Faculty of Enigeering

Cairo University

TUNING FROM OPEN LOOP TESTS

Presented for ELC 4046 Lab 9

Presented to:

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LABORATORY EXERCISE 9
(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.

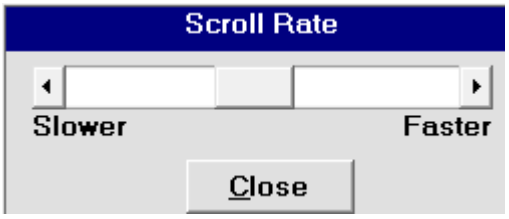
1. RUNNING THE PROGRAM

Run **PC – ControLAB**.

Slow down the simulation speed via **View | Scroll Rate** and select a mid-value, to have more practical experience.

If PC-Control LAB 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.



Confirm the following:

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

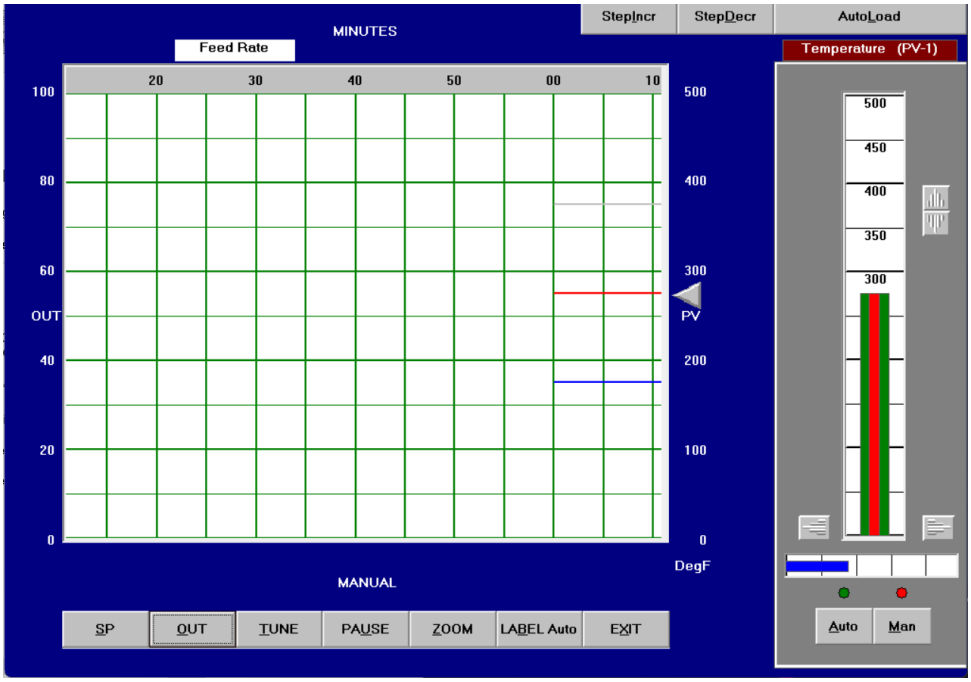


Figure 1. Confirming 'GENERIC' and 'FEEDBACK'

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.

Select **Load** and set Manual Load Change Step size to 20%.

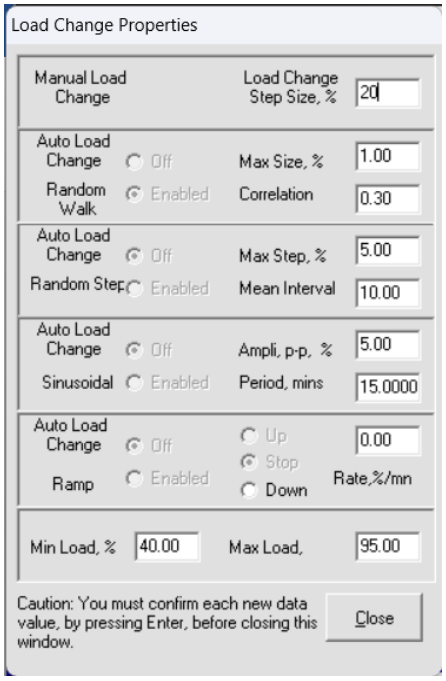


Figure 2. Set manual load change step size to 20%

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

2. TRIAL-AND-ERROR TUNING

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.

Trial-and-error tuning requires the engineer to observe the PV response to an event, usually a setpoint change, then decide what tuning parameter (or parameters) should be changed, in which direction, and by how much.

For the sake of comparison with formal tuning (to be done later in this exercise), first follow the procedure in Basic and Advanced Regulatory Control, chapter 6, page 127, to tune the controller by trial and error. Document your tuning parameters for the PI controller.

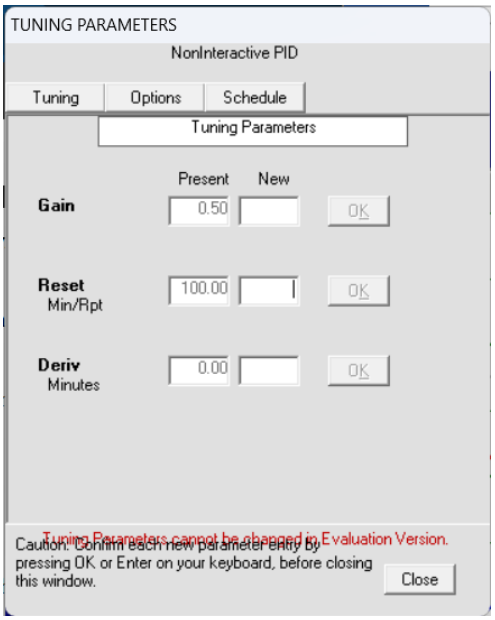


Figure 3. Step 1 and 2: take out all reset and derivative action and set gain to a low value

