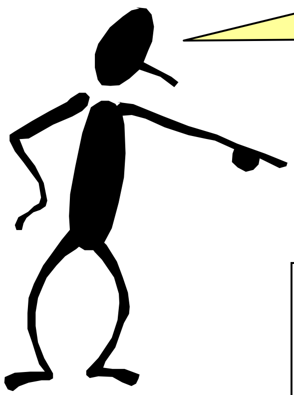
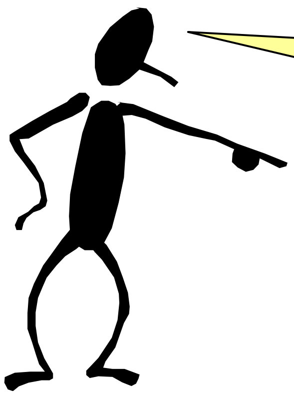
CHAPTER 7: THE FEEDBACK LOOP



When I complete this chapter, I want to be able to do the following.

- **Identify the major elements in the feedback loop**
- **Select appropriate candidate variables to be controlled and manipulated**
- **Evaluate the control performance data using standard measures of dynamic performance**

CHAPTER 7: THE FEEDBACK LOOP



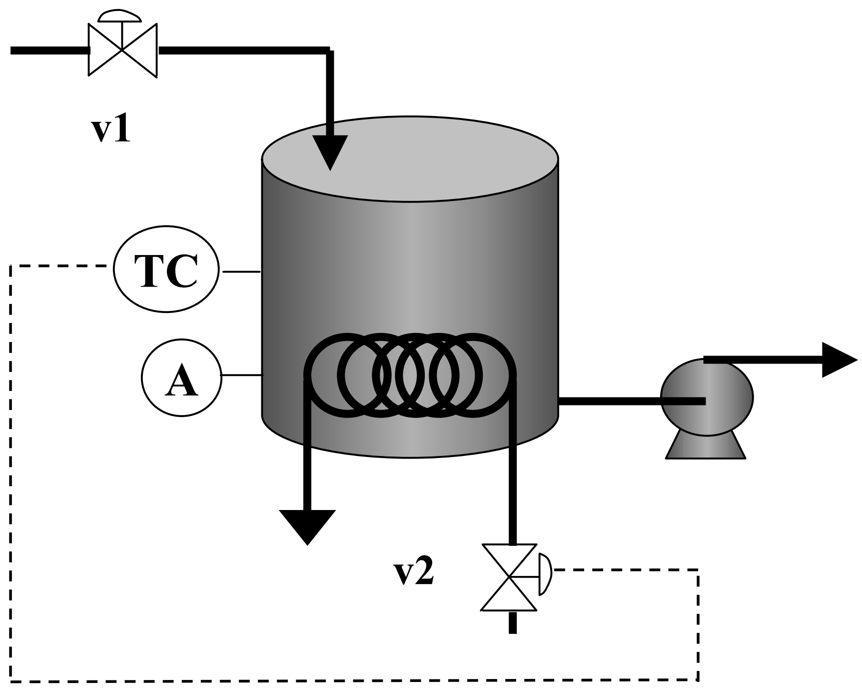
Outline of the lesson.

- **Typical loop elements**
- **Relating variables to control objectives**

  - Examples
- **Typical control performance measures**
- **Five approaches to feedback control**

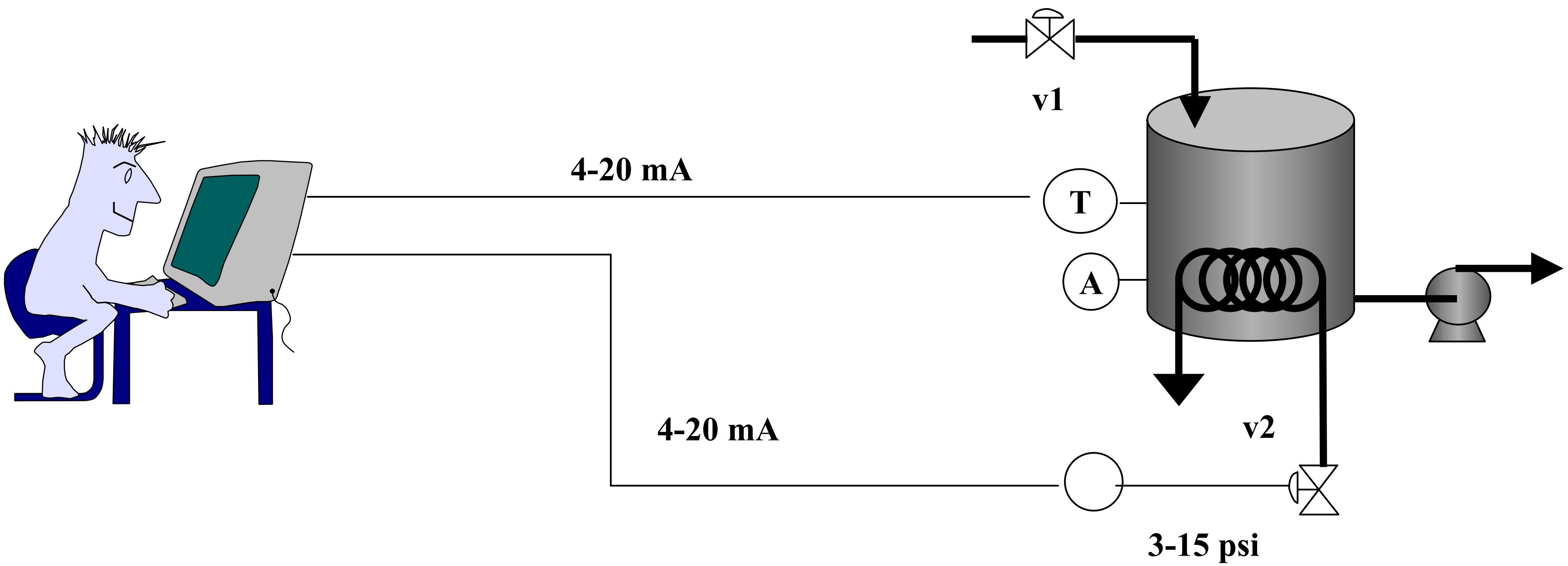
CHAPTER 7: THE FEEDBACK LOOP

The Concept: **We show limited detail in the piping and instrumentation (P&I) drawing. We see the sensor location, variable measured, connection to the final element (valve) and the location of the final element.**



CHAPTER 7: THE FEEDBACK LOOP

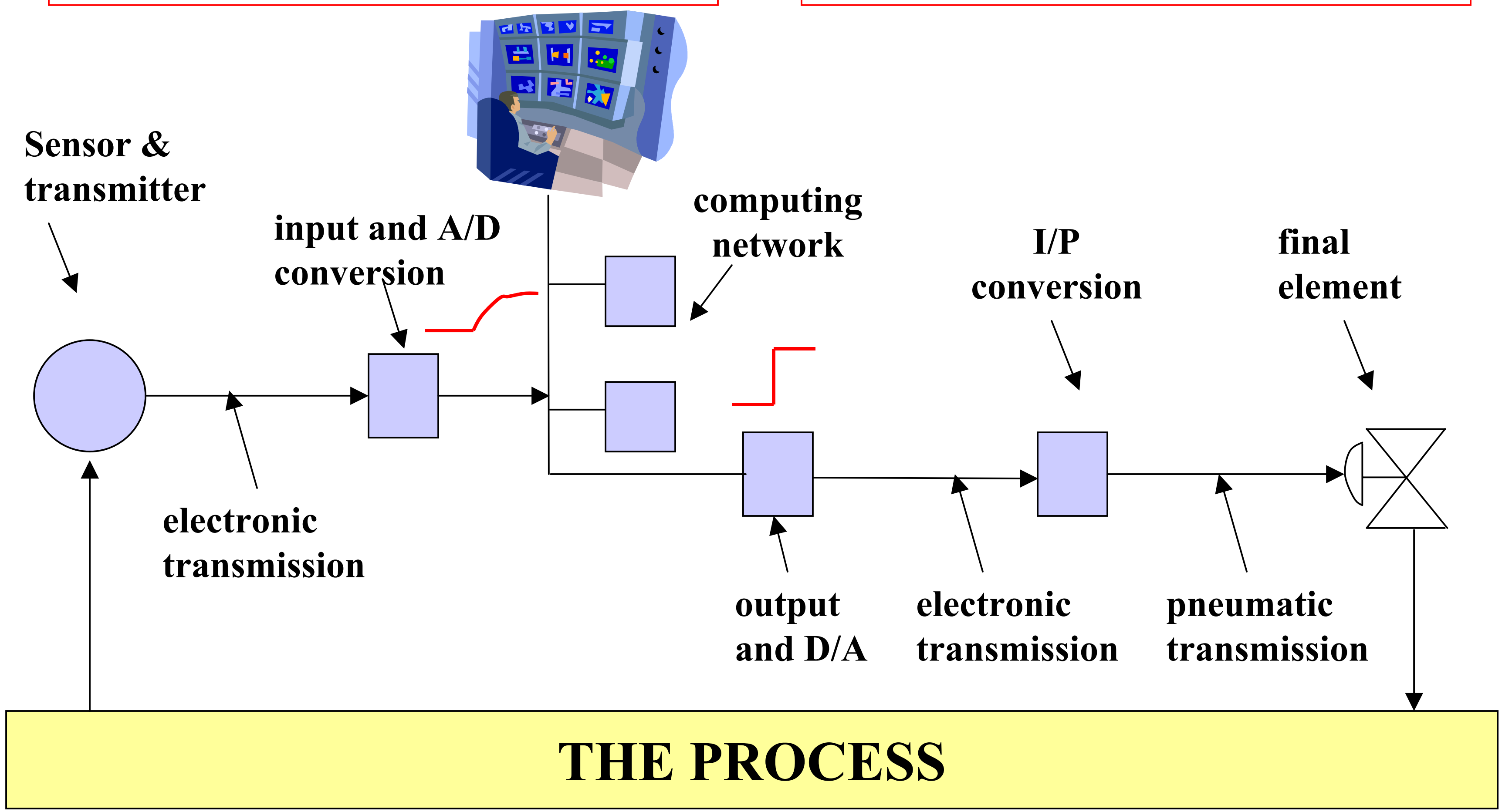
The Reality: Many elements in the loop affect the safety, reliability, accuracy, dynamics and cost. Engineers need to understand the details!



CHAPTER 7: THE FEEDBACK LOOP

What affects the response to the computer?

Make a step (without feedback control)



CHAPTER 7: THE FEEDBACK LOOP

Class exercise: Given the following dynamics, sketch the responses for a step in manual station to the displayed value.

TABLE 7.2

Dynamic models for elements in Example 7.1

Element	Units*	Case A	Case B
Manual station	mA/% output	0.16	0.16
Transmission		1.0	1.0
Signal conversion	psi/mA	$0.75/(0.5s+1)$	$0.75/(0.5s+1)$
Final element	%open/psi	$8.33/(1.5s+1)$	$8.33/(1.5s+1)$
Process	°C/psi	$\boxed{1.84e^{-1.0s}/(3s+1)}$	$\boxed{1.84e^{-100s}/(300s+1)}$
Sensor	mV/°C	$0.11/(10s+1)$	$0.11/(10s+1)$
Signal conversion	mA/mV	$1.48/(0.51s+1)$	$1.48/(0.51s+1)$
Transmission		1.0	1.0
Display	°C/mA	$6.25/(1.0s+1)$	$6.25/(1.0s+1)$

*Time is in seconds.

