Modern Control System Theory and Design

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Chemical Engineering Program

Tongji University

Syllabus

- Instructor: Huang, Min PhD
- Time and Place to meet
- Office Hours:
- Text Book and References
  - "Modern Control Engineering", 5ed, (2010) [现代控制工程], Katsuhiko Ogata
  - Modern Control System Theory and Design, 2nd Ed., (1998) Stanley M. Shinners
  - Lecture Notes

Syllabus

  - **Supplementary MATLAB Software (http:\\ftp.hacettepe.edu.tr\pub\mirrors\MathLab\)**
- **Assignments**
  - **Weekly assignments are to be given and are due at the following week regular lecture time**
  - **Late assignments will be accepted with 50% credit**
- **Examinations (Tentative Schedule)**
  - **Quiz, every time we meet**
  - **Midterm I,**

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  - Midterm II,
  - Final, to be announced
- Policy
  - Homework +Quizzes 25%, Midterm I/II 25%, Final 25%, Term paper, translations are encouraged for extra credits.
  - Average exceeds
    - 90% A 80% B
    - 70% C 60% D

Syllabus

- Tentative Schedule
  - General Concept of Control-System Design
  - Fourier and Laplace Transform
  - Transfer Function
  - Signal-Flow Graphs and Mason’s Theorem
  - State-Variable
  - Matrix Form
  - Midterm I

Syllabus

- – Mathematical Modeling of Chemical Processes
- – Transfer-Function Representation of Control-System Elements
- – Time-Domain Response
- – Development of Empirical Dynamic Models from Step Response Data
- – Midterm II

Syllabus

- Performance Criteria
- Nyquist-Diagram
- Bode-Diagram
- Nichols Chart
- Root-Locus Method
- Linear Control-System Compensation and Design
- Final

