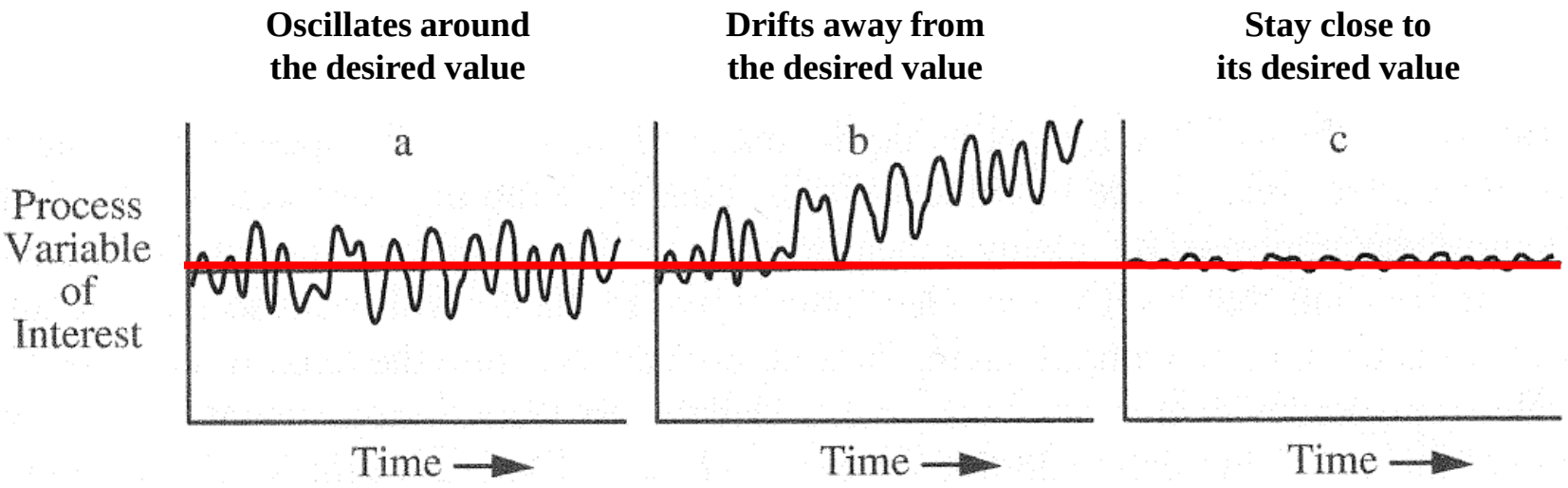
Introduction to Chemical Engineering

Chapter 12

Controlling the Process

12.1 The need for process control

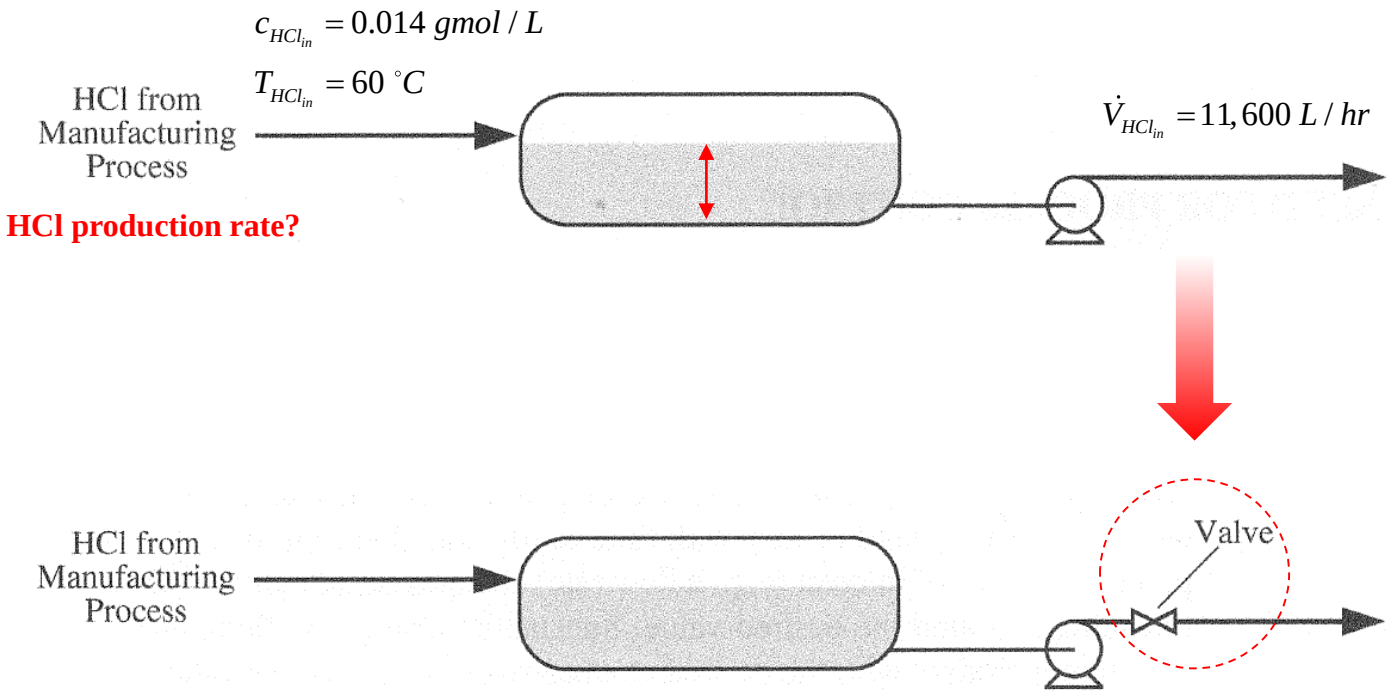
- **Variation of a process variable**



12.1 The need for process control

- **HCl neutralization process**

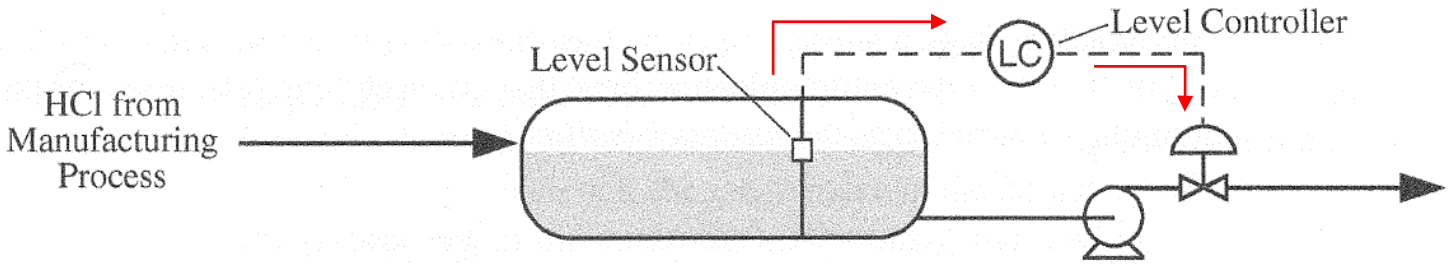
Manual control



12.1 The need for process control