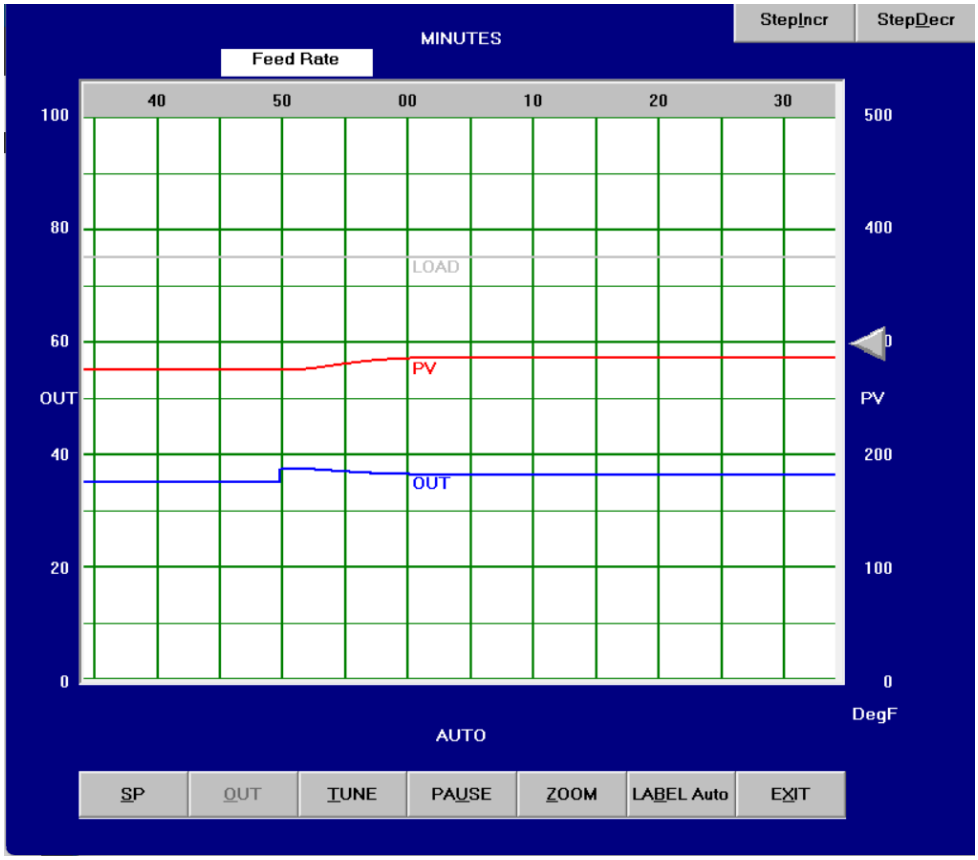


Figure 4. First try with gain of 0.5

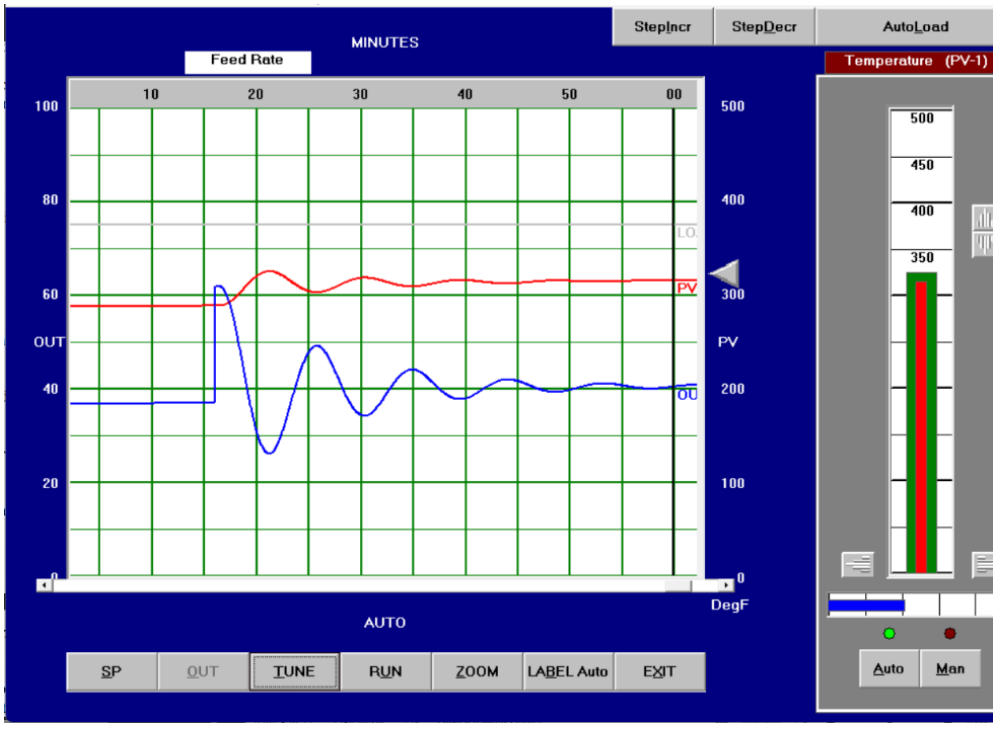


Figure 5. After several tries with gain of 5

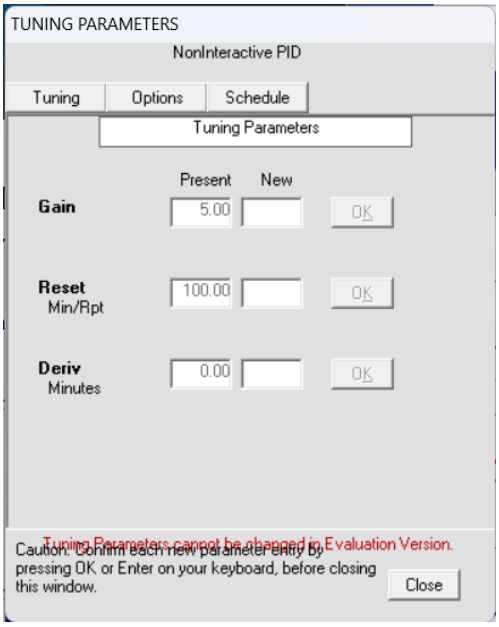


Figure 6. Gain = 5

Gain (K_C)	5
Reset Time (T_I) (min/rpt.)	10

Change the setpoint, either up or down, by 50 DegF. Calculate or measure the overshoot, decay ratio, period, manipulated variable overshoot (see Figure 2), the settling time and ITAE. You may need to zoom in by pressing **ZOOM** and selecting appropriate values.

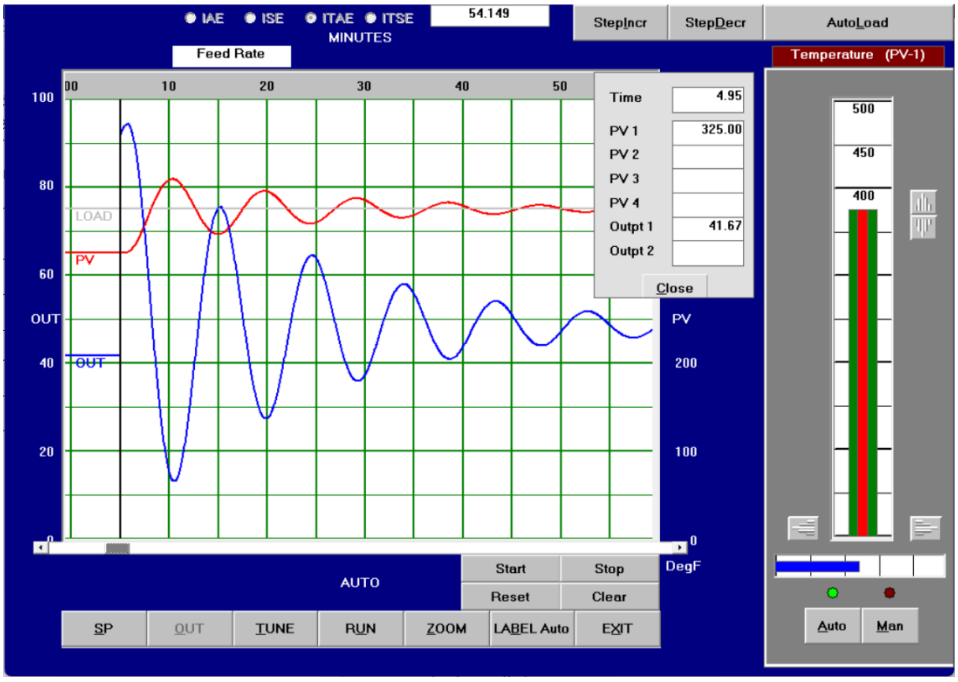


Figure 7. Time of changing Set point from 325 to 375

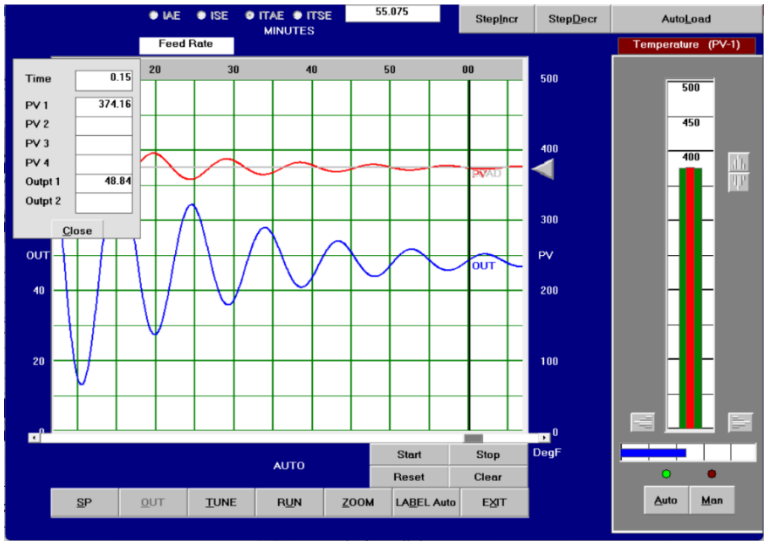


Figure 8. Settling time

Setpoint change	
Settling time	60.15 - 4.95 = 55.2 minutes
Overshoot (%)	$\frac{409.18-375}{50} * 100$ =68.36%
Decay Ratio	$\frac{395.62-375}{409.18-375}$ =0.603
Manipulated variable overshoot (%)	$\frac{94.39-48.33}{48.33-41.67} * 100$ = 691.59%
Period / T_I	(27.40 – 18.10) / 10 = 0.93
ITAE (How to view?)	56.819

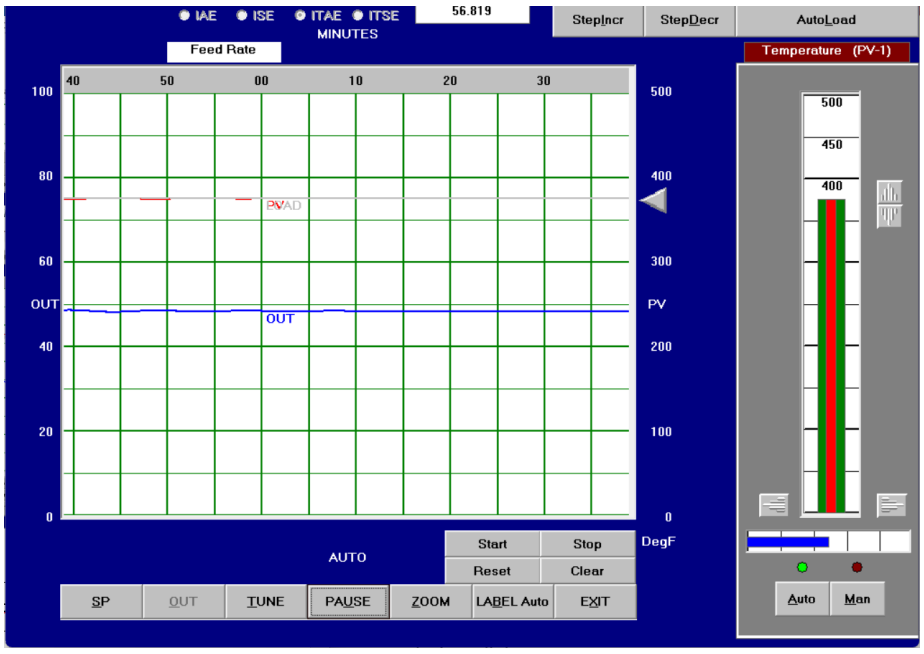


Figure 9. Final value of ITAE

Further, test the controller by making 20% load change. Press **StepIncr** or **StepDecr** once**.** Record the relevant data in the following table.

Load upset	
Peak deviation from setpoint (DegF)	394.8 – 375 = 19.8 DegF
Settling time (Measure after you have done part 4)	59 – 19.5 = 39.5 minutes
Decay Ratio	$\frac{386.55-375}{394.8-375}=0.58$
Manipulated variable overshoot (%)	$\frac{28.34-23.48}{48.33-28.34}*100=24.312\%$
ITAE	21.185

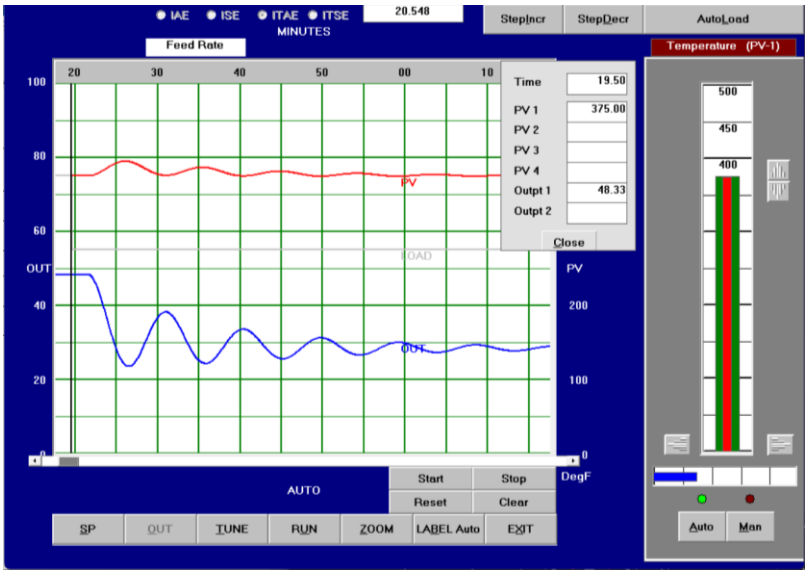


Figure 10. Time of applying load change (decrease the load)

