LABORATORY EXERCISE 7
LEVEL CONTROL LOOP CHARACTERISTICS

OBJECTIVE: To illustrate the characteristics of level control loops, in particular the non-self-regulating character, and methods of obtaining data useful in controller tuning.

PREREQUISITE: Completion of Exercise 1, Process Dynamic Characteristics

BACKGROUND: Whereas most processes exhibit some degree of self-regulation, level control applications are usually non-self regulating. That is, unless the inflow and outflow are exactly equal, the level will continue to rise or fall until the vessel overflows or becomes empty.

For most self-regulating processes, three parameters (process gain, dead time and time constant) can be used to approximate the process dynamic characteristics. For most liquid level loops, one, or at most two, parameters characterize the process. Instead of process gain, a relevant parameter is the *tank residence time, T_R*. For a vertical tank, the residence time of the vessel is given by

$$T_R = \frac{\text{Quantity of fluid between upper and lower level taps}}{\text{Maximum flow rate through vessel}}$$

$$= \frac{\pi\, d^2\, h}{4\, F_m}$$

where
- d = diameter of vessel, feet
- h = distance between upper and lower level taps, feet
- F_m = maximum controllable throughput through vessel, cu ft/min

Notes: (1) 1 cu ft = 7.48 gallons.
(2) The residence time could also be computed using any compatible units, such as metric units.

If the level controller is cascaded to a flow controller, then F_m is simply the maximum reading of the flow transmitter, and d and h come from tank geometry.

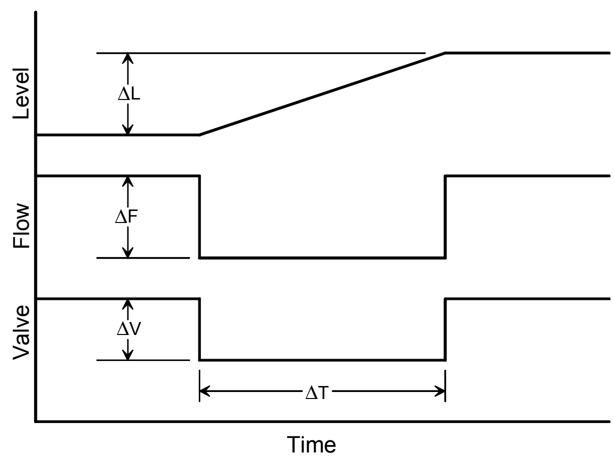
If the level controller output goes directly to a valve, then $\mathbf{T_R}$ for the current operating point can be found by making a process test. In addition, another parameter, K_V, the valve gain, can also be found from the same test.

Test procedure:

1. When the tank is in a steady state condition, put the controller in Manual.

2. Change the controller output a slight amount.

3. The level should start to change at a constant rate. Before the level reaches an extreme (either 0% or 100%), put the controller output back to its original value. The level should stop changing. Your chart or trend record should look something like this:



4. Note the following:

   ΔV = the amount you changed the controller output (signal to valve), %

   ΔL = the amount the level changed, % of full scale

   ΔF = the amount the flow changed, % of full scale

   ΔT = the time duration of the test, minutes

5. Calculate the following:

   Tank residence time: $T_R = \dfrac{\Delta T \text{ x } \Delta F}{\Delta L}$

   Valve gain: $K_V = \dfrac{\Delta F}{\Delta V}$

1. STARTING THE PROGRAM

Start **Windows**.

Run **PC-ControLAB**.

Be sure the control strategy is Feedback and that the controller is in Manual.

Select **Process I Select Model**. Highlight “Level.mdl” and click Open.

Select **View I Variable Plot Selection**. Select “Yes” for PV-2. Press **Clear**.

> *This displays the outflow as a magenta trace. It may not be visible immediately, since it is the same as the same as the inflow and is covered up by the gray trace labeled “Load”.)*

Click on the label above the trend chart reading “Inflow.” Note the maximum flow rate of inflow from the scale at the right of the trend graph. Then click on the ”Liquid Level (PV-1)” label above the controller. Maximum inflow, GPM:

2. TESTING THE PROCESS

Decrease the controller output by 5% from its initial value.

Before the level reaches a limit, change the controller output back its original value. Then press **Pause**.

> *If you weren't fast enough, select* **Process I Initialize** *so you can try again. You will have to again select* **View I Variable Plot Selection** *and select "Yes" for PV-2. This time, after you have made the initial change to the controller output, press* **Pause**. *Then you can change the controller output back to its original value while the program is suspended. Press* **Run** *to resume program operation.*

With the controller output at the decreased value, does it appear that the level will ever come to an equilibrium? ________

> *This illustrates the* non-self-regulating *nature of liquid level processes.*

From your test, determine the following:

ΔT	=	the time duration of the test, minutes	________
ΔV	=	the amount of change in the controller output, %	________
ΔL	=	the amount the level changed, % of full scale	________
ΔF	=	the amount the flow changed, % of full scale	________

(Be sure to convert your flow reading to %. See *the maximum flow factor determined at the end of Section 1.)*

Calculate the following:

Tank residence time: $T_R = \dfrac{\Delta T \times \Delta F}{\Delta L}$ ____________ mins.

Valve gain: $K_V = \dfrac{\Delta F}{\Delta V}$ ________________

3. CALCULATING RESIDENCE TIME FROM TANK DIMENSIONS

Select **Control I Select Strategy I Cascade**.

With the Outflow controller selected (if the label reading “Outflow (PV-2)” is NOT highlighted in red, click on the label, or press **Sel** on the controller), note the maximum outflow rate (PV scale at right hand side of trend chart).

________GPM.

The dimensions of this vertical tank are:

Diameter:	3.0 feet
Distance between level sensor taps:	5.0 feet

Calculate the tank residence time. (See equation in “Background”) TR = _________mins.

(Your answer should be close to the tank residence time you determined experimentally in Section 2. If not, recheck your results, either here or in Section 2.)

The tank residence time, T_R, and the valve gain, K_V, will be used to calculate the level controller tuning parameters in Exercise 12.