Date: ________________ Name: ___________________________________

# LABORATORY EXERCISE 11
# IMPROVING "AS FOUND" TUNING

**OBJECTIVE:** To provide practice in improving "as found" tuning for proportional plus integral (PI) control of a self-regulating process.

**PREREQUISITES:** Completion of Exercises

9 PID Tuning from Open Loop Tests
10 PID Tuning from Closed Loop Tests

**BACKGROUND:** Quite often a control systems engineer or instrumentation technician is called upon to improve the behavior of a loop that is currently in operation, but without resorting to either the open loop or closed loop testing methods. Assuming that the loop is not behaving acceptably at present, and that process and equipment problems (e.g., sticking valve) have been eliminated, then most persons resort to "trial and error" tuning. For novice tuners, this is often simply an exploratory procedure; "How about changing this knob in this direction and see what happens".

This laboratory exercise presents a method for directed trial and error tuning, where each tuning parameter change is made for a deliberate reason. The objective is to go from the current unacceptable behavior to acceptable behavior as efficiently as possible; i.e., in the fewest number of tuning parameter changes.

This method is based upon the premise that if a PI controller, controlling a self-regulating process, is well tuned (that is, exhibiting a slightly underdamped oscillation with a quarter wave decay), then there will be a predictable relationship between the period of oscillation (P) and the integral time $\left(T_I\right)$. This relationship (stated in three different ways) is:

$$1.5 \le \frac{P}{T_I} \le 2.0 \tag{1}$$

$$1.5T_I \le P \le 2.0T_I \tag{2}$$

$$0.5P \le T_I \le 0.67P \tag{3}$$

This premise leads to the following rule-based procedure:

1. If the loop is not oscillating, increase the gain, say by 25 to 50%.

2. If the loop is oscillating then:

    2.1 If the Period is between 1.5 and 2.0 times the integral time (or the period-to-reset ratio is between 1.5 and 2.0), then either increase or decrease the gain as required to obtain the desired decay ratio (such as quarter wave damping)

    2.2 If the Period is greater than 2.0 times the integral time (or the period-to-reset ratio is greater than 2.0), then choose a new integral time according to the criterion:

$$0.5P \le T_I \le 0.67P$$

2.3 If the Period is less than 1.5 times the integral time (or the period-to-reset ratio is less than 1.5), then

2.3.1 If the decay ratio is greater than 1/4, then decrease the gain, say by 25 to 50%, depending upon how much the decay ratio exceeds 1/4.

2.3.4 If the decay ratio is less than, or approximately equal to, 1/4, then choose a new integral time, using the criterion given in 2.2.

3. After each adjustment, make a slight set point change to test the response to the latest combination of tuning parameters.

The essence of the rule-based procedure listed above is shown in flow chart form in a figure at the back of this laboratory exercise.

## 1. RUNNING THE PROGRAM

Start **Windows**

Start **PC-ControLAB**

## 2. LOOP TUNING

Select **Control | Retrieve Strategy, Model and Tuning.** Highlight "Feedbck1" (not "Feedback") and press **Open**.

Observe from the top row that this opens the normal Feedback control strategy, as well as the Generic process model which you have worked with in previous laboratory exercises. The thing that is different here is that the loop has already been tuned – for better or for worse. Press **Tune** and note the existing tuning parameters.

If the PV scale is not in engineering units, select **View | Display Range | Engineering Units.**

Put the loop in AUTO.

Change the set point to 300 DegF.

*NOTE: The following two procedures will NOT product the same response:*
*Make the set point change first, then put the loop into AUTO.*
*Put the loop in AUTO first, then make the set point change.*
*For the purpose of the procedure described in this laboratory exercise, it is important for you to see the set point response with the loop already in AUTO. Therefore, the correct procedure is to put the loop into AUTO then make the set point change.*

Observe the response. Suppose that this is the behavior of the loop when you are asked to make tuning parameter changes. In other words, this is your "as found" condition.

Does the loop need to be retuned? ________

If so, list the “as found” conditions in the top line of the table below. Then use the procedure listed in “BACKGROUND”, or use the flowchart, to make tuning parameter changes. Keep track below of each tuning change you make. (Suggestion: Use set point values of 275 DegF and 300 DegF.)

| Trial No. | Gain (See Note 1) | $T_I$ (See Note 2) | Period | Decay Ratio | $\frac{\text{Period}}{T_I}$ |
|---|---|---|---|---|---|
| As found | | | | | |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

**NOTE 1:** If you are working in Proportional Band, enter the value of Proportional Band, rather than Gain.

**NOTE 2:** If you are working in Reset Rate (repeats/min), rather than Reset Time (minutes/repeat), take the reciprocal of the reset rate to obtain Reset Tiime ($T_I$).

## 3. A COMPARISON

Many (novice) loop tuners, faced with the “as found” condition, would simply reduce the controller Gain until acceptable damping (e.g., quarter-wave decay) was achieved. We will demonstrate why that may not be a good idea.

**3.1** Re enter the original tuning parameters.

With the loop in Automatic, set the set point at 275 DegF and let the loop come to equilibrium.

Working between set point values of 275 and 325 DegF, adjust the Gain until quarter-wave damping is achieved. Do not change the reset.

Gain: ________

Reset (Min/repeat): ________

Suppose the product specifications require that the PV be within a certain tolerance above and below SP to be "within specs" then one of two criteria can be used to evaluate the response of the loop to a disturbance:

(1) Maximum deviation from set point, for a step disturbance of specified size;

(2) The time required for the loop to regain "on spec" production; that is, to get within the tolerance band with no further deviation outside the band.

