Advanced Process Control

CBEg 6142

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Chapter 5

Cascade Control Systems

Cascade control: Introduction

- Next to feedback control, cascade and ratio control are probably the most commonly used advanced regulatory control techniques
- A cascade control system employs a secondary measured variable and a secondary feedback controller.
- The upper-level controller is called the “primary,” (master) while the lower level is called the “secondary.”(slave)
- The primary controller adjusts the set point of the secondary controller.
- A typical application of cascade control is a temperature controller cascaded to a flow controller.

Cascade control: Introduction

- The potential benefits of cascade include:
  - Isolating the controller for a key process variable from a problem element, such as a control valve stiction, nonlinearity, hysteresis.
  - Responding faster to disturbances associated with manipulated variable
  - Providing more consistent performance over a wide range of process conditions.

Cascade control: Introduction

- Cascade controllers are turned on into full automatic operation and tuned from inside out.
  - That is, the inner controller is first tuned and set into remote set-point mode while the other loops are in manual.
- The inner-loop in cascade control must be made as fast as possible.
- In a cascade control system, the “secondary” controller is usually a P controller and the “primary” controller is often a PI controller.

The Cascade Control Structure

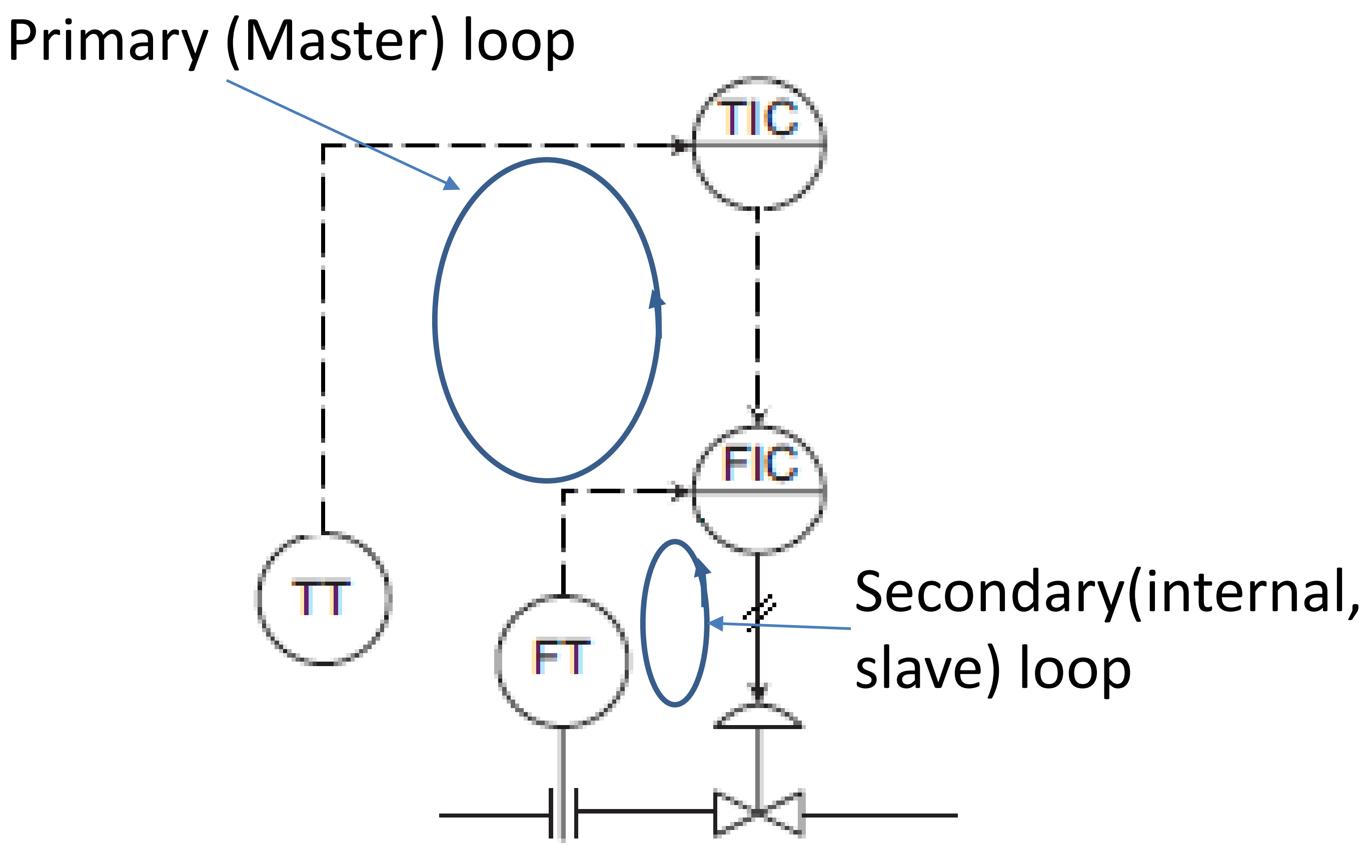

Figure 5.1 Temperature control cascaded to a flow control

Schematic and Block Diagrams

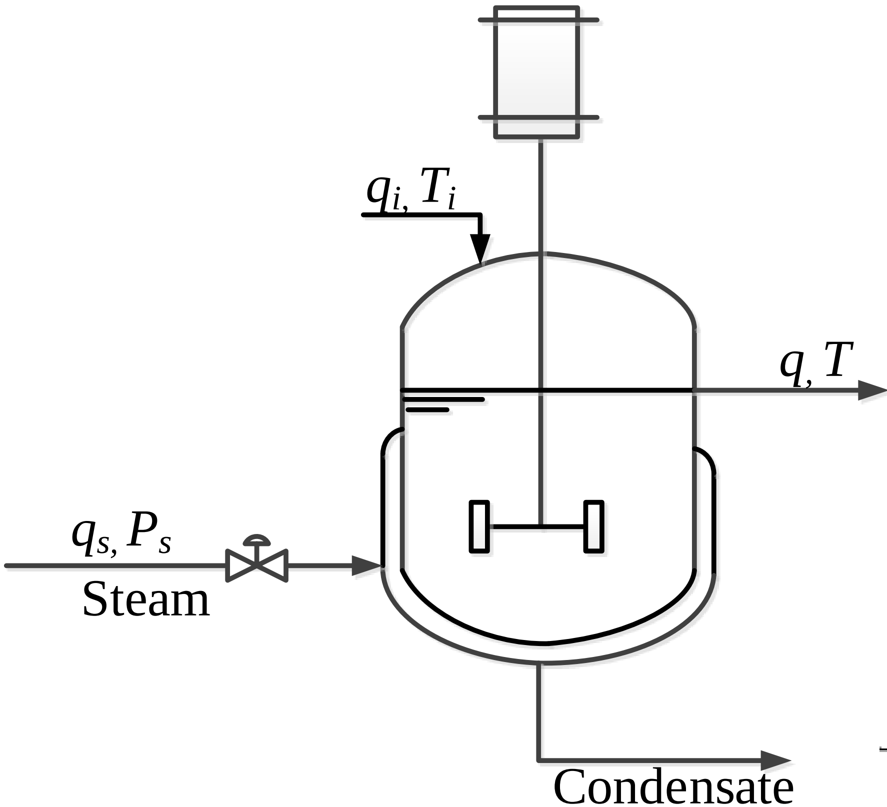

Figure 5.2. Stirred Tank Heater

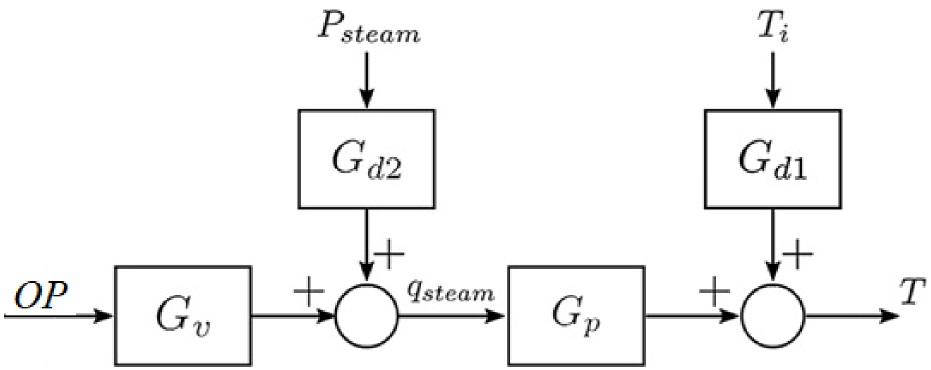

Figure 5.3. Block Diagram of Stirred Tank Heater

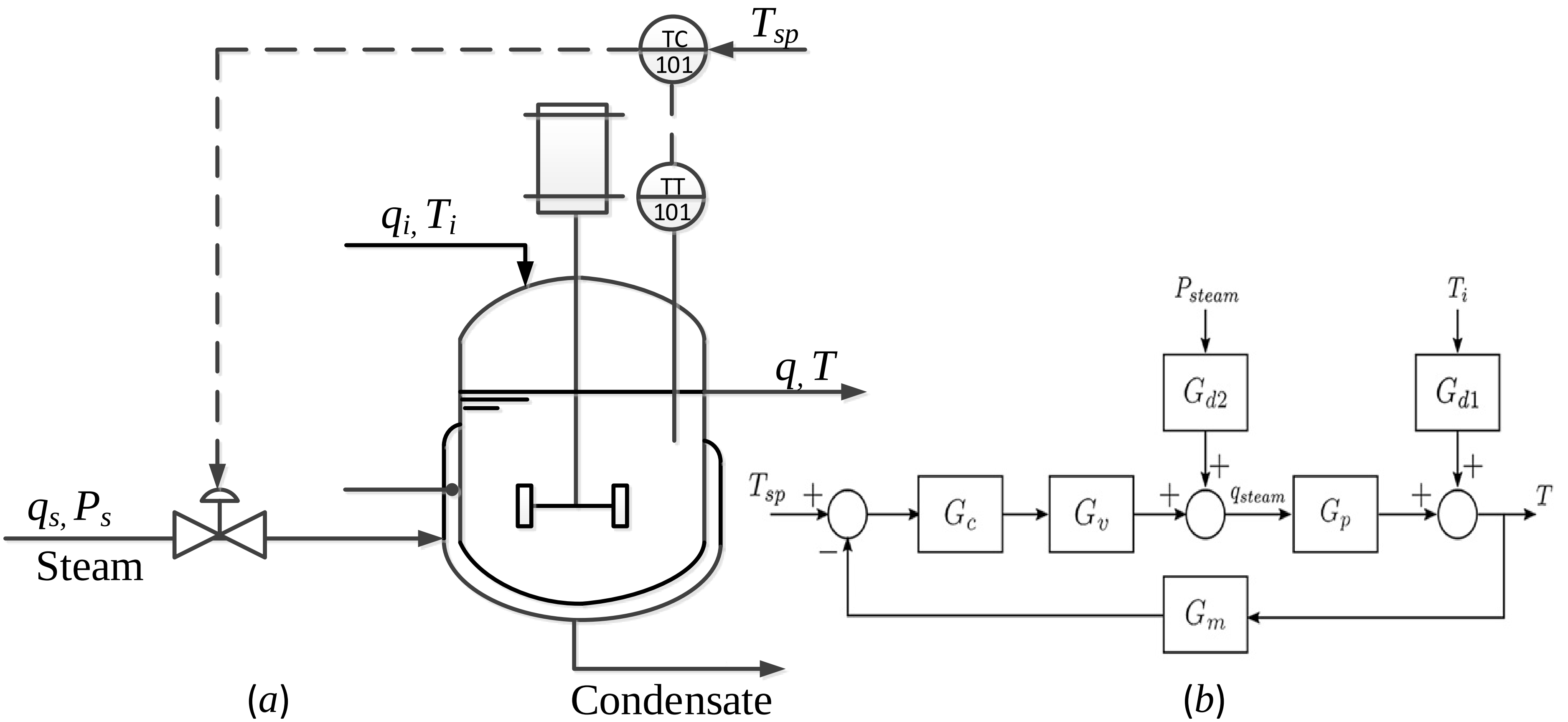

Figure 5.4 Simple feedback control system, (a) Schematic diagram (b) block diagram

Schematic Diagram of Cascade Control

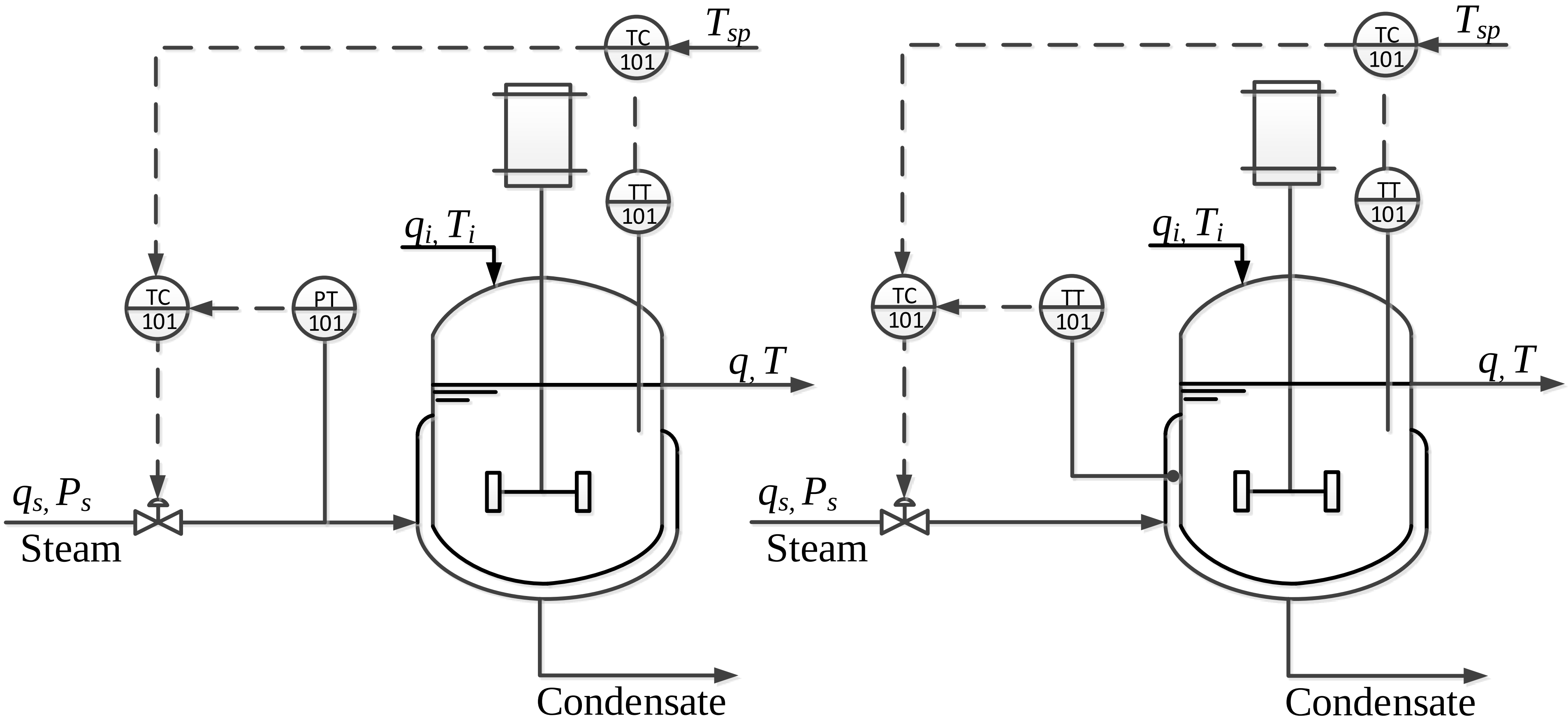

Figure 5.5 Two possible cascade configuration for controlling the outlet temperature