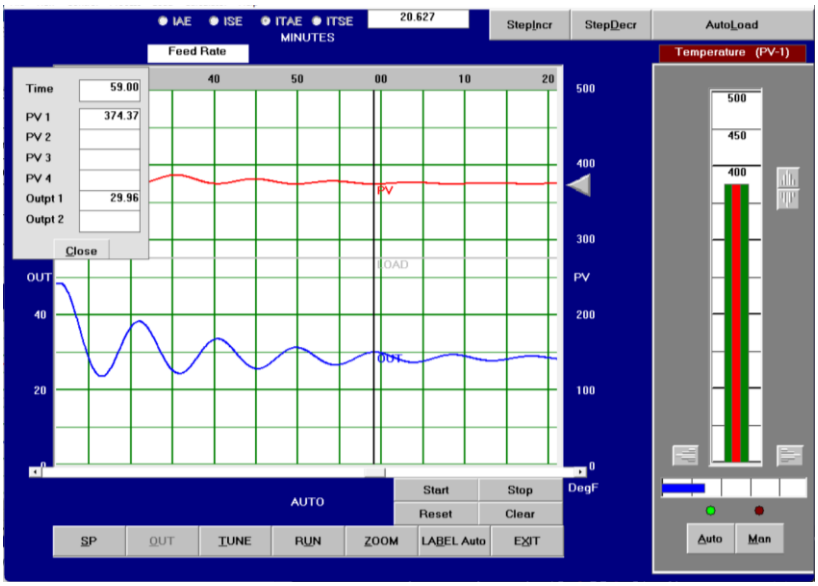


Figure 11. Settling time

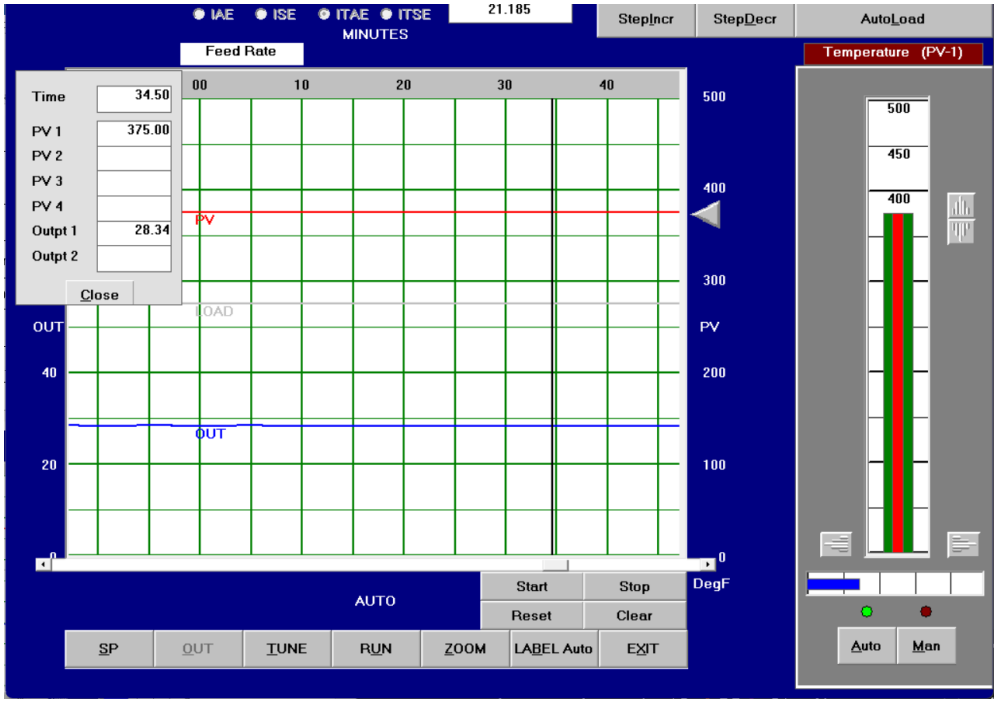


Figure 12. Final value of ITAE

3. IDENTIFICATION FROM OPEN LOOP DATA

Return to the normal operating point of 275 DegF, controller output of 35% and a load variable of 300 GPM.

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

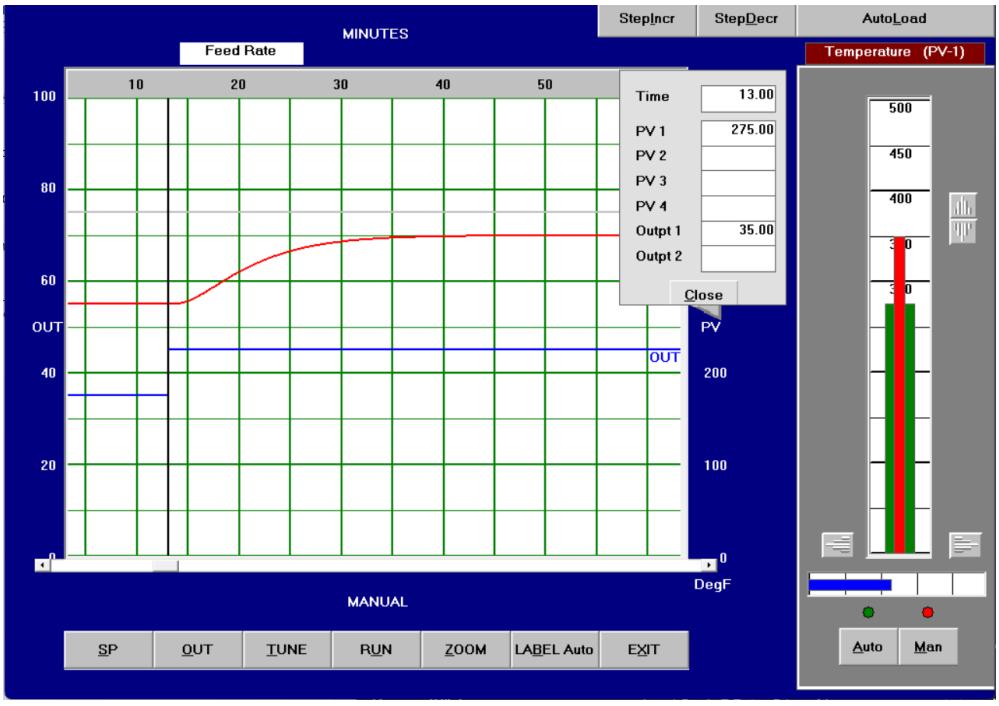


Figure 13. Time of changing controller output

- Estimate:
- (See Figure 1 at the back of this exercise on how to estimate process parameters.)

- Process gain (KP) $= \frac{\frac{75}{500}}{\frac{10}{100}} = \mathbf{1.5}$
- $t_{25} = t(PV = 275 + 75 * .25 = 293.75) = 17.50 - 13.00 = 4.5\ minutes$ (as shown in fig 14)
- $t_{75} = t(PV = 275 + 75 * .75 = 331.25) = 24.45 - 13.00 = 11.45\ minutes$ (as shown in fig 15)
- $\tau = 0.91 * (11.45 - 4.5) = 6.324\ minutes$
- $\theta = 11.4 - 1.4 * 6.37 = 2.482\ minutes$

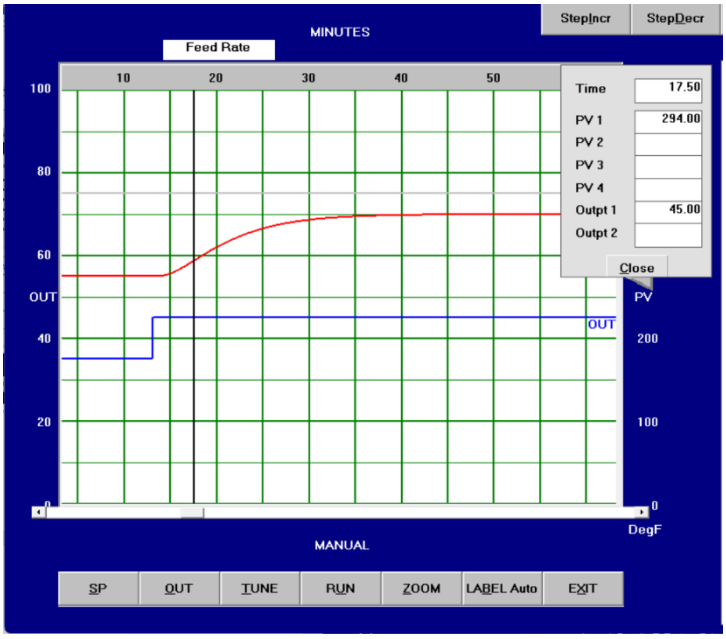


Figure 14. Time of 25% of PV change

Return the controller output to 35%.

In a later section, you will have the chance to try a more rigorous process identification method.

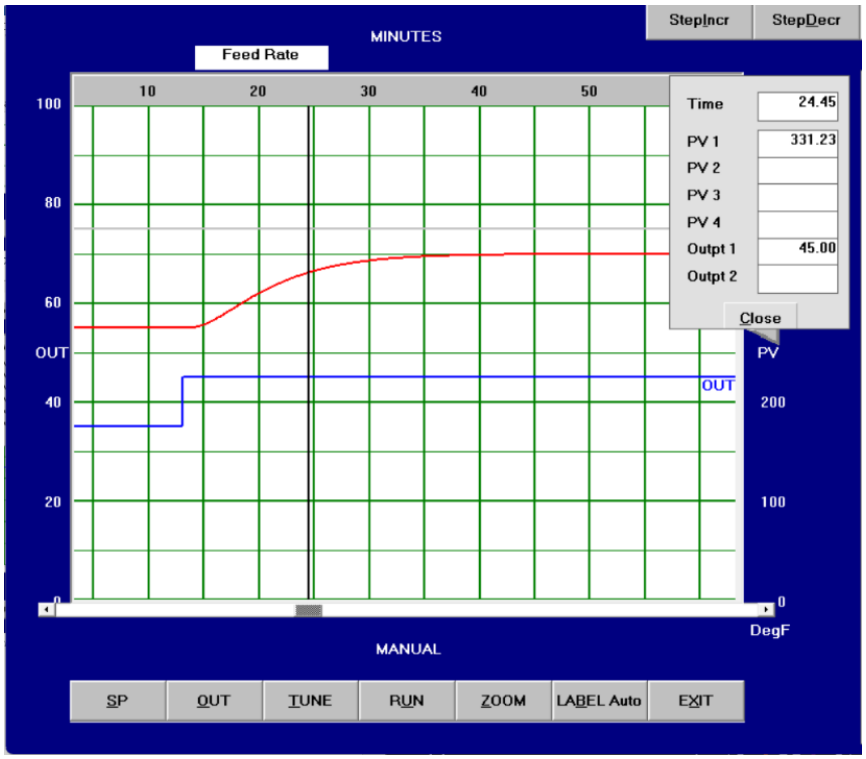


Figure 15. Time of 75% of PV change

4. TUNING AND TESTING THE FEEDBACK LOOP RESPONSE

Calculate tuning parameters for the PI controller, for each algorithm below. Enter them at the following table.

