Effective
Control Loop Optimization

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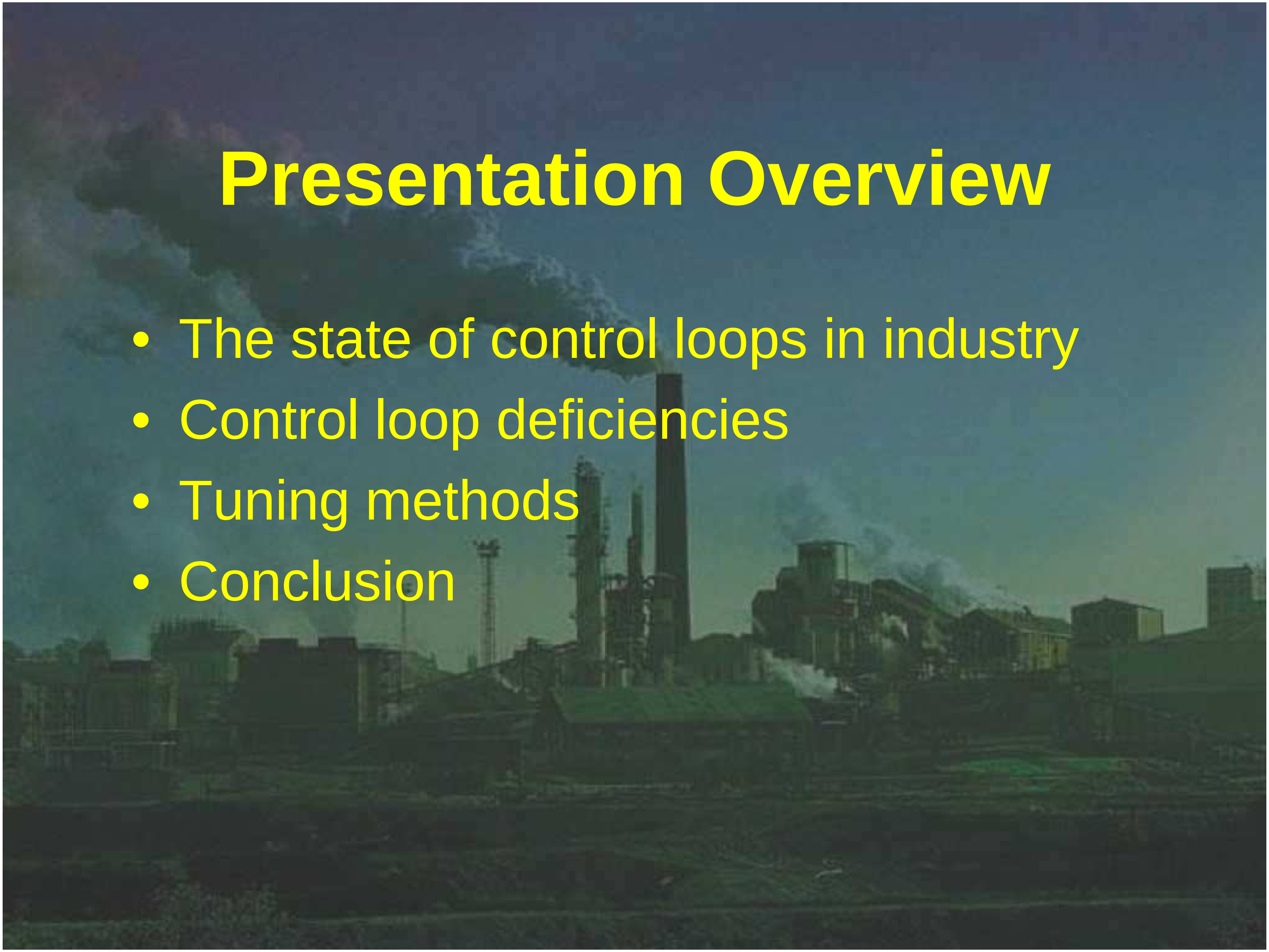


Presentation Overview

- The state of control loops in industry
- Control loop deficiencies
- Tuning methods
- Conclusion

State of Control Loops in Industry

- 50% of loops have equipment problems
- 85% of controllers are not optimally tuned
- 20% of controllers run in manual mode
- Loops with problems are simply detuned
- Plants run well only with frequent operator intervention