Block Diagram

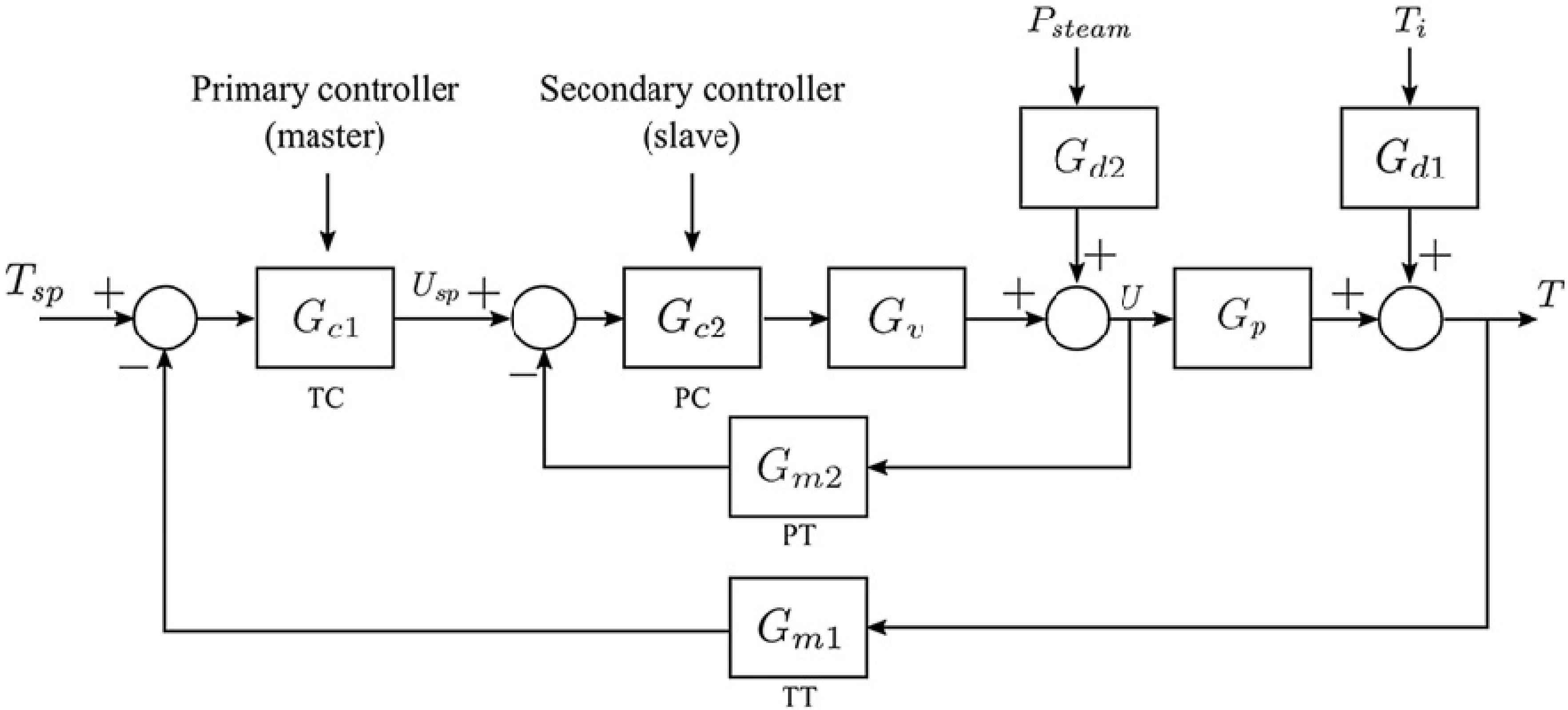

Figure 5.6 Two possible cascade configuration for controlling the outlet temperature

Exercise 5.1

The block diagram of a stirred tank heater is given below. Using MATLAB simulation, show the difference in performance of a simple feedback and a cascade controller for servo and regulator problems.