- **HCl neutralization process**

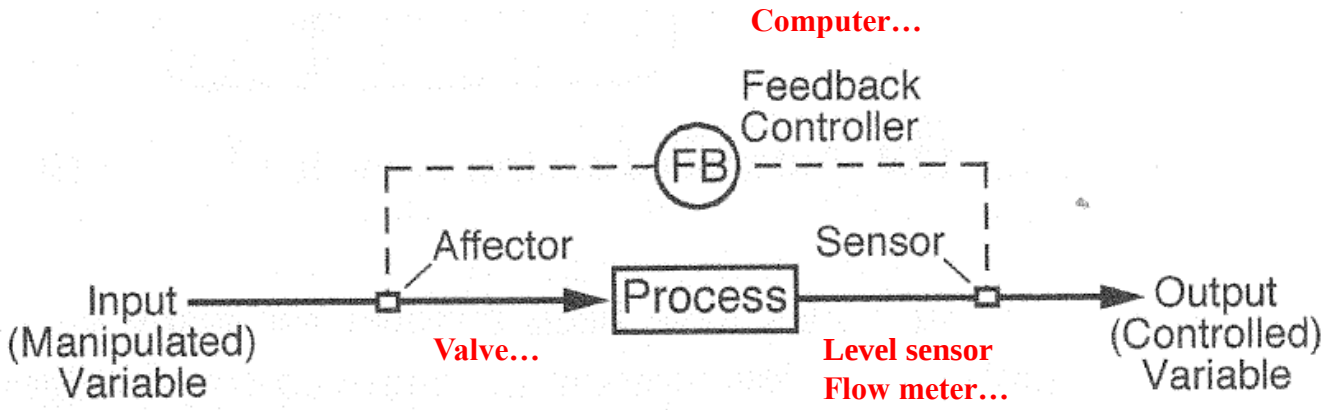
Fully-automated control system



- Controlled variable: HCl level in the tank
- Setpoint: the desired HCl level
- Input variables (inputs): variables that affect the controlled variable
- Disturbances: uncontrolled changes by inputs
- Error: difference between controlled variable value and setpoint
- Manipulated variable: adjusted input

