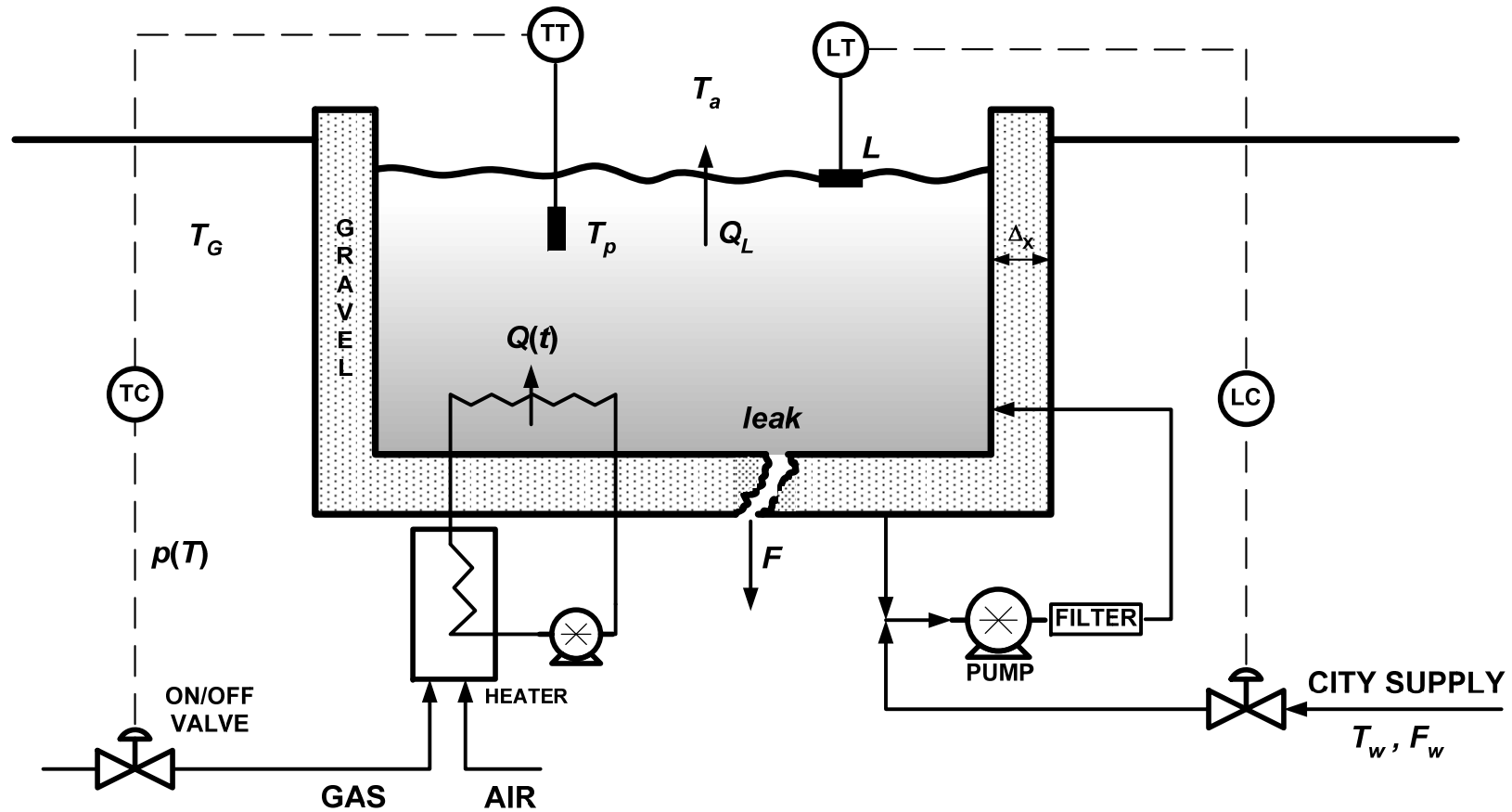


Process Dynamics

Class 3

1.8. Homework Review



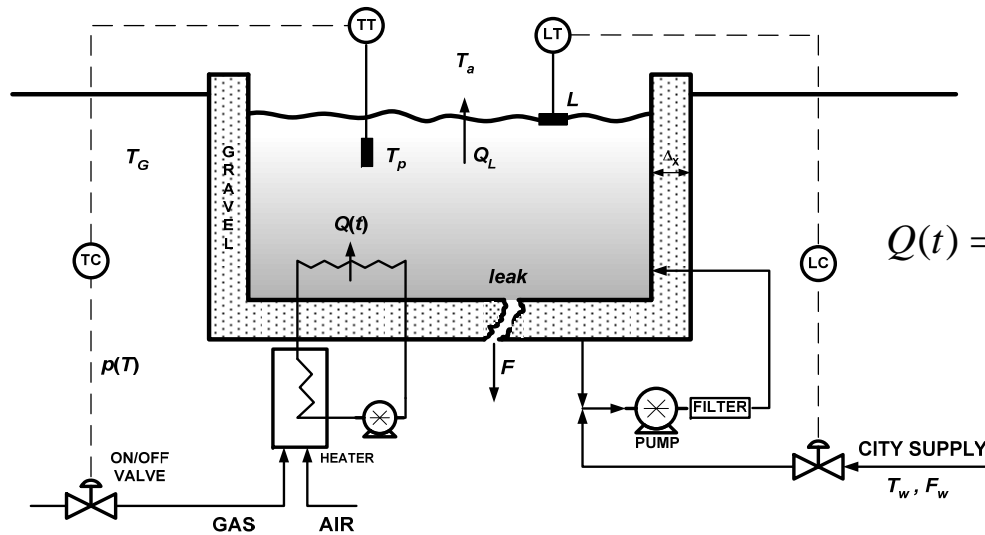
Outputs: T_p , L (level)

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



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

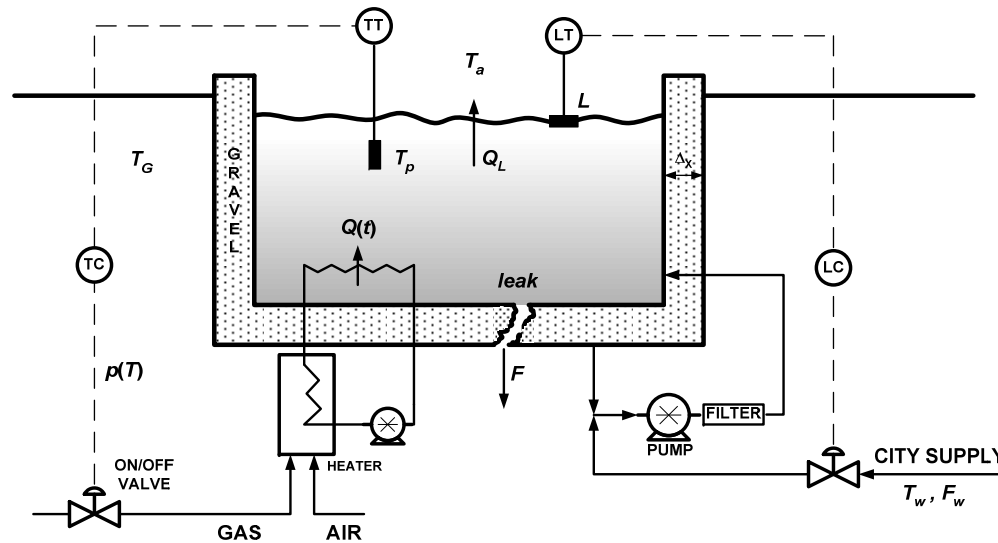
Accumulation = In - Out + Gen - Cons

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

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

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

1.8. FOPDT Model



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

τ = Time constant

K = Gain

θ = Dead - time

Assume $T_a = T_p$ and $T_g = T_p$

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

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


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

τ = Time constant

K_u = Manipulated Variable Gain

K_d = 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
 -  Your Choice of System