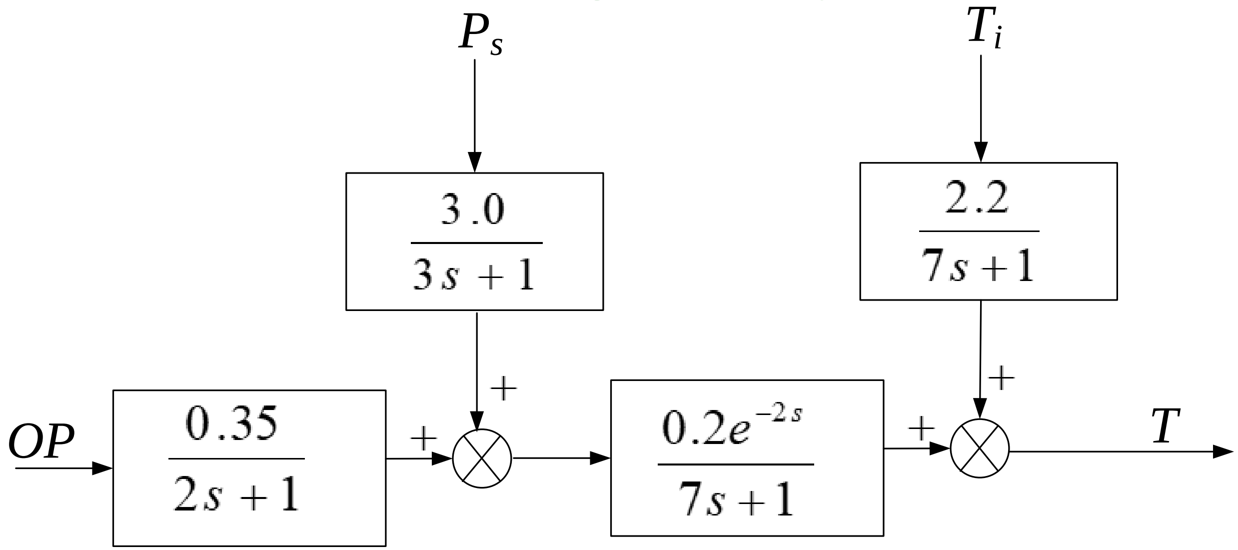

Figure 5.7 Block Diagram of Stirred Tank Heater

Exercise 5.2

A constant capacity, jacketed, stirred tank cooler is used to cool a process stream from 110 ^oC to 80 ^oC as shown in Figure 5.8. The inlet stream has flow rate of 12 m^3/s at steady state. The density and specific heat capacity of the process stream are 1110kg/ m^3 and 3.2 kJ/kg K. The volumes of the tank and the cooling jacket are 84 and 29.6 m^3, respectively. Cooling water is available at 18± 5 ^oC. A variation ± 5 ^oC is expected in the inlet temperature of the process stream. Design alternative control systems (Feedback, Cascade) and evaluate their performance. The jacket temperature is measurable.