	Heuristic	**Ziegler-Nichols**	**Lambda tuning** $\lambda =$	**Ciancone-Marlin**	**Myke King P on PV**
Gain (K_C)		1.458			0.774
Reset Time (T_I) (min/rpt.)		8.658			5.622

NOTES:

(1) With the controller in MAN, select **Control | Control Options,** and select PID

Non-interacting control algorithm.

(2) For the P on PV algorithm ONLY, remember to select **Control | Control Options,** and select Prop on Meas.

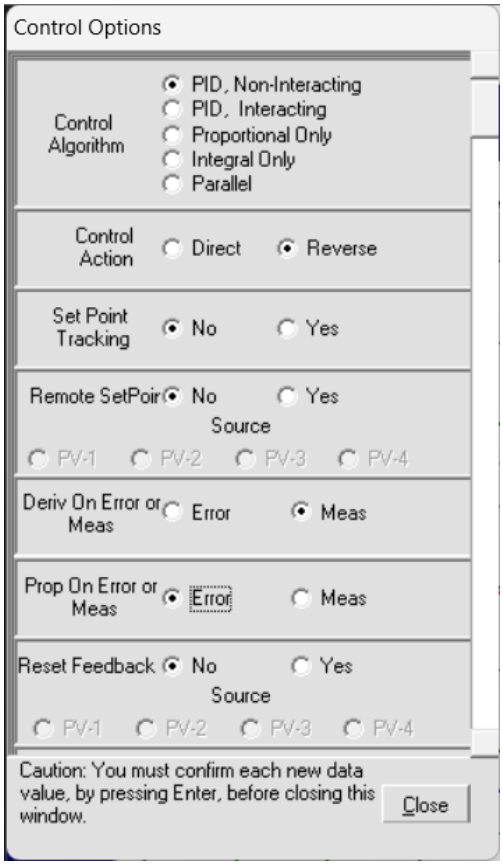


Figure 16. Select PID Non-interacting algorithm

For each tuning method, enter the parameters above (and, naturally, Deriv. Time = 0), put the controller in AUTO and make a setpoint change.

(Change the setpoint, either up or down, by 50 DegF. On the job, you probably cannot make that large of change.)