12.2 Feedback control

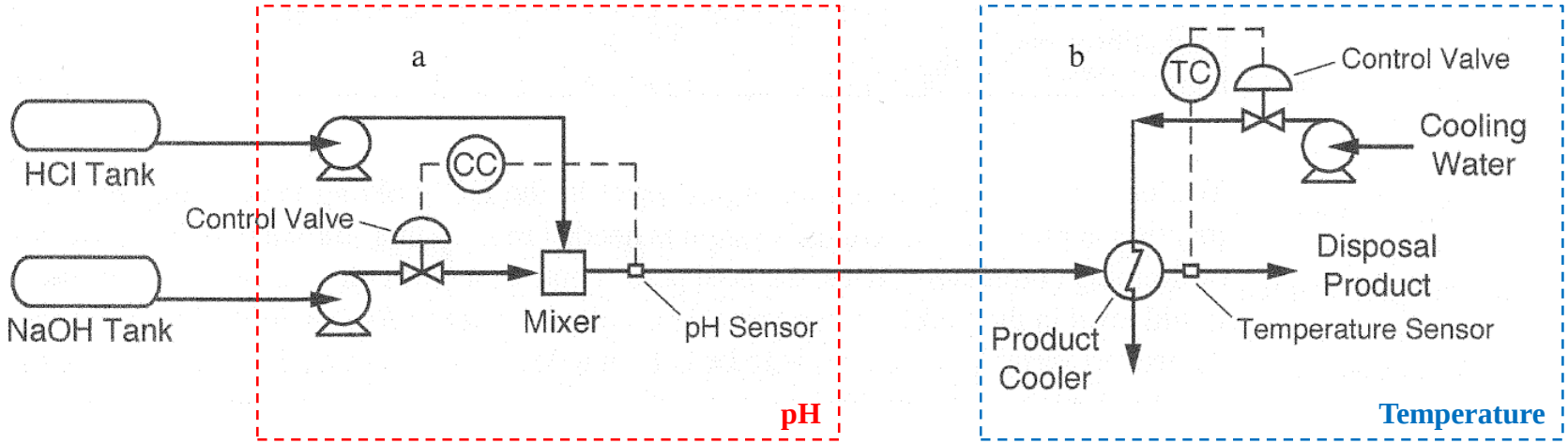
➢ **Feedback control loop**



- The controlled variable is monitored over time via some sort of sensor.
- The feedback controller adjusts an input variable via one or more affectors.

