Date: ________________ Name: ___________________________________

LABORATORY EXERCISE 9
PID TUNING FROM OPEN LOOP TESTS

OBJECTIVE: To provide practice in open-loop testing, estimation of process parameters and calculation of tuning parameters from the open loop test data.

PREREQUISITE: Completion of Exercises

1 Process Dynamic Characteristics
2 PID Controller Characteristics

or equivalent level of instruction or experience

1. RUNNING THE PROGRAM

Start **Windows**.

Start **PC-ControLAB**.

If PC-ControLAB is already running, then re-read the “GENERIC” process model to initialize the program:
From the menu bar, select **Process | Select Model**
Highlight “Generic.mdl” and press **Open**

Note: *The* Generic *model will not produce similar tuning results from Open Loop testing (this Laboratory Exercise) and from Closed Loop testing (Laboratory Exercise 10.) If similar results are desired, use* Generic2 *model rather than* Generic.

Confirm the following:

Process:	GENERIC	(see the top line, left hand side)
Control Strategy	FEEDBACK	(see the top line, right hand side)

OPTIONAL: If you are more familiar with “Proportional Band” rather than “Gain”, or the reset setting in “Repeats/Minute” rather than “Minutes/Repeat”, then go to **Tune | Options** tab and choose the settings that you are more familiar with.

2. OPEN LOOP TESTING

This program begins operation with a PV of 275 DegF, a controller output of 35% and a load variable (feed rate) of 300 GPM. Assume that this is the normal operating point for this process.

If the right hand scale of the grid is not in engineering units, then select
View | Display Range | Engineering Units

With the controller in Manual, change the output to 45%. (On a real process, you may not be able to make that much change in controller output.

Estimate (see Figures 1 and 2 at the back of this exercise for methods of estimating process parameters.)

Process gain (K_p) $\dfrac{\text{\% change in PV}}{\text{\% change in controller output}}$ ____________

Dead time (T_d) ____________

Time constant (τ) ____________

Return the controller output to 35%.

Calculate tuning parameters for a P, PI and PID controller, using the Ziegler-Nichols equations. (See Table 1 at the back of this Exercise.) Enter these in the table below.

(If you are using Proportional Band rather than Gain, or Reset Rate (minutes/repeat) rather than Reset Time (minutes/repeat), then first calculate Gain (K_C), Integral time (T_I) and Derivative (T_D) from the equations. Then, calculate PB from the Gain, or calculate Reset Rate from than Reset Time.)

	P (See Note)	**PI (See Note)**	**PID (See Note)**
Gain (K_C)			
Prop Band (PB)			
Integ Time (T_I) (min/rpt)	___		
Reset Rate (rpt/min)	___		
Deriv Time (T_D)	___	___	

For each type of controller, enter the parameters, put the controller in Auto and test the loop for a set point change. (Suggestion: Change the set point, either up or down, by 50 DegF. On the job, you probably cannot make that large of change.)

NOTE: For the Proportional Only controller, with the controller in Manual, select **Control | Control Options**, and select the Proportional only control algorithm.
For the PI and PID controllers, with the controller in Manual, select **Control | Control Options,** and select PID-Non-interacting control algorithm.

Calculate or measure the decay ratio, period and (for the PI controller only) the period-to-integral time ratio. (This will be used in a subsequent Laboratory Exercise.)

	P	**PI**	**PID**
Decay Ratio			
Period, mins			
Period . / Integral Time	_____		_____

For each type of controller, make a 5% (40 GPM) load change. Press **StepIncr** or **StepDecr**.

Which controller type, PI or PID, do you prefer, for:

Set point response ________

Load (disturbance) response ________

PID control appears to be better than PI for both a set point change and a load change. However, what you have seen so far is a perfectly noise-free process. Real processes usually have some noise on the measurement.

Enter the PID tuning parameters from the table above, then, with the controller in Auto:

Select **Process | Change Parameters**
Use the scroll bar to scroll down until you see
“PV#1 Meas Noise 0-N; 1-Y”
Highlight that, then enter “1"
Press **OK** then **Clear**

Describe what you see:

____

____

Frequently the measurement signal is filtered to “hide” the effect of the noise. (The noise is still there - you just can’t see it!) We will put a filter on the measurement. This is equivalent to implementing a software filter on the analog input block on a DCS. EXCEPT: Due to the relatively slow sampling rate of this simulation, as compared with the typical sampling rate of a DCS, we will use a larger filter time constant here than would be used in real life.