Most common control loop deficiencies

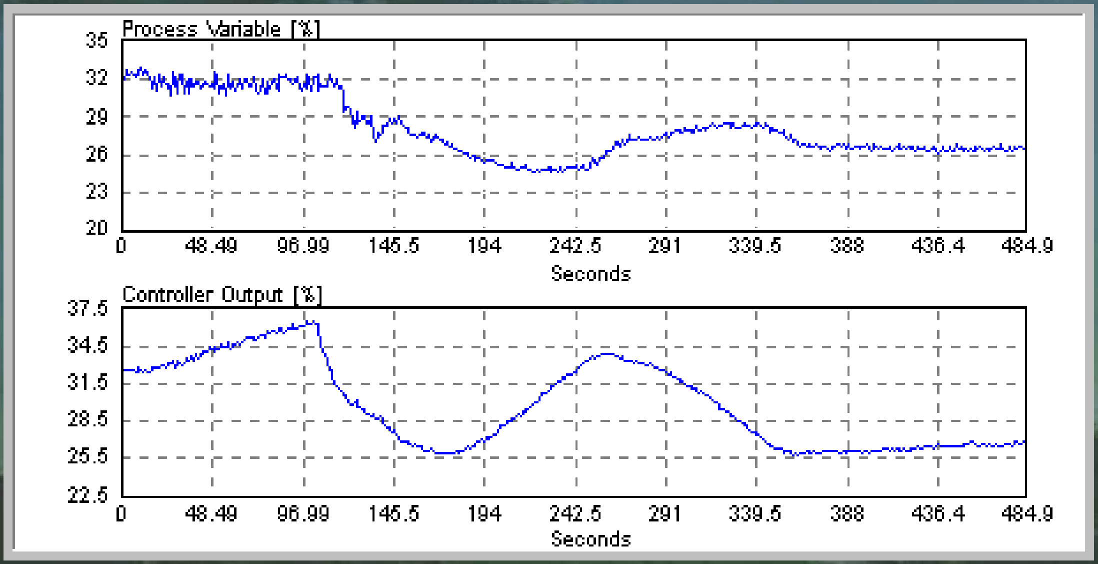
- Hysteresis
- Stiction
- Nonlinearity
- Incorrect controller settings

Hysteresis

- Acts like backlash or deadband
- Mostly due to:
  - Play in mechanical linkages
  - Excessive friction in valve
  - Undersized actuator
  - Sticky positioner
- It decreases control loop performance
  - Adds dead time to control loop
  - Increases variability

Effects of Hysteresis

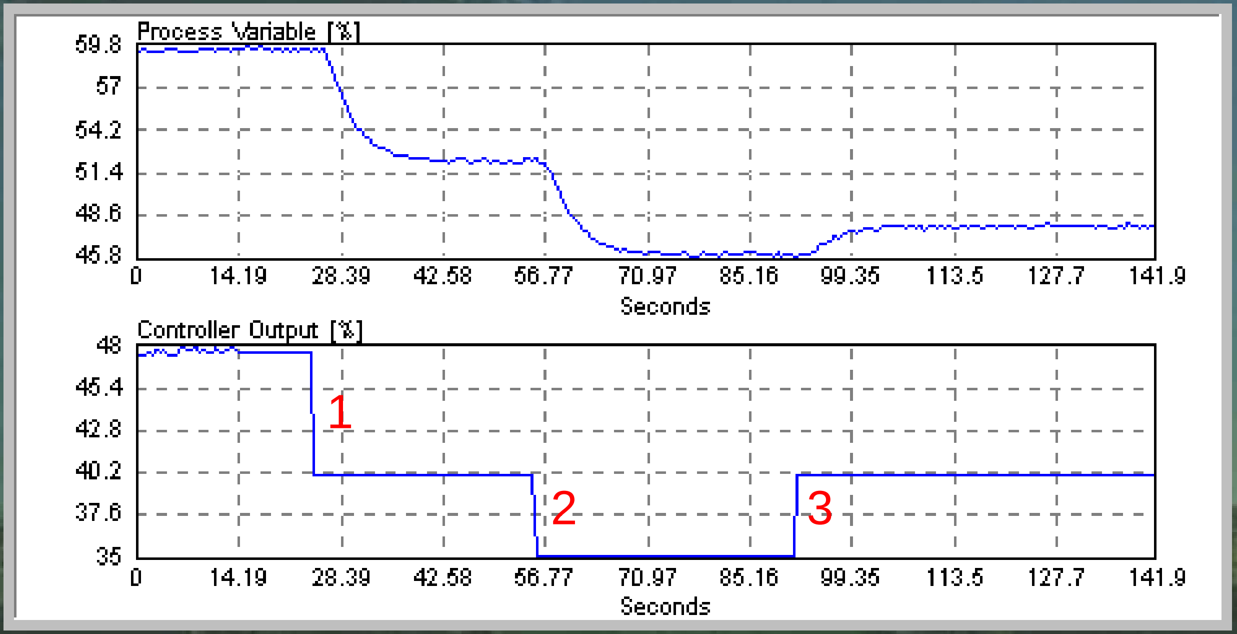
Cycling after setpoint change on flow loop