General Concept of Control-System Design

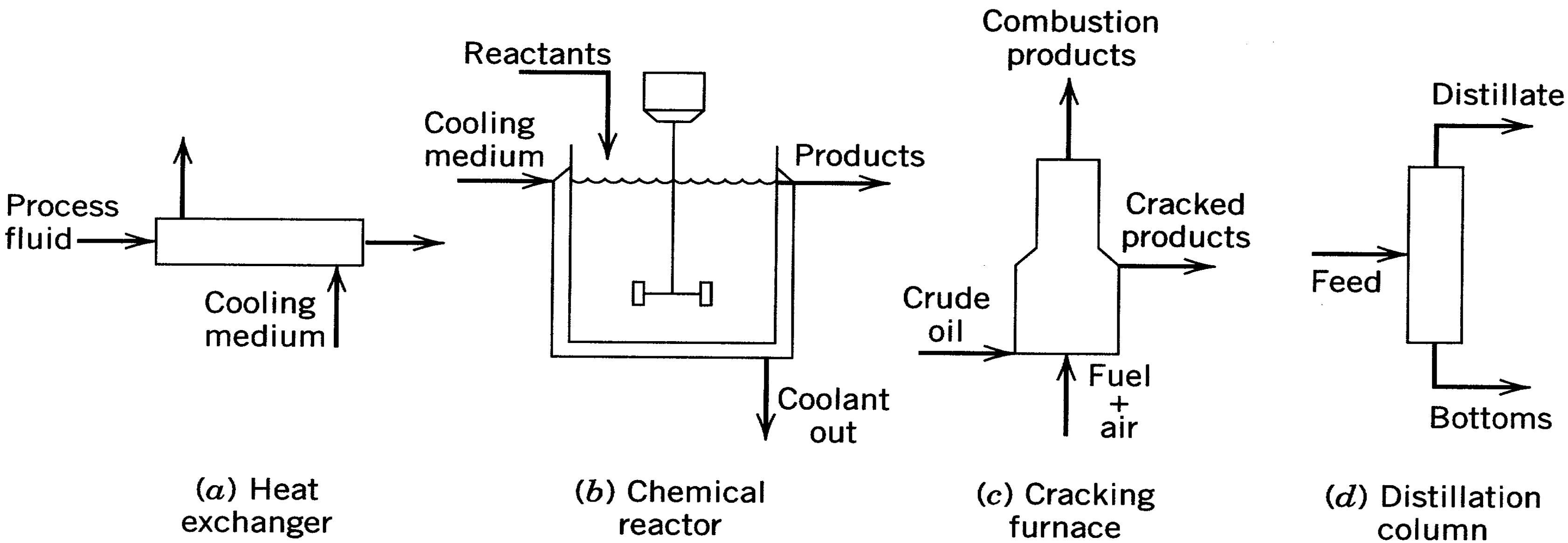
