SKF 3143

Process Control and Dynamics: Introduction to Process Control

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Learning Objectives

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

1. explain the function and importance of process control in chemical plants
2. identify and describe simple control systems used in every day life and in a chemical plant
3. demonstrate understanding of a process and instrumentation diagram

Outline of this lecture

1. **Illustrative Examples**
2. **Incentives for Process Control**
3. **Hardware Configuration, P&ID and Block Diagrams**
4. **Classification of Control Strategies**
5. **Typical Control Loops**

Why have a process control course?

A career in process control.

Process Control Terminology.

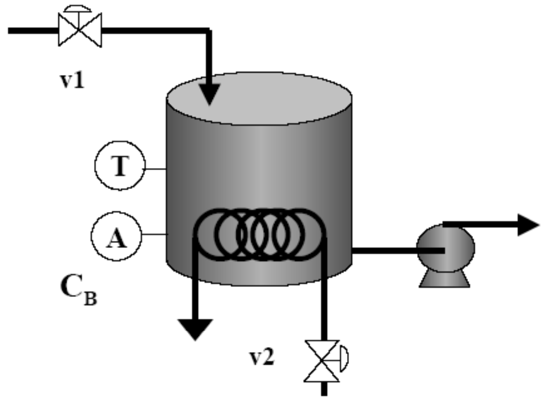
Everyday example of process control.

Chemical engineering example of process control.

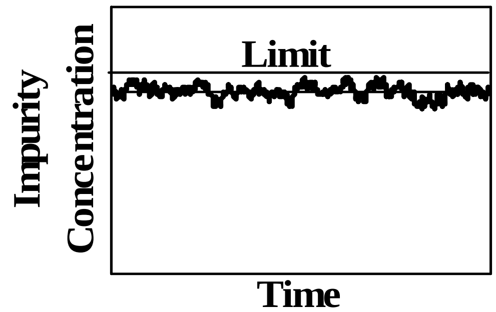
ILLUSTRATIVE EXAMPLES

Why have a process control course?

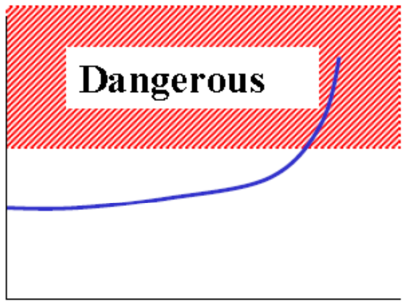
- When I run a kinetics experiment, how do I maintain the temperature and level at desired values?



- How do I manufacture products with consistently high quality when raw material properties change?



- How much time do I have to respond to a dangerous situation?



A career in process control.

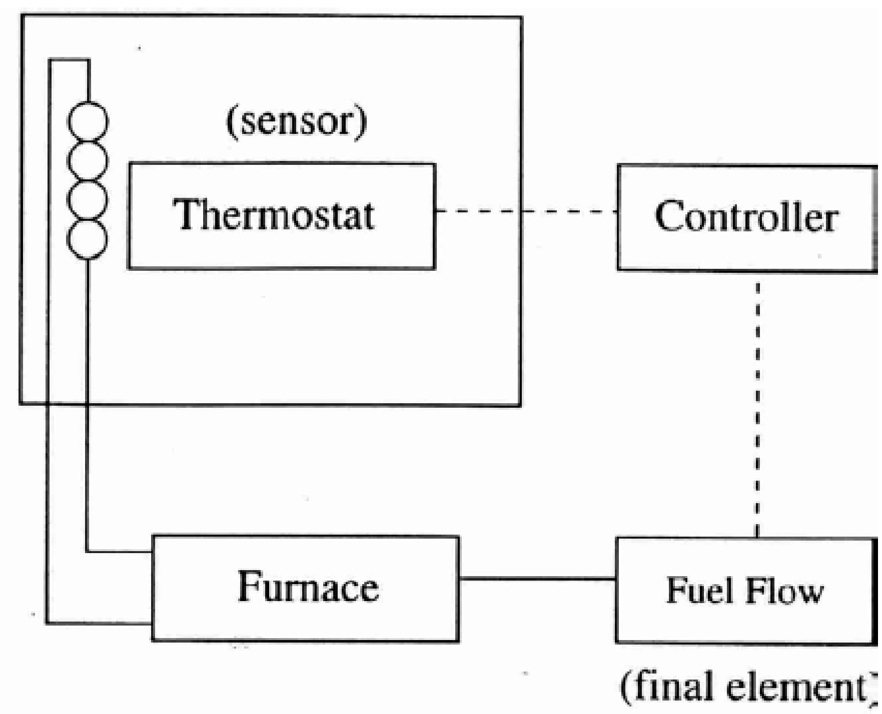
- Requires that engineers use all of their chemical engineering training (i.e., provides an excellent technical profession that can last an entire career)
- Can become a technical "Top Gun"
- Allows engineers to work on projects that can result in significant savings for their companies (i.e., provides good visibility within a company)
- Provides professional mobility. There is a shortage of experienced process control engineers.
- Is a well paid technical profession for chemical engineers.

Let's look at a few examples first. Then, we will develop a general concept.

- Describe your method for driving a car.
- Could you drive a car without looking out the windshield?
- What must be provided by the car designer?
- Can a "good design" eliminate the need to steer?

Let's look at a few examples first. Then, we will develop a general concept.

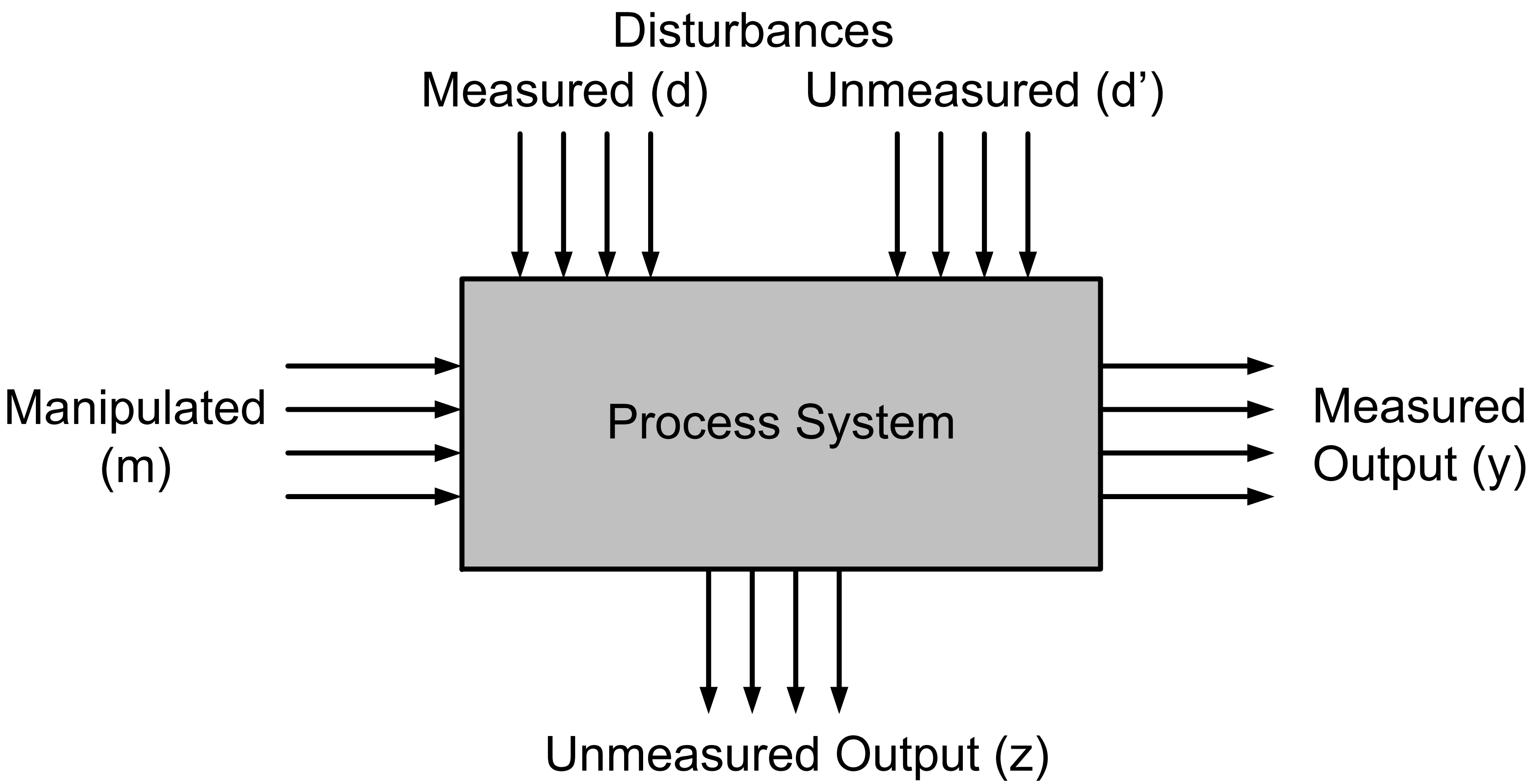
- Describe how home heating works.
- Describe the dynamic behaviour of T.
- What must be provided by the house designer?
- Can a "good design" eliminate the need to change the heating?



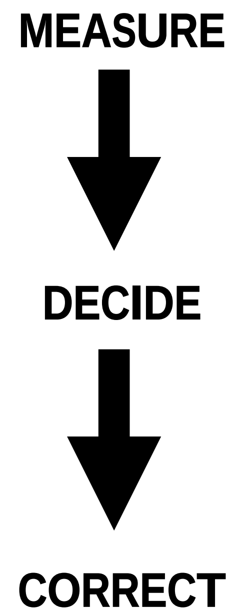
Process Control Terminology

- **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.
- **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.