Valve had 6.1% hysteresis

Testing for hysteresis

- Do two CO steps in same direction, then one in reverse



$$\%Hysteresis = dCO_3 - \left(dPV_3 \frac{dCO_2}{dPV_2} \right)$$

Limits on hysteresis

- Hysteresis should be kept below 2%
- Process Gain amplifies the effect of hysteresis
- Hysteresis x Gain should also be kept below 2%

Reducing hysteresis

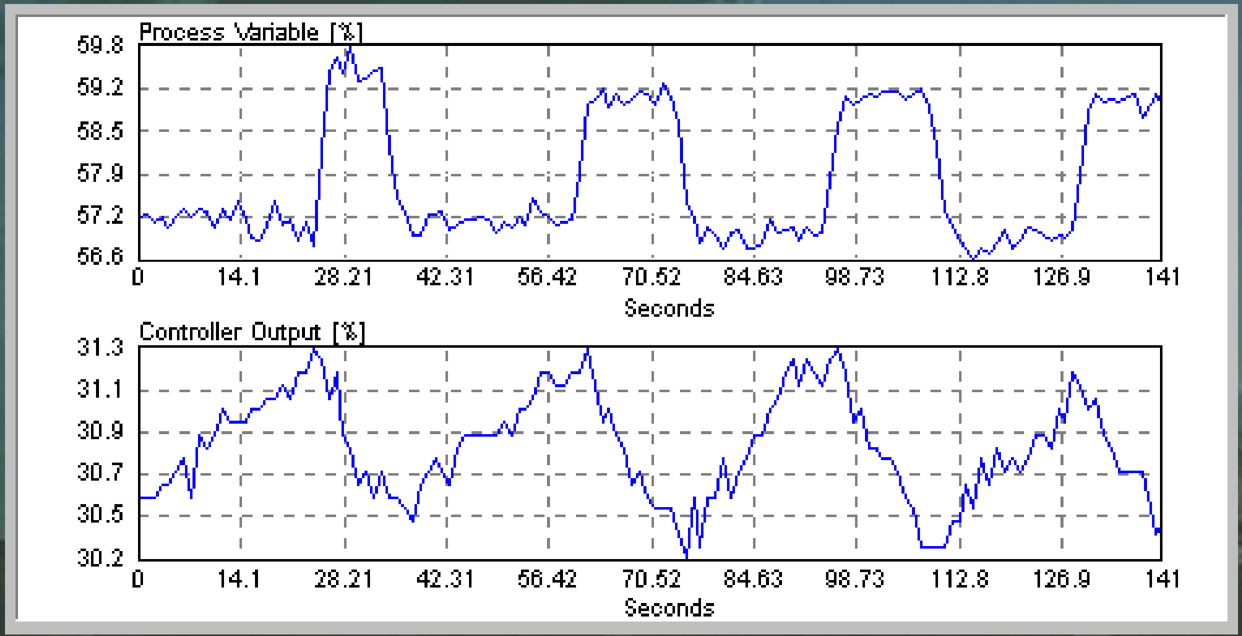
- Overhaul or replace actuator linkages
- Replace or overhaul valve
- Use a larger actuator
- Overhaul an existing positioner
- Add a positioner

Stiction

- Static Friction
  - More force is required to induce movement than to sustain movement.
- Mostly due to:
  - Over-tightned valve stem seal
  - Sticky valve internals
  - Undersized actuator
  - Sticky positioner
- It decreases control loop performance
  - Introduces cycling into the control loop
  - Increases variability