Lab Project Ideas

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

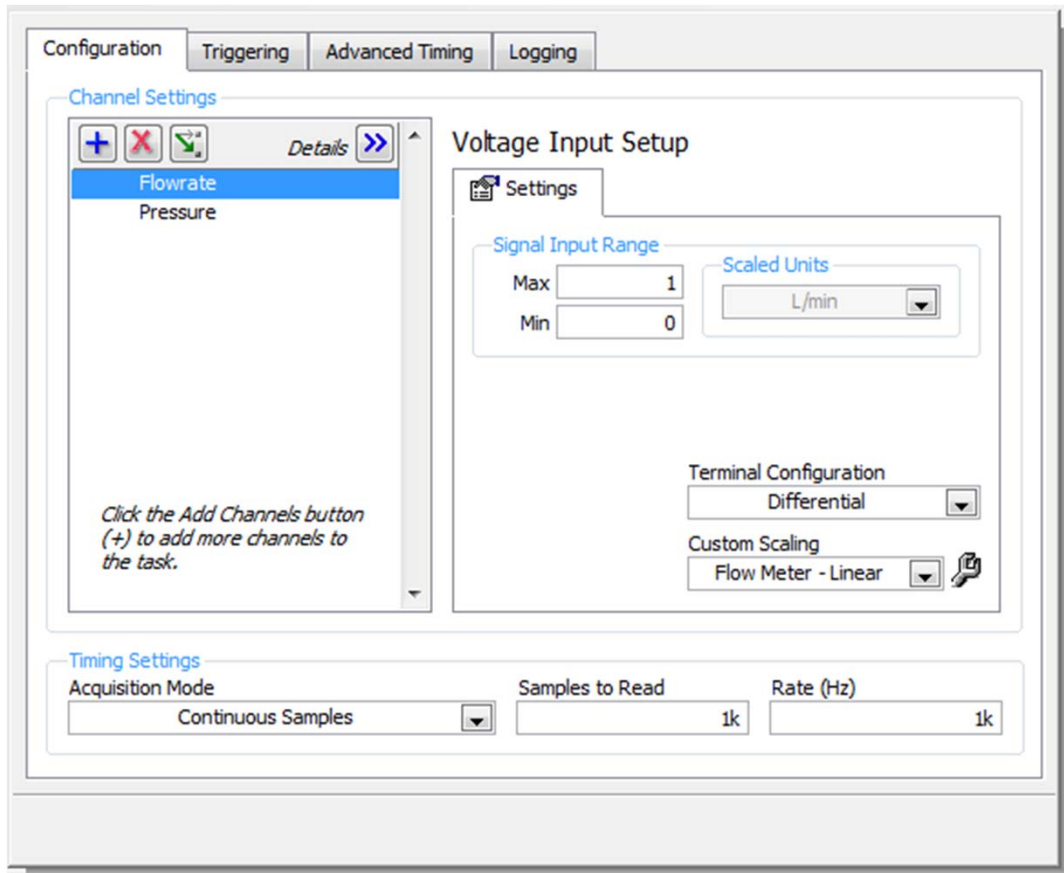


Temperature	Flow	Pressure	Level
Thermocouple	Orifice	Bourdon tube	Flood
Thermister	Venturi	Diaphragm	Head device
Resistance Temperature Detector (RTD)	Rotameter	Bellows	Electrical conductivity
	Turbine	Strain gauge	
	Vortex-shedding	Piezoelectric	
	Thermal mass	Piezoresistive	

- Your Own Project:

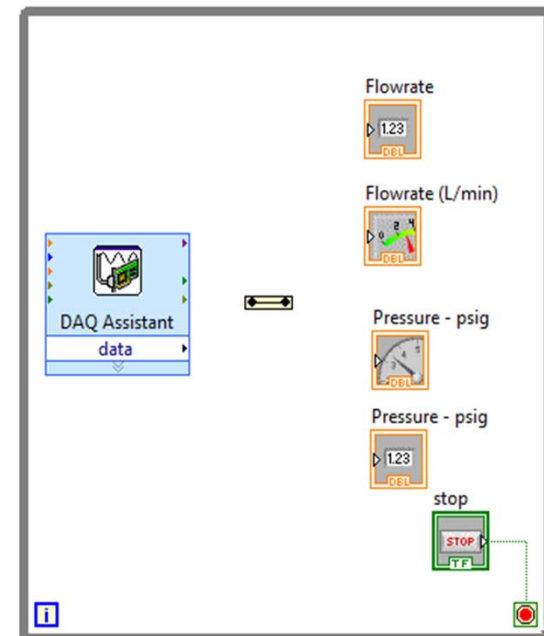
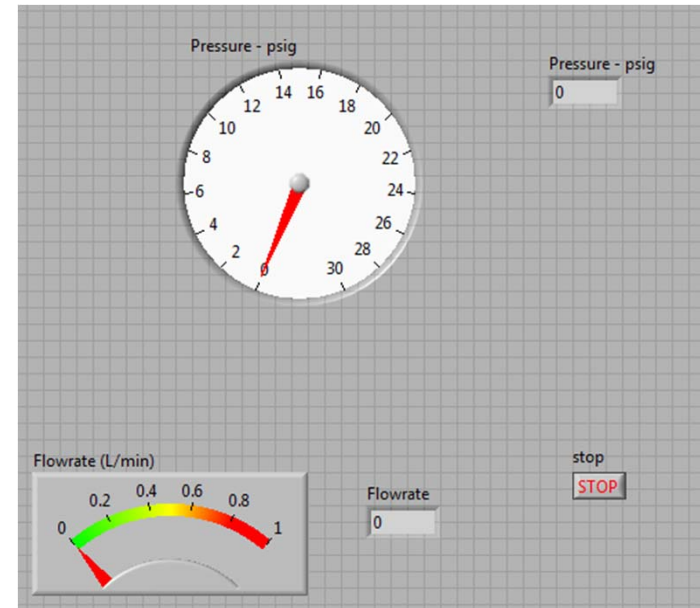
- Actuator: _____
- Measurement: _____
- Controller: _____

LabView Example (ChE 475)



The Configuration Panel is divided into several sections:

- Configuration:** Includes tabs for Triggering, Advanced Timing, and Logging.
- Channel Settings:** Features a list of channels with 'Flowrate' and 'Pressure' selected. A 'Details' button is next to the list. A note at the bottom says: "Click the Add Channels button (+) to add more channels to the task."
- Voltage Input Setup:** Contains a 'Settings' sub-panel with:
 - Signal Input Range:** Max value set to 1, Min value set to 0.
 - Scaled Units:** A dropdown menu currently set to 'L/min'.
 - Terminal Configuration:** A dropdown menu set to 'Differential'.
 - Custom Scaling:** A dropdown menu set to 'Flow Meter - Linear'.
- Timing Settings:** Includes fields for 'Acquisition Mode' (set to 'Continuous Samples'), 'Samples to Read' (set to '1k'), and 'Rate (Hz)' (set to '1k').

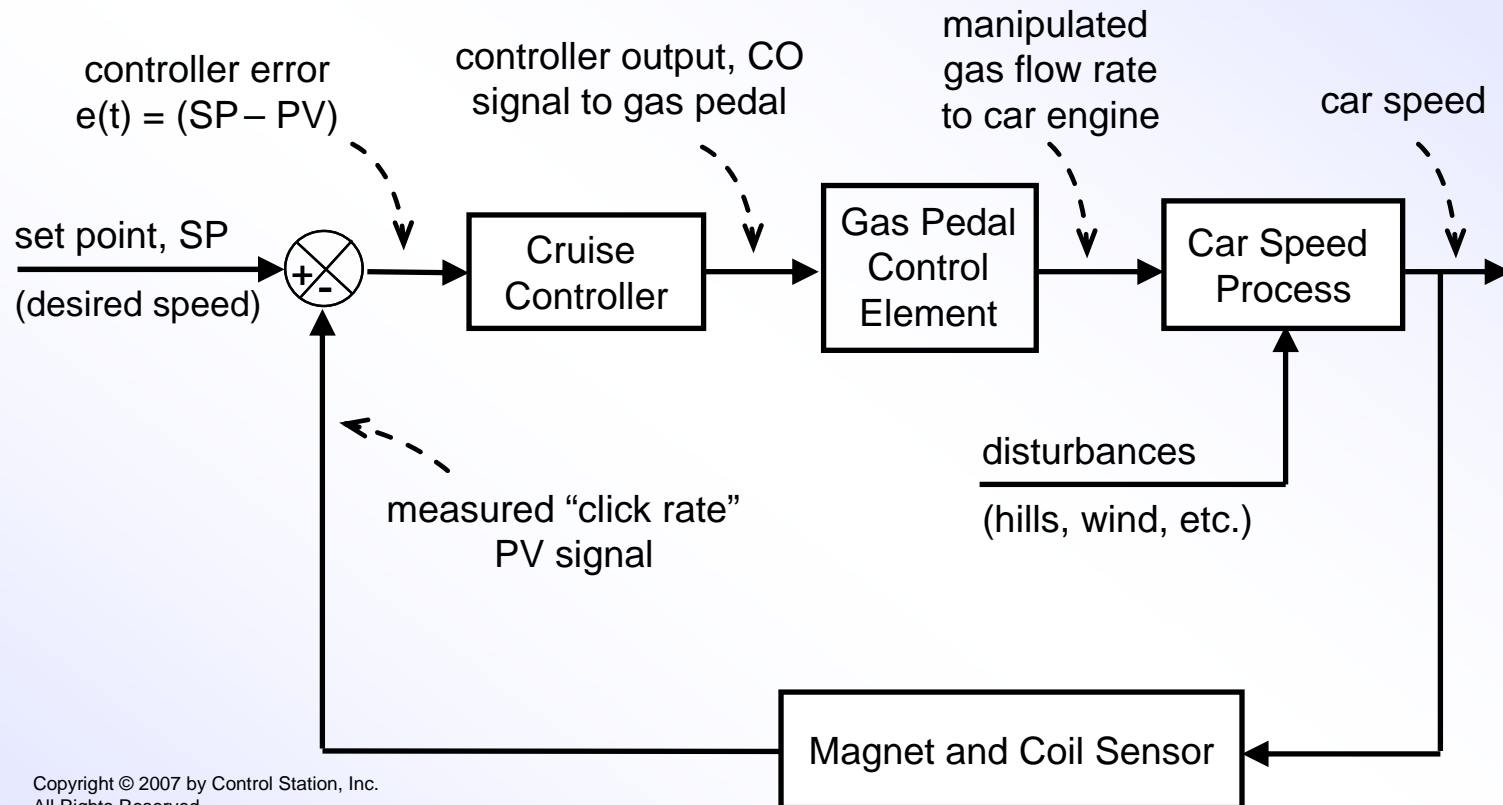


Thought Experiment: Cruise Control in a Car

- 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....



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

K_c = 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