Process Control Terminology

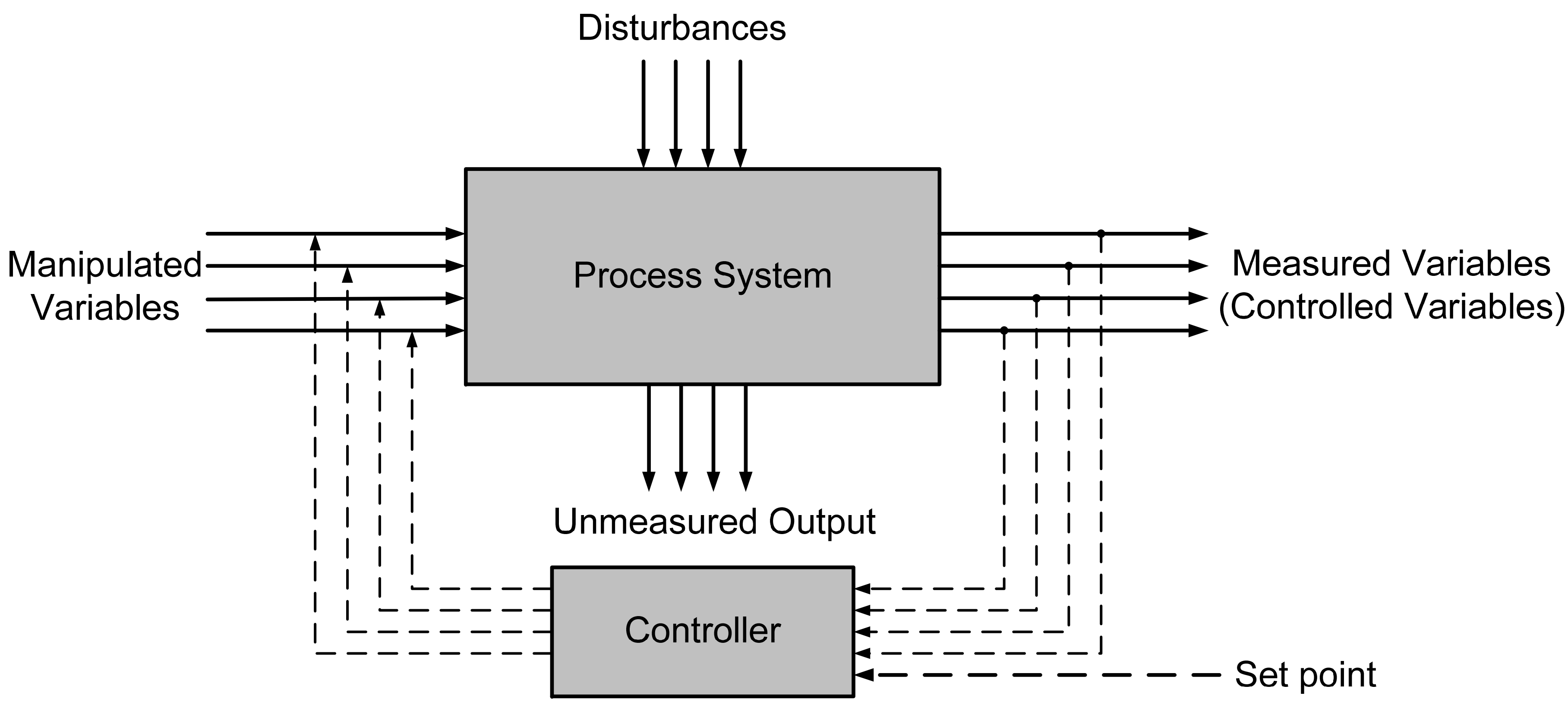


What is control?



Control is to maintain desired conditions in a system by adjusting selected input variables of the system

The control systems appear to have three basic elements.



Everyday example of process control.

Controlling Water Temperature of a Shower

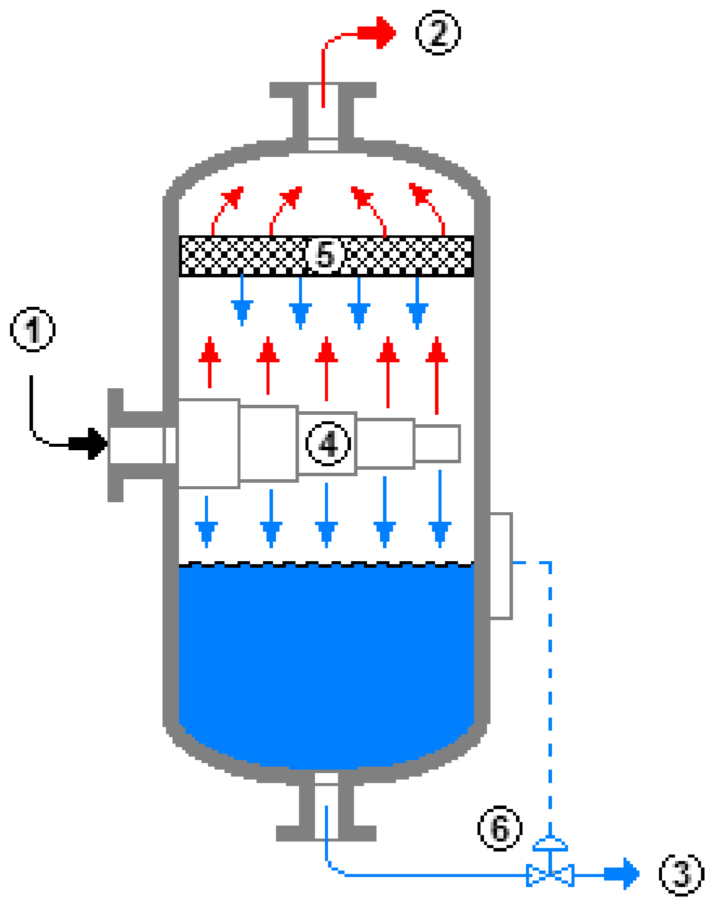
- *Process:*
- *Sensor:*
- *Controlled var.:*
- *Setpoint:*
- *Manipulated var.:*
- *Final Control Element:*
- *Controller:*

Everyday example of process control.

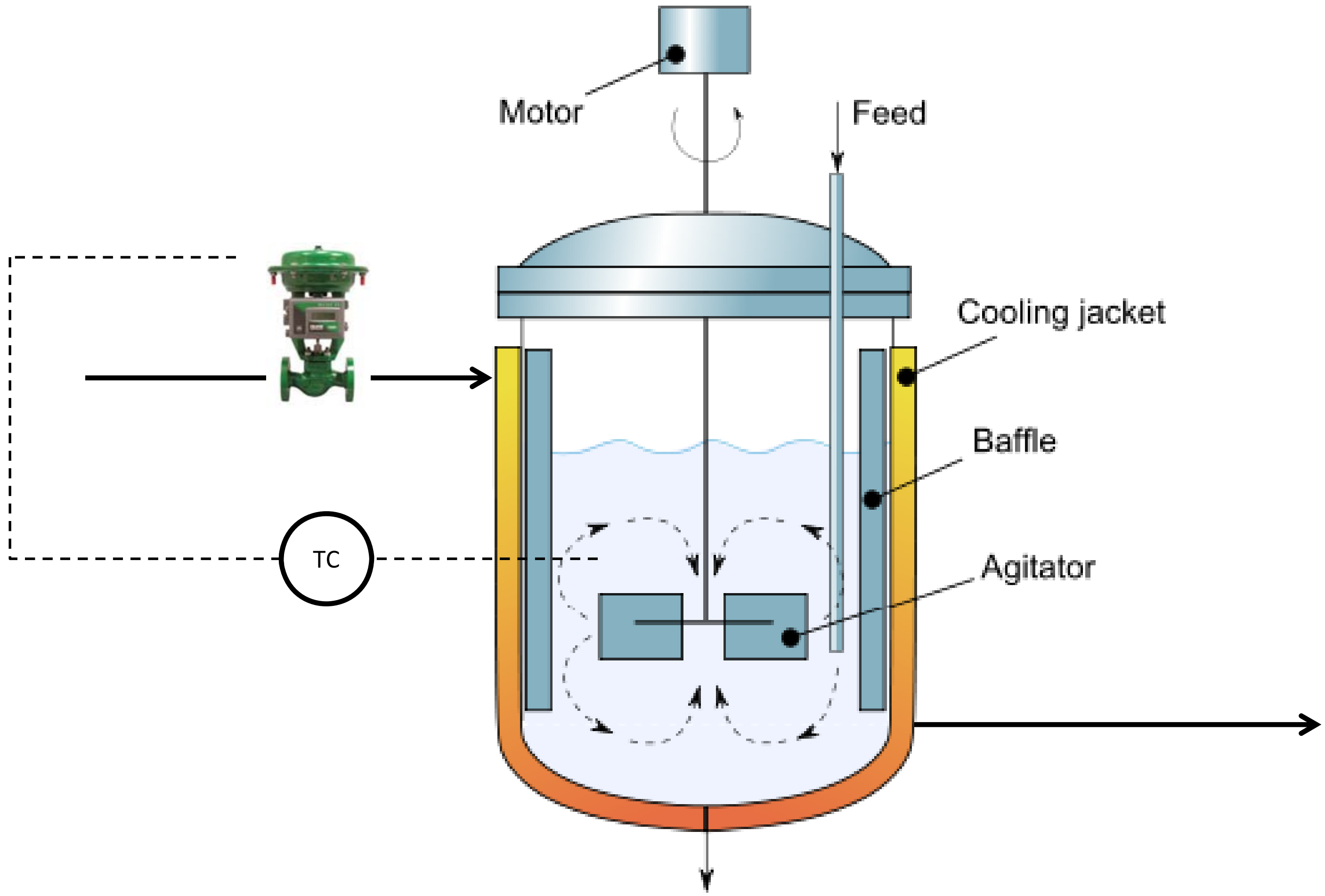
Driving a Car

- *Setpoint:*
- *Control variable:*
- *Manipulated var.:*
- *Actuators:*
- *Sensors:*
- *Controller:*
- *Disturbances:*