Select **Control | Measurement Options** in the drop down menu
Click in the circle “Yes” in the section “Measurement Filter”
Enter “1.0" (minutes) for the filter time constant
Press **Clear**

Describe the effect:

____

____

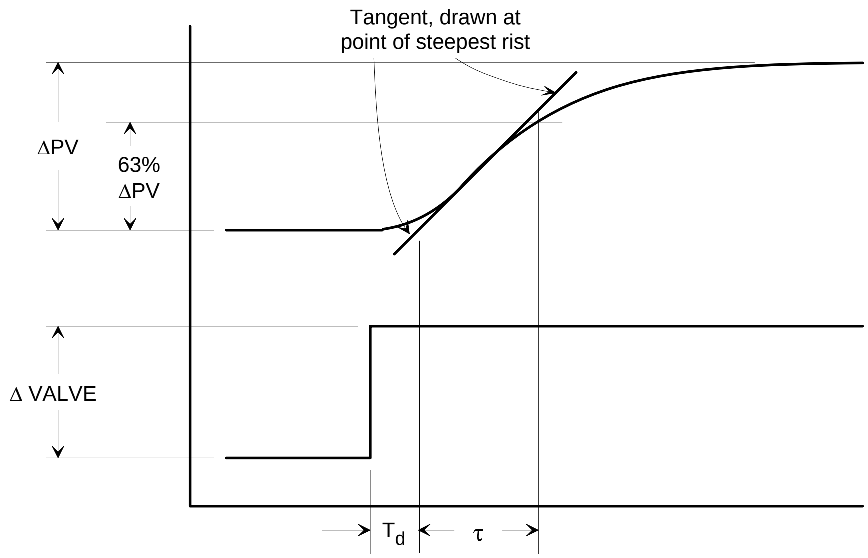

Figure 1
GRAPHICAL METHOD OF DETERMINING PROCESS PARAMETERS

Process Gain: $K_p = \dfrac{\Delta PV}{\Delta VALVE}$

Draw a tangent at the point of steepest rise. Be sure it intersects the initial equilibrium line; it is not necessary to carry the tangent all the way until it intersects the final equilibrium line.

Dead Time: T_d = Time from valve change to intersection of tangent with initial equilibrium line.

Time Constant: τ = Time, from end of dead time (as determined above) until the process changes by 63.2% of its final amount.

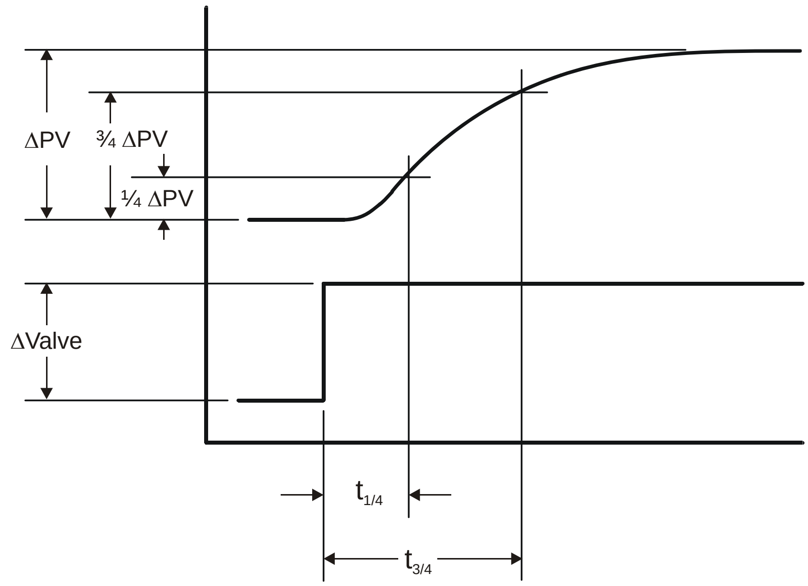

Figure 2
ANOTHER METHOD OF DETERMINING PROCESS PARAMETERS

Process Gain: $K_p = \dfrac{\Delta PV}{\Delta VALVE}$

Measure the time from the instant of valve change until the process rises by 1/4 of its total amount. (This obviously must be done from a chart record after the process has reached its new equilibrium.) Call this time $\mathbf{t_{1/4}}$ **.**

$$t_{1/4} = T_d + 0.3\tau$$

Measure the time from the instant of valve change until the process rises to 3/4 of its final amount. Call this time $\mathbf{t_{3/4}}$ **.**

$$t_{3/4} = T_d + 1.4\tau$$

When these two times are determined, calculate the dead time and process time constant from the following equations:

$$\tau = 0.9(t_{3/4} - t_{1/4})$$

$$T_d = t_{3/4} - 1.4\tau$$

TABLE 1
ZIEGLER-NICHOLS TUNING PARAMETER CORRELATION FOR OPEN LOOP PROCESS DATA

CONTROLLER	PROP ONLY	PI	PID
GAIN K_C	$\frac{\tau}{K_P\ T_d}$	$\frac{0.9\tau}{K_P\ T_d}$	$\frac{1.1\tau}{K_P\ T_d}$
RESET T_I – Mins/Repeat	—	$3.33\ T_d$	$2.0\ T_d$
DERIVATIVE T_D - Minutes	—	—	$0.5\ T_d$

NOTE: K_p = Process Gain T_d = Dead time τ = Time constant

$$\text{Proportional Band (PB)} = \frac{100}{K_C}$$

$$\text{Reset Rate (Repeats/Min)} = \frac{1}{T_I}$$