LABORATORY EXERCISE 13
USING SCHEDULED TUNING

OBJECTIVE: To demonstrate the benefits of scheduled tuning for non-linear processes.

PREREQUISITES: Completion of Exercises

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

BACKGROUND: If a process is highly non-linear and is operated over a wide operating region, then either the tuning parameters must be changed for different operating conditions, or else the controller will be tuned for the "worst case" condition, resulting in less than optimum tuning at other conditions. One means of coping with this is to issue instructions to the operator to change tuning parameters for different operating conditions. Another possibility is to develop a set of tuning parameters for each operating condition and employ some mechanism which applies the correct tuning parameter set for each condition. This is known as "scheduled tuning" (also sometimes called "adaptive gain"). A basic premise is that the operating condition can be indexed by a single variable, such as the measured process variable, the set point, controller output, or a disturbance variable to the loop. This variable can then become the key to finite regions of the operating zone, each with its own set of tuning parameters.

A slight variation of the above is to assign nominal parameters, then apply a unique multiplying factor to each of the parameters for each defined region. This is the approach used by PC-ControLAB.

1. RUNNING THE PROGRAM

Start **Windows**

Start **PC-ControLAB**

2. INITIAL TUNING

2.1 Preparatory

Confirm that you are running the Feedback control strategy.

Select **Process | Select Model.** Highlight "Temp.mdl" and press **Open**.

2.2 Tuning for Base Conditions

Notice that the PV scale is 0 to 100 DegC, that the set point is at 60 DegC, and that the load variable (process flow rate) is 0 to 100 m^3/hr. For this exercise, we will assume that the base conditions (normal operating point) is close to the current set point value of 60 DegC with a load variable of 75% of full scale. The load variable can vary, however, between 50 and 100% of its full range.

We're going to be making fairly small set point changes, so press **Zoom** and change the vertical scale of the PV from 0 – 100 to 55 – 65 DegC. *(Why small SP changes? To* *avoid having the controller output hit a limit when we are working at high loads.)*

With the controller in Manual, change the controller output from 48% to 53% (a 5% change). Use the open loop testing method (Laboratory Exercise 9) to determine an initial set of tuning parameters for a PI controller.

Enter these parameters. Put the controller in AUTO. Fine tune these parameters if necessary, using the "Improving As Found Tuning" method (Laboratory Exercise 11). Make your set point changes between 60 and 62 DegC.

When you have determined satisfactory tuning parameters for this condition (load variable = 75 m^3/hr), record them below:

Process Flow: 75 m^3/hr. Gain: ________ Reset: ________ min/rpt.

Now make load changes of 5% (Press **StepDecr** once. After the PV settles out, press **StepIncr** once.) and observe the response.

Return the Set Point to 60 DegC.

2.3 Other Operating Points

Change the process load to 95% of full scale. (Press **StepIncr** 4 times).

Change the SP to 62 DegC, then to 60 DegC. Observe the responses.

Also make load changes of 5% (press **StepDecr** once. After the PV settles out, press **StepIncr** once.) Observe the responses.
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How do these responses (to SP and load changes) compare with what you observed when the load was at 75%?

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Change the process load to 55% of full scale. (Press **StepDecr** 8 times).

Change the SP to 62 DegC, then to 60 DegC. Observe the responses.

Also make load changes of 5% (Press **StepDecr** once. After the PV settles out, press **StepIncr** once.) Observe the responses.

How do these responses (to SP and load changes) compare with what you observed when the load was at 75%?

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What you should have observed so far: Starting with the controller tuned acceptably when the load is 75%, a significant load increase with the same tuning parameters causes the control loop to be slightly more sluggish. A significant load decrease with the same tuning parameters causes the loop to be too aggressive.

Tuning for Other Operating Points

While we are at a load of 55%, adjust either the Gain or the Reset, or both, until you get approximately the same type of response for a SP change from 60 to 62 as you did when the load was 75%. Record your tuning parameters.

Process Flow: 55 m^3/hr. Gain: ________ Reset: ________ min/rpt.

Now go to 95% load and adjust the tuning parameters to get approximately the same type of response as you did when the load was 75%.

Process Flow: 95 m^3/hr. Gain: ________ Reset: ________ min/rpt.

2.4 Calculation of Tuning Schedule

Suppose we divide the operating zone into 3 regions, based upon the load value.

Region 1 Load < 65%. (Actually, we never use a load less than 50%.)
Region 2 Load between 65% and 85%.
Region 3 Load ≥ 85%.

Since we said that in our base case (See Section 2.2) the load was 75%, then Region 2 is our base operating region. We will enter tuning parameters for that region as our nominal parameters, and adjust the parameters for the other regions by multiplicative factor. (The multiplicative factor for Region 2 will be 1.00.)

Calculate the Gain multiplier and Reset (Min/Rpt) multiplier for Region 1 and Region 3.

$$\text{Region 1 Gain Multiplier} = \frac{\text{Gain determined at 55\% load (Section 2.4)}}{\text{Gain determined at 75\% load (Section 2.2)}} = \underline{\qquad\qquad}$$

$$\text{Region 1 Reset Multiplier} = \frac{\text{Reset determined at 55\% load (Section 2.4)}}{\text{Reset determined at 75\% load (Section 2.2)}} = \underline{\qquad\qquad}$$

$$\text{Region 3 Gain Multiplier} = \frac{\text{Gain determined at 95\% load (Section 2.4)}}{\text{Gain determined at 75\% load (Section 2.2)}} = \underline{\qquad\qquad}$$

$$\text{Region 3 Reset Multiplier} = \frac{\text{Reset determined at 95\% load (Section 2.4)}}{\text{Reset determined at 75\% load (Section 2.2)}} = \underline{\qquad\qquad}$$

Enter these values into the table below. (Note that the Deriv multipliers can be left at the default value of 1.0, since the base Deriv value is 0.0. Also note that Region 2 represents our base case, so those multipliers are 1.0.)

Region	Low	High	Gain Multiplier	Min/Rpt Multiplier	Deriv Multiplier
1	0	65			1.0
2	65	85	1.0	1.0	1.0
3	85	100			1.0

Press **Tune | Schedule** tab.

Enter, or confirm, that the Number of Regions is set at 3.

Select PV-4 for the Key variable. (This process model has PV-4 connected directly to Load-1, which represents the process flow disturbance.)

Fix up the table to resemble columns 2 - 6 listed above.

Select Scheduled Tuning **ON**.

Return to the **Tuning** tab. Re-enter the tuning values you determined for the base case (Section 2.2).

Press **Clear** to remove the Tuning dialog box.

2.5 Testing of Scheduled Tuning

Change the load to 55%.

For each load value between 55% and 95%, make set point changes to 62, then to 60. Observe the response. Then increment (press **StepIncr**) the load to the next level and repeat.

Ideally, you should see a fairly satisfactory response at each load level. If not, consider what changes you might make to the schedule. Consider changing one or more of the following:

Number of regions
Break points between regions
Multiplying factors.

Record your final tuning schedule in the table below:

Number of Regions: ________

Region	Low	High	Gain Multiplier	Min/Rpt Multiplier	Deriv Multiplier
1	0				1.0
2			1.0	1.0	1.0
3					1.0
4					1.0
5					1.0