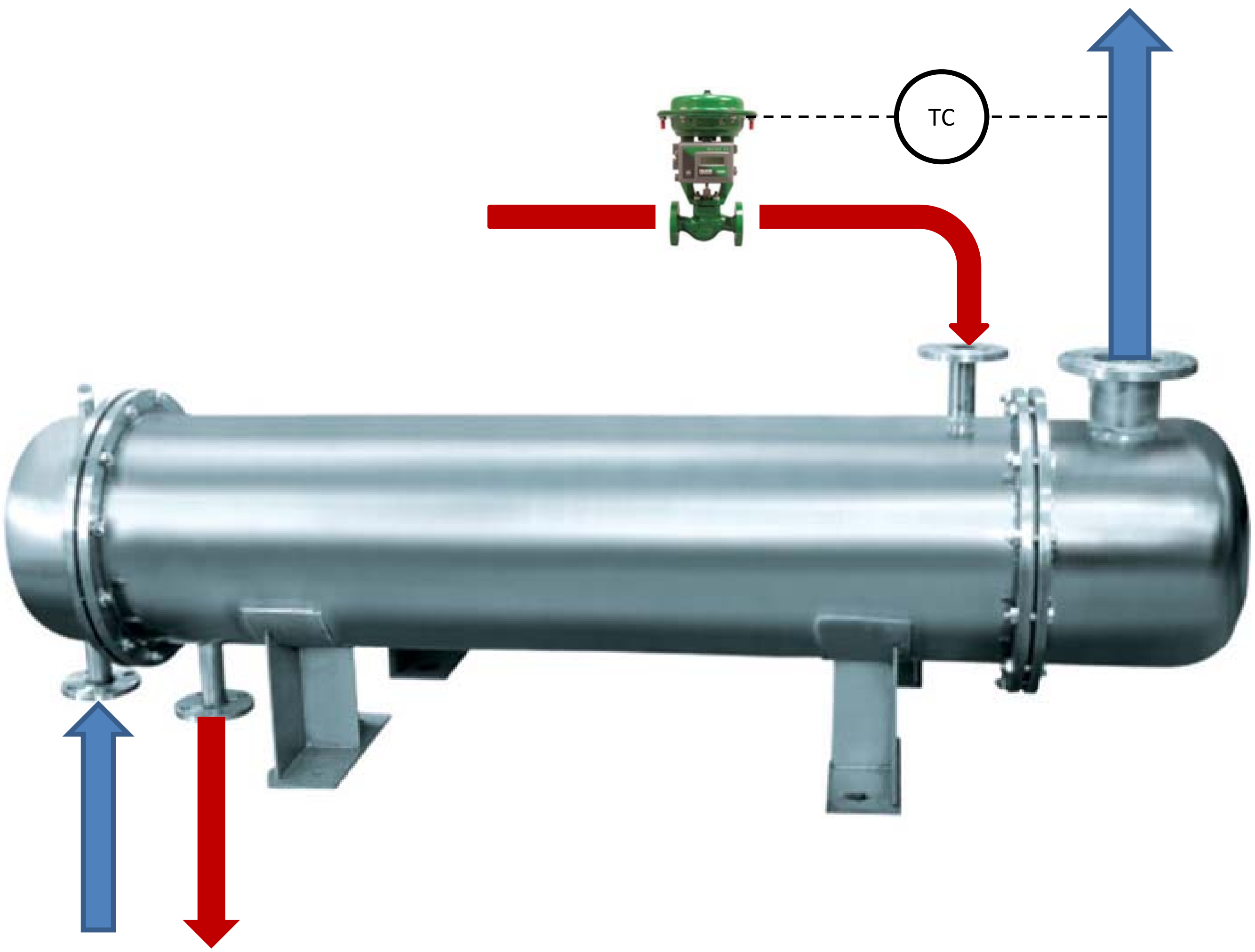
Chemical engineering example of process control – Vapour-Liquid Separator



Chemical engineering example of process control – Continuous Stirred Tank Reactor



Chemical engineering example of process control – Heat Exchanger



Objectives of a process plant.

Safety in plant operation must be ensured.

Process control objectives.

Example of Flash separation.

INCENTIVES FOR PROCESS CONTROL

Objectives of a process plant.

- Purpose:
  - Process plants transform raw materials into useful products
- Objectives:
  - Plants must satisfy production Specification
    - Good quality products
    - Minimal pollution-noise, air, water, safety standards
  - Plant must make profit
- How to achieve these objectives?
  - Good plant design
  - Good plant operation

Safety in plant operation must be ensured.

- Safety for the equipment, and hence everybody
  - Never violate important constraints
- Safety for the workers, and hence everybody
  - Noise level, leakage
- Safety to the surrounding, and hence everybody
  - Environmental regulation : Effluent (air, water)

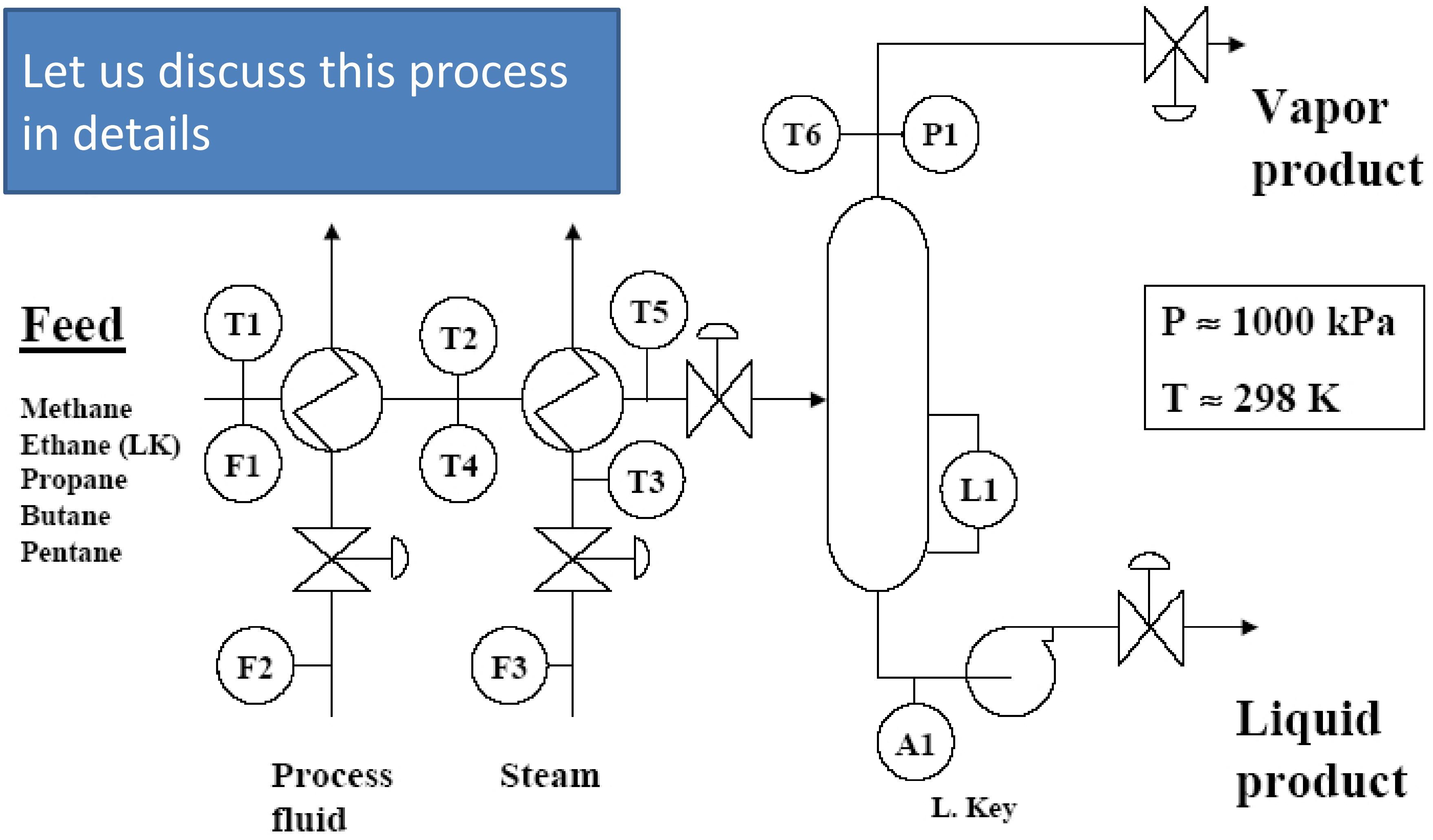
- How do we achieve all these?...

Process control objectives.