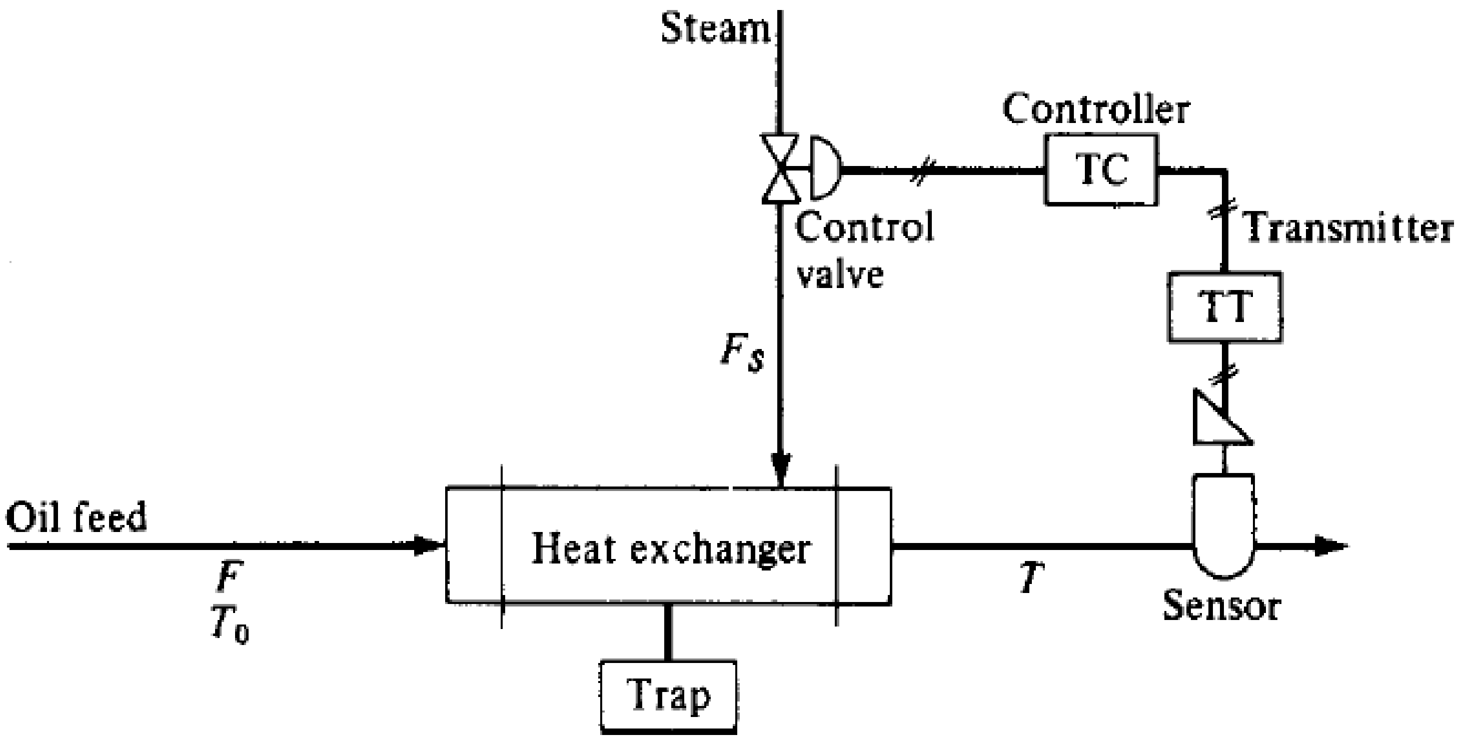
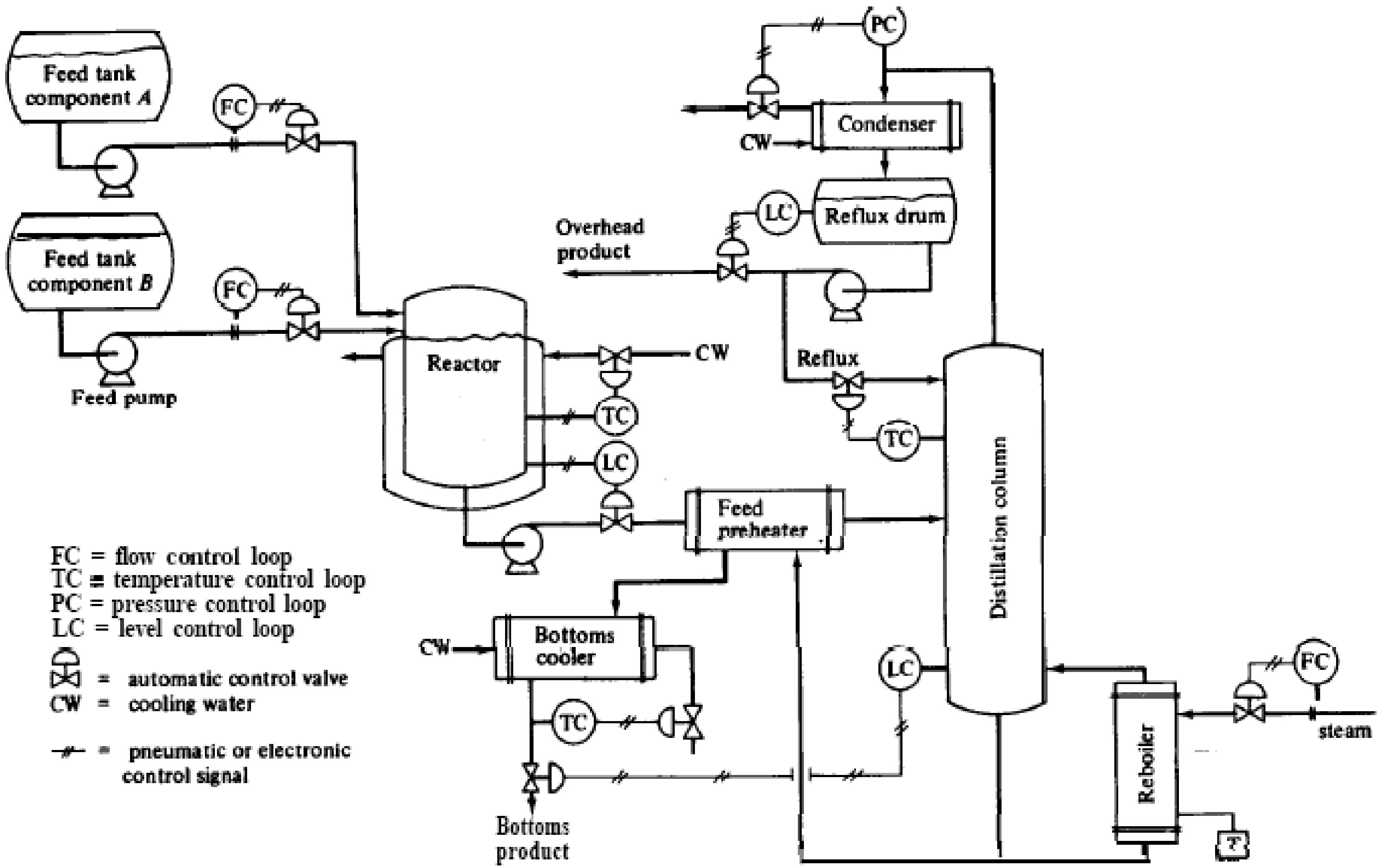