12.2 Feedback control

➢ **HCl neutralization process**

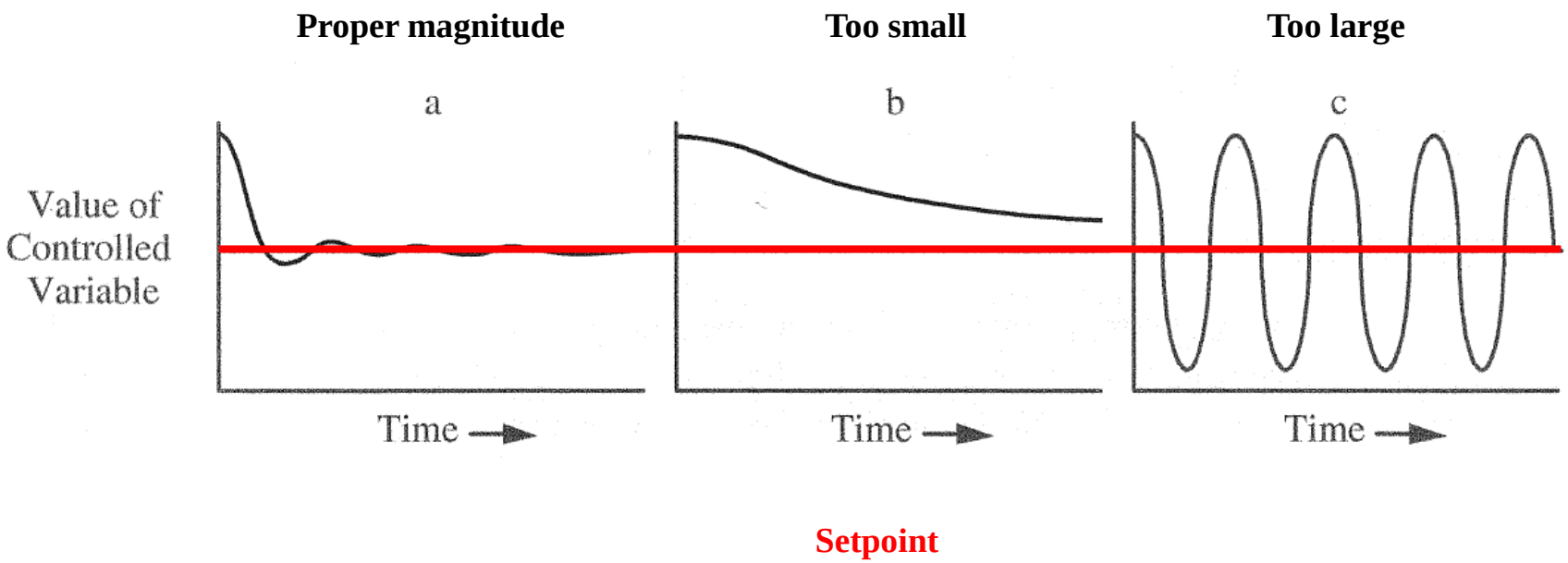


- Controlled variable: pH of liquid leaving the mixer
- Setpoint: pH 6.5
- Input variables (inputs): flow rate of HCl/NaOH
- Manipulated variable: flow rate of NaOH

- Controlled variable: temperature of product
- Setpoint: 27°C
- Input variables (inputs): temperature of HCl/NaOH
- Manipulated variable: temperature of NaOH

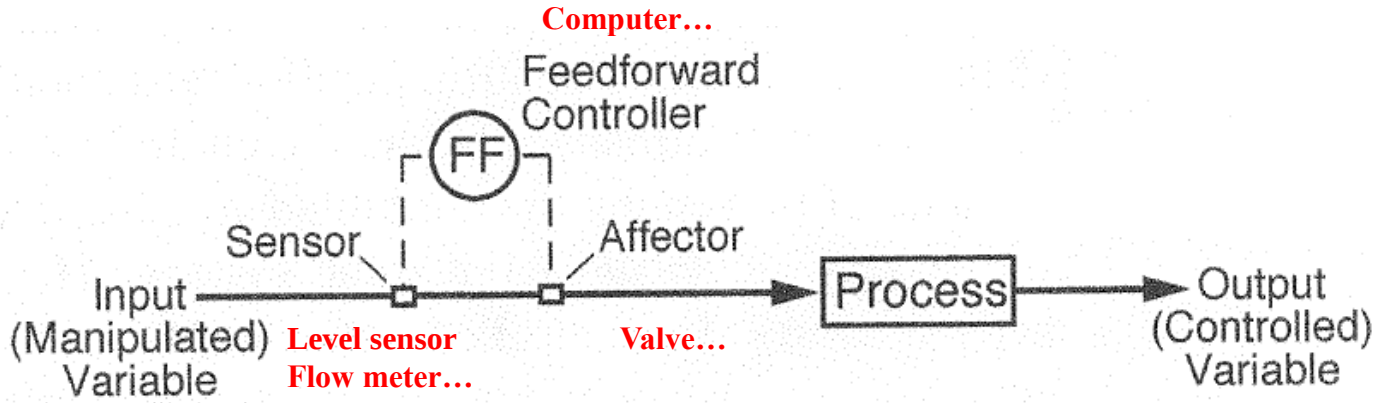
12.2 Feedback control

- **Feedback control response curves**



12.3 Feedforward control

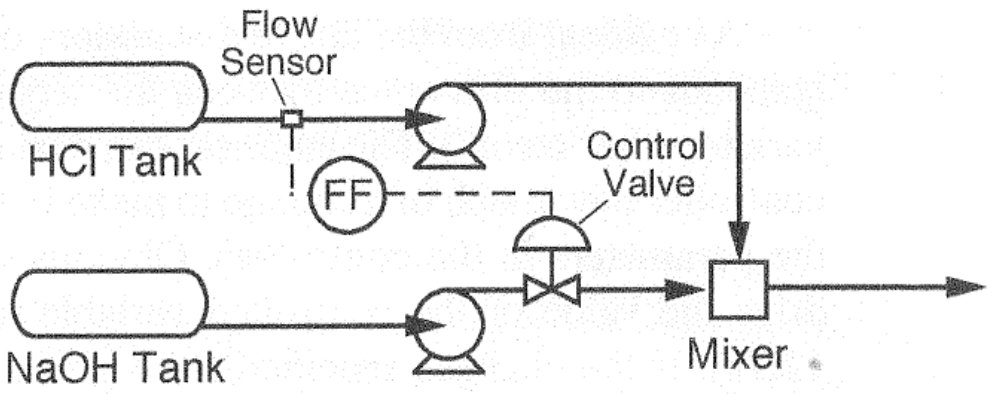
➢ **Feedforward control loop**



- The input variables (disturbances) are monitored over time via some sort of sensor.
- The feedforward controller predicts the effect of the disturbances on the output and adjusts the manipulated variable to offset the predicted effect.