1. Safety
2. Environmental Protection
3. Equipment Protection
4. Smooth Operation
5. Product Quality
6. Profit
7. Monitoring and Diagnosis

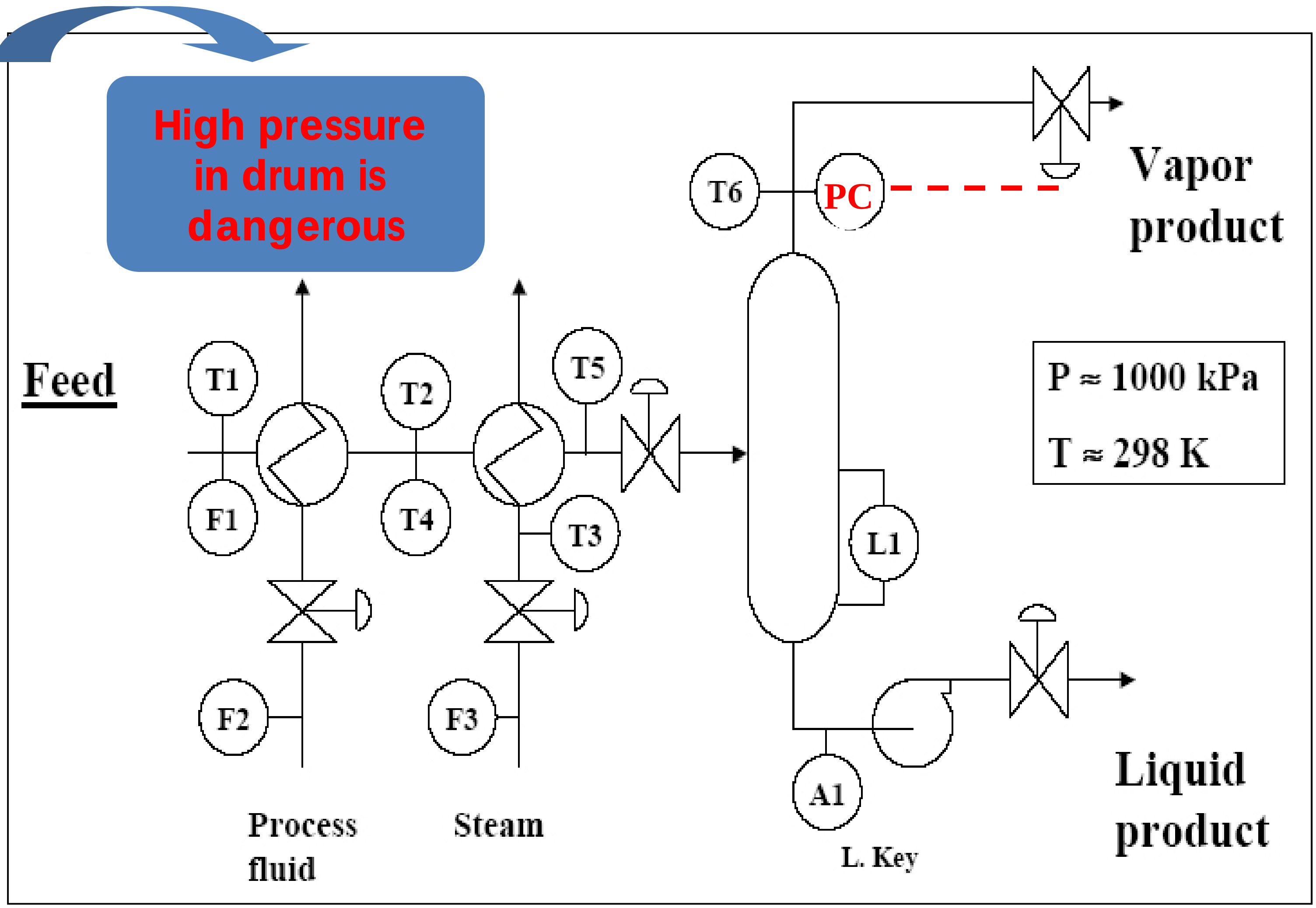
Control objectives: Example of Flash separation

Let us discuss this process in details



Control objectives: Example of Flash separation

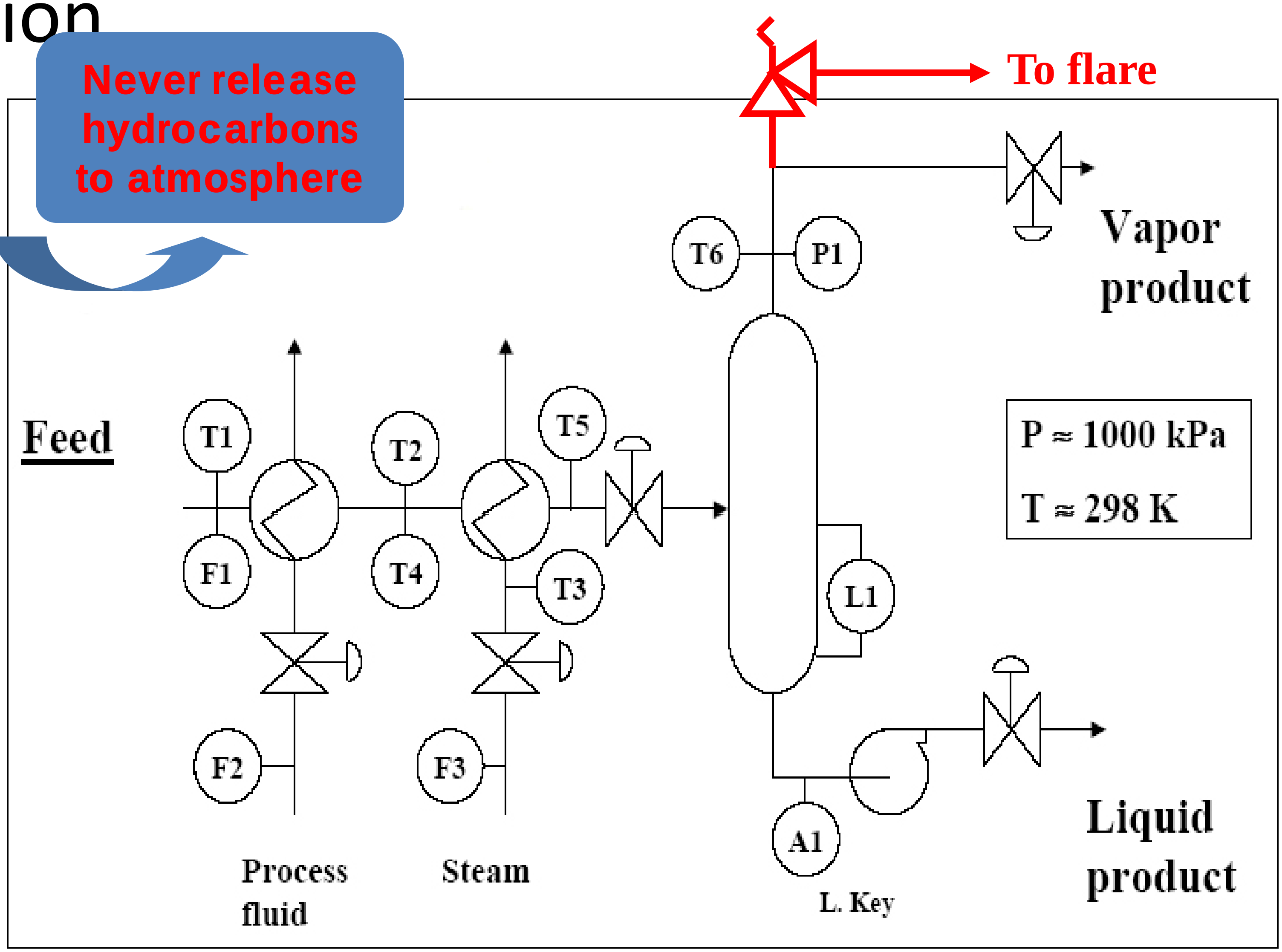
1. **Safety**
2. Environmental Protect
3. Equipment Protect
4. Smooth Operation
5. Product Quality
6. Profit
7. Monitoring and Diagnosis



Control objectives: Example of Flash separation

1. Safety
2. **Environmental Protect**
3. Equipment Protect
4. Smooth Operation
5. Product Quality
6. Profit
7. Monitoring and Diagnosis