Figure 1.1 Some typical continuous processes.

Heat Exchanger



Typical Chemical Plant



Stirred-tank Blending System

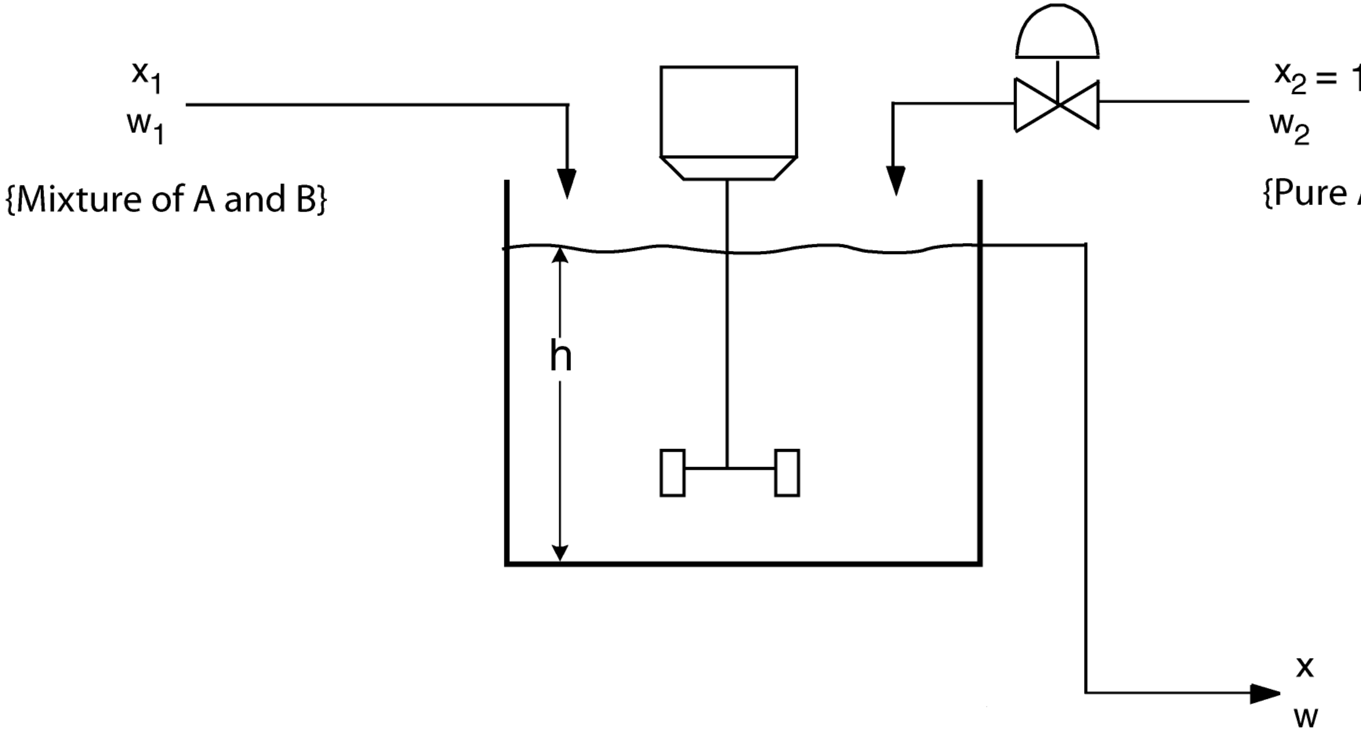


Figure 1.3. Stirred-tank blending system.

Stirred-tank Blending System

- **Notation:**
  - w_1, w_2 **and w are mass flow rates**
  - x_1, x_2 **and** x **are mass fractions of component A**
- **Control Objective:**
  - **Keep** x **at a desired value (or "set point")** x_{sp}**, despite variations in** $x_1(t)$**. Flow rate** w_2 **can be adjusted for this purpose.**

Stirred-tank Blending System

- **Terminology:**
  - **Controlled variable (or "output variable"): x**
  - **Manipulated variable (or "input variable"): w_2**
  - **Disturbance variable (or "load variable"): x_1**

Control Terminology

- **Controlled Variables - these are the variables which quantify the performance or quality of the final product, which are also called output variables.**
- **Manipulated Variables - these input variables are adjusted dynamically to keep the controlled variables at their set-points.**

Control Terminology

- **Disturbance Variables - these are also called "load" variables and represent input variables that can cause the controlled variables to deviate from their respective set points.**

Control Terminology

- **Set-point change - Implementing a change in the operating conditions. The set-point signal is changed and the manipulated variable is adjusted appropriately to achieve the new operating conditions. Also called servomechanism (or "servo") control.**

Control Terminology

- **Disturbance change - the process transient behavior when a disturbance enters, also called regulatory control or load change. A control system should be able to return each controlled variable back to its set-point.**

What value of w_2 is required to have $x = x_{sp}$

Some Possible Control Strategies

- **Control Objective:**

  Keep *x* at a desired value (or "set point") x_{sp}, despite variations in $x_1(t)$.

