedal angle, flow of gas to engine
- Controller Output (CO):
  - signal to actuator that adjusts gas flow
- Set point (SP):
  - desired car velocity
- Disturbances (D):
  - hills, wind, curves, passing trucks....

control station

Cruise Control Block Diagram



The PID Controller

$$OP = OP_{bias} + K_c e(t) + \frac{K_c}{\tau_I} \int e(t)dt - K_c \tau_D \frac{\partial PV}{\partial t}$$

where:

- OP = controller output signal (also seen as CO in PPC)
- OP_{bias} = controller bias or null value
- PV = measured process variable
- SP = set point
- e(t) = controller error = SP – PV
- Kc = controller gain (a tuning parameter)
- τ_I = controller reset time (a tuning parameter)
- τ_D = controller derivative action (a tuning parameter)

- τ_I is in denominator so smaller values provide a larger weighting to the integral term
- τ_I and τ_D have units of time and are always positive