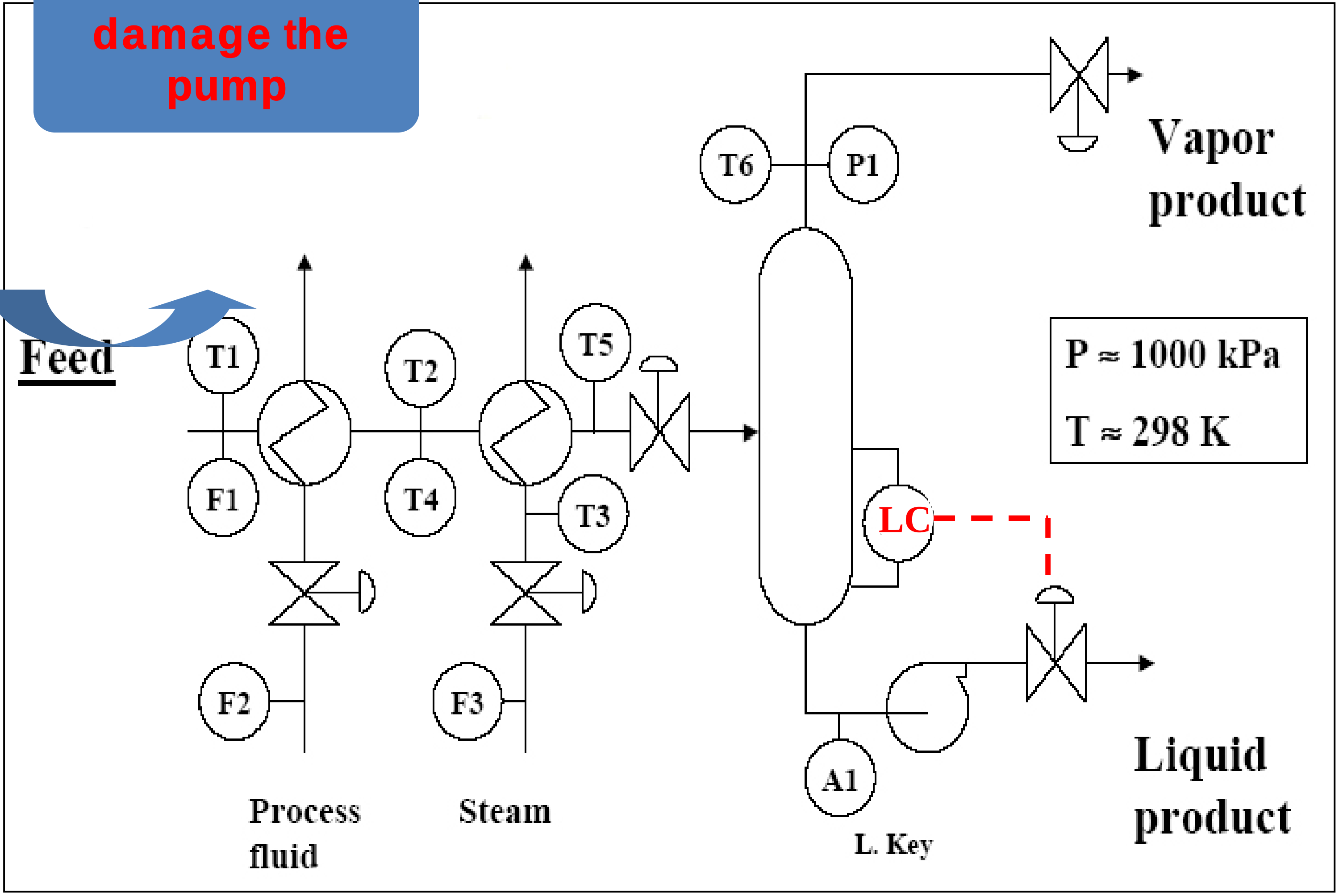
Never release hydrocarbons to atmosphere



Control objectives: Example of Flash separation

1. Safety
2. Environmental Protect
3. **Equipment Protect**
4. Smooth Operation
5. Product Quality
6. Profit
7. Monitoring and Diagnosis

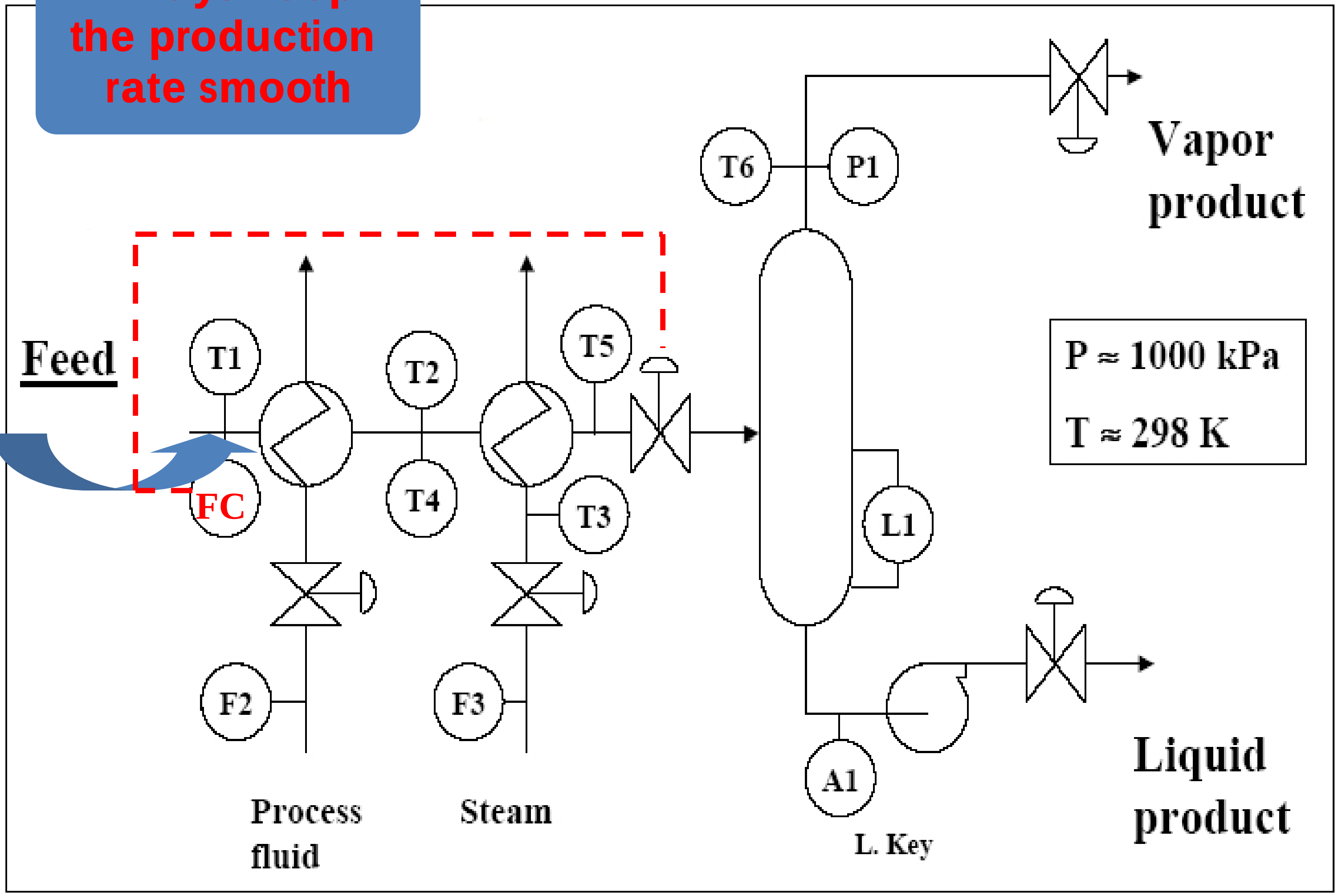
No flow could damage the pump



Control objectives: Example of Flash separation

1. Safety
2. Environmental Protect
3. Equipment Protect
4. **Smooth Operation**
5. Product Quality
6. Profit
7. Monitoring and Diagnosis

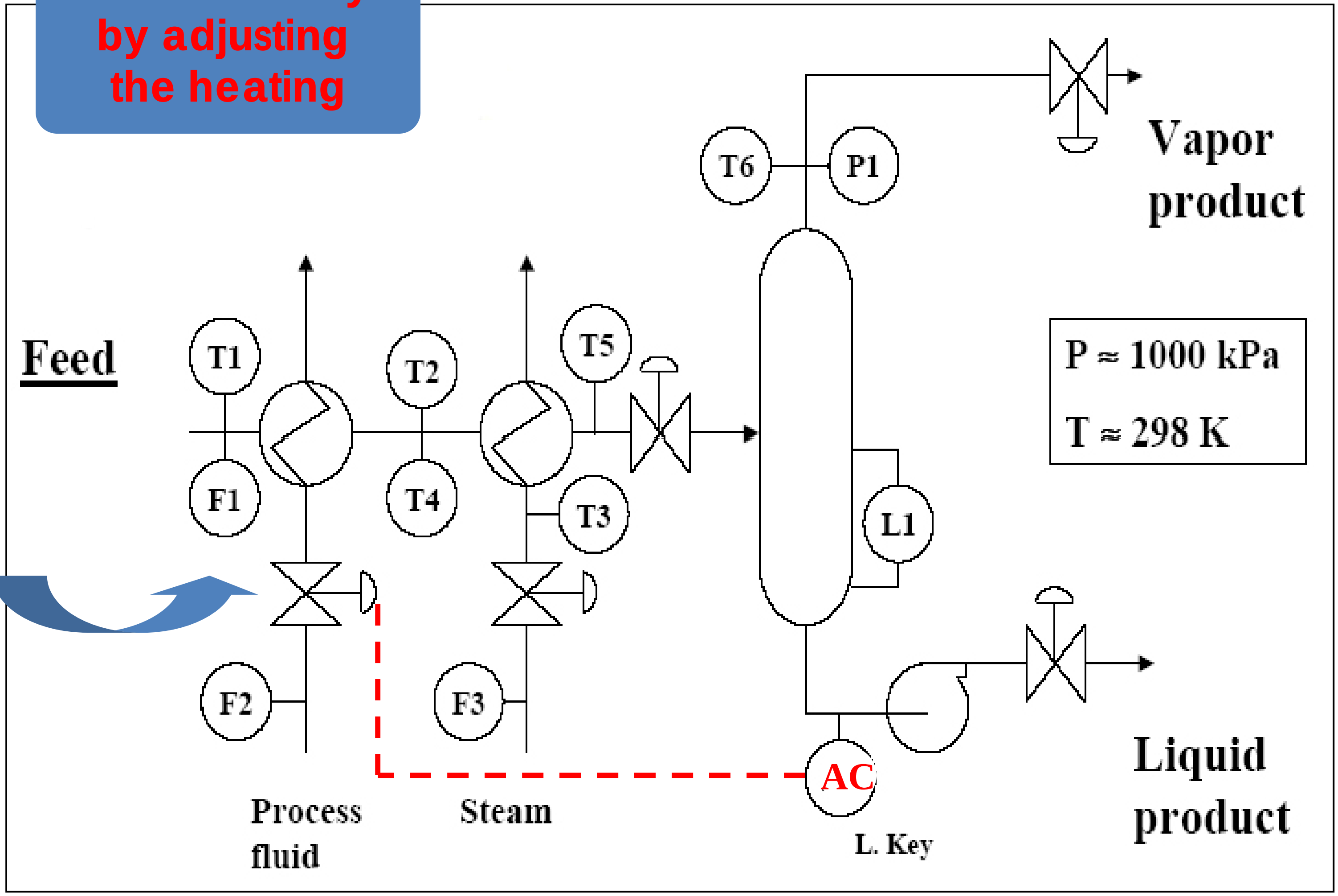
Always keep the production rate smooth



Control objectives: Example of Flash separation

1. Safety
2. Environmental Protect
3. Equipment Protect
4. Smooth Operation
5. **Product Quality**
6. Profit
7. Monitoring and Diagnosis