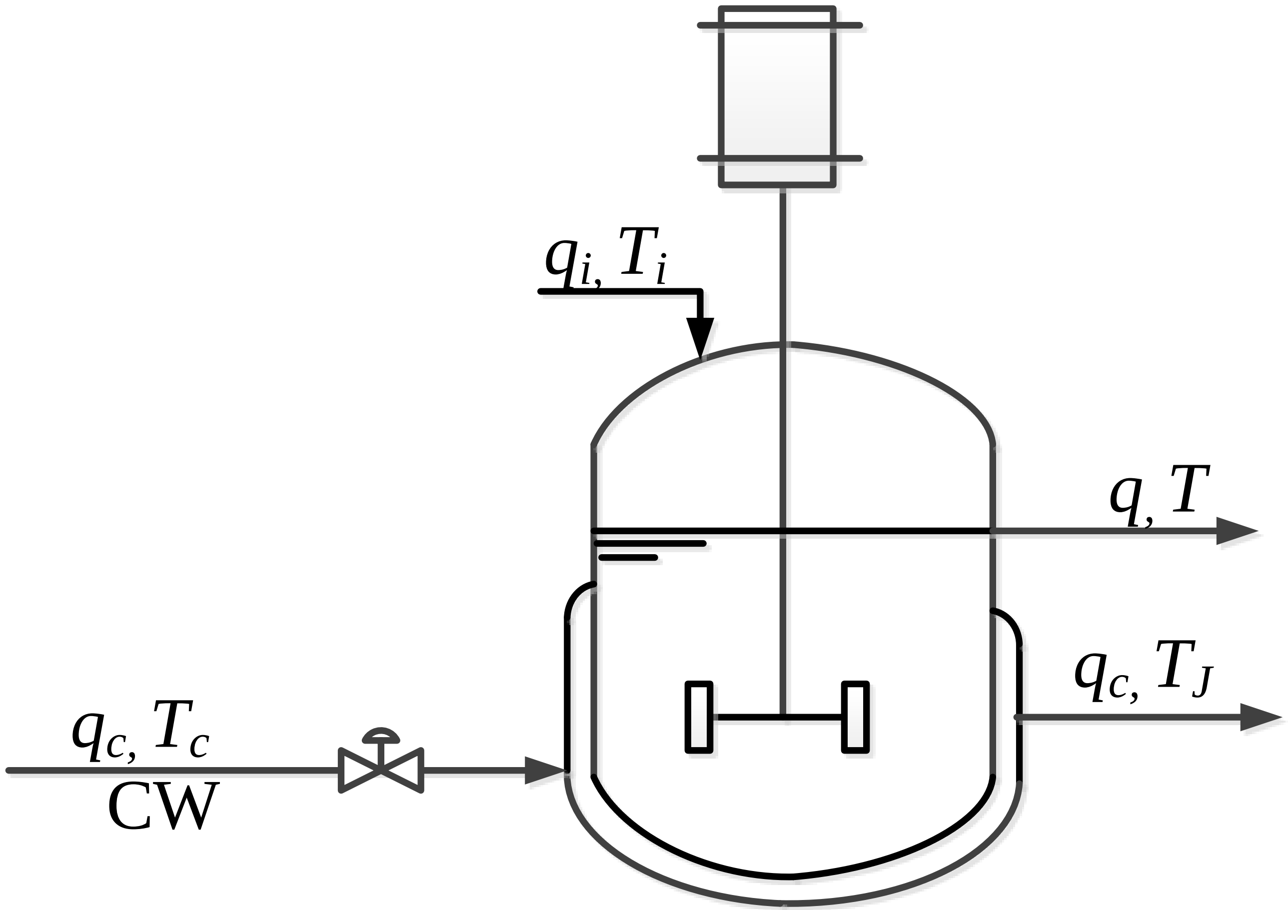

Figure 5.8 Stirred Tank Cooler

Other Examples Cascade Control

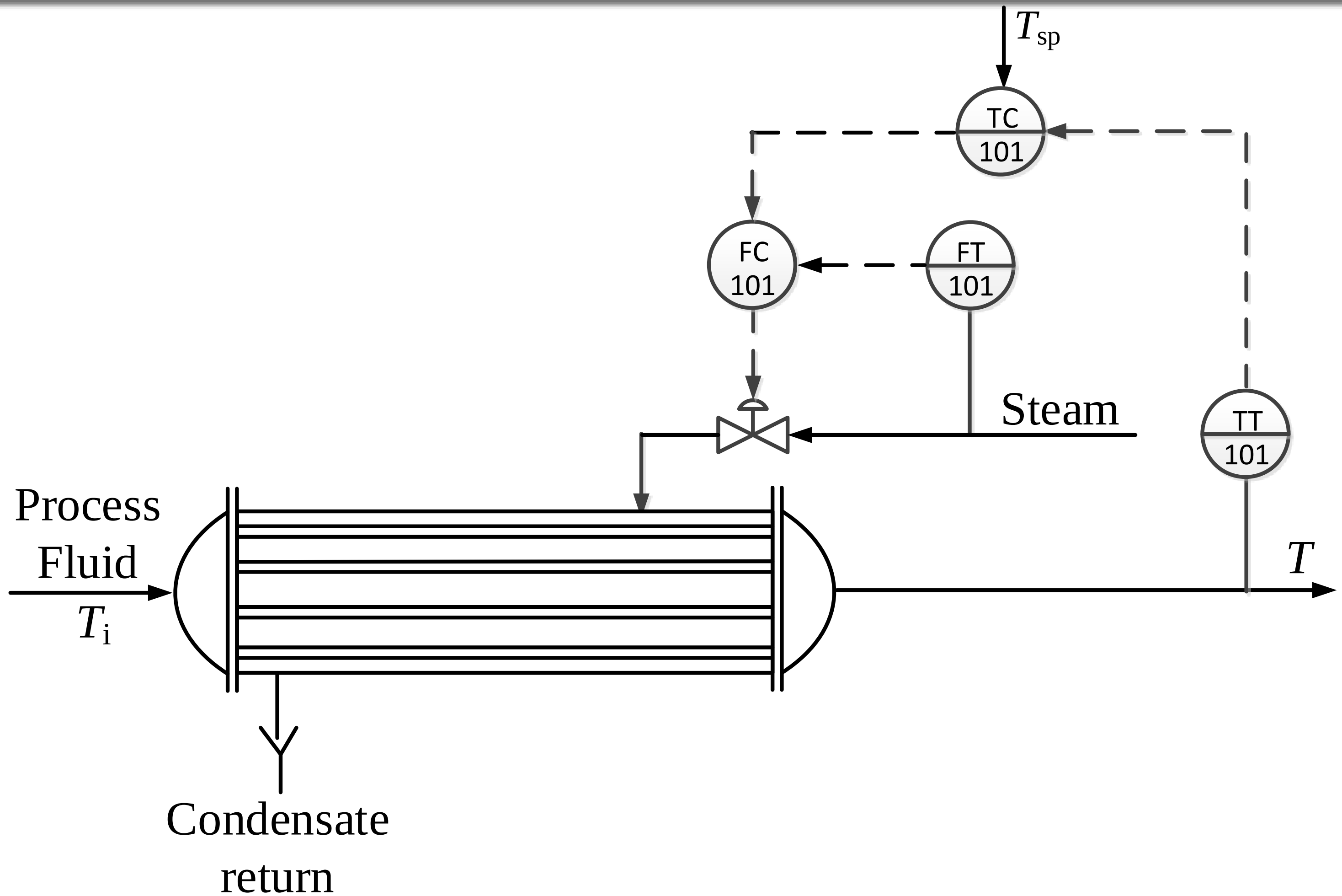