Press [Zoom] and select a display range from 275 to 300.
'
Change the set point to 287.5 (This is midway of the chosen display range.). When the loop comes to equilibrium, press **StepIncr** to make a 5% disturbance (load change).**StepIncr**.

Record:

Maximum deviation of PV from set point: _________

How long before loop "settles down" to within 1/2% (± 2.5 Deg) of SP _________
(At this Zoom range, the horizontal green lines on the display are 2.5 Deg apart. So the tolerance band is within one green line above and below SP.)

**3.2** Enter your final tuning parameters from part 2.0. (These should have produced a quarter wave decay response following a set point change, and a period-to-reset ratio which meets the criterion stated in "BACKGROUND".

With the loop in Automatic, set the set point at 287.5 DegF and let the loop come to equilibrium.

Make a 5% disturbance (load change) by pressing **StepIncr**.

Record:

Maximum deviation of PV from set point: _________

How long before loop settles down to within 1/2% of SP _________

**3.3** Which tuning combination (Section 3.1 or 3.2) produced the best response to a load change?

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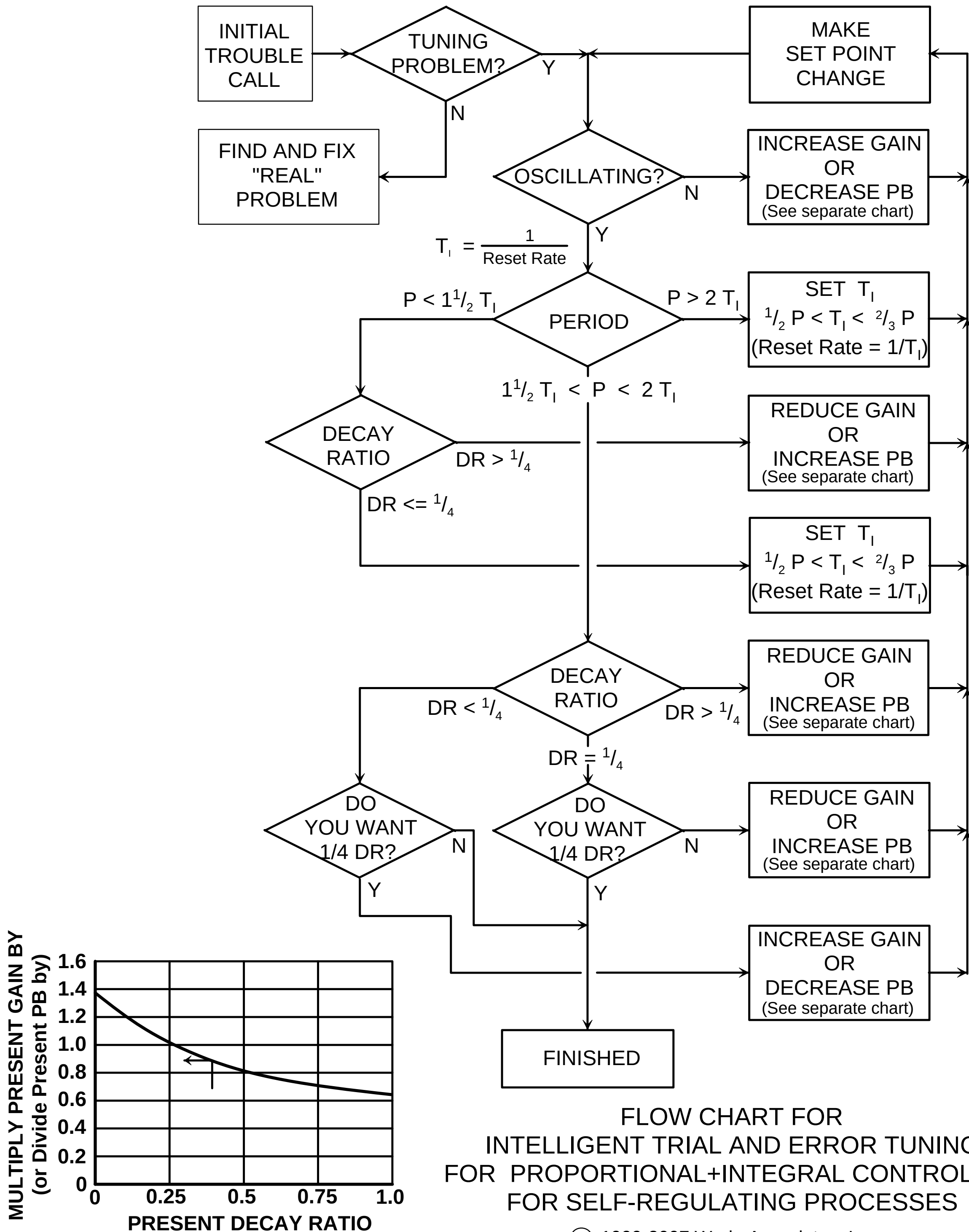
> The tuning in used in Section 3.1 might represent the results of attempting to achieve acceptable damping by adjusting gain only, followed by an attempt to return to set point faster by making the reset faster. (Not wise choices!) The tuning in Section 3.2 is the result of "intelligent trial and error tuning." The comparison shows less deviation from set point, as well as a faster return to "on spec" production.




FLOW CHART FOR
INTELLIGENT TRIAL AND ERROR TUNING
FOR PROPORTIONAL+INTEGRAL CONTROLLER
FOR SELF-REGULATING PROCESSES