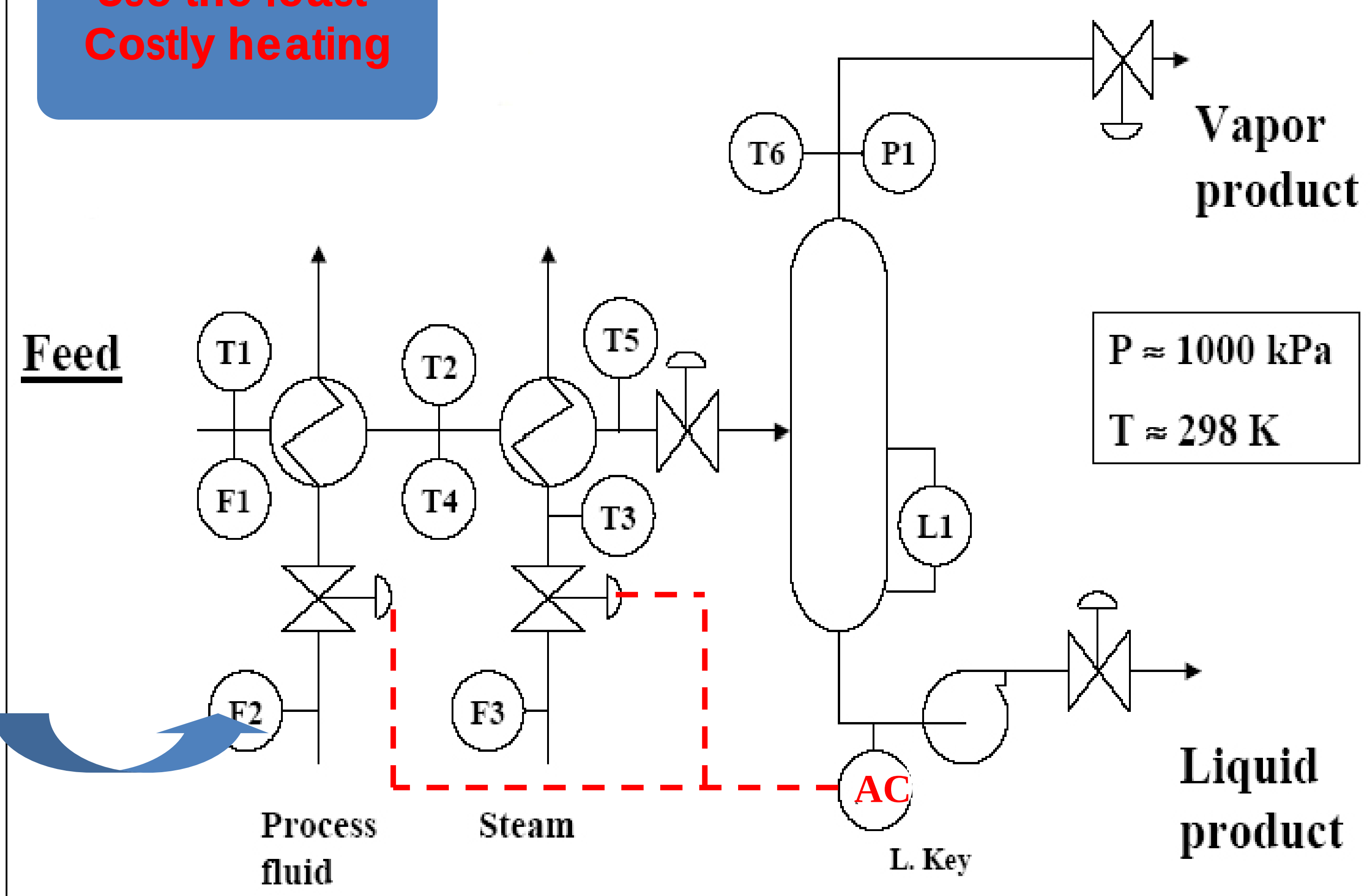
Achieve L.Key by adjusting the heating



Control objectives: Example of Flash separation

1. Safety
2. Environmental Protect
3. Equipment Protect
4. Smooth Operation
5. Product Quality
6. **Profit**
7. Monitoring and Diagnosis

Use the least Costly heating



Control objectives: Example of Flash separation

1. Safety
2. Environmental Protect
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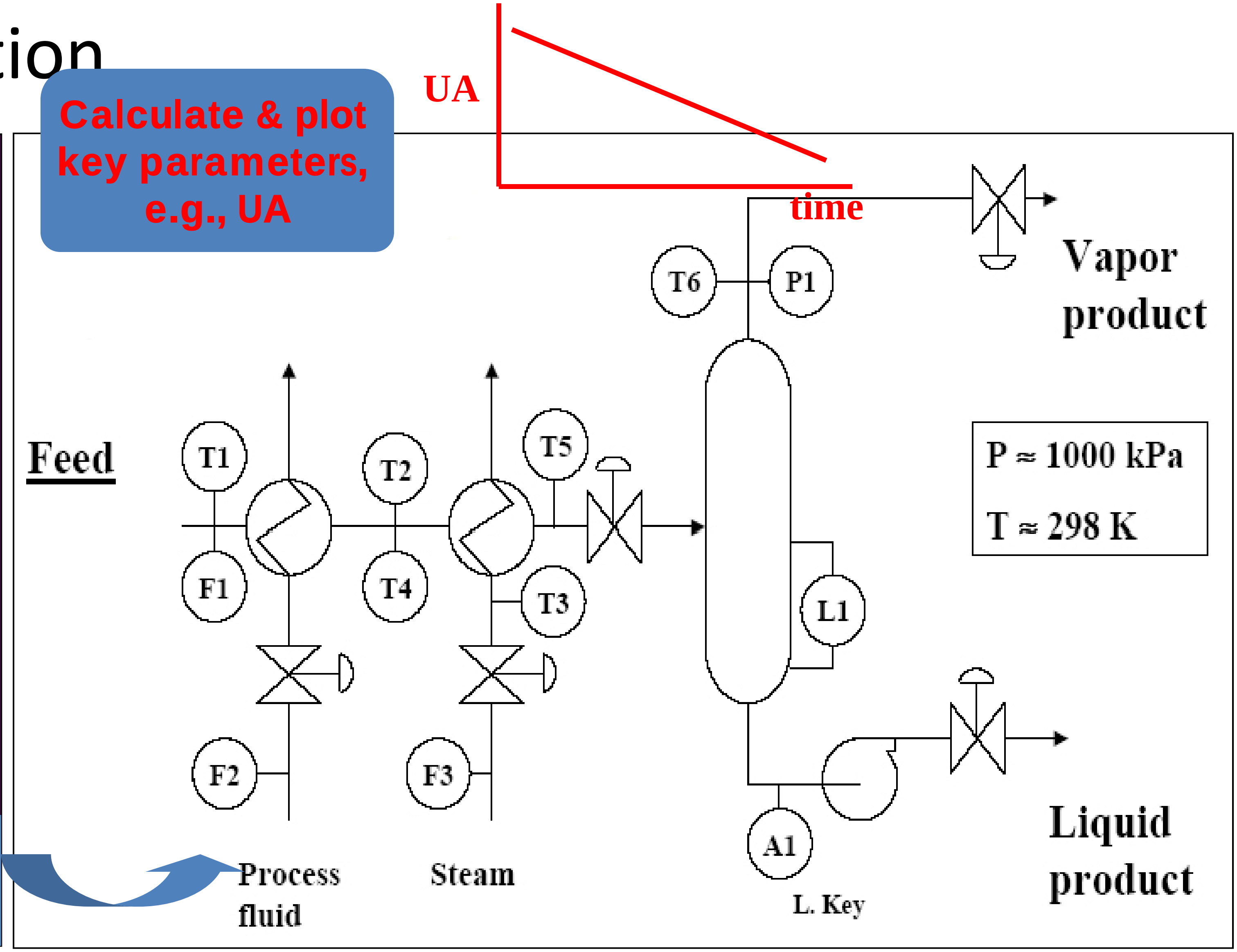
6. Profit
7. **Monitoring and Diagnosis**