Effects of Stiction

Loop cycled continuously in automatic

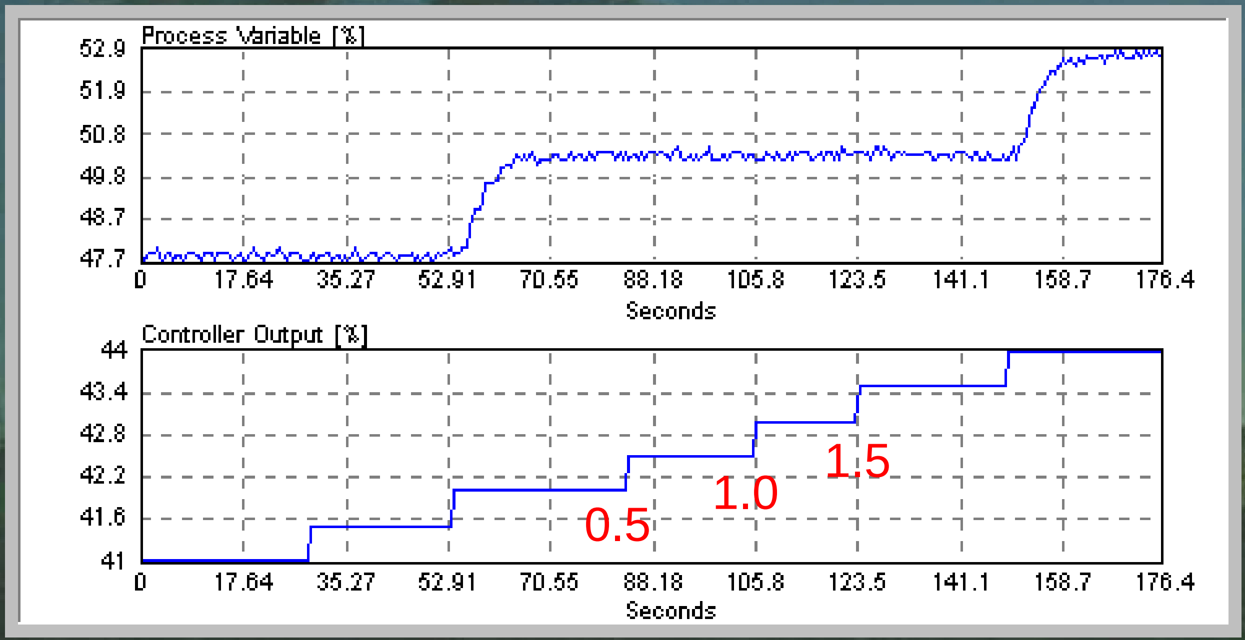


This is called a stick-slip cycle

Valve had 1% stiction

Testing for stiction

- Do small CO steps in the same direction until the PV has moved twice.



- Record %CO change between PV movements.

Limits on stiction

- Stiction should be kept below 1%
- Process Gain amplifies the effect of stiction
- Stiction x Gain should also be kept below 1%