Figure 5.9 Flow cascaded temperature control

Feedback vs Cascade Control

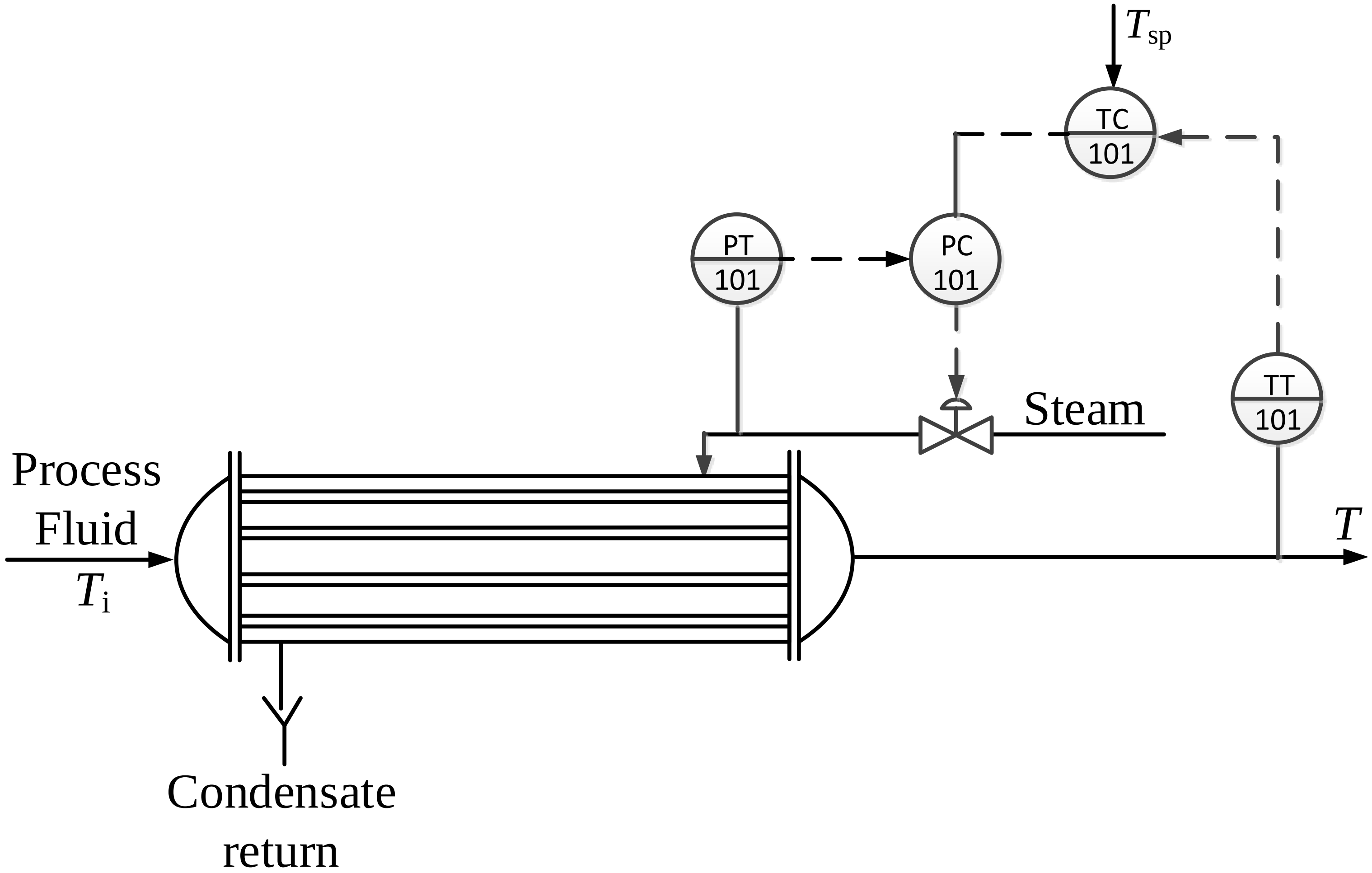

Figure 5.10 Temperature control (Feedback control)