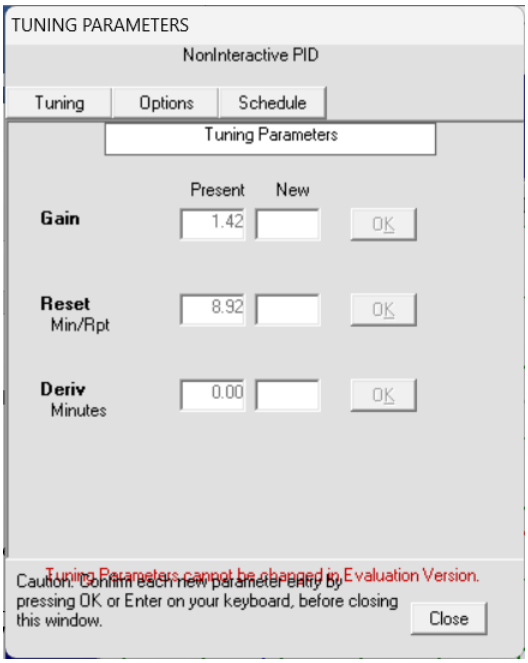


Figure 17. Tuning parameters of Ziegler-Nichols

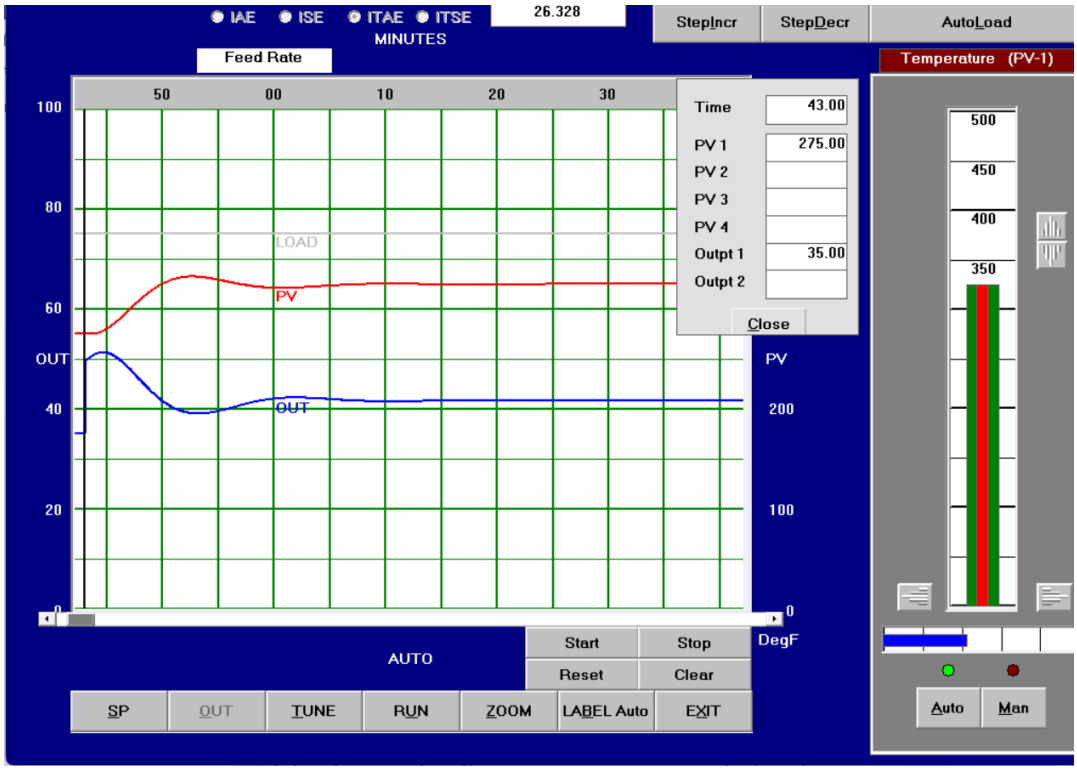


Figure 18. Time at which SP changed for Ziegler-Nichols

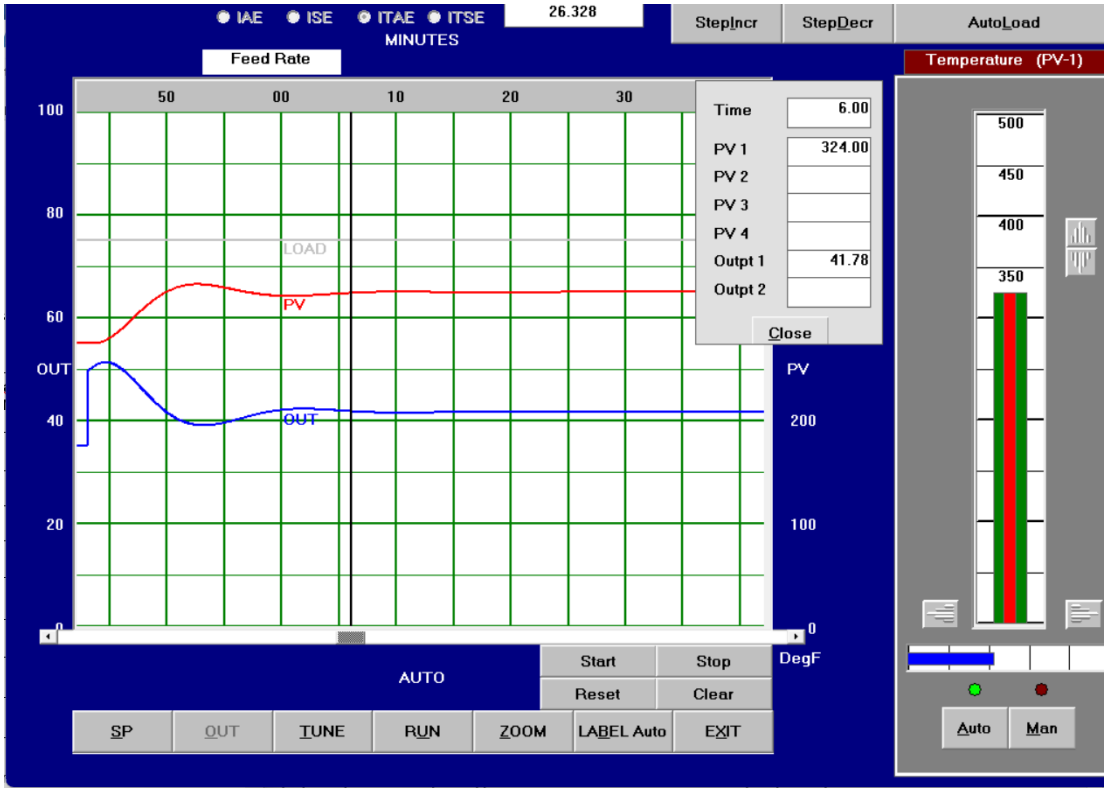


Figure 19. Settling time for Ziegler-Nichols

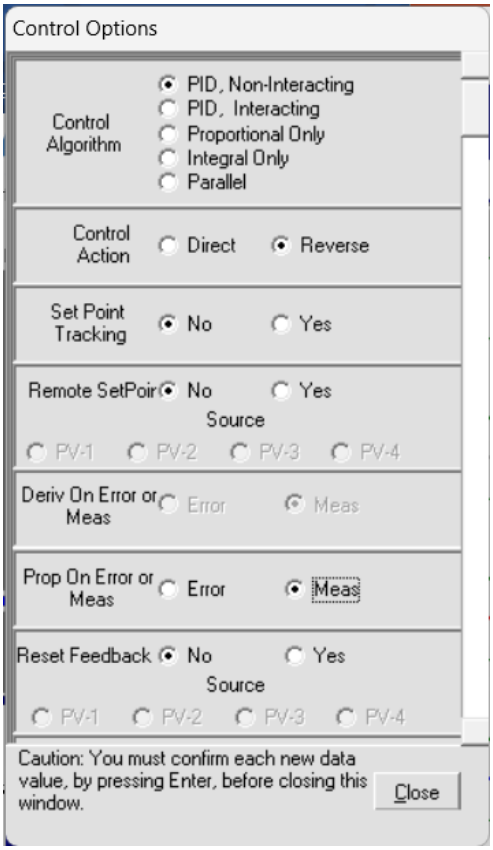


Figure 20. Select P on PV algorithm for Myke King

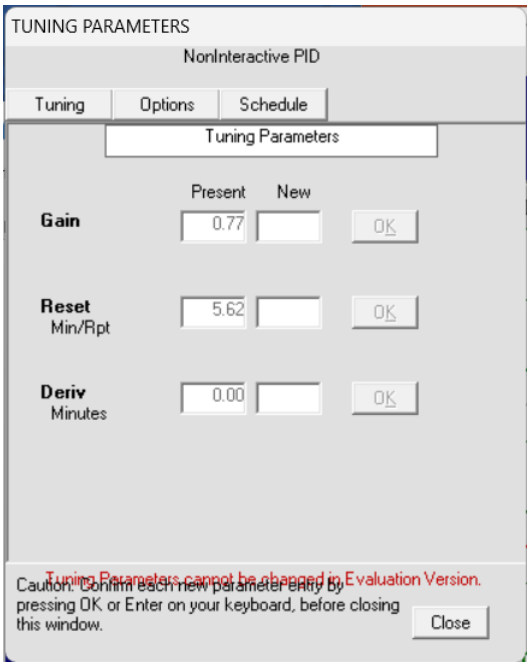


Figure 21. Tuning parameters for Myke King

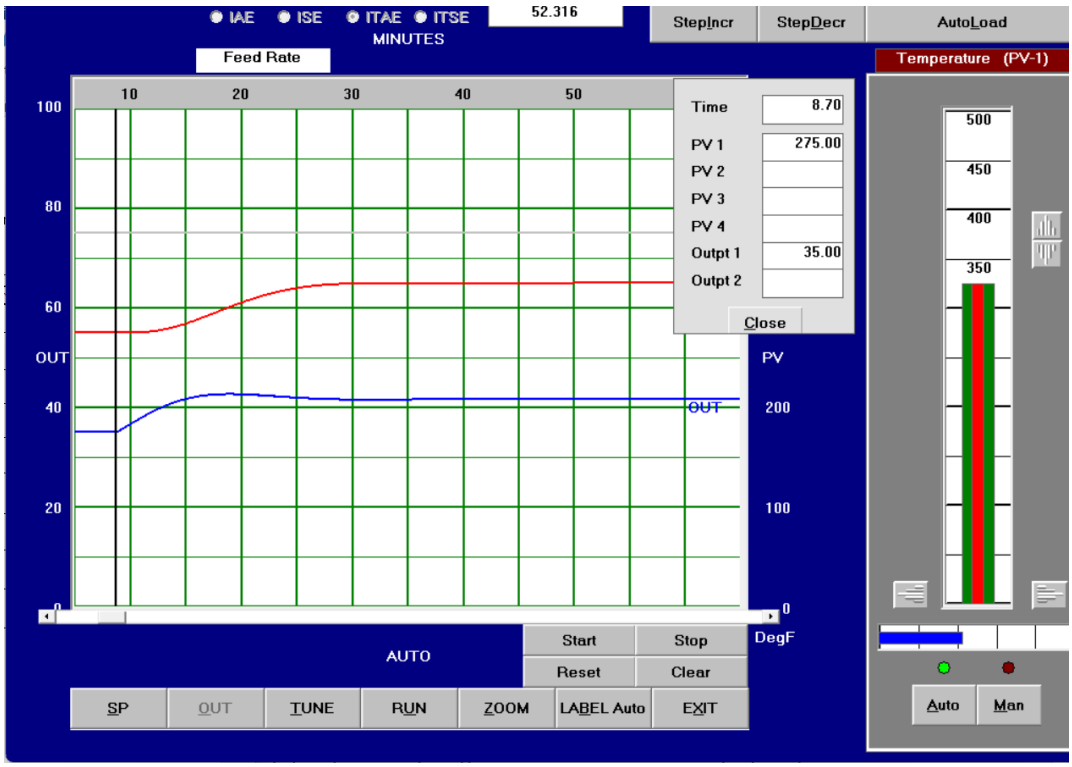


Figure 22. Time at which SP changed for Myke King

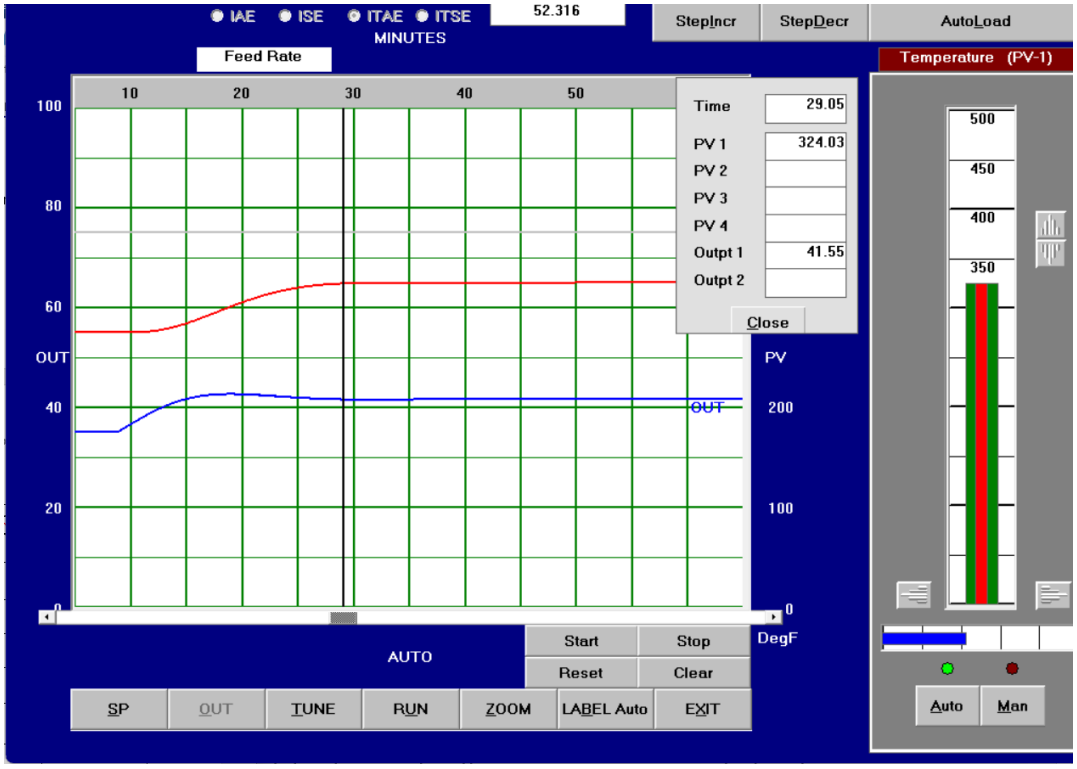


Figure 23. Settling time for Myke King

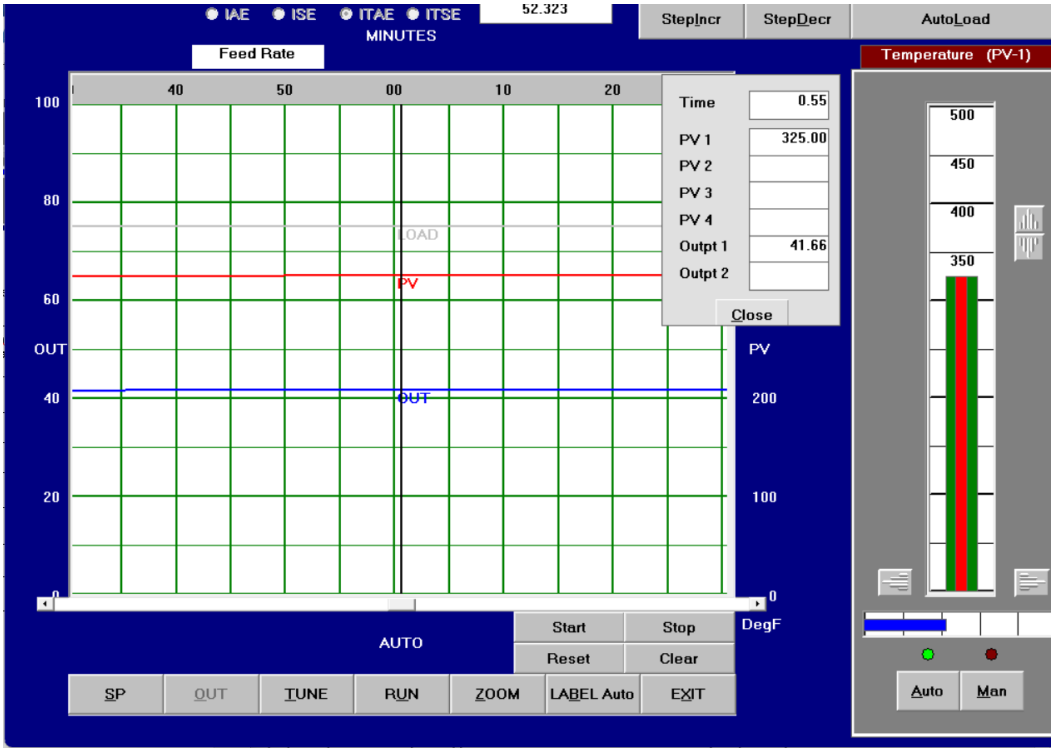


Figure 24. Final value of ITAE for Myke King

Fill in the table below. You may need to zoom in by pressing **ZOOM** and selecting appropriate values.