Reducing stiction

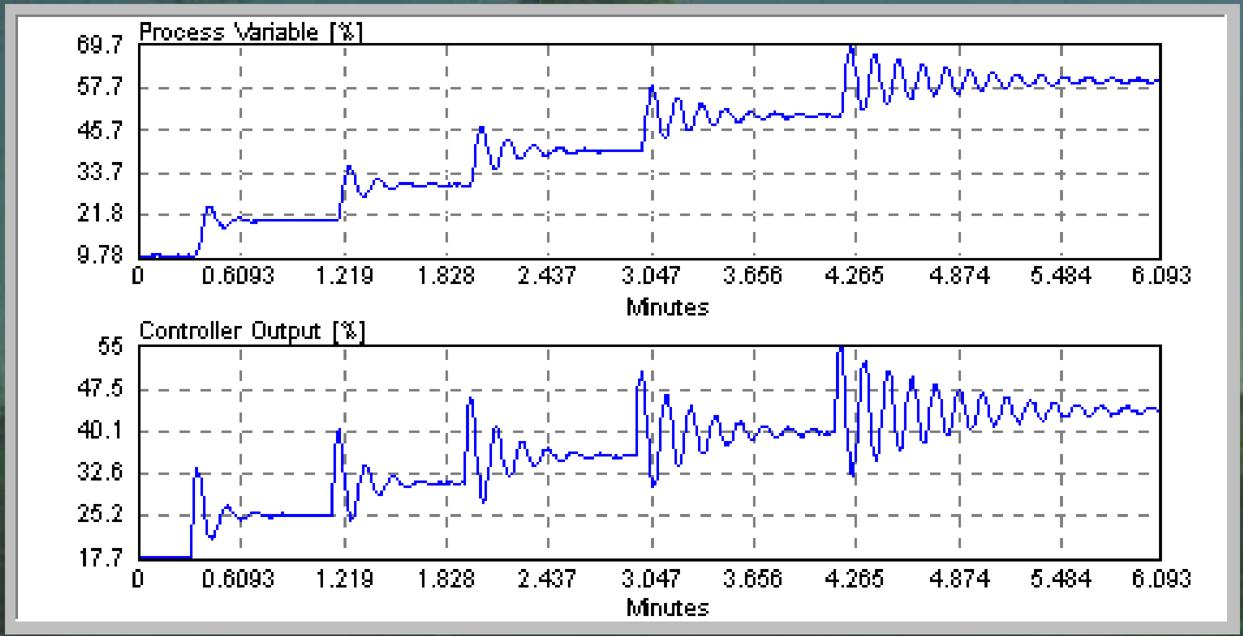
- Replace or overhaul valve or its internals
- Use a larger actuator
- Overhaul existing positioner
- Add a positioner

Nonlinearity

- Different gains under different conditions
- Mostly due to:
  - Valve characteristic not matched with process characteristic
  - Nonlinear process e.g. pH control
- It decreases control loop performance
  - Optimal PID tuning only at one point
  - Instability or sluggishness everywhere else

Effects of Nonlinearity

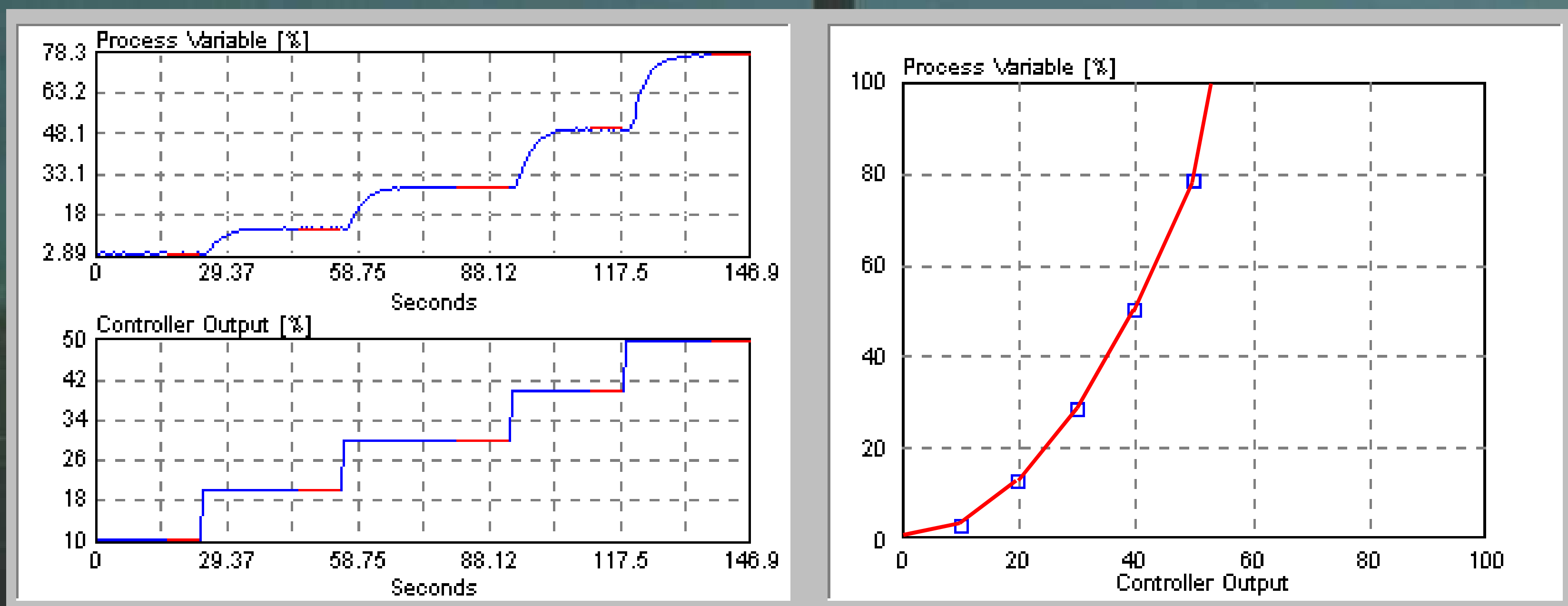
Control loop reacts differently depending on load