Feedback vs Cascade Control

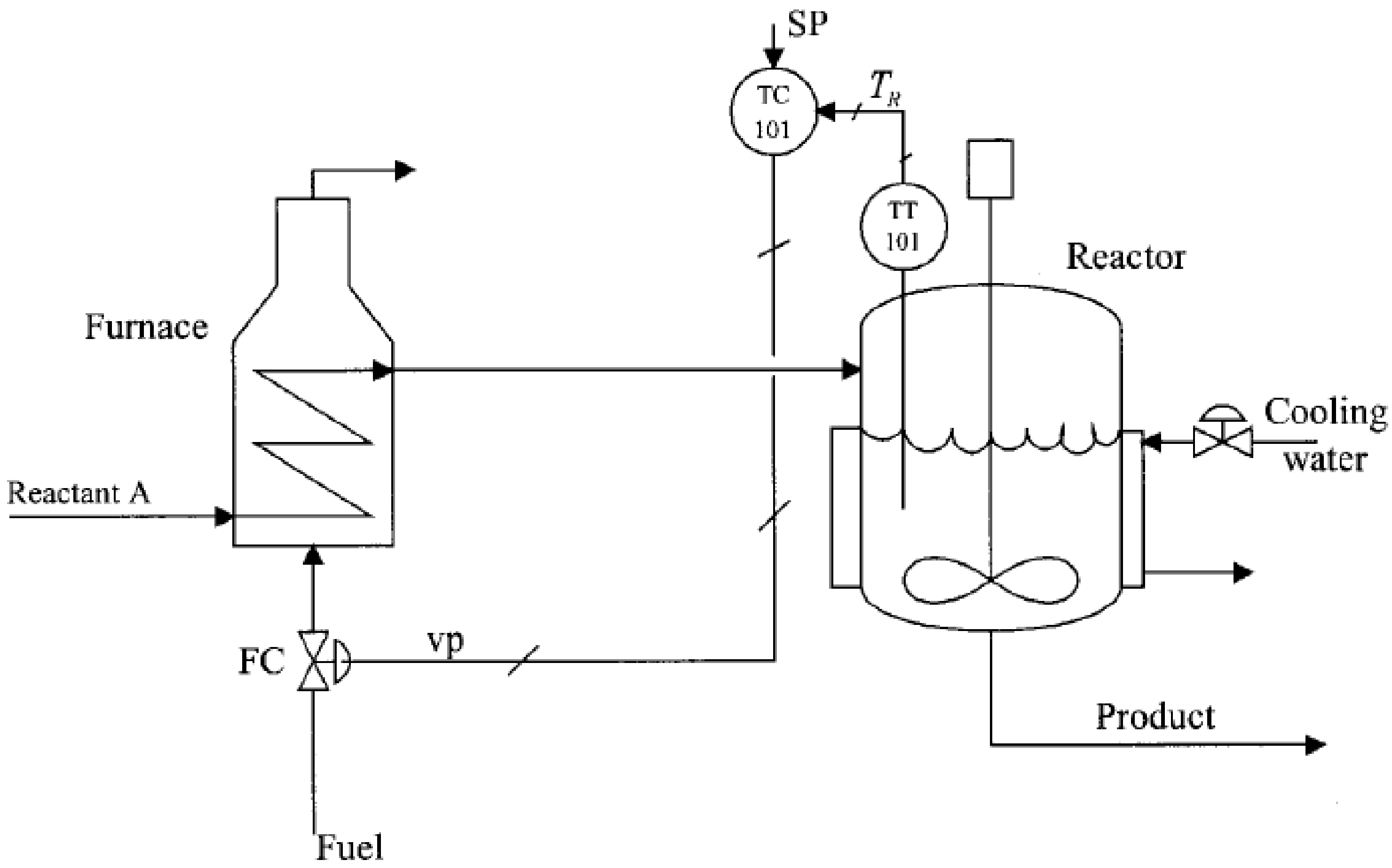

Figure 5.11 Feedback control

Feedback vs Cascade Control

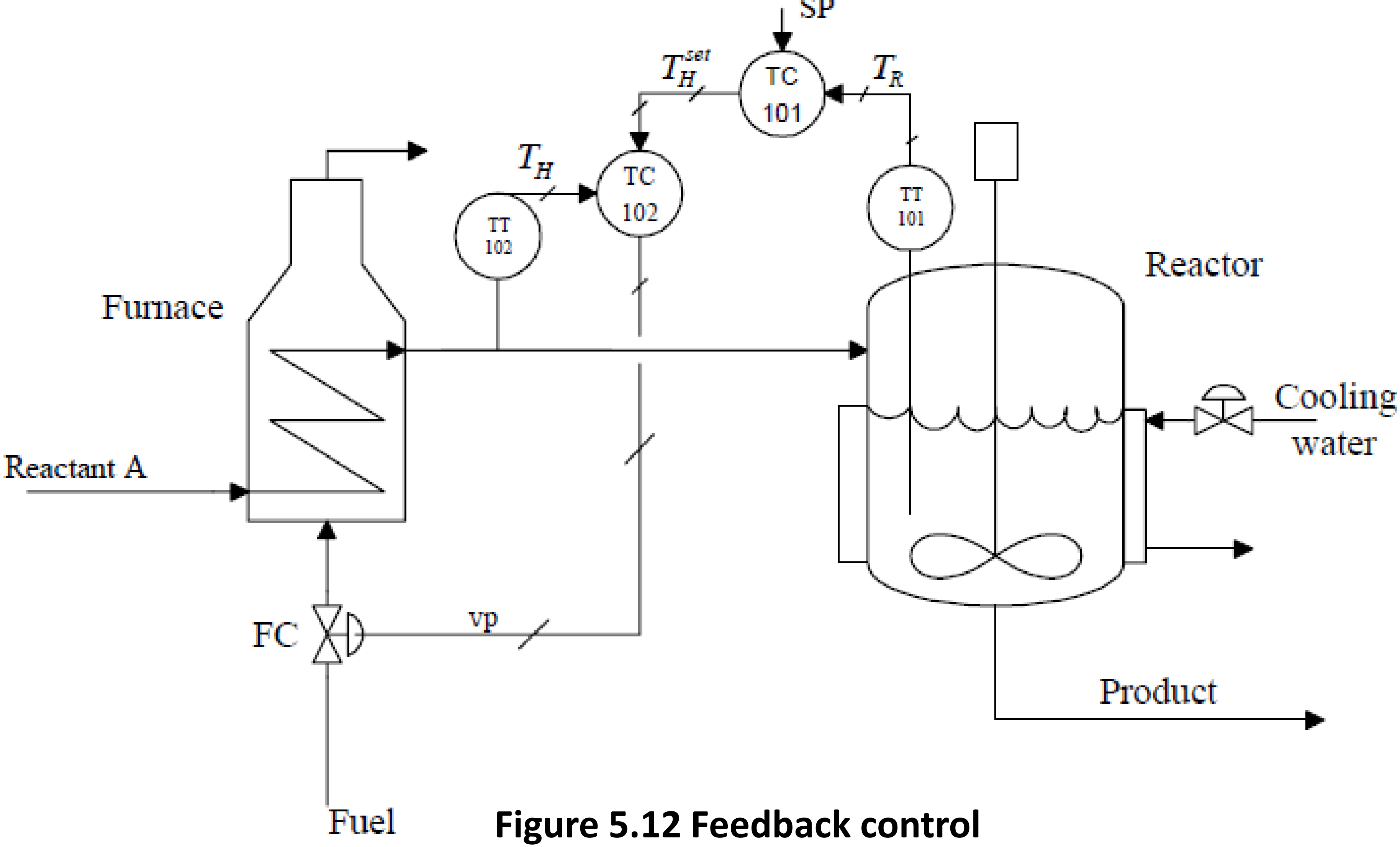

Figure 5.12 Feedback control

Exercise

Exercise 5.3

Develop the block diagram of a cascade control system and derive the closed-loop equation and the characteristics equation.