Appendix D: PID Controller Tuning Guides

D.1 PID Tuning Guide for *Self Regulating* (Stable) Processes

Begin by fitting a first order plus dead time (FOPDT) dynamic model to process data. "Process" is defined to include all dynamic information from the output signal of the controller through the measured response signal of the process variable.

Generate process data by forcing the measured process variable with a change in the controller output signal. For accurate results:

- the process must be at steady state before forcing a dynamic response; the first data point recorded must equal that steady state value
- the data collection sample rate should be ten times per time constant or faster ($T \le 0.1\,\tau_P$)
- the controller output should force the measured process variable to move at least ten times the noise band

Use *Design Tools* to fit a FOPDT dynamic model to the process data set. A FOPDT model has the form:

Time Domain: $\tau_P \dfrac{dy(t)}{dt} + y(t) = K_P\, u(t - \theta_P)$

Laplace Domain: $\dfrac{Y(s)}{U(s)} = \dfrac{K_P\, e^{-\theta_P s}}{\tau_P s + 1}$

where:
- $y(t)$ = measured process variable signal
- $u(t)$ = controller output signal
- K_P = process gain; units of $y(t)/u(t)$
- τ_P = process time constant; units of time
- θ_P = process dead time; units of time

also:
- K_C = controller gain; units of $u(t)/y(t)$
- τ_I = controller reset time; units of time
- τ_D = controller derivative time; units of time
- α = derivative filter constant; unitless

Values of K_P, τ_P and θ_P that describe the dynamic behavior of your process are important because:

- they are used in correlations (listed below) to compute initial PID controller tuning values K_C, τ_I, τ_D and α
- the sign of K_P indicates the action of the controller ($+K_P \rightarrow$ reverse acting; $-K_P \rightarrow$ direct acting)
- the size of τ_P indicates the maximum desirable loop sample time (be sure sample time $T \le 0.1\,\tau_P$)
- the ratio θ_P / τ_P indicates whether a Smith predictor would show benefit (useful when $\theta_P \ge \tau_P$)
- the model itself is used in feed forward, Smith predictor, decoupling and other model-based controllers

These correlations provide an excellent start for tuning. Final tuning may require online trial and error. "Best" tuning is defined by you and your knowledge of the capabilities of the process, desires of management, goals of production, and impact on other processes.

IMC (lambda) Tuning

Aggressive Tuning:	τ_C is the larger of $0.1\,\tau_P$ or $0.8\,\theta_P$
Moderate Tuning:	τ_C is the larger of $1.0\,\tau_P$ or $8.0\,\theta_P$
Conservative Tuning:	τ_C is the larger of $10\,\tau_P$ or $80\,\theta_P$

* This is an ITAE correlation as no P-Only IMC exists

	K_C	τ_I	τ_D	α
P-Only*	$K_C = \dfrac{0.2}{K_p}(\tau_p/\theta_p)^{1.22}$			
PI	$\dfrac{1}{K_P}\dfrac{\tau_P}{(\theta_P + \tau_C)}$	τ_P		
PID Ideal	$\dfrac{1}{K_P}\left(\dfrac{\tau_P + 0.5\,\theta_P}{\tau_C + 0.5\,\theta_P}\right)$	$\tau_P + 0.5\,\theta_P$	$\dfrac{\tau_P\theta_P}{2\tau_P + \theta_P}$	
PID Interacting	$\dfrac{1}{K_P}\left(\dfrac{\tau_P}{\tau_C + 0.5\,\theta_P}\right)$	τ_P	$0.5\,\theta_P$	
PID Ideal w/filter	$\dfrac{1}{K_P}\left(\dfrac{\tau_P + 0.5\,\theta_P}{\tau_C + \theta_P}\right)$	$\tau_P + 0.5\,\theta_P$	$\dfrac{\tau_P\theta_P}{2\tau_P + \theta_P}$	$\dfrac{\tau_C(\tau_P + 0.5\,\theta_P)}{\tau_P(\tau_C + \theta_P)}$
PID Interacting w/filter	$\dfrac{1}{K_P}\left(\dfrac{\tau_P}{\tau_C + \theta_P}\right)$	τ_P	$0.5\,\theta_P$	$\dfrac{\tau_C}{\tau_C + \theta_P}$