  – **Method 1.** *Measure x and adjust* w_2

  – ***Method 2.*** *Measure* x_1 *and adjust* w_2

  – ***Method 3.*** *Measure* x_1 *and x, adjust* w_2

  This approach is a combination of Methods 1 and 2

Measure x and adjust w_2

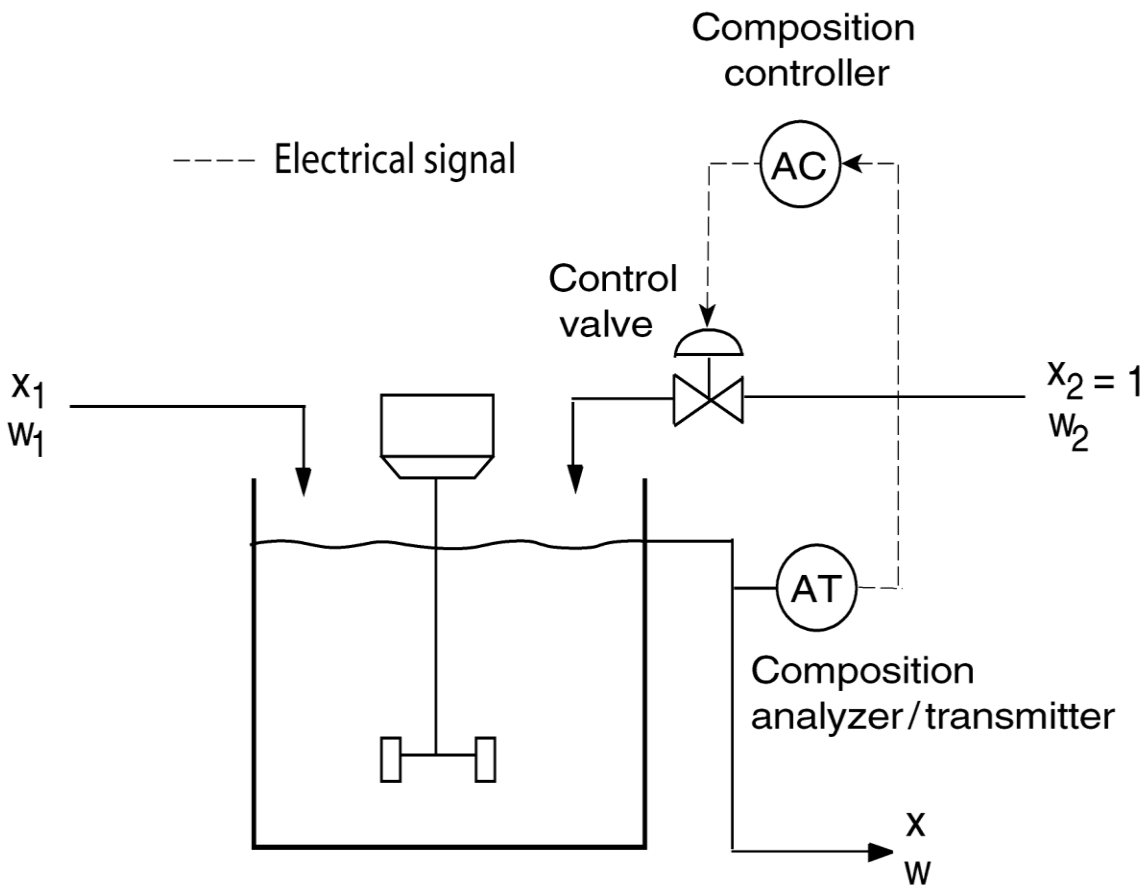
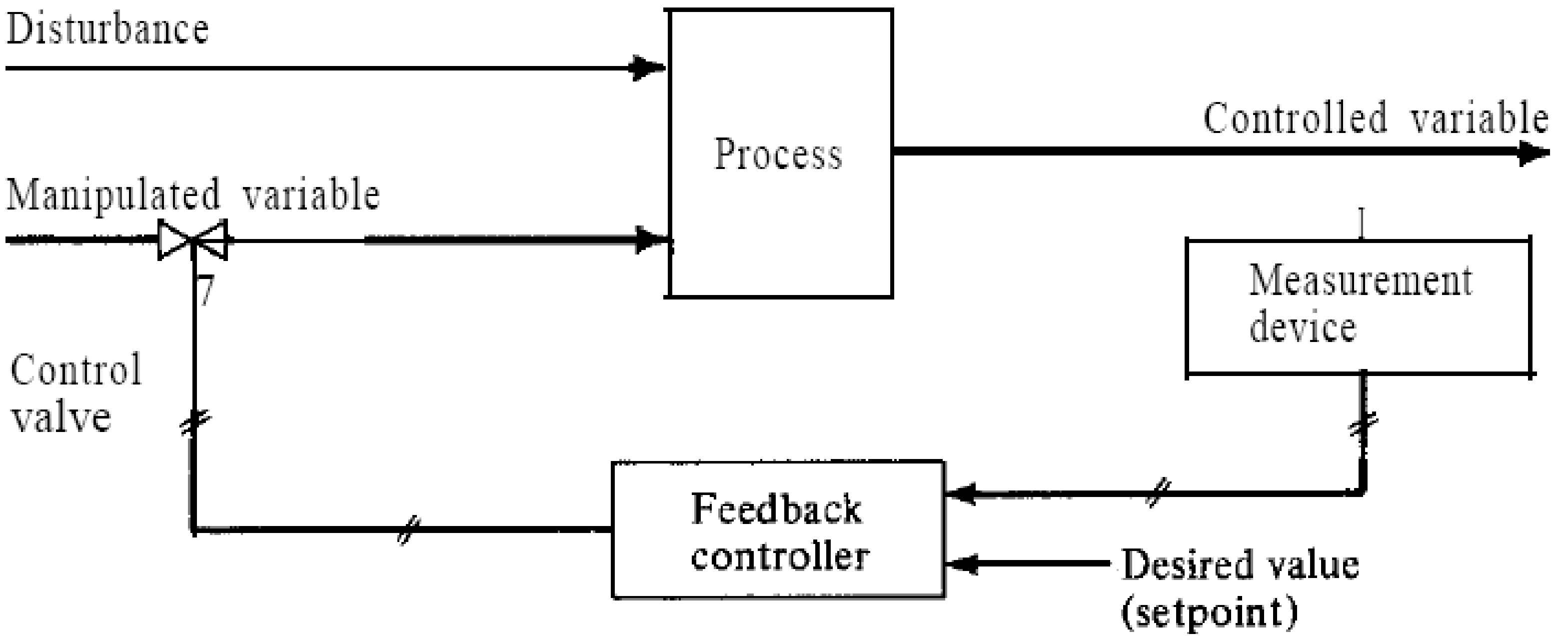