Setpoint change	Heuristic	Zeigler-Nichols	Lambda tuning	Ciancone -Marlin	Myke King P on PV
Settling time		66 – 43 = 23 minutes			29.05 – 8.7 = 20.35 minutes
Overshoot (%)		$\frac{332.45-325}{50} * 100 = 15\%$			0%
Decay Ratio		$\frac{325.12-325}{332.45-325} = 0.016$			0
Period		Not applicable			Not applicable
Manipulated variable overshoot (%)		$\frac{51.31-41.67}{41.67-35} * 100 = 144.5\%$			$\frac{42.62-41.67}{41.67-35} * 100 = 14.24\%$
Period / T_I		Not applicable			Not applicable
Settling time / $(\theta+\tau)$		2.578			2.28
ITAE		26.345			52.323

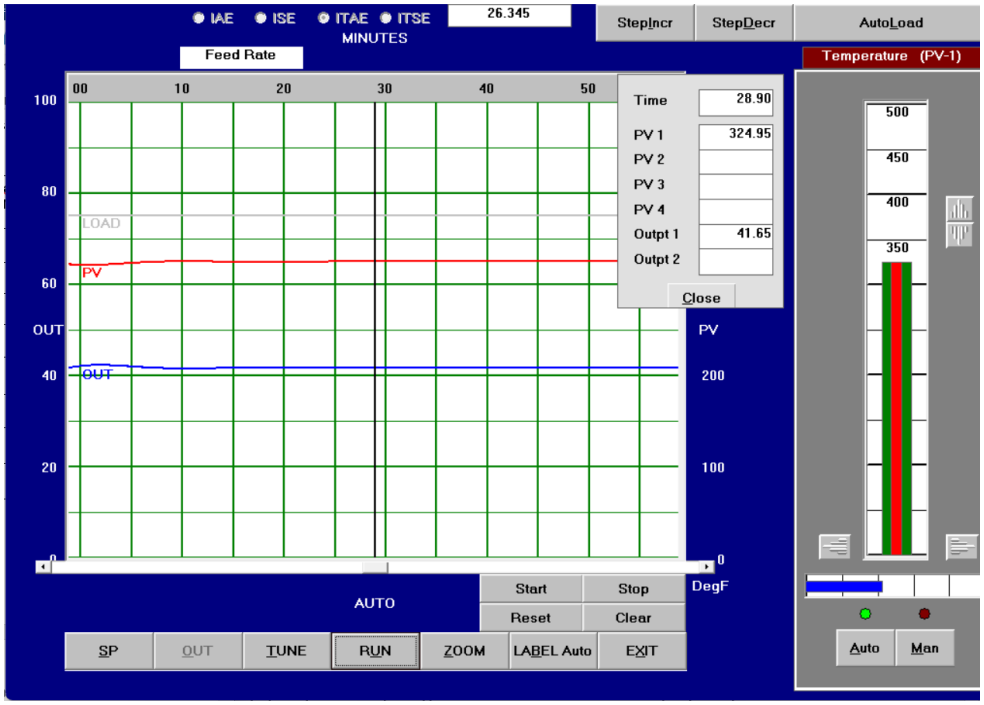


Figure 25. Final value of ITAE for Ziegler-Nichols

Repeat the above test, enabling the **SetPoint Ramp** option (enter a rate from 5 to 7 DegF/min, tweak this value as required) before making the same setpoint change. We use setpoint ramping since the more common setpoint filtering is not supported by this version of the software.