Valve had an incorrect characteristic

Testing for nonlinearity

- Obtain steady CO and PV over as wide a range as possible
- Plot PV against CO



Limits on nonlinearity and Process Gain

- Gp_{max} should be less than 2
- Gp_{min} should be greater than 1/2
- Gp_{max} / Gp_{min} should be less than 1.5

Reducing nonlinearity

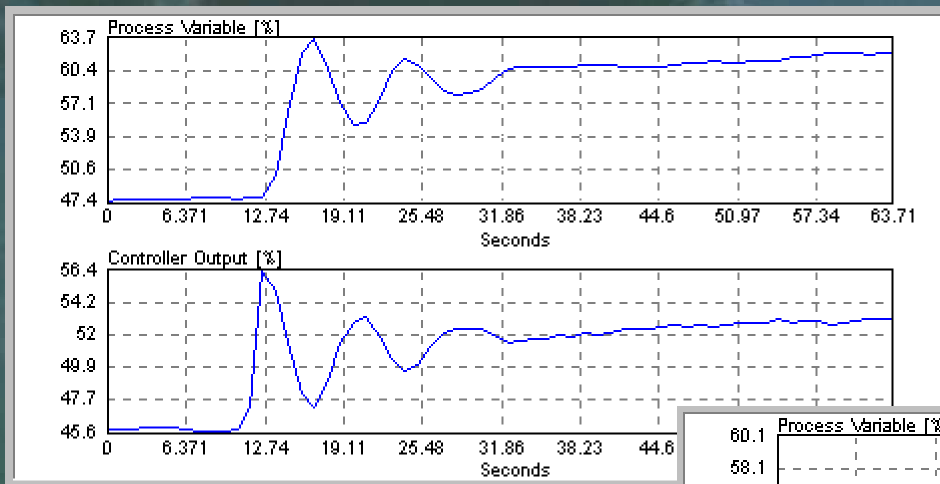
- Correct valve trim
- Use a valve with correct characteristic
- Use a different feedback cam on positioner
- Use a smart positioner with a characterizer
- Characterize controller output in PLC or DCS

Controller tuning

- Adjusting controller parameters:
  - Proportional
  - Integral
  - Derivative
- To control a process with
  - Gain
  - Dead time
  - Lag

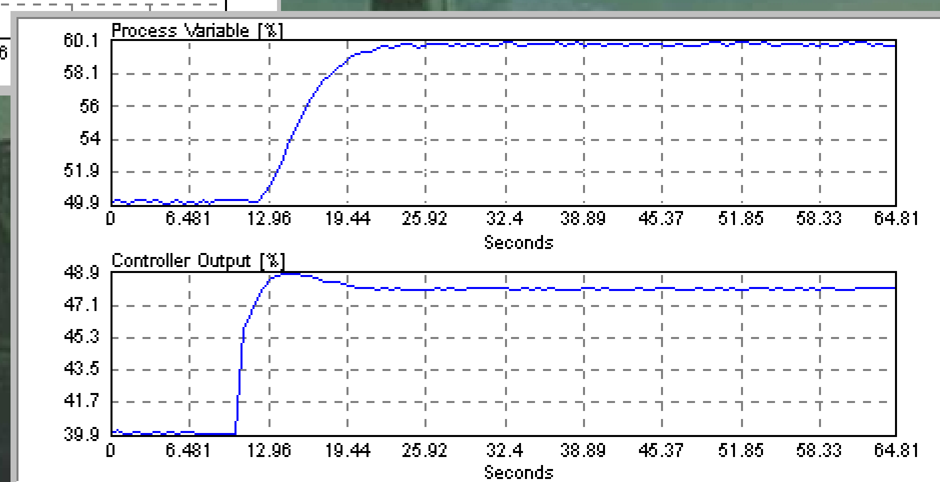
Effects of improper tuning

- Cyclic and slow recovery rate



Most control loops respond like this!