Control objectives: Example of Flash separation

1. Safety
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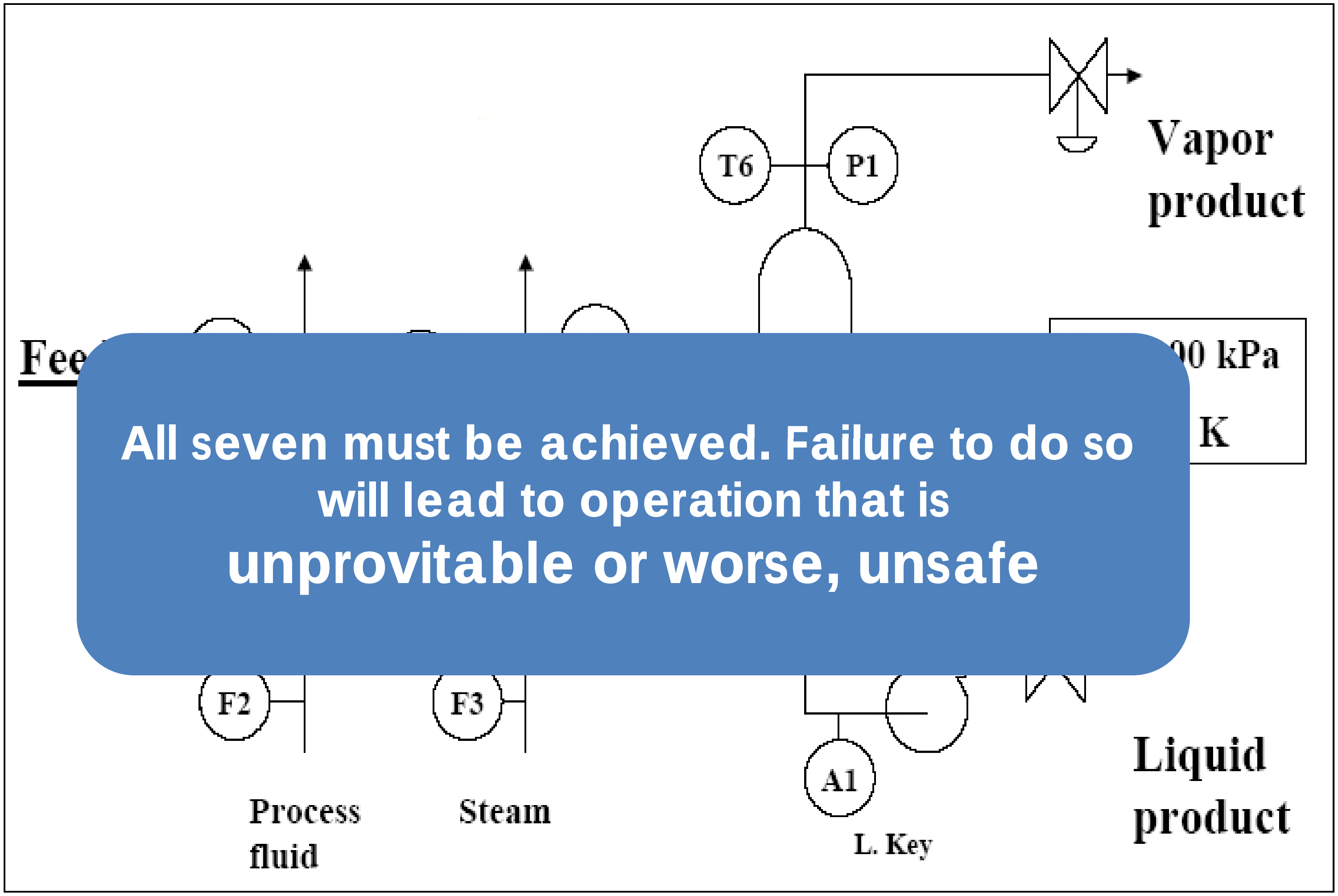


All seven must be achieved. Failure to do so will lead to operation that is unprovitable or worse, unsafe

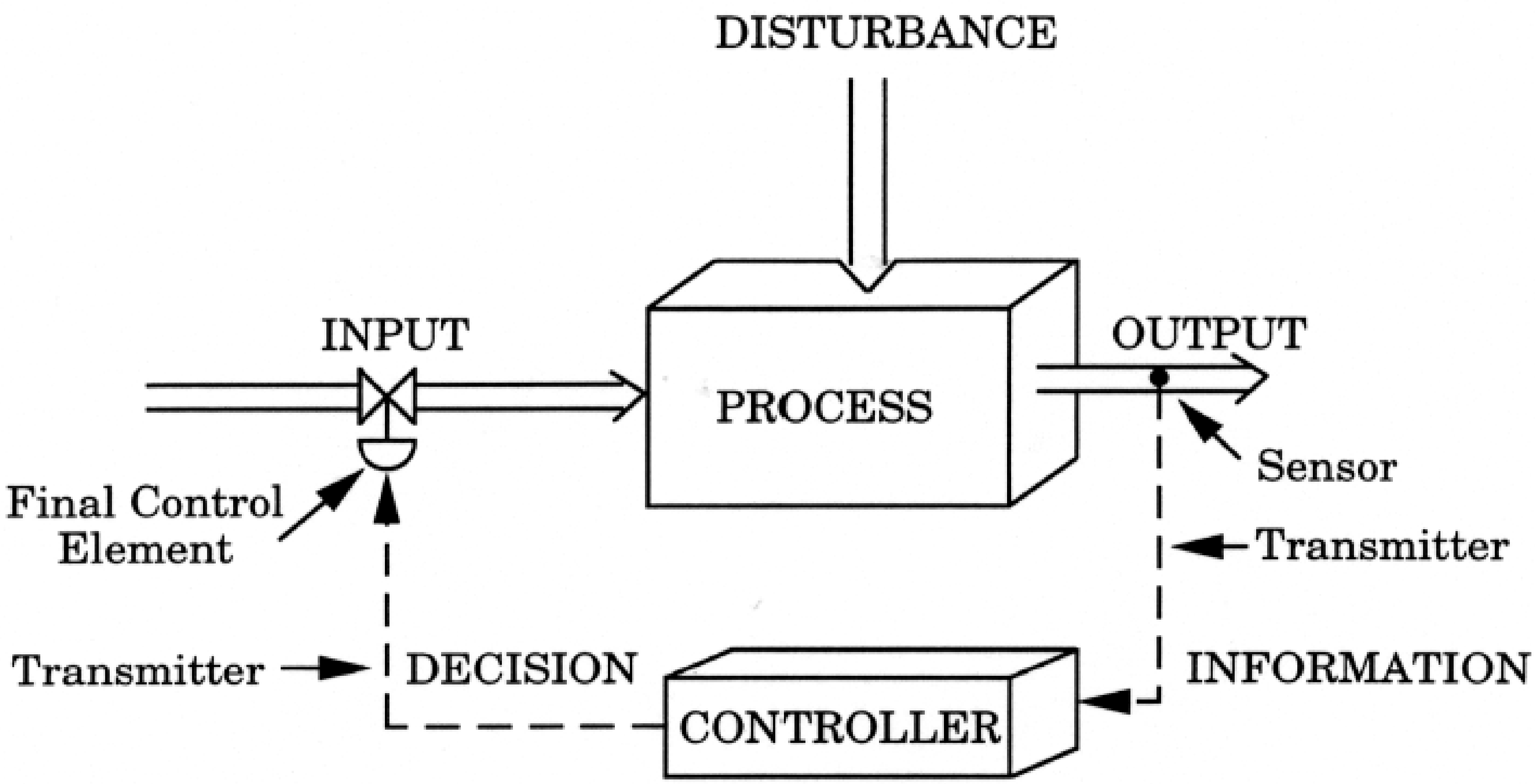
Control hardware elements.

Process and Instrumentation Diagram (P&ID).