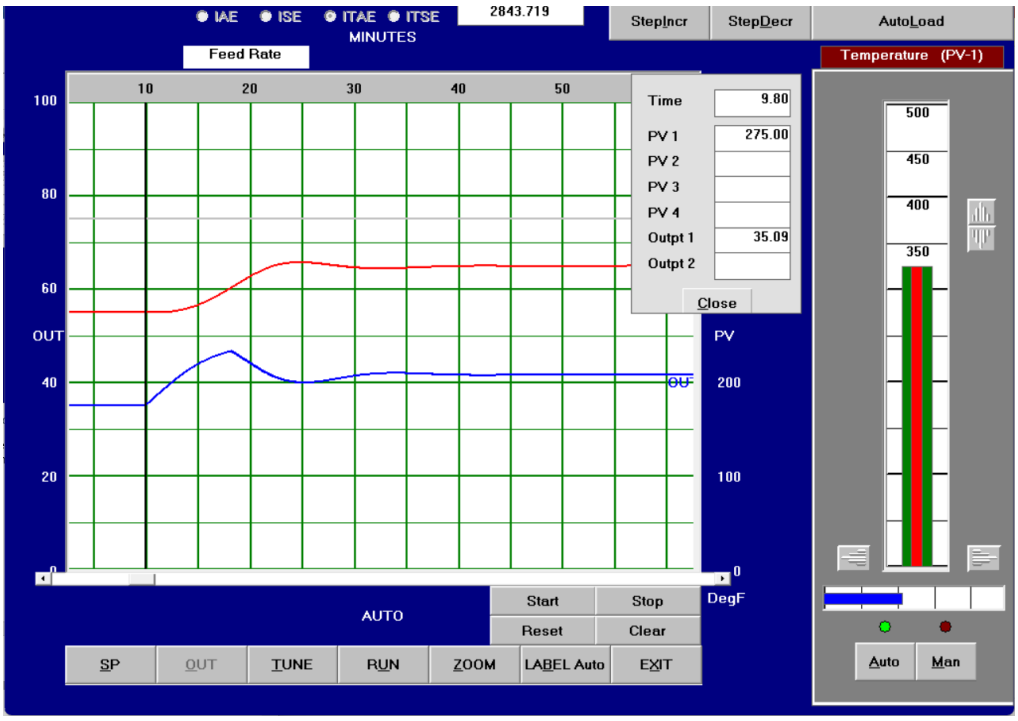


Figure 26. Time at which SP changed for SP ramping

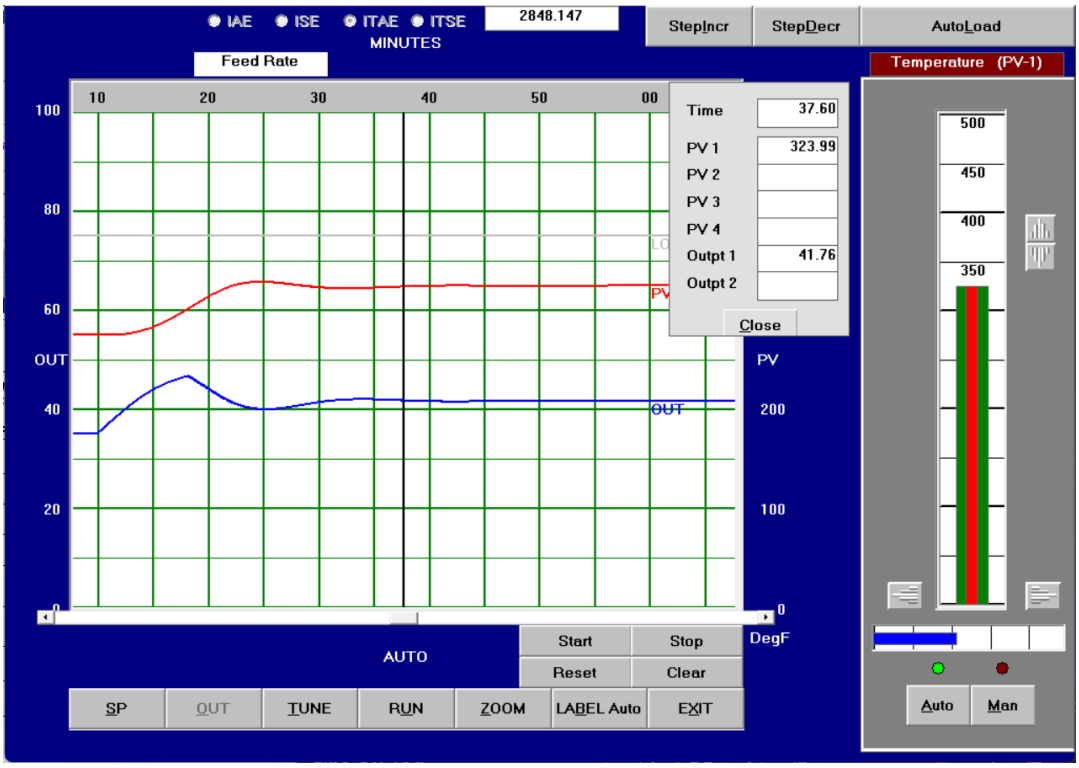


Figure 27. Settling time for SP ramping

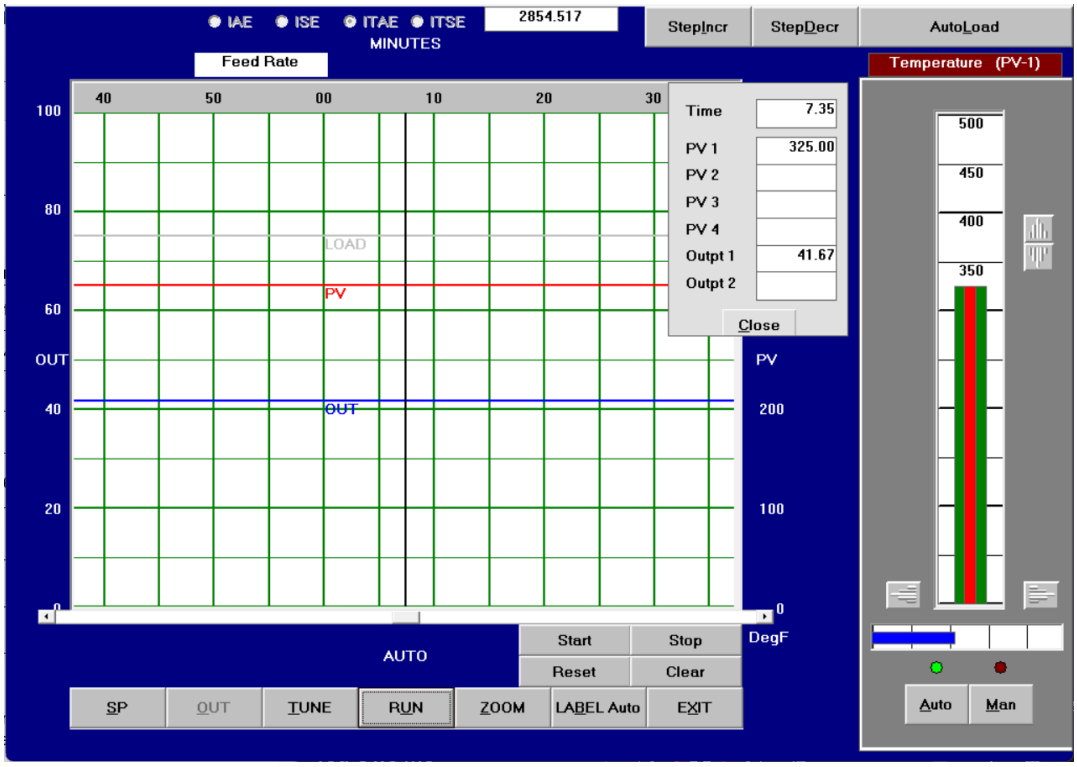


Figure 28. Final value of ITAE for SP ramping

Setpoint change	Zeigler-Nichols + setpoint ramping Ramp rate = 6 EU/min	Ciancone-Marlin + setpoint ramping Ramp rate =
Settling time	37.6 – 9.8 = 27.8 minutes	
Overshoot (%)	$\frac{328.72-325}{50} * 100 = 7.44\%$	
Decay Ratio	0	
Period	Not applicable	
Manipulated variable overshoot (%)	$\frac{46.59-4167}{41.67-35} * 100 = 73.763\%$	
Period / T_I	Not applicable	
Settling time / $(\theta+\tau)$	3.12	
ITAE	2854.517	

For the P on PV algorithm, does the smoother manipulated variable movement at the onset of a setpoint change degrade its performance compared to the other algorithms?

No

Which responses above appear to be well-damped?

Myke king

Further, test each controller by making 20% load change.
Press **StepIncr** or **StepDecr** once**.** Record the relevant data in the following table.

Load upset	Heuristic	Zeigler-Nichols	Lambda tuning	Ciancone-Marlin	Myke King P on PV
Peak deviation from setpoint (DegF)		364.42 – 325 = 39.42 DegF			376.15 – 325 = 51.15 DegF
Settling time (How to calculate?)		68.75 – 15.1 = 53.65 minutes (When PV = 325.78 DegF)			48.55 – 4.15 = 44.4 minutes (When PV = 326.02 DegF)
Decay Ratio		0			0
Manipulated variable overshoot (%)		$\frac{23.29-21.71}{41.67-21.71} * 100 = 7.92\%$			0%
ITAE		59.382			72.635