Improper tuning

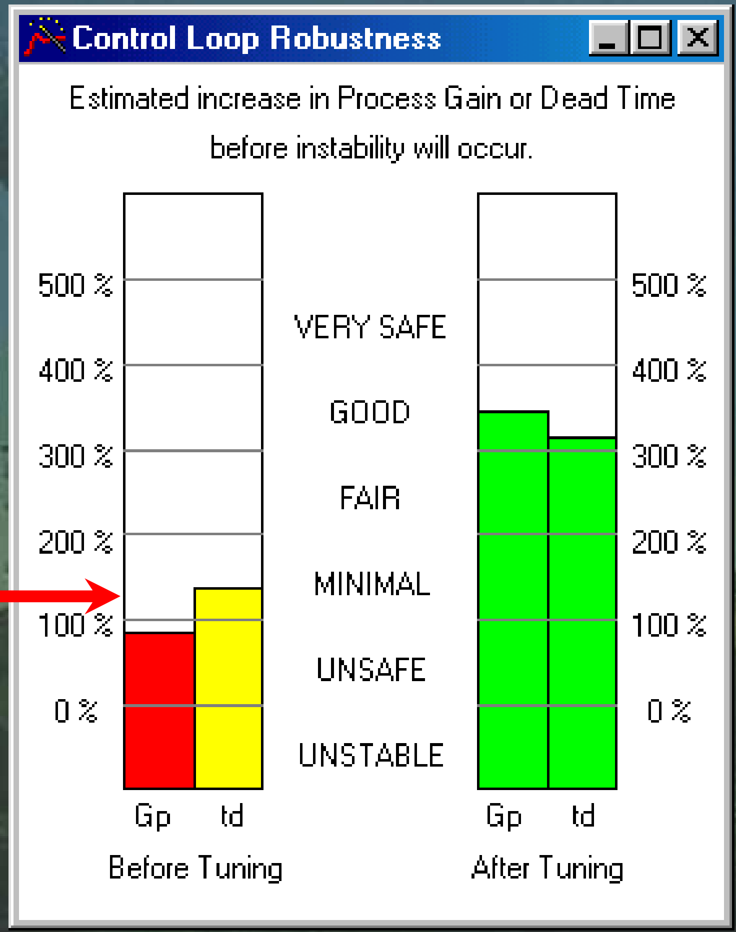


Proper tuning

Effects of improper tuning - II

- Poor robustness

Most control loops are not robust!



Origins of improper tuning

- Trial and error tuning
- Tuning at only one operating point
- Compensating for process deficiencies
- Most tuning rules give inadequate robustness