12.3 Feedforward control

- **HCl neutralization process**



- The measured flow rate of HCl by sensor predicts the final pH and adjusts the flow rate of NaOH in order to achieve the desired pH.

12.4 Comparison of strategies

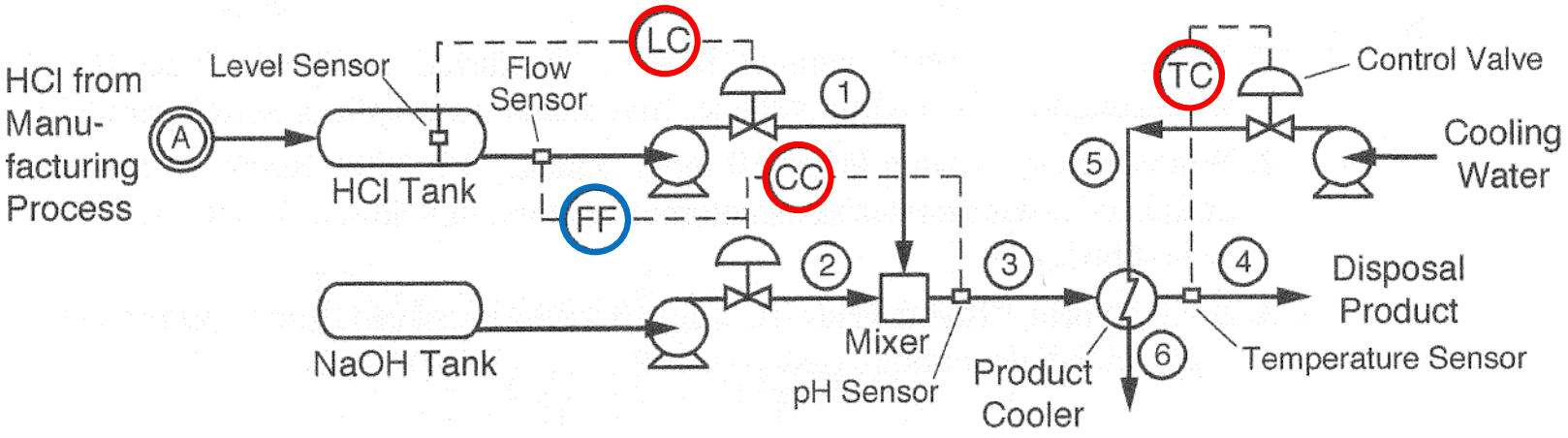
	Feedback control	Feedforward control
Advantages	• Easy response to all disturbances	• Easy correction for measured disturbances before the process
Disadvantages	• Operation with existed deviation • Not available with slow response system	• Errors in model (e.g. inaccurate equations)

12.4 Comparison of strategies

- **The acid-neutralization process**

  with feedback control loops including a level controller (LC), temperature controller (TC) and concentration controller (CC)

  with a feedforward controller (FF)



Homework problems

Homework problem 1.

For each of the following systems, identify the control mode as either feedback of feedforward, and identify the controlled variable and the manipulated variable:

a. Thermostat in your home or apartment
b. Speed (cruise) control in an automobile

Homework problem 2.

Each of the following activities has some aspects that exhibit feedback control and some that exhibit feedforward control. For each activity, describe at least one aspect that is feedback and one that is feedforward:

a. Riding a bicycle
b. Being a student

Feedback:
1. After receiving a poor exam score, the student studies harder.
2. After finding a certain learning technique to be effective, the student uses it more.

Feedforward:
1. On anticipating a particularly-difficult exam (or one for which he/she is not as well prepared), the student studies harder.
2. Approaching a period in which several big assignments are due, the student arranges his/her schedule to work on those assignments.

Homework problems

Homework problem 3.

Considering a feedforward control loop to control the cooling water flow rate in the acid-neutralization process.

a. What disturbances might be important to anticipate in the controller?
b. Design (sketch) such a control loop and identify the important components.
c. If you could only use a feedback loop or a feedforward loop for this particular application, which is preferred? Why?