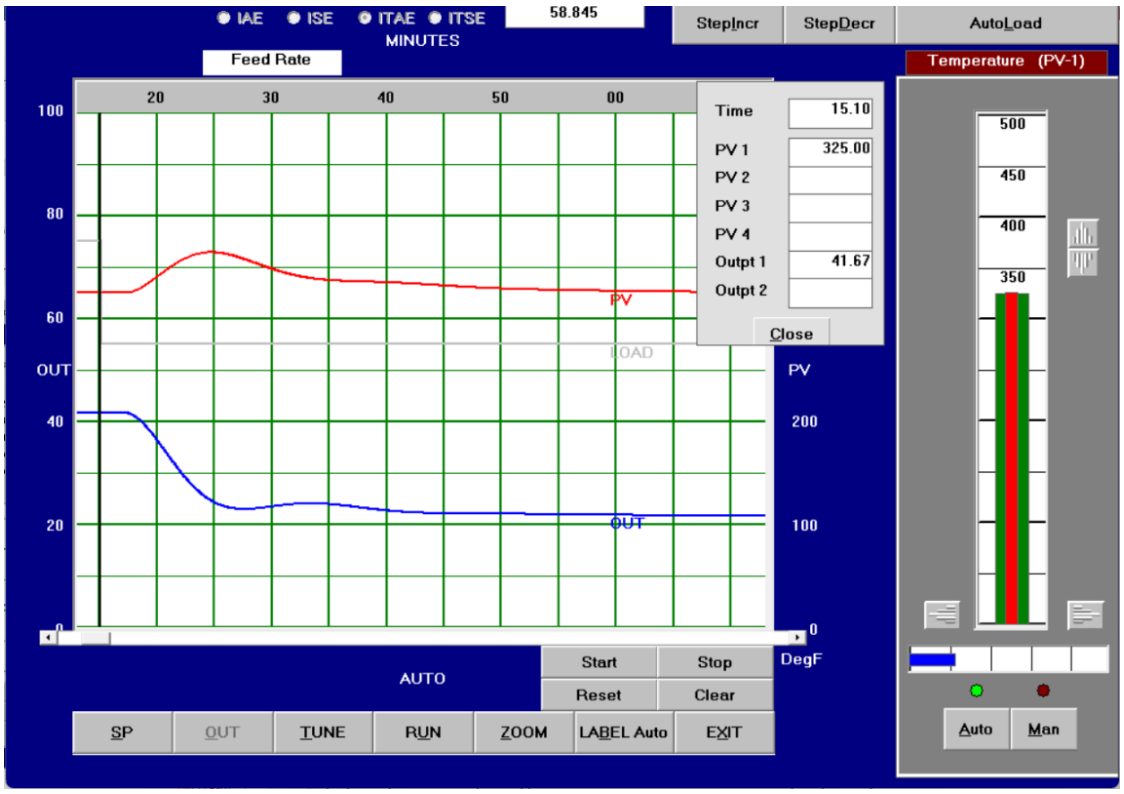


Figure 29. Time at which load is applied for Ziegler-Nichols

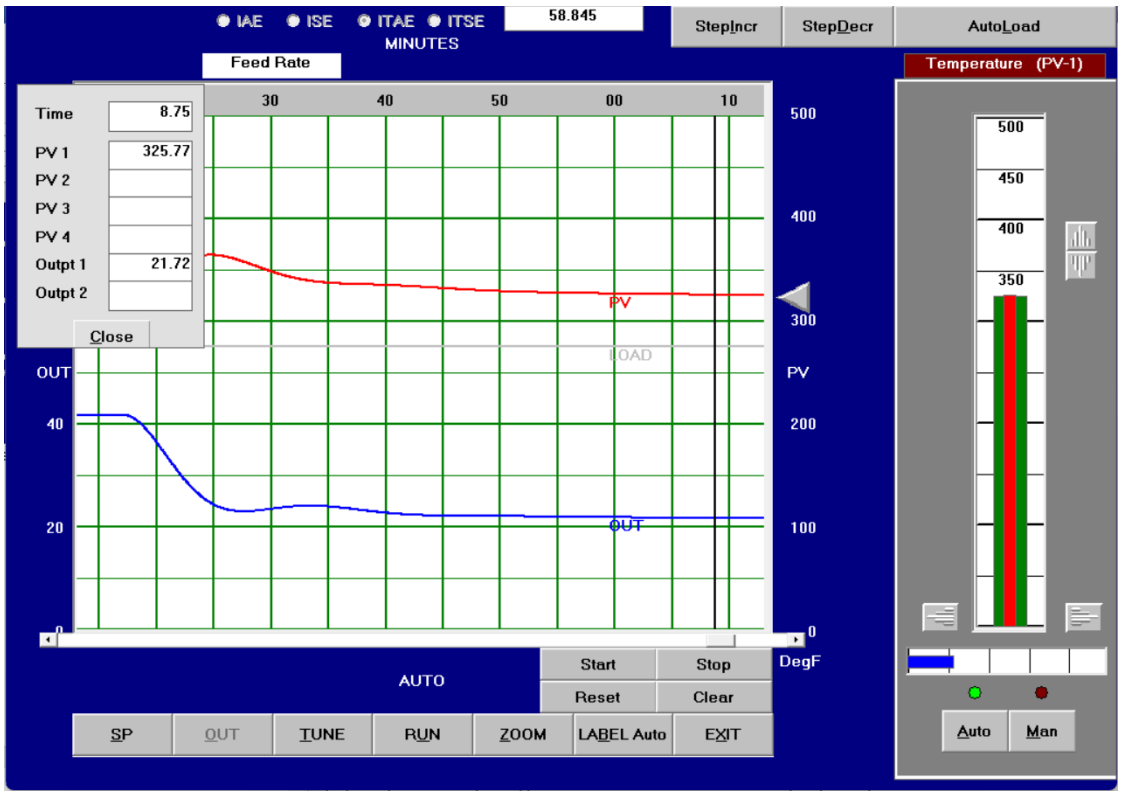


Figure 30. Settling time for Ziegler-Nichols

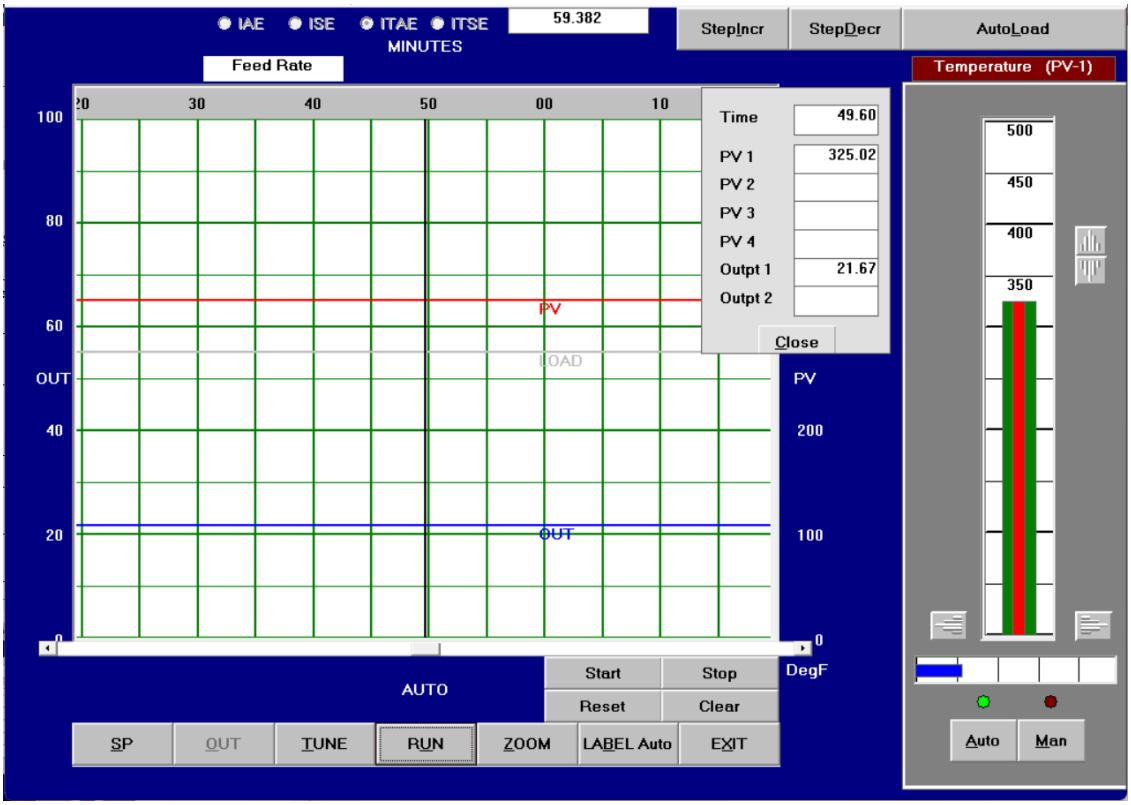


Figure 31. Final value of ITAE for Ziegler-Nichols

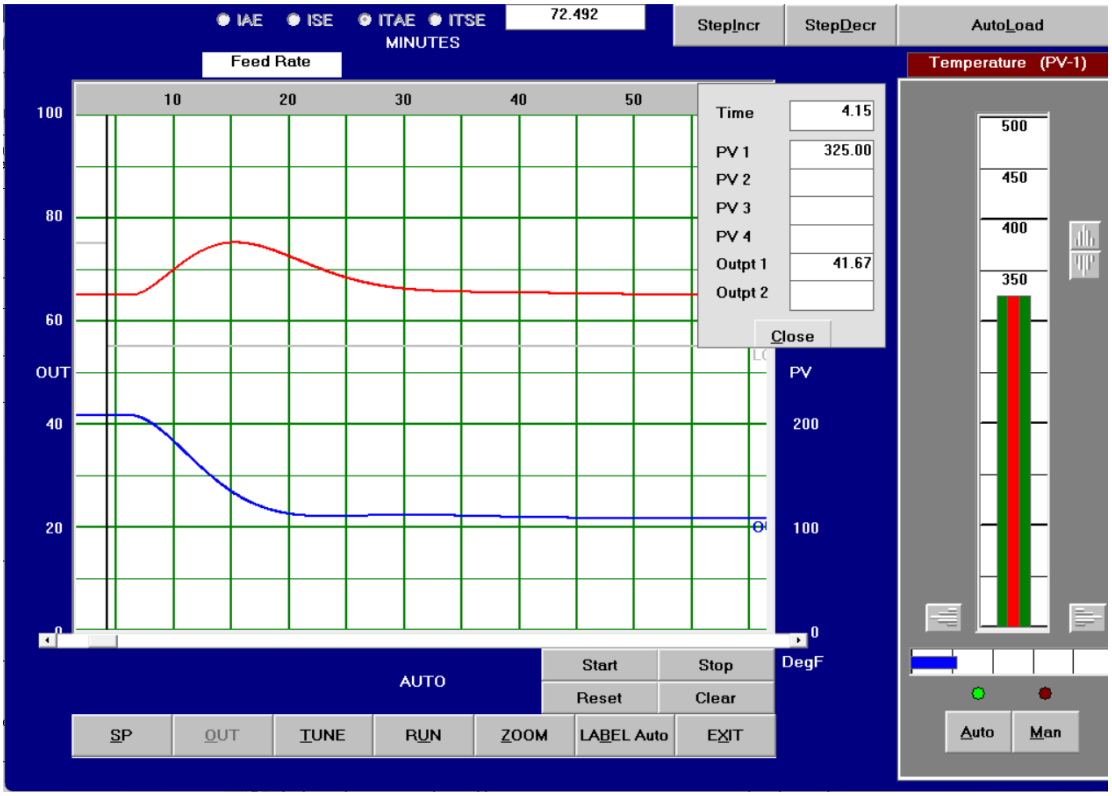


Figure 32. Time at which load is applied for Myke King

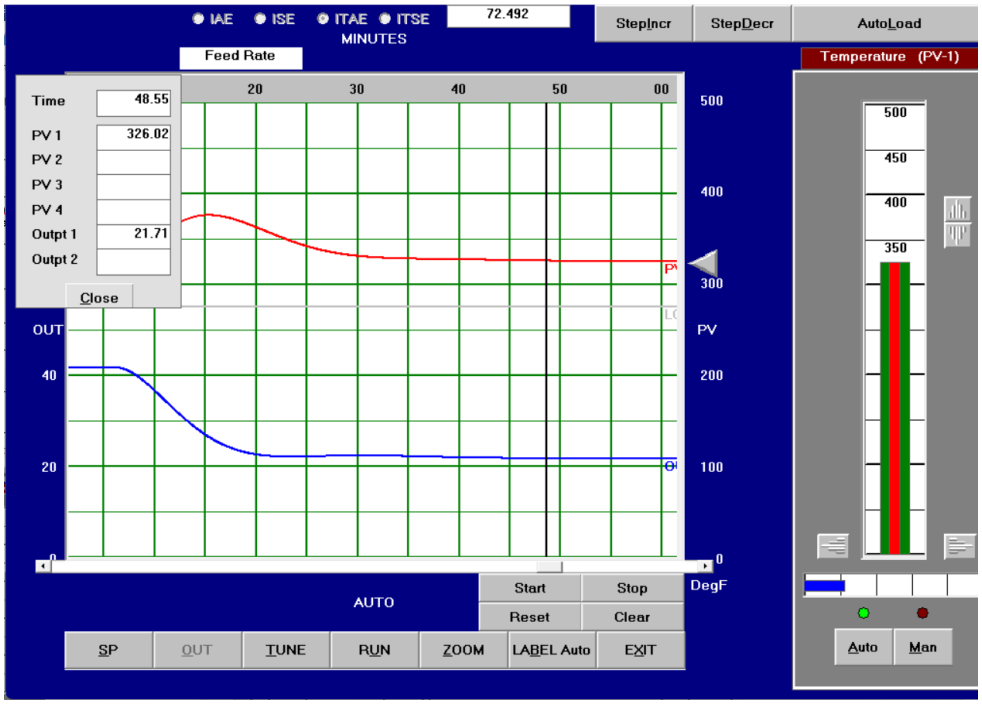


Figure 33. Settling time for Myke King

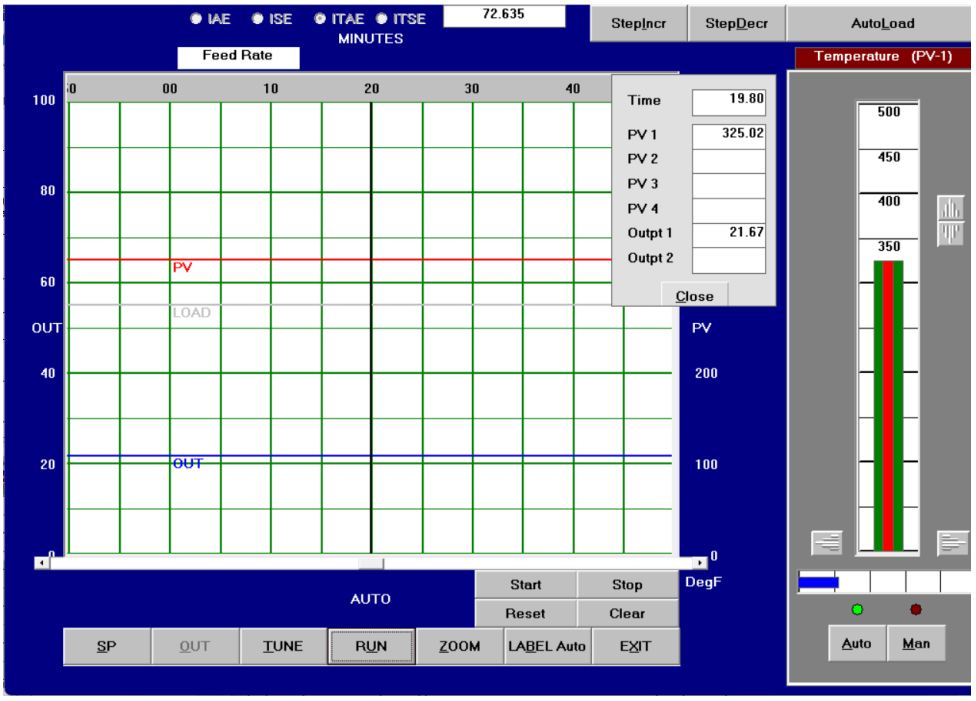


Figure 34. Final value of ITAE for Myke King

Does Zeigler-Nichols's method achieve quarter cycle decay as it aims for? **No**

Should we redo the load upset test above with setpoint ramping enabled? Why?

No, because the PV experiences a gradual load effect.

Based on your findings above, which tuning method would you use?

Myke King Method

How does trial-and-error tuning in section 2 compared to formal tuning, in time, effort, and results?

The trial-and-error approach required more time and effort but yielded poorer results than formal tuning.