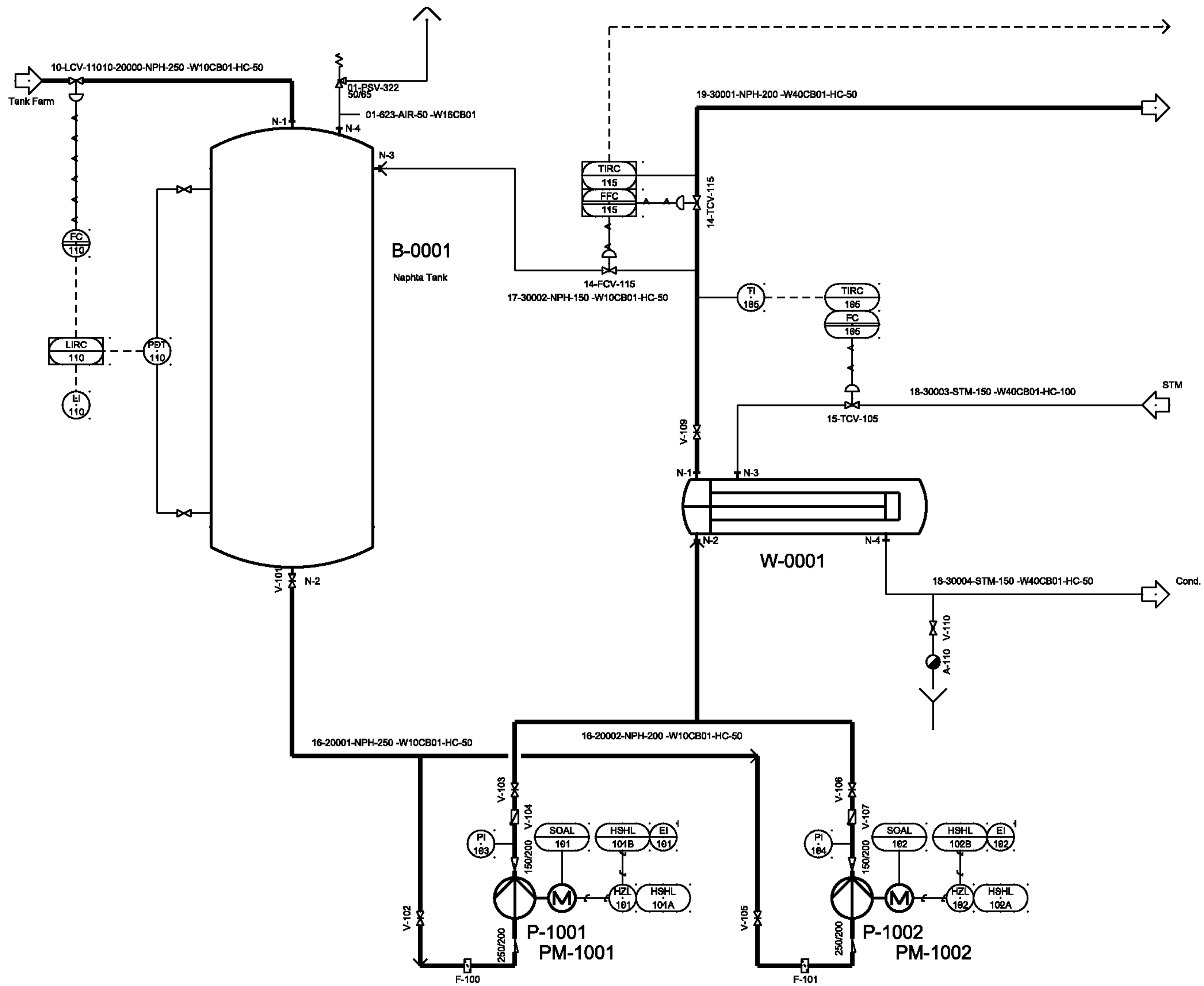
Block diagrams.

HARDWARE CONFIGURATION, P&ID AND BLOCK DIAGRAMS

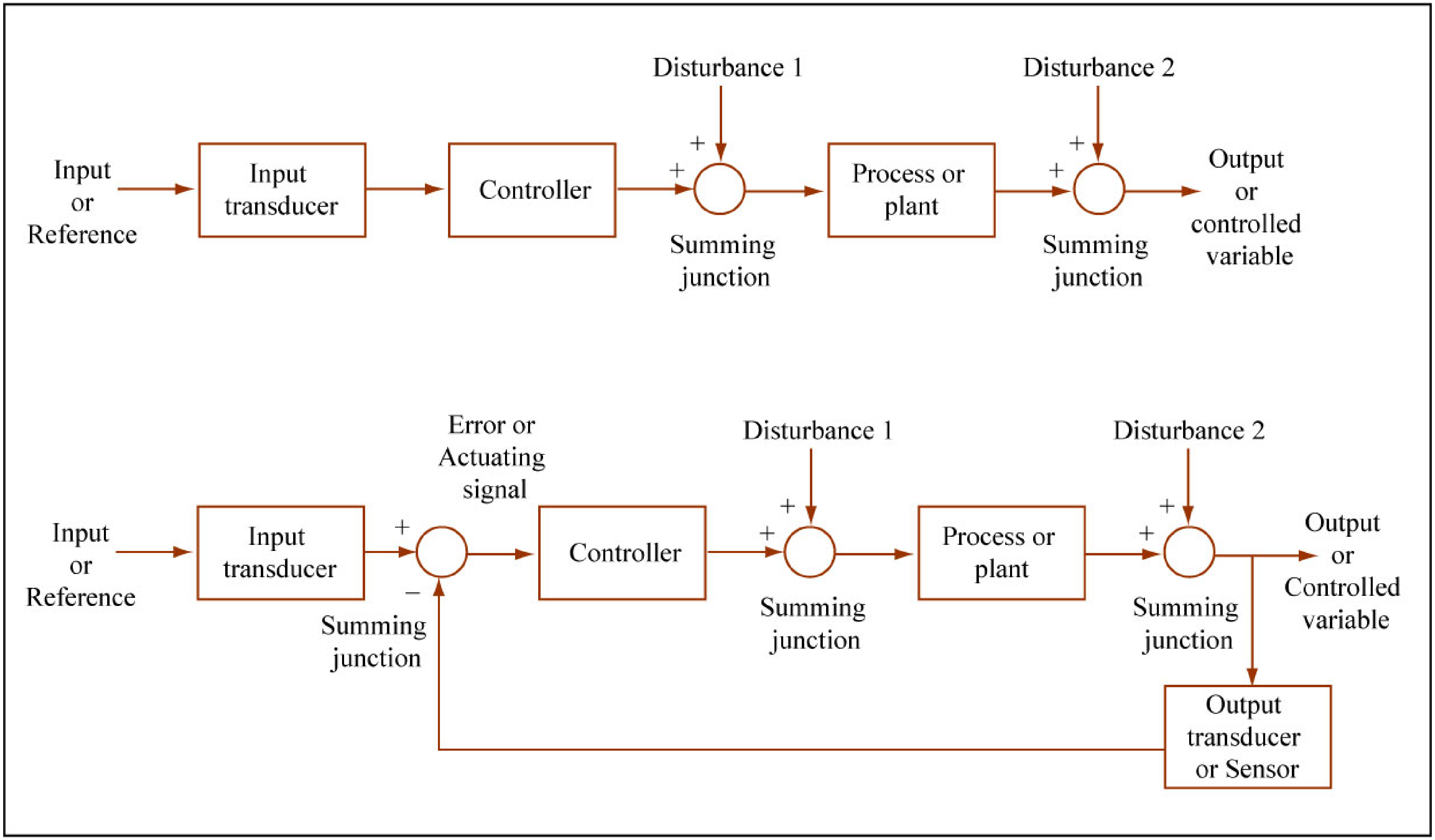
Control hardware elements.



Process and Instrumentation Diagram (P&ID)



Block diagrams.



Types of feedback controllers.

Manual control.

Feedback control.

Feedforward control.

Feedforward/feedback control.

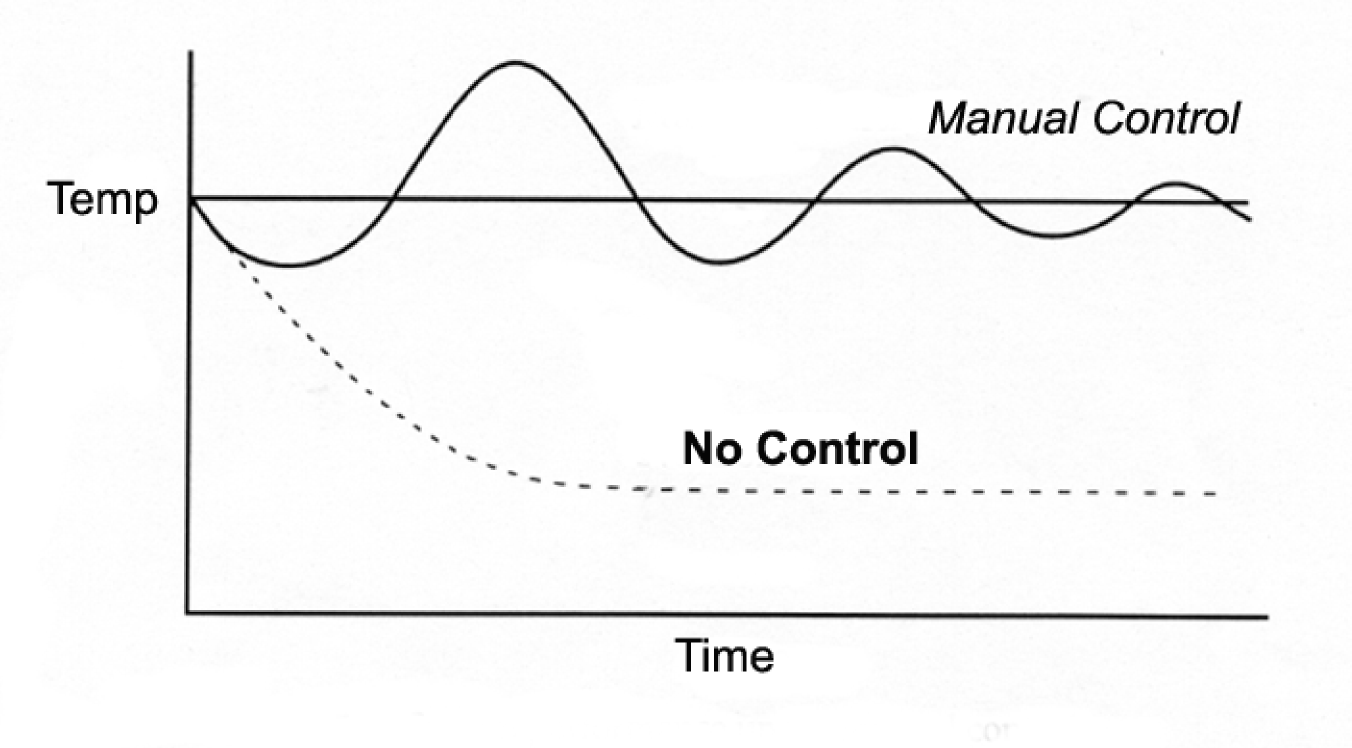
FB/FF + Cascade control.

CLASSIFICATION OF CONTROL STRATEGIES

Types of feedback controllers.