CHAPTER 7: THE FEEDBACK LOOP

Class exercise: Given the following dynamics, sketch the responses for a step in manual station to the displayed value.

What you see (from the display) is not always what is occurring!!

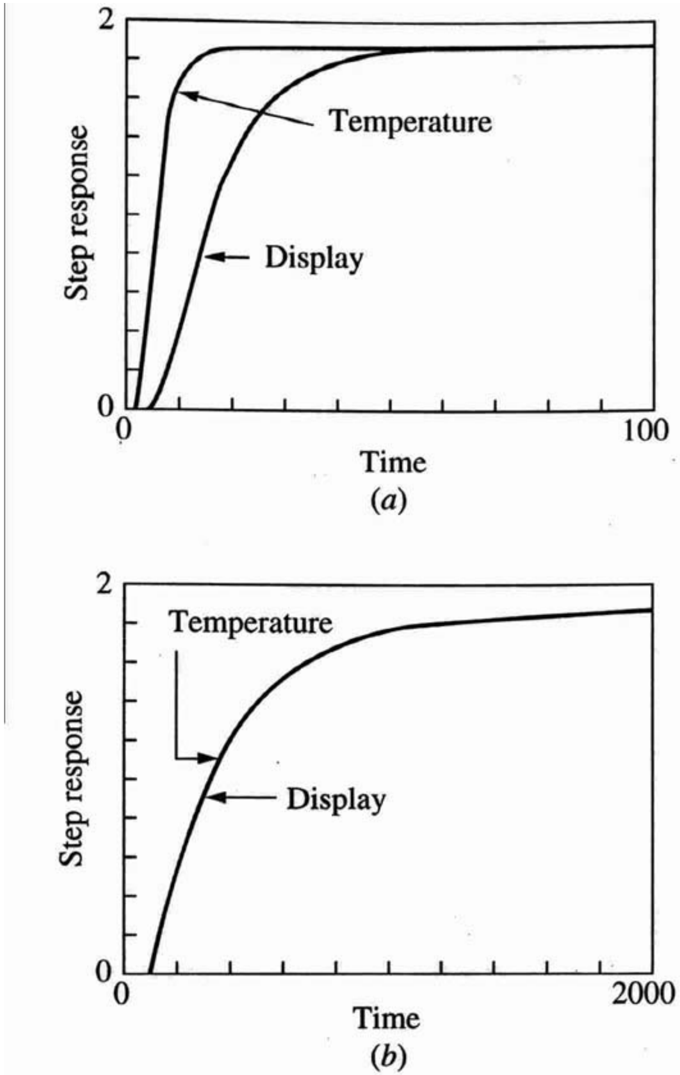
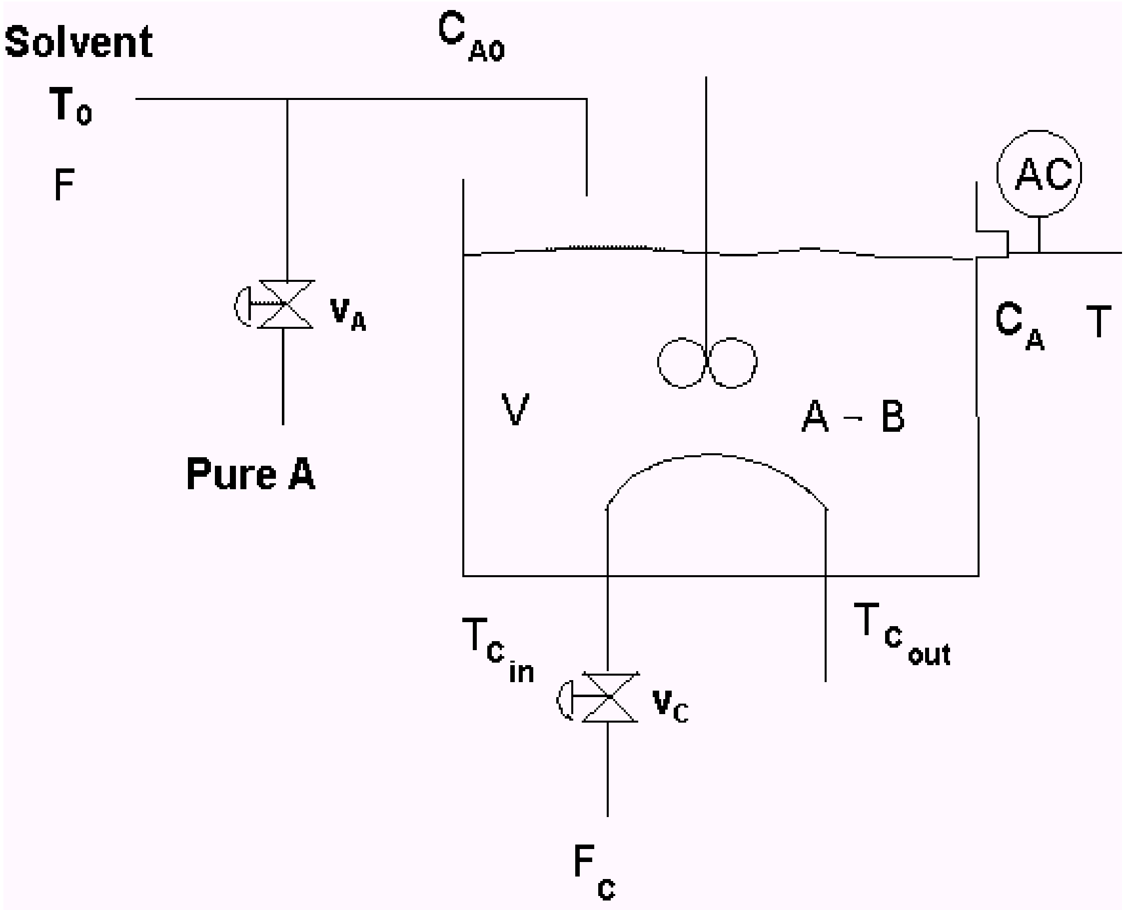


FIGURE 7.3

CHAPTER 7: THE FEEDBACK LOOP

The engineer must decide what measurement to control and what valve to adjust (and provide the equipment to support the decisions).



CHAPTER 7: THE FEEDBACK LOOP

The engineer must decide what measurement to control and what valve to adjust (and provide the equipment to support the decisions).

CV to control ? Use seven categories of control objectives!

control objective	process variable	sensor
1) Safety		
2) Environmental protection		
3) Equipment protection		
4) Smooth plant operation and production rate		
5) Product quality →	Concentration of reactant A in the effluent →	Analyzer in reactor effluent measuring the mole % A
6) Profit optimization		
7) Monitoring and diagnosis		

CHAPTER 7: THE FEEDBACK LOOP

The engineer must decide what measurement to control and what valve to adjust (and provide the equipment to support the decisions).

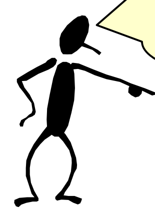
MV to adjust ?

1. Causal relationship
2. Automated
3. Fast dynamics
4. Compensate for large disturbances
5. Can adjust quickly with little adverse affect on process performance

CHAPTER 7: THE FEEDBACK LOOP

The engineer must decide what measurement to control and what valve to adjust (and provide the equipment to support the decisions).

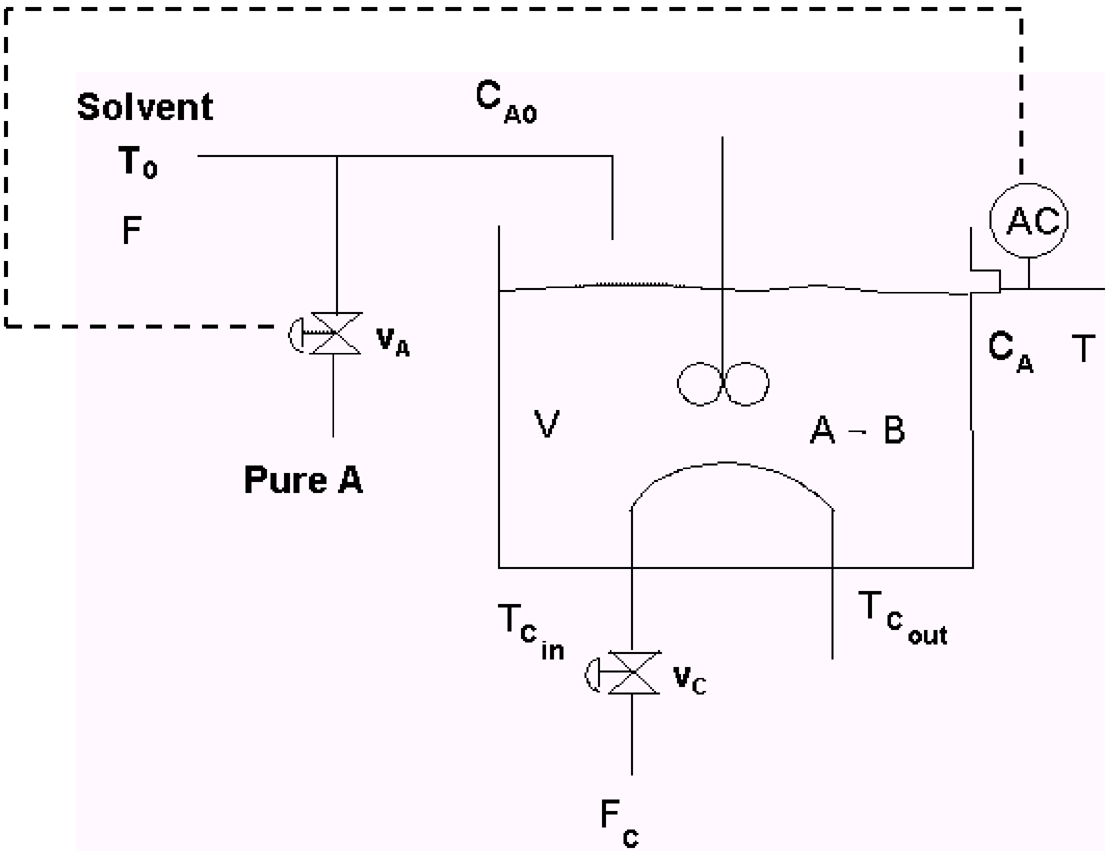
	Input variables that affect the measured variable	Selected adjustable flow	Manipulated valve
disturbances	Feed temperature		
	Solvent flow rate		
	Feed composition, before mix		
	Coolant inlet temperature		
adjustable	Flow of pure A →	Flow of pure A →	v_A
	Flow of coolant		