Proper tuning methods

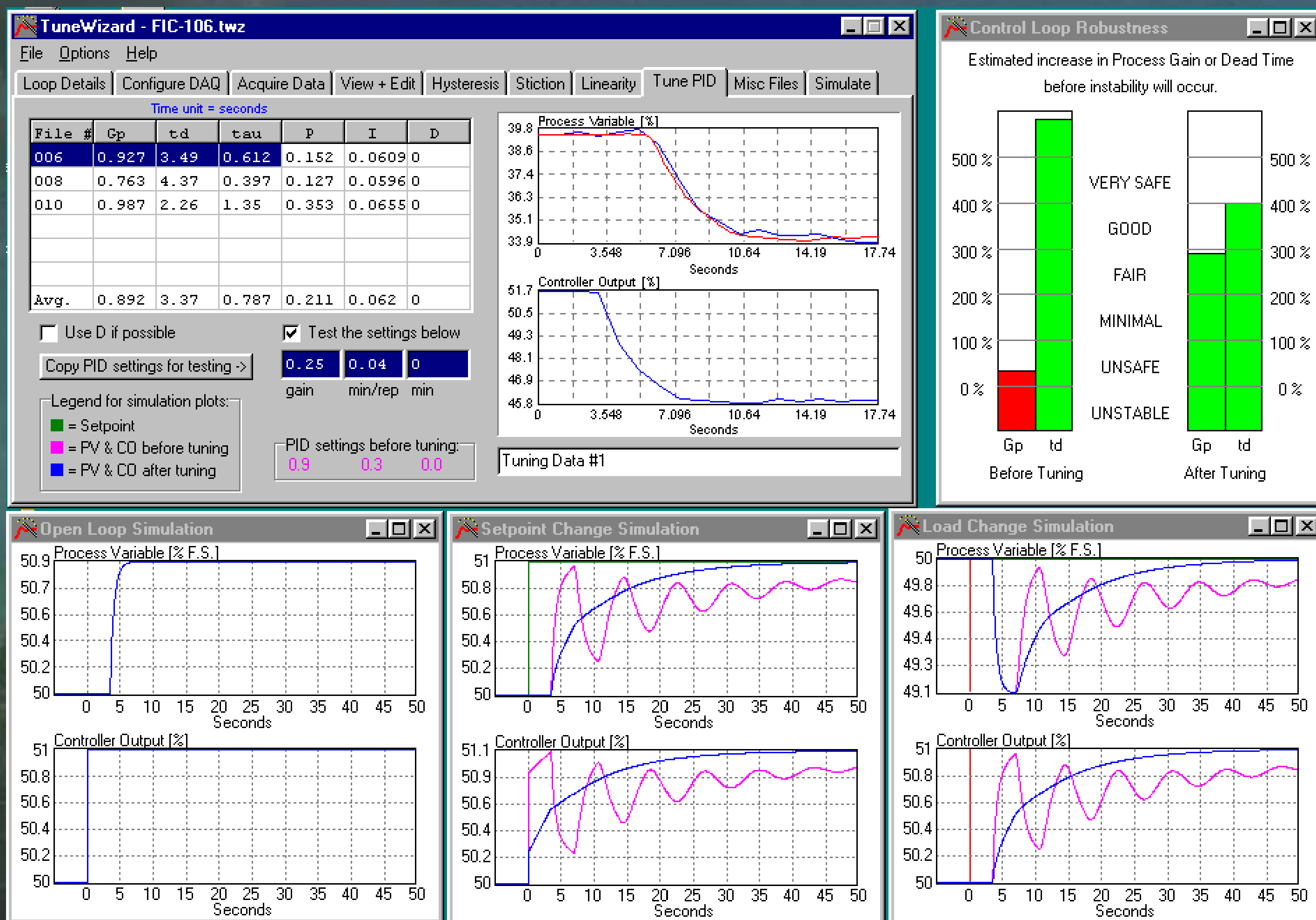
- Use a scientific tuning method - not trail and error
  - Do bump test on process
  - Measure Process Gain, Dead Time, Lag Time
  - Use a tuning rule to calculate controller settings
- Use simulations for fine-tuning
- Ensure adequate robustness
  - In most cases reduce the controller gain by 50%
- Try the settings on different process models

Software Tuning Tools

- Quick, easy, get it right the first time round

- Hysteresis, Stiction, Linearity diagnostics
- Modelling and Tuning
- Simulations, Robustness plots
- Report writing

TuneWizard™



TuneWizard - FIC-106.twz
File Options Help
Loop Details Configure DAQ Acquire Data View + Edit Hysteresis Stiction Linearity Tune PID Misc Files Simulate
Time unit = seconds
File # Gp td tau P I D
006 0.927 3.49 0.612 0.152 0.0609 0
008 0.763 4.37 0.397 0.127 0.0596 0
010 0.987 2.26 1.35 0.353 0.0655 0
Avg. 0.892 3.37 0.787 0.211 0.062 0
Use D if possible
Test the settings below
Copy PID settings for testing ->
0.25 0.04 0
gain min/rep min
Legend for simulation plots:
= Setpoint
= PV & CO before tuning
= PV & CO after tuning
PID settings before tuning:
0.9 0.3 0.0
Process Variable [%]
Controller Output [%]
Seconds
Tuning Data #1
Control Loop Robustness
Estimated increase in Process Gain or Dead Time before instability will occur.
VERY SAFE
GOOD
FAIR
MINIMAL
UNSAFE
UNSTABLE
Gp td
Before Tuning
After Tuning
Open Loop Simulation
Setpoint Change Simulation
Load Change Simulation
Process Variable [% F.S.]
Controller Output [%]
Seconds

Conclusion

- Most control loops have deficiencies
- Check valve hysteresis
- Check for stiction
- Ensure process linearity
- Use a scientific tuning method
- Ensure adequate control loop robustness


Thank you,
and Stay Tuned!
Any questions?
Booth M-52