Figure 1.4. Blending system and Control Method 1.

Feed-back Control

Measure the controlled variable



Feed-back Control

- **Advantages**
  - **Corrective action is taken regardless of the source of the disturbance.**
  - **Reduces sensitivity of the controlled variable to disturbances and changes in the process (shown later)**

Feed-back Control

- **Disadvantages**
  - **No corrective action occurs until after the disturbance has upset the process, that is, until after *x* differs from x_{SP}.**
  - **Very oscillatory responses (close-loop system + time delay), or even unstable**

Measure x_1 and adjust w_2

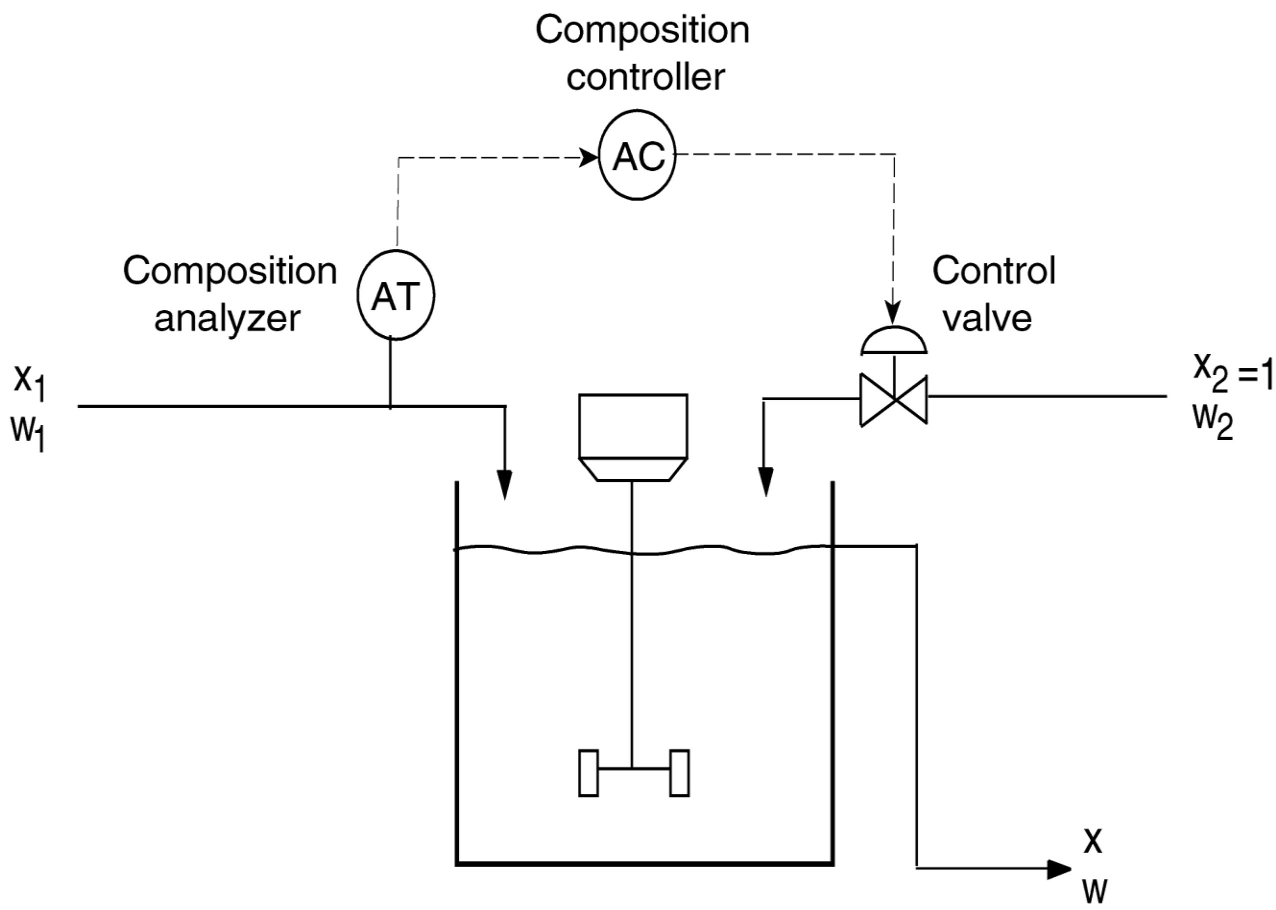


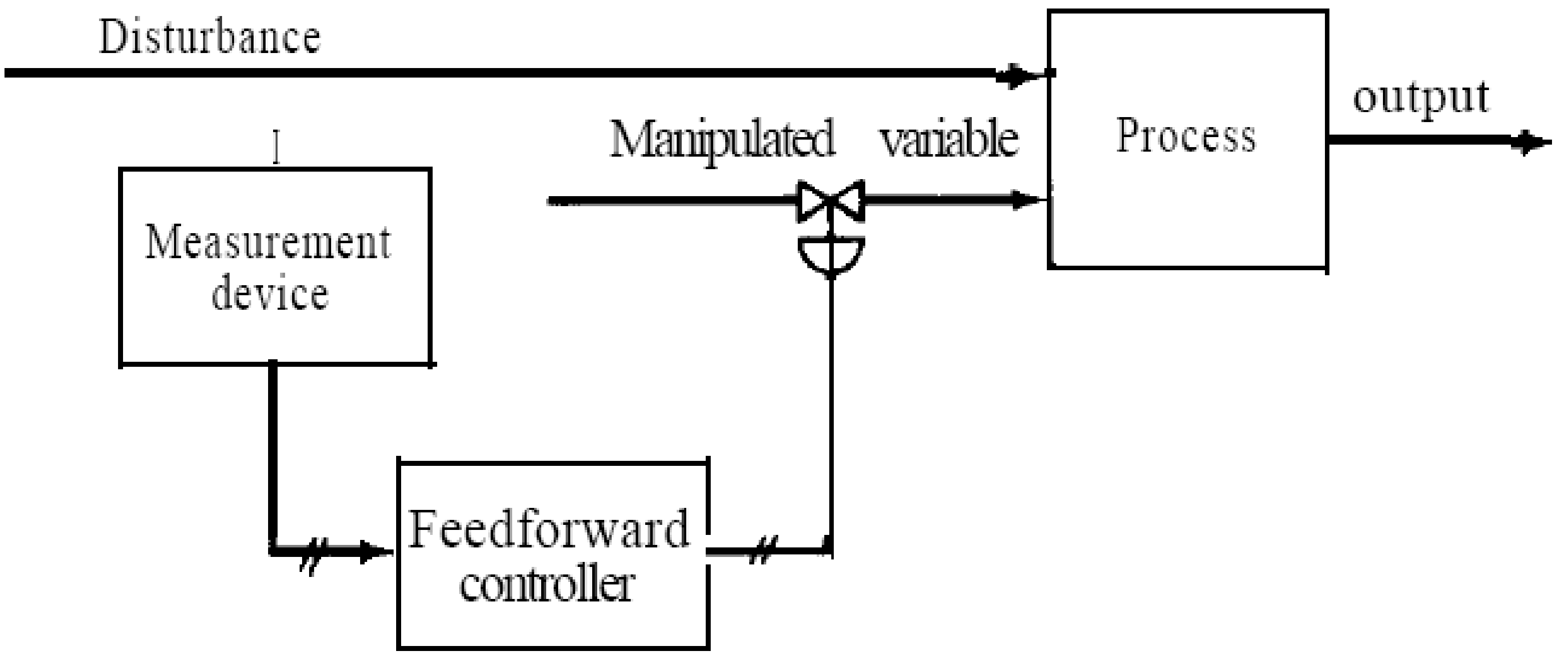
Figure 1.5. Blending system and Control Method 2.

