Date: ________________ Name: ___________________________________

LABORATORY EXERCISE 15
CHARACTERISTICS OF CASCADE CONTROL

OBJECTIVE: To demonstrate the advantage of cascade control over non-cascade control for some types of load upsets.

PREREQUISITE: Completion of Exercises

9	PID Tuning from Open Loop Tests
10	PID Tuning from Closed Loop Tests
11	Improving "As Found" Tuning

or equivalent level of experience.

BACKGROUND: With cascade control, the output of one feedback controller (the "primary") sets the set point of a second feedback controller (the "secondary"). A significant advantage is that disturbances to the inner loop, controlled by the secondary, have minimal effect on the primary process variable.

1. RUNNING THE PROGRAM

Start **Windows**.

Run **PC-ControLAB**.

2. CASCADE LOOP SET UP

After the title display, the initial operational display contains the Feedback control strategy.

You can call in a CASCADE control strategy with the controllers already tuned for a particular process model. Select **Control | Retrieve Strategy, Model and Tuning**.

Highlight "Cascade.stg" and press **Open**.

The default configuration of the Cascade control strategy is that of cascade control loop, with the Secondary controller (right hand controller on display) controlling a relatively fast process (Flow) and the Primary Controller (left hand controller on display) controlling a slower process (Temperature). The measurement range for the Primary controller is 0 to 500 DegF. For the Secondary Controller, the measurement range is 0 – 1000 P/hr of steam flow. The simulation represents control of temperature leaving a heat exchanger. A disturbance to the primary loop is feed rate to the exchanger; a disturbance to the secondary loop is the steam pressure to the control valve. Disturbances (load upsets) can be introduced separately into either the secondary loop or primary loop.

Press **SEL** on the Secondary Controller to enable accessing the Secondary Controller tuning parameters. (The label above the Secondary Controller should be red with white letters when it is selected.)

Press **TUNE**.

Note the following tuning values have already been entered for the Secondary Controller:

Gain:	0.5
Reset:	0.15 minutes/repeat
Deriv:	0.00 minutes

Press **Clear**.

Confirm acceptable operation of the Secondary Controller. Change the Secondary Controller to Automatic, and change the set point to 400 P/hr.

Observe the secondary loop response:

Is it appropriately fast, as a flow loop should be? ________

Return the Secondary set point to 280, then place the Secondary Controller in Cascade. (Note the change in color of the LEDs on the Primary Controller. This signifies that the Primary Controller can now send a signal to the Secondary.) Use the controller output buttons on the Primary to make slight changes in its output. You should observe changes to the Secondary set point.

Press **SEL** on the Primary controller, then press **Out** and change the Primary controller output to 28%. This returns the Secondary set point to 280 P/hr.

With the Primary Controller **SEL**ected, press **TUNE.**

Note that the following tuning values have already been entered for the Primary Controller:

Gain:	2.5
Reset:	8.0 minutes/repeat
Deriv:	0.0 minutes

Press **Clear** to remove the Primary Controller tuning dialog box.

Check the Secondary Controller. Is it in Cascade? (It should be, if you followed instructions.) If so, put the Primary Controller in Automatic. Increase its set point to 325. (Select the Primary Controller. Press **SP** and key in in the new value in the dialog box.)

Observe the response:

Is it approximately quarter decay? ________

Period of oscillation? ________

3. CASCADE LOOP OPERATION

With the Secondary in Cascade and the Primary in Auto, set the set point for the Primary to 275.

When the loops have stabilized, read and record the values for the following variables:

Primary process variable: ________

Primary Controller output or Secondary Controller set point ________

Secondary Controller output (valve signal): ________

In order to have a better display of the process response in the following sections, you may want to **SEL**ect the Temperature controller and zoom the PV scale to 250 – 300 degF.

Select the Primary Controller. (Very important that the PRIMARY is selected!) Press **StepIncr** (above the faceplates) once, to make a load change on the primary loop. (This simulates an increase in process flow.) The primary control loop load variable affects the outer loop process, but has no effect on the inner loop process.

Observe the response of the primary process variable:

Maximum deviation from set point: ________

Did the primary PV eventually return to set point? ________

Primary Controller output (secondary controller set point) ________

Secondary Controller output (valve): ________

You have observed a load change on the outer loop. To compensate for this, the Primary Controller increased the demand on the inner loop; i.e., it changed the set point of the Secondary Controller. To meet this additional demand, the Secondary Controller output also changed.

With the Primary Controller still selected, press **StepDecr** to return to the load to its original value.

When the control loops have stabilized, select the Secondary Controller. (Very important here that the SECONDARY is selected!) Press **StepDecr** once to cause a disturbance to the secondary loop. (This simulates a drop in steam pressure.) Observe the response and record the following:

Maximum deviation from set point of primary PV: ________

Does the primary PV eventually return to set point? ________

Primary Controller output (secondary set point) after inner loop load change: ________

Secondary Controller output after inner loop load change: ________

You have just observed a load change on the inner loop. Since the load on the outer loop has not changed, the long term demand of the Primary Controller on the inner loop (i.e., the set point of the secondary controller) does not change - it may undergo some fluctuation in the short term. But to compensate for the changed load on the inner loop, the Secondary Controller output had to change.

The most significant observation is that the secondary process load change was contained within the inner loop. The effect on the primary process variable was fairly slight.

Before going on, while the Secondary Controller is still selected, press **StepIncr** to return the secondary load to its original value.

4. NON-CASCADE CONTROL OPERATION

This section of the exercise will make the same type of load changes, but the control structure will be a simple feedback controller. The Secondary Controller will be eliminated, and the Primary Controller output will go directly to the valve.

First, switch both controllers to Manual. (In a real control system, you can't make changes to the configuration of a controller that is in Automatic. The same thing applies here.)

With either controller selected, select **Control | Control Options**. Use the scroll bar at the left of the options table to scroll to the end of the table. Choose the option YES for "Bypass Secondary Controller."

You have just "softwired" around the Secondary Controller. The Primary Controller output now goes directly to the valve. This operation was performed without bumping the process, since the primary controller's output was initialized to be the same as the output of the Secondary Controller before the switch was made. The display still shows both faceplates, although the Secondary Controller is inactive.

Select the Primary Controller and press **TUNE**. Are the tuning parameters the same as previously set for this controller? ________

Change the Primary Controller to Automatic.

Was there a bump in the process variable? ________

Although the control structure has been altered, the process itself has not. There is still a secondary process which feeds a primary process, with independent load disturbances to each.

With the Primary Controller Selected, press **StepIncr** once to increase the load (increase the process flow rate) on the primary loop.

Observe the response and record the following:

Maximum deviation from set point: ________

Is this response approximately the same or significantly different from the response with cascade present? ________

Observation: With a disturbance to the primary process, the presence or absence of a cascade loop makes very little difference.

Press **StepDecr** to return the primary process load to its original value.

When the control loop is stabilized, select the Secondary controller and press **StepIncr** to cause a load change (drop in steam pressure) on the secondary process.

Observe and record the following:

Maximum deviation from set point: ________

Is the response to this load change approximately the same or significantly different from the response to the same load change with cascade present?

____

Is the response to this load change approximately the same or significantly different from the response to a primary load upset, both without cascade control being present? ________

You have observed load upsets on both the secondary and primary processes, without cascade control present. Since there is no closed inner loop to compensate for the load upset on the secondary process, the responses are approximately the same. Comparing the response to a secondary load upset both with and without cascade, you should observe that there is a very significant improvement when cascade is present.