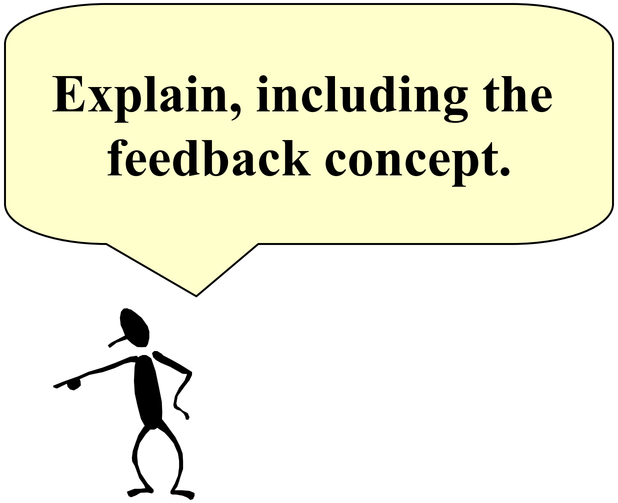


We could use either valve. We will revisit this choice later (Chapter13)

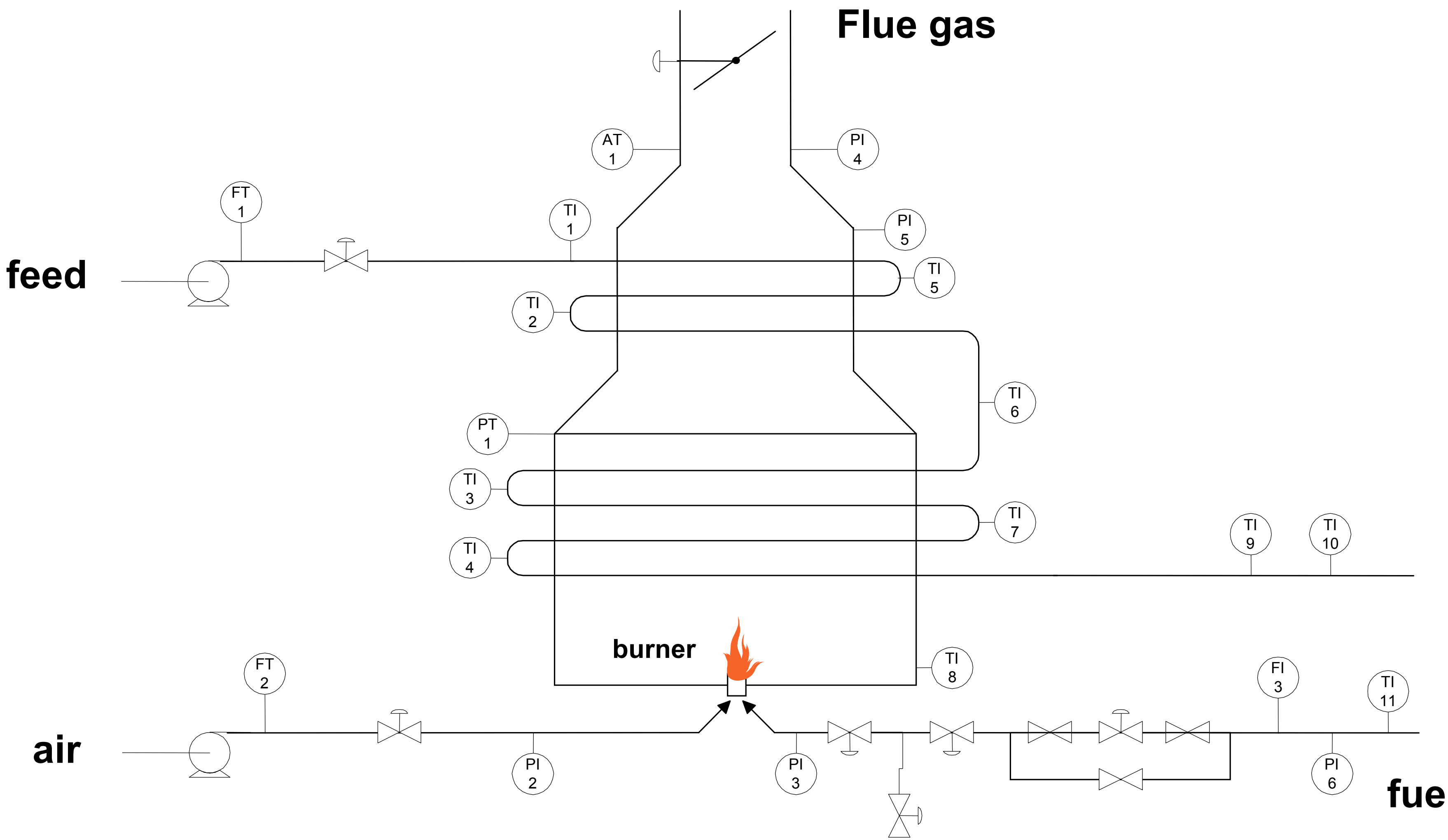
CHAPTER 7: THE FEEDBACK LOOP

The figure shows the feedback loop We'll see the calculation in the next chapter.





Class exercise on the feedback loop: Using the methods just described, select ONE variable to be controlled and for that variable, ONE valve to be manipulated.



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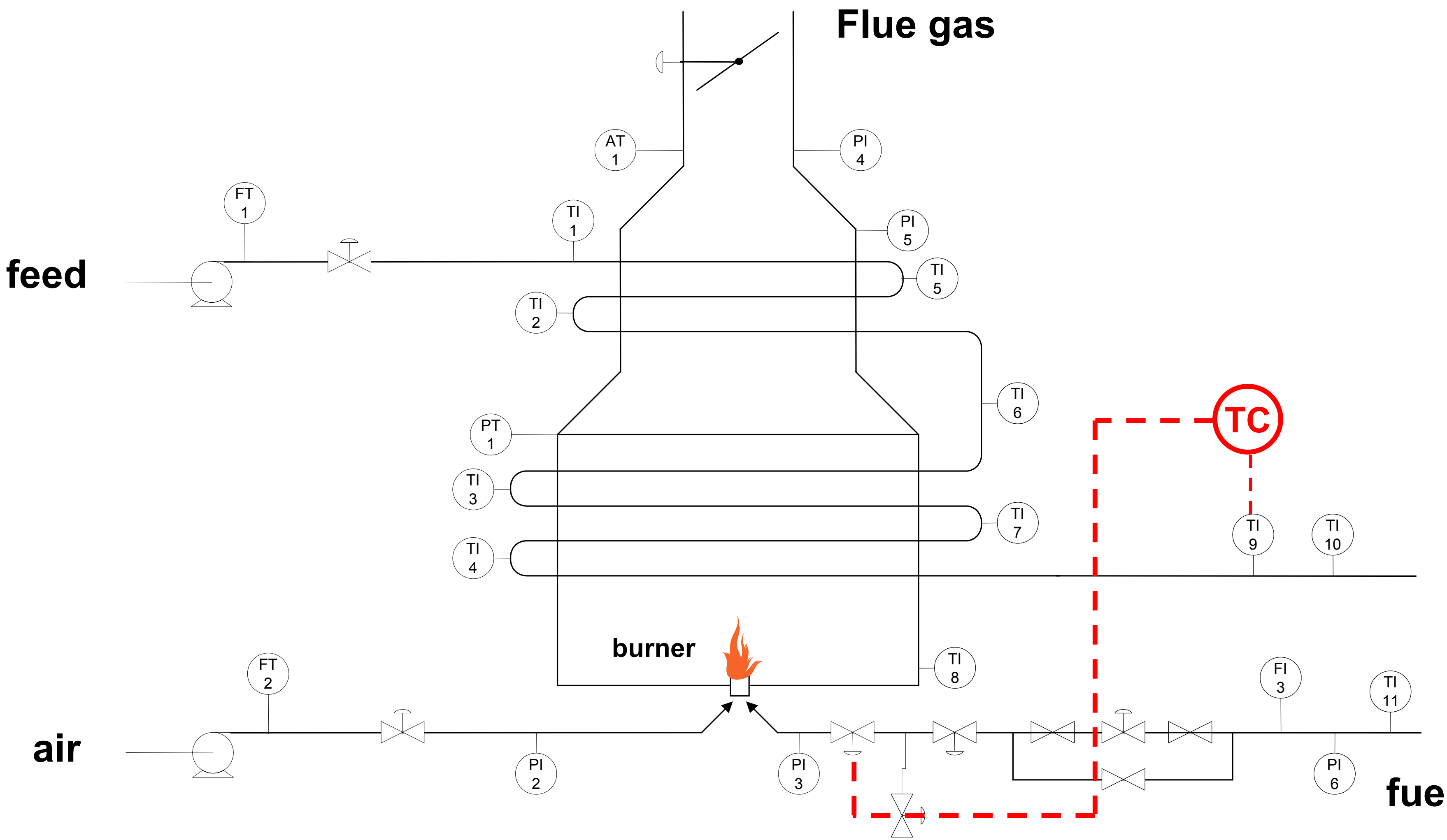
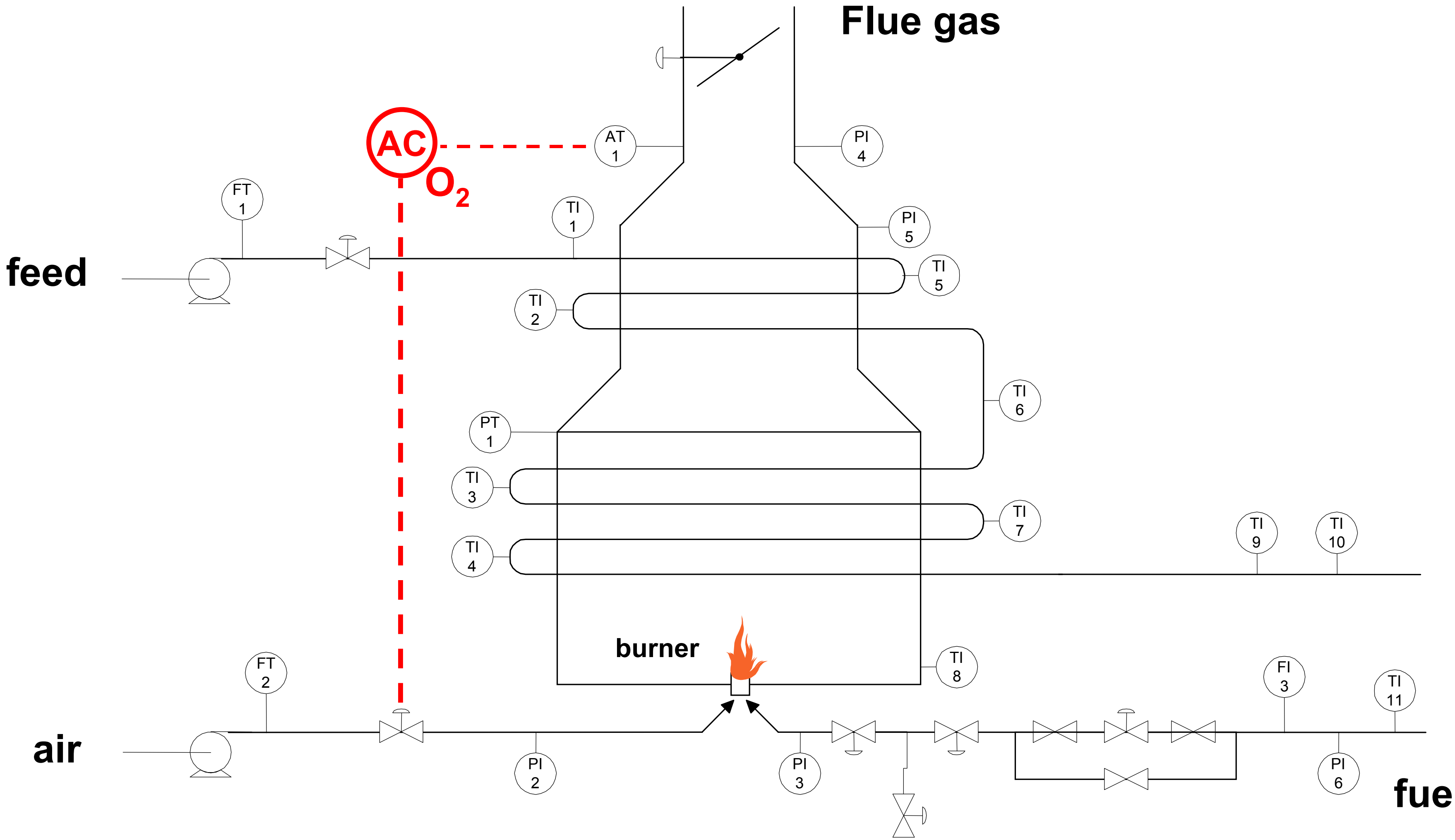


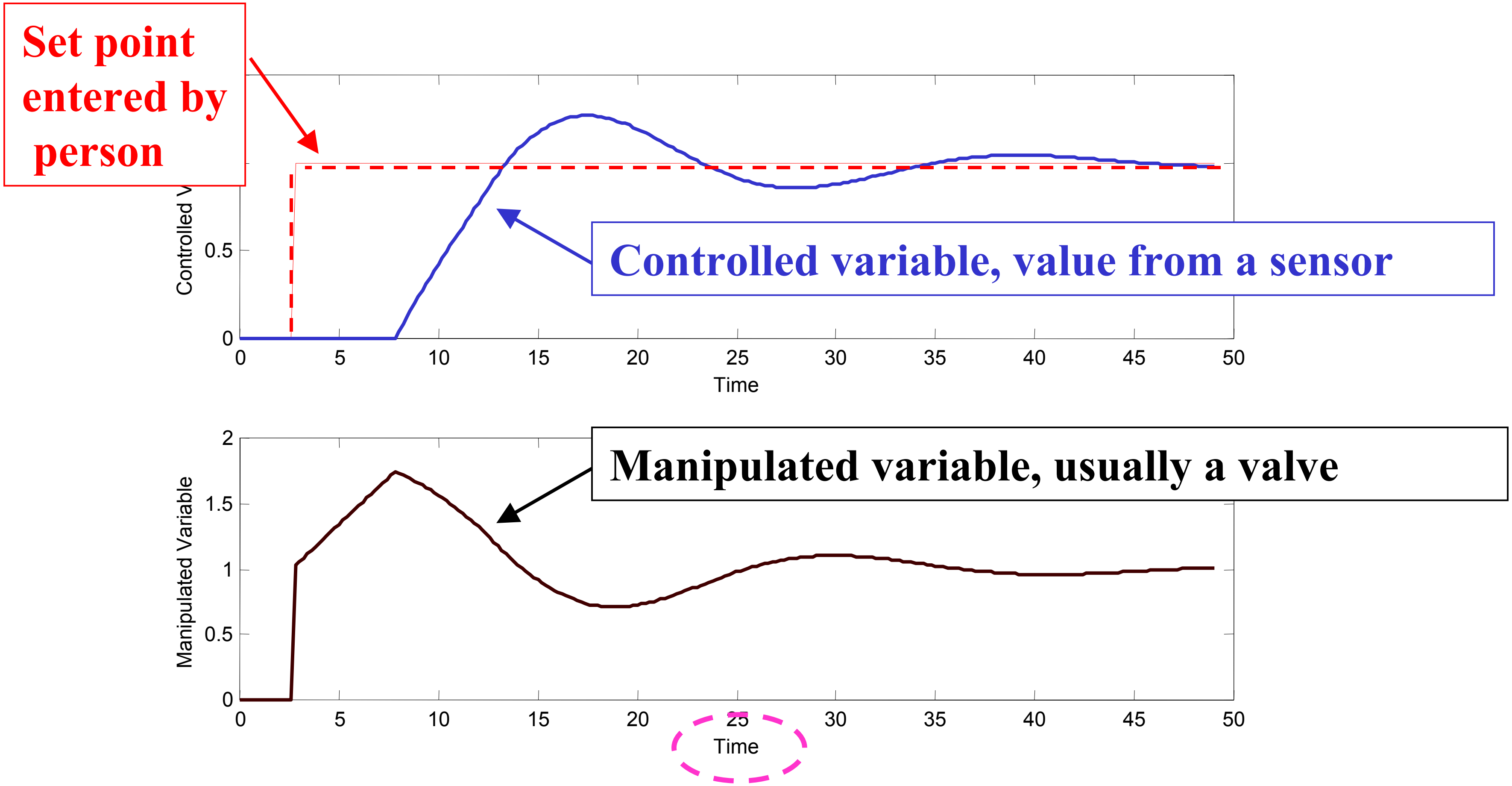
Class exercise on the feedback loop: Using the methods just described, select ONE variable to be controlled and for that variable, ONE valve to be manipulated.



CHAPTER 7: THE FEEDBACK LOOP

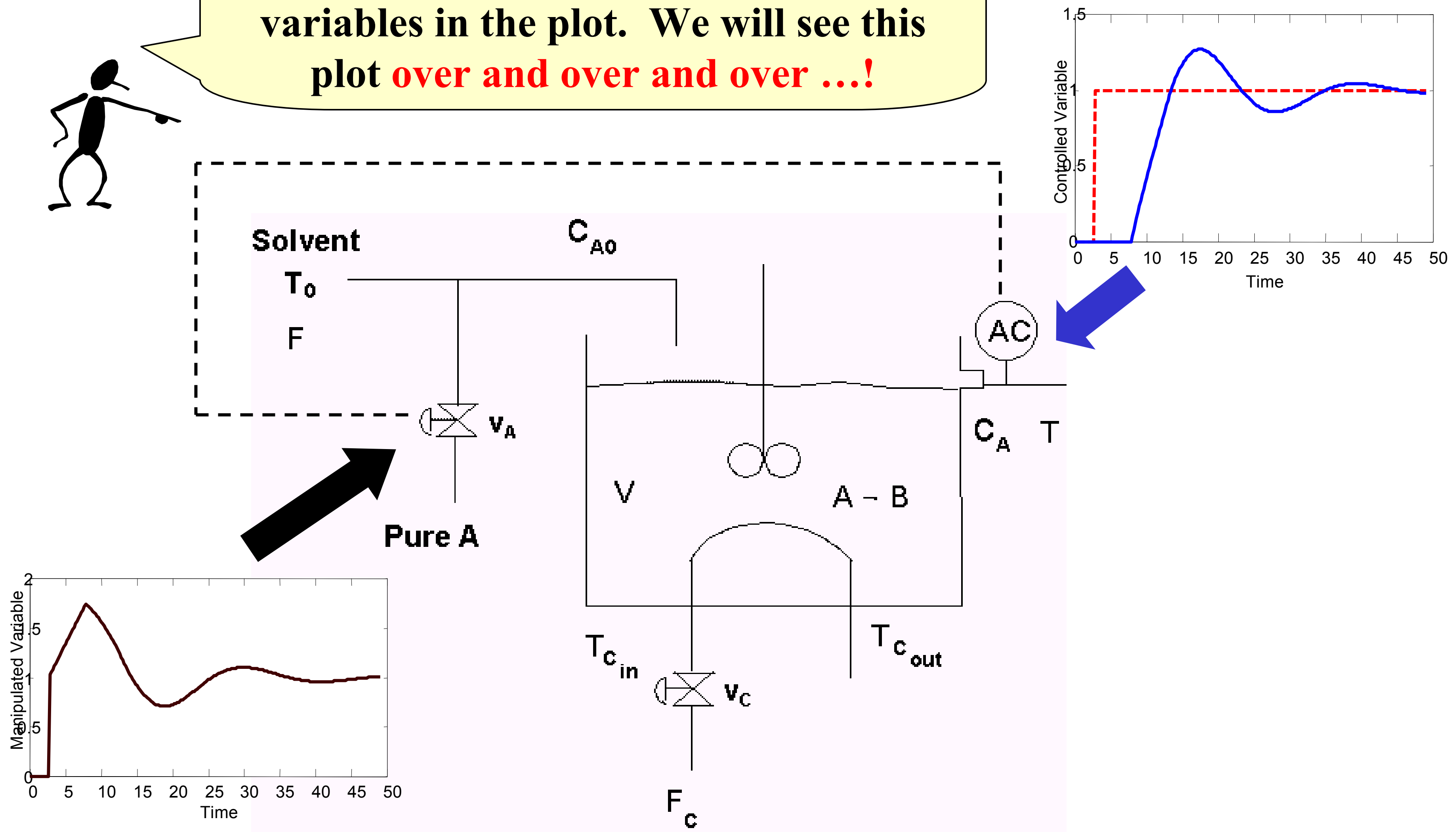
Music: **"I cannot define good music, but I know what I like."**

Control Performance: We must be able to define what we desire, so that we can design equipment and controls to achieve our objectives.



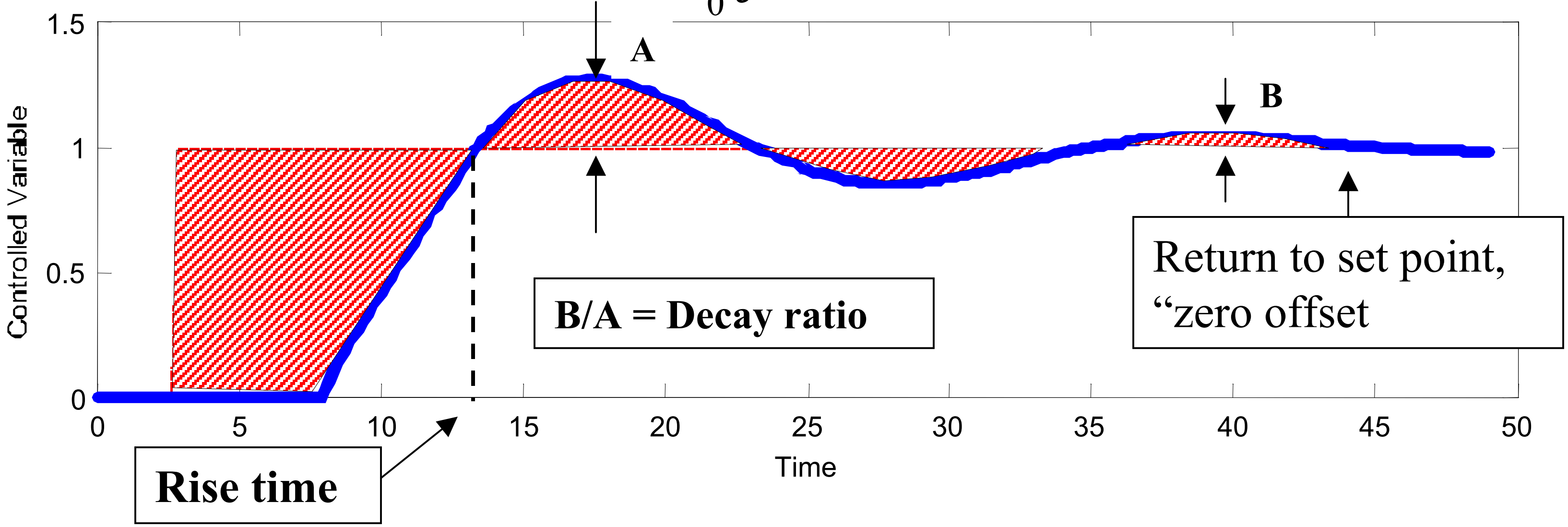
CHAPTER 7: THE FEEDBACK LOOP

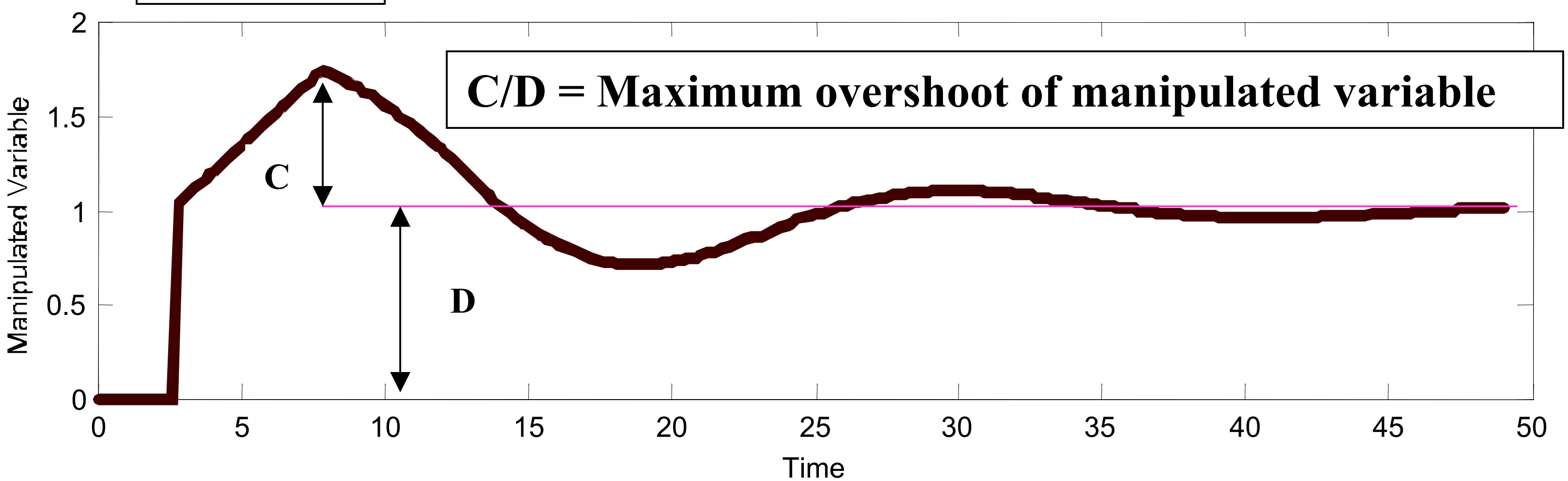
Let's be sure we understand the variables in the plot. We will see this plot over and over and over …!



CHAPTER 7: THE FEEDBACK LOOP
Set point Change

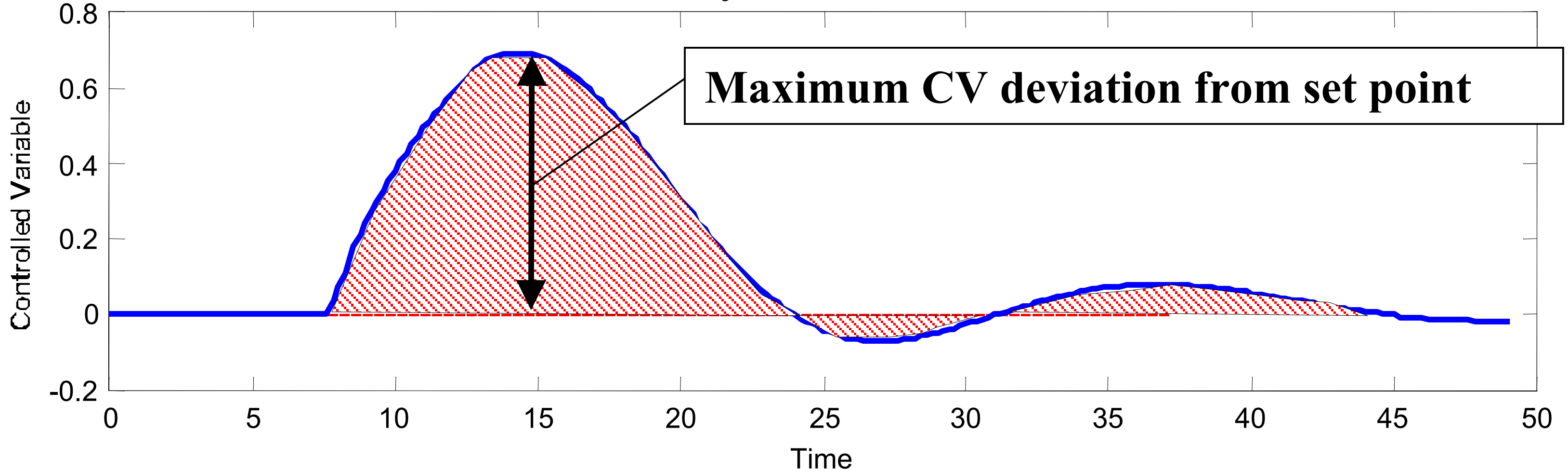
$$= \text{IAE} = \int_0^{\infty} |SP(t)-CV(t)|\, dt$$

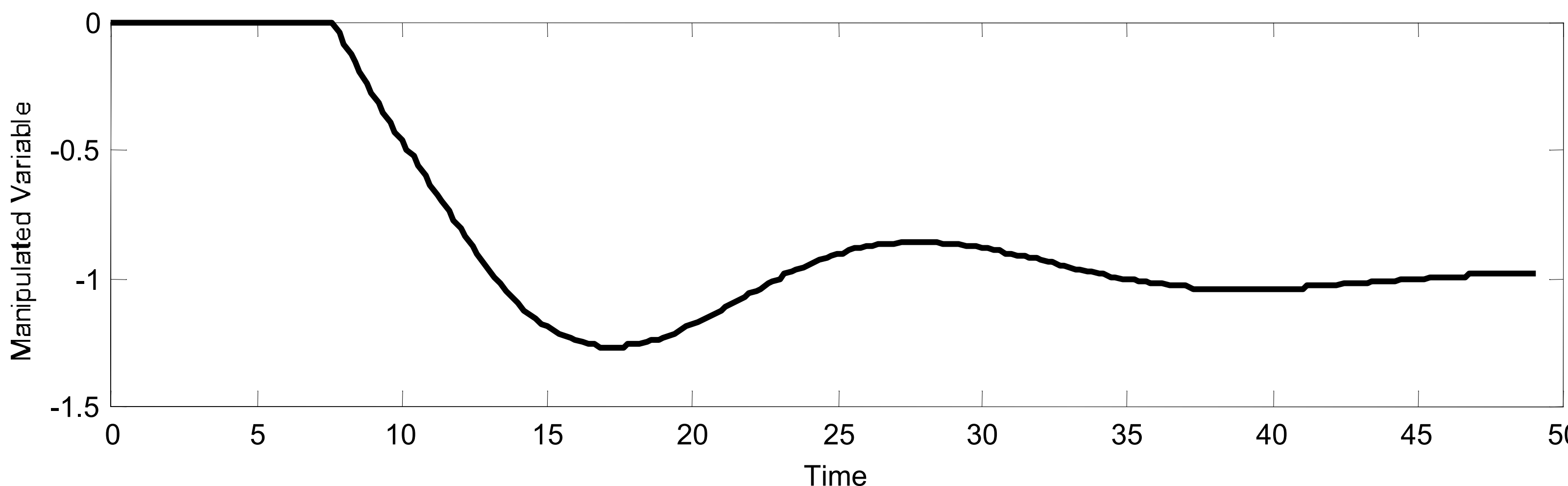




CHAPTER 7: THE FEEDBACK LOOP
Disturbance Response

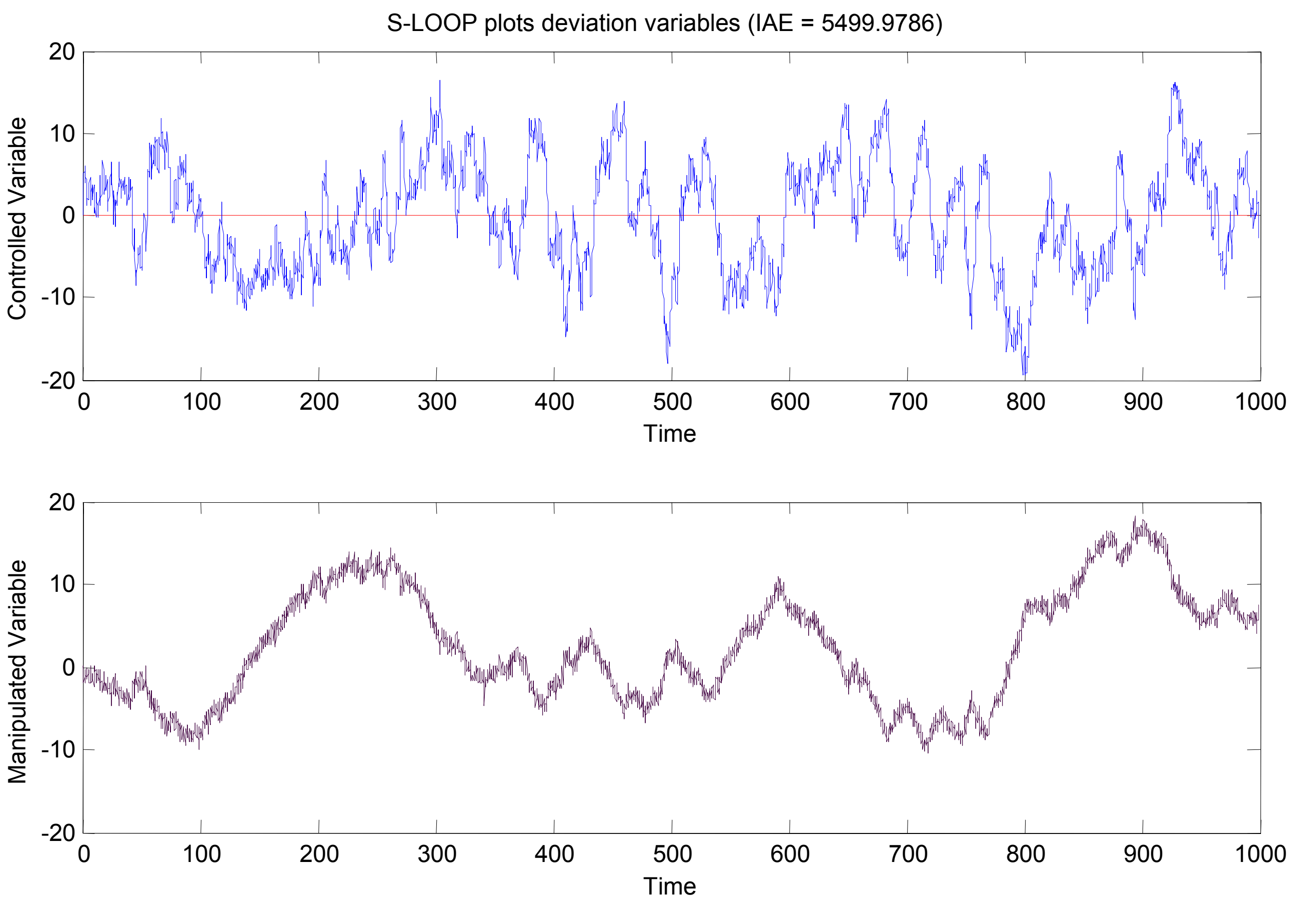
$$\text{[hatched area]} = \text{IAE} = \int_0^\infty |SP(t)-CV(t)|\, dt$$





CHAPTER 7: THE FEEDBACK LOOP
Disturbance Response

Often, the process is subject to many large and small disturbances and sensor noise. The performance measure characterizes the variability.

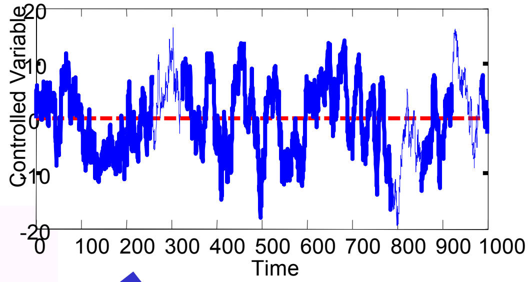


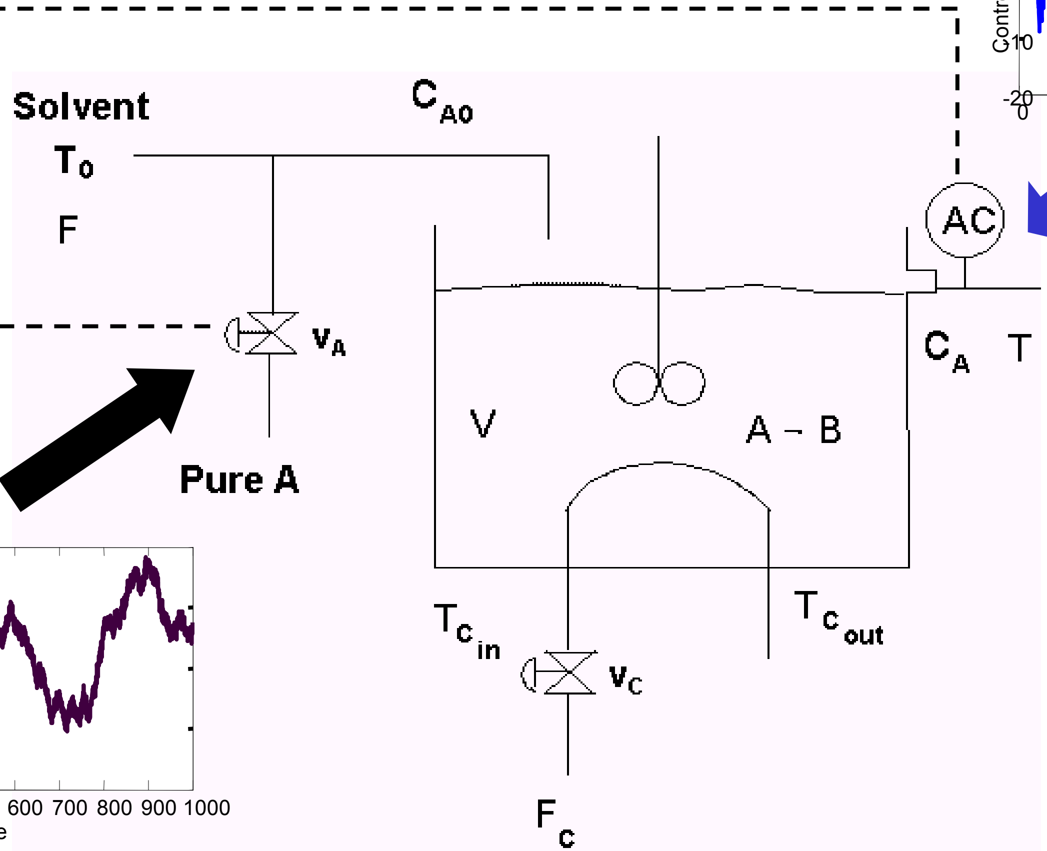
Variance or standard deviation of CV

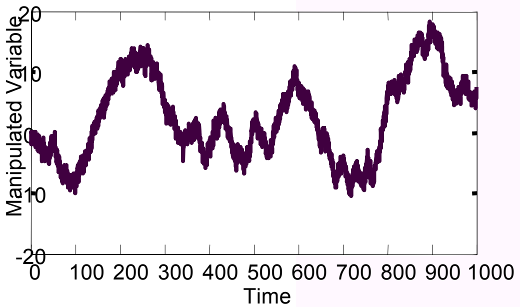
Variance or standard deviation of MV

CHAPTER 7: THE FEEDBACK LOOP

- To reduce the variability in the CV, we increase the variability in the MV.
- We must design plant with MV's that can be adjusted at low cost.



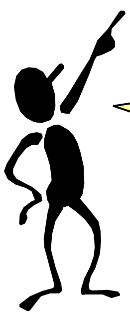




CHAPTER 7: THE FEEDBACK LOOP

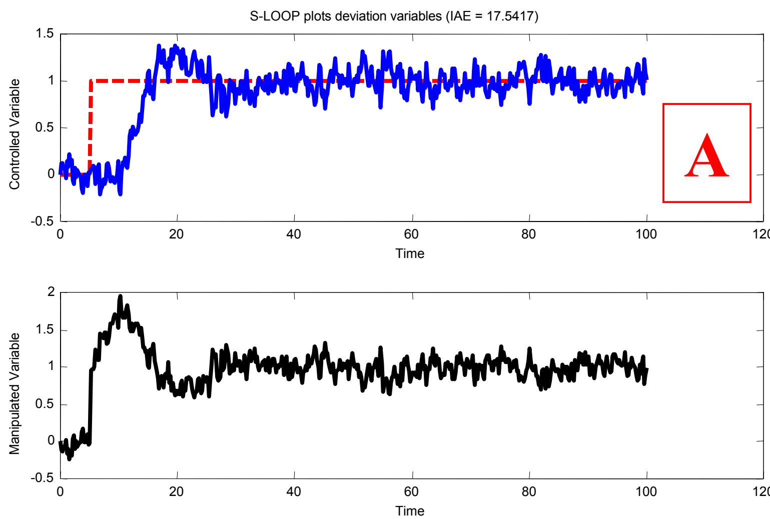
Class exercise: **For each of the performance measures below, determine a <u>good value</u>, i.e., large/small, positive/negative, etc.**

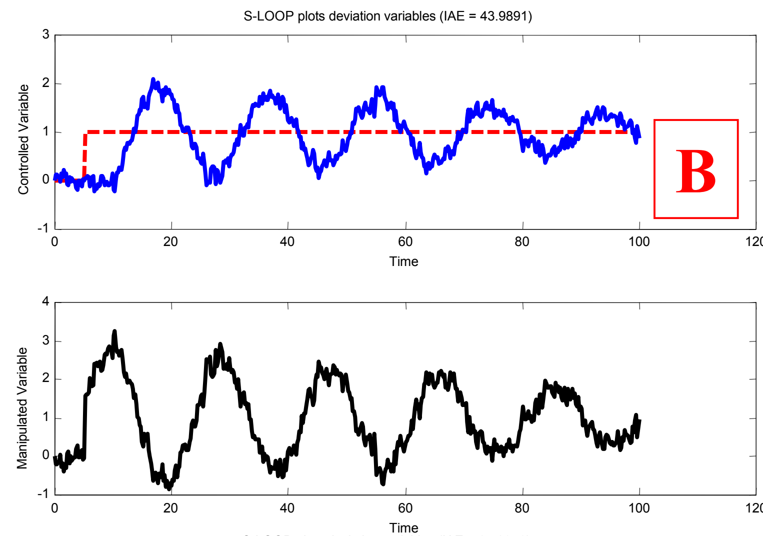
- **Offset**
- **IAE**
- **Decay ratio**
- **Rise time**
- **Settling time**
- **MV overshoot**
- **Maximum CV deviation**
- **CV variance**
- **MV variance**

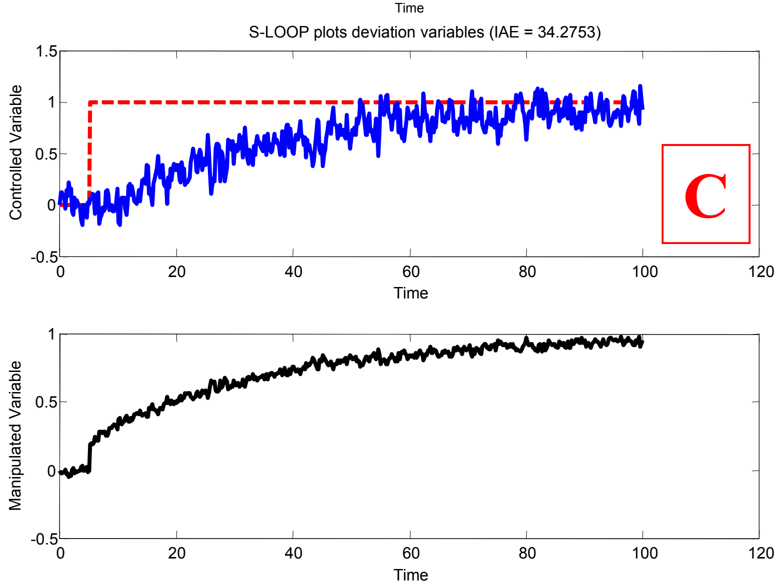


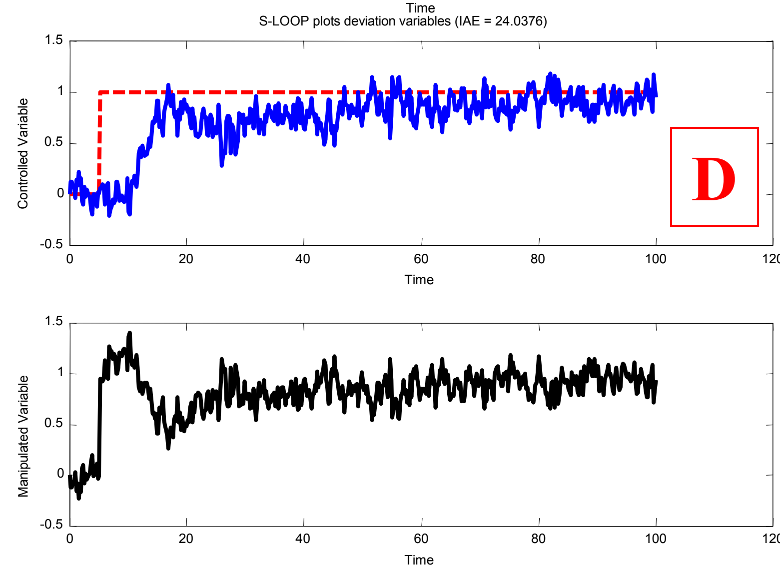
Can we achieve good values for all at the same time?
What are the tradeoffs?

Class exercise: Comment on the quality of control for the four responses below.

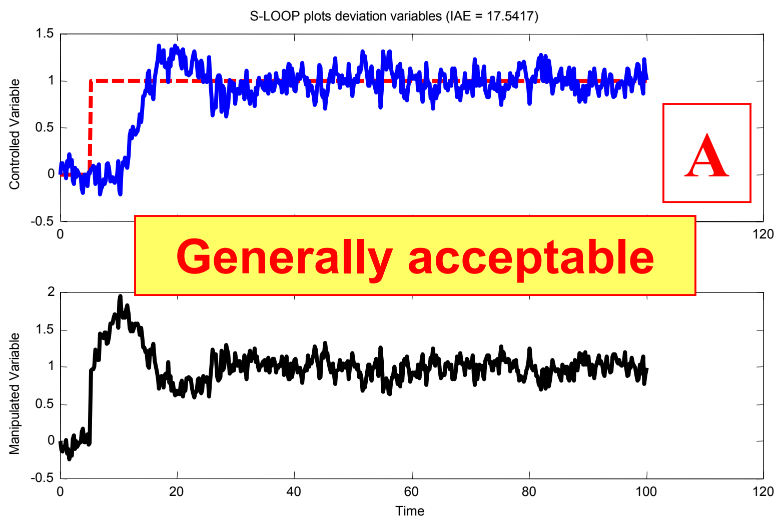


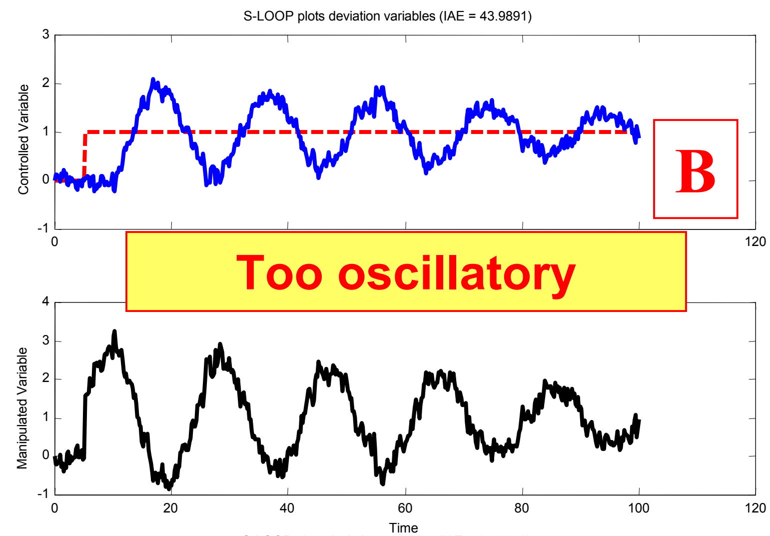


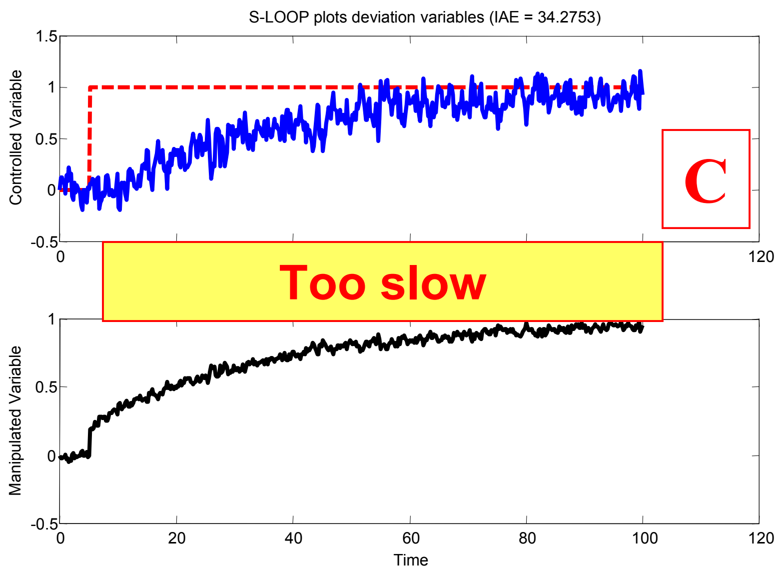


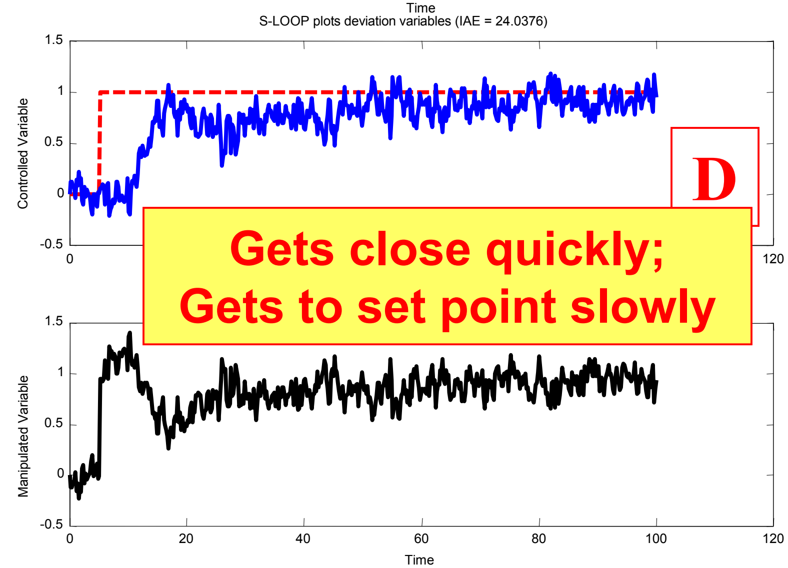


Class exercise: **Comment on the quality of control for the four responses below.**









CHAPTER 7: THE FEEDBACK LOOP

We can apply feedback via many approaches

1, **No control** - **The variable responds to all inputs, it "drifts".**

2. **Manual** - **A person observes measurements and introduces changes to compensate, adjustment depends upon the person.**

3. **On-Off** - **The manipulated variable has only two states, this results in oscillations in the system.**

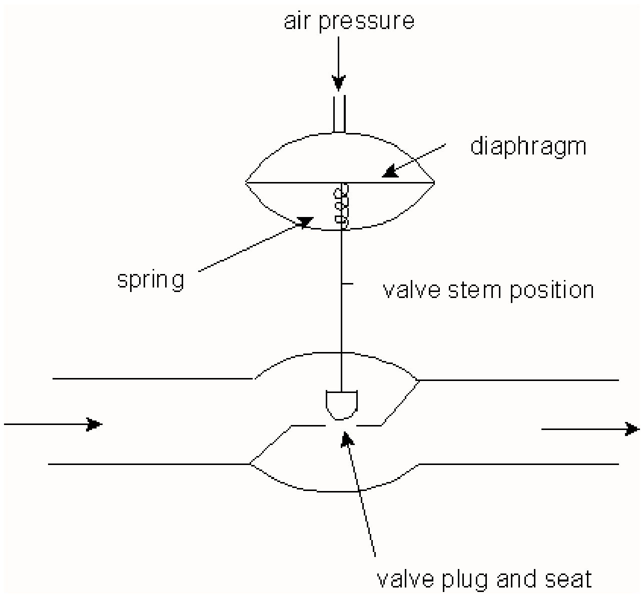
4. **Continuous, automated** - **This is a modulating control that has corrections related to the error from desired.**

5. **Emergency** - **This approach takes extreme action (shutdown) when a dangerous situation occurs.**

CHAPTER 7: THE FEEDBACK LOOP, WORKSHOP 1

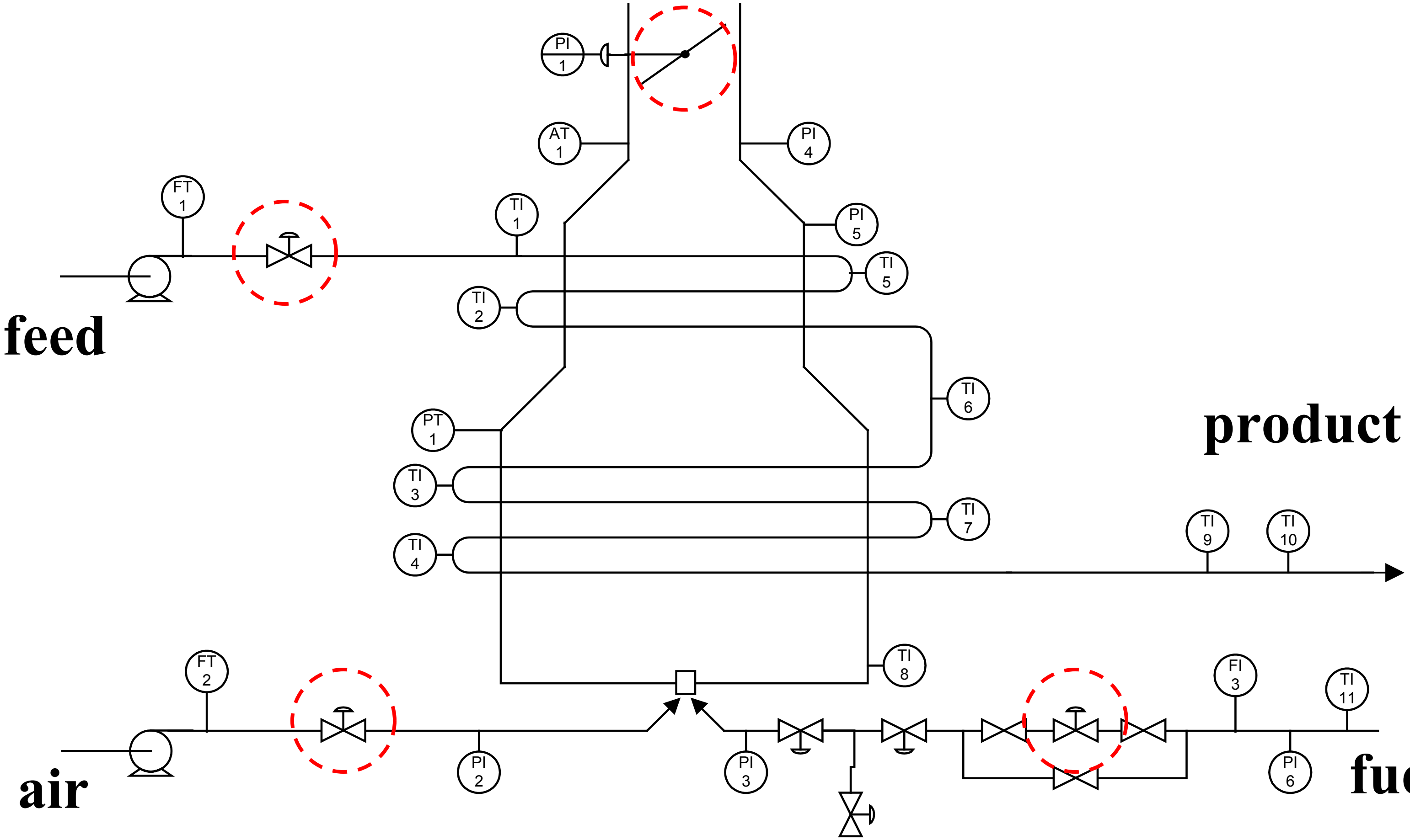
The control valve is used to introduce a variable resistance to flow.

- What is the body of the valve?
- Describe three bodies and what factors are important in selecting.
- What is the actuator?
- What power source is used? What happens when the power source fails?



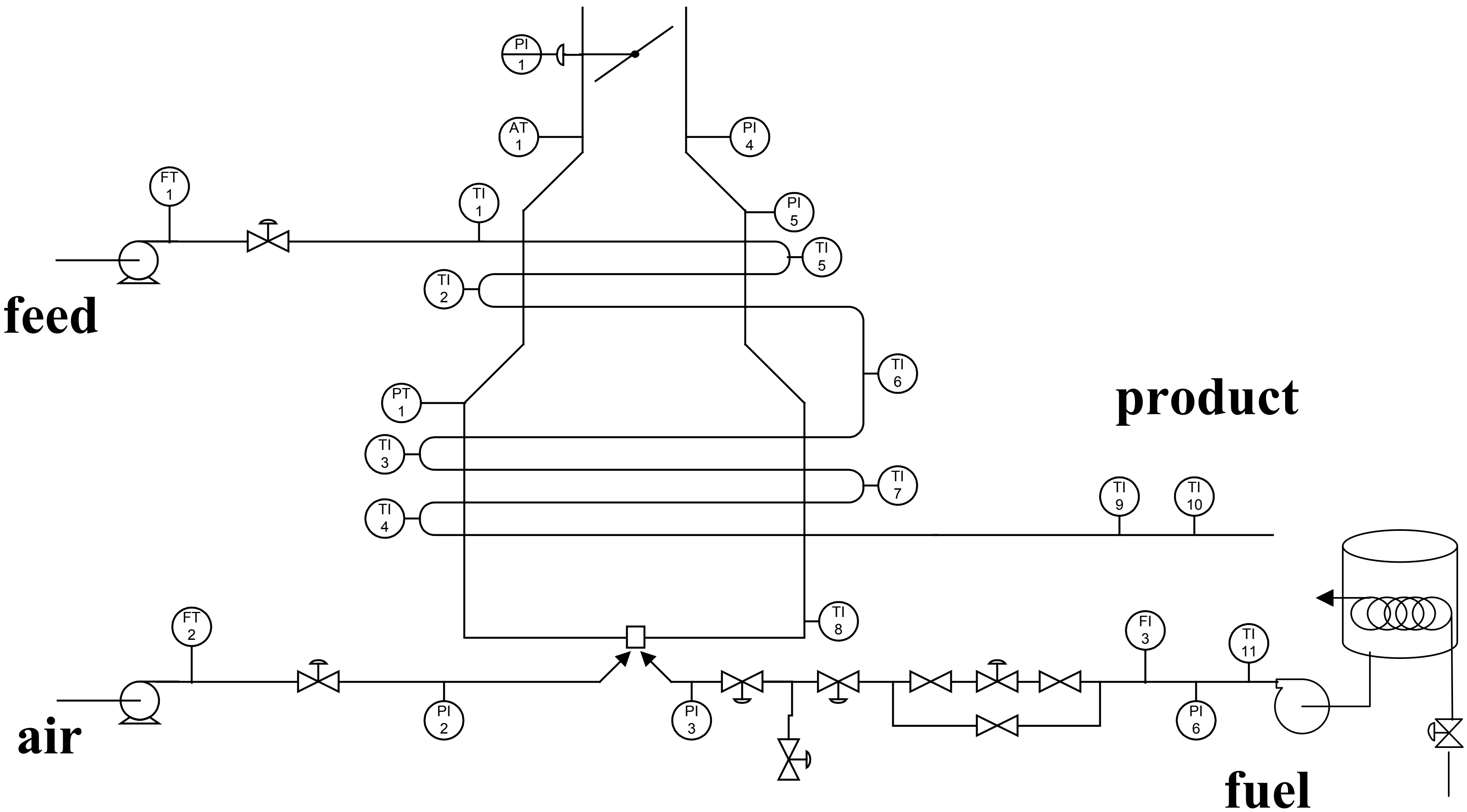
CHAPTER 7: THE FEEDBACK LOOP, WORKSHOP 2

Recommend the correct failure position (open or closed) for each of the circled control valves.



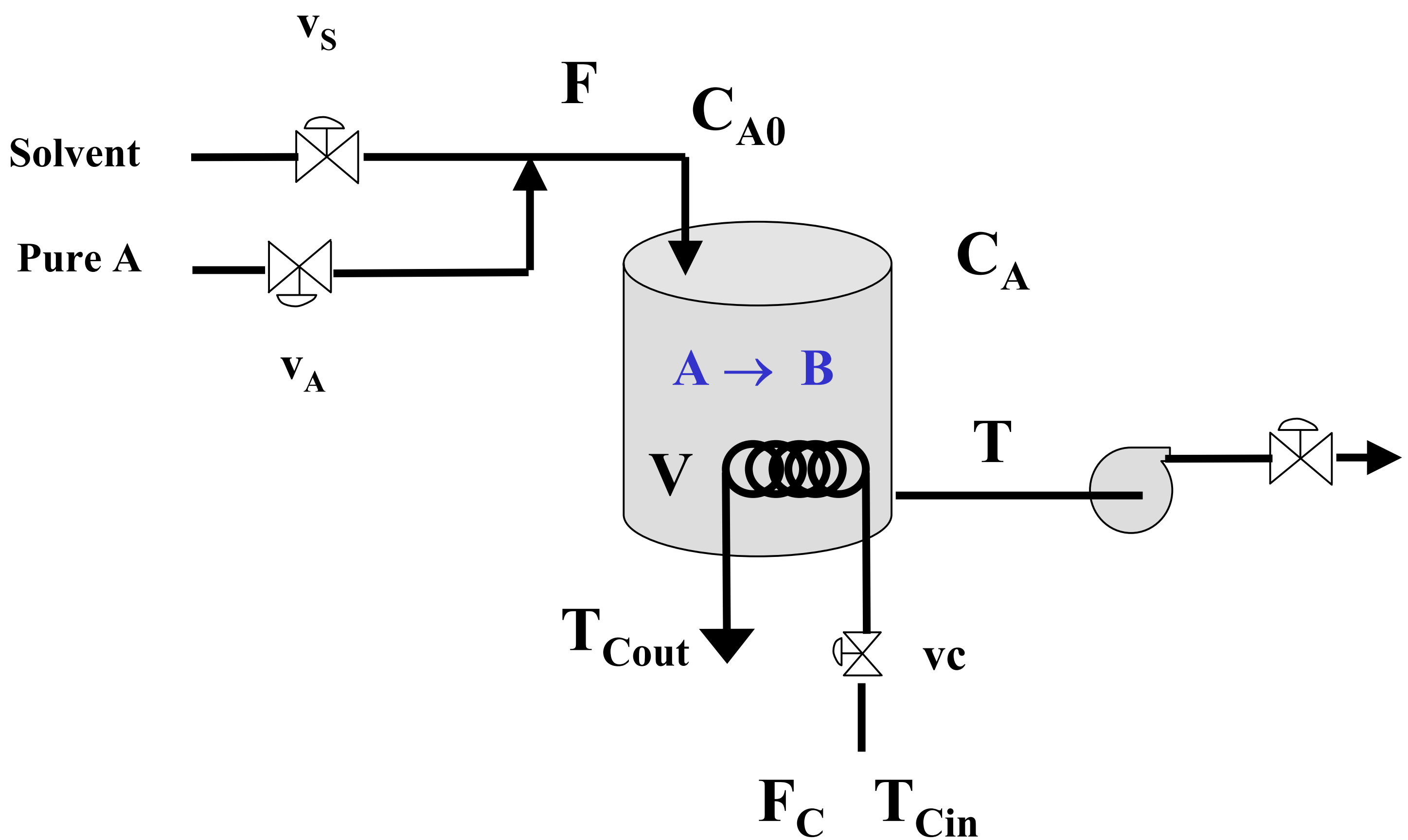
CHAPTER 7: THE FEEDBACK LOOP, WORKSHOP 3

Find at least one variable that could be handled by each of the five approaches; no control, manual, on/off, continuous, and emergency.

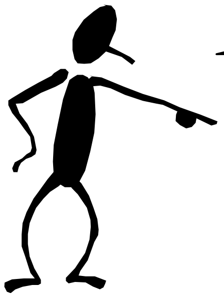


CHAPTER 7: THE FEEDBACK LOOP, WORKSHOP 4

Select several pairs of controlled and manipulated variables for the following process.



CHAPTER 7: THE FEEDBACK LOOP



When I complete this chapter, I want to be able to do the following.

- **Identify the major elements in the feedback loop**
- **Select appropriate candidate variables to be controlled and manipulated**
- **Evaluate the control performance data using standard measures of dynamic performance**

Lot’s of improvement, but we need some more study!

- **Read the textbook**
- **Review the notes, especially learning goals and workshop**
- **Try out the self-study suggestions**
- **Naturally, we’ll have an assignment!**

CHAPTER 7: LEARNING RESOURCES

- **SITE PC-EDUCATION WEB**
  - Instrumentation Notes
  - Interactive Learning Module (Chapter 7)
  - Tutorials (Chapter 7)

CHAPTER 7: SUGGESTIONS FOR SELF-STUDY

1. **Find a sample process in each of your previous courses and select a pair of controlled and manipulated variables**
   - Heat Transfer (heat exchanger)
   - Fluid Mechanics (flow in a pipe
   - Mass Transfer (stripper, distillation)
   - Reaction Engr. (packed bed reactor)

2. **Compare the measures of control performance in this chapter with the seven control objectives given in Chapter 2.**

3. **Describe the actions you would take if you measured a disturbance and did not want to wait for feedback corrections.**