Feed-forward Control

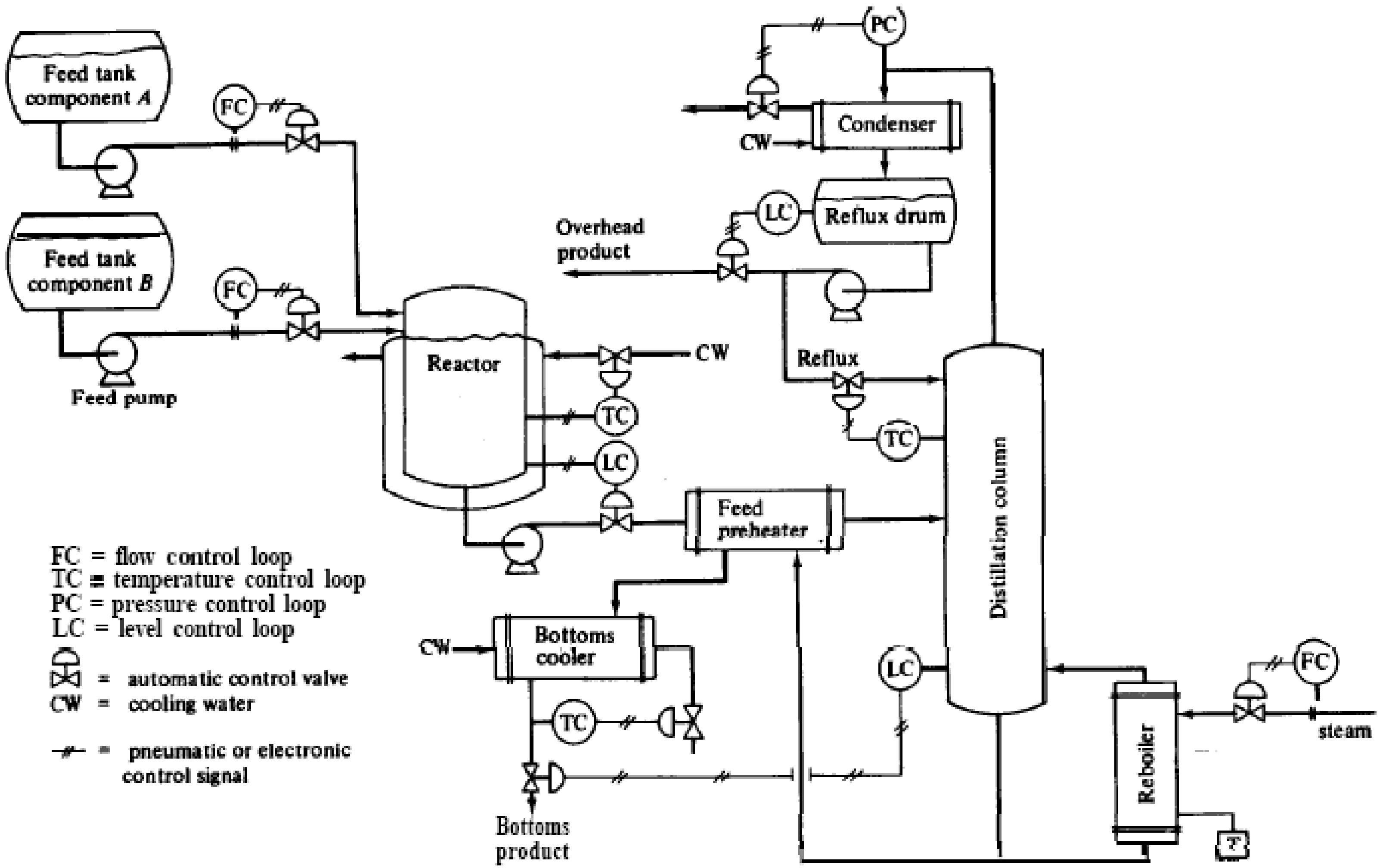
- **Advantage**
  - **Correct for disturbance before it upsets the process**
- **Disadvantage**
  - **Must be able to measure the disturbance**
  - **No corrective action for unmeasured disturbances**

Feed-forward Control

- **Measure a disturbance variable**

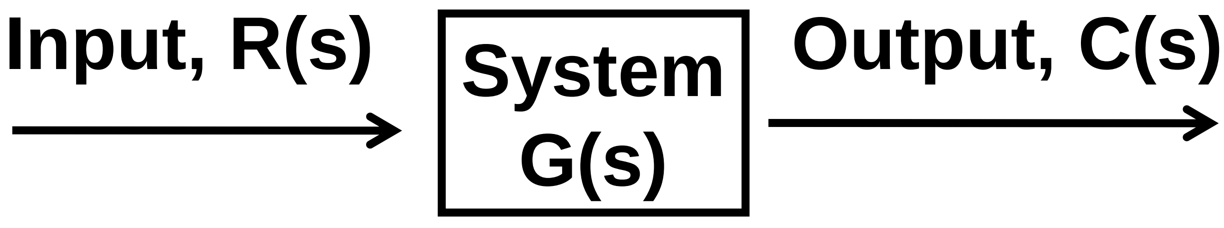


Typical Chemical Plant



Block Diagram

- Signal-flow representation of a physical system



Steering of an Automobile

- **Pre adjustment of the steering wheel when the alignment is poor**
- **Stop the automobile in front of the stop sign or traffic light**
- **Negotiate a turn at the cross-section**
- **Adjust the steering wheel to negotiate the curvatures of the road**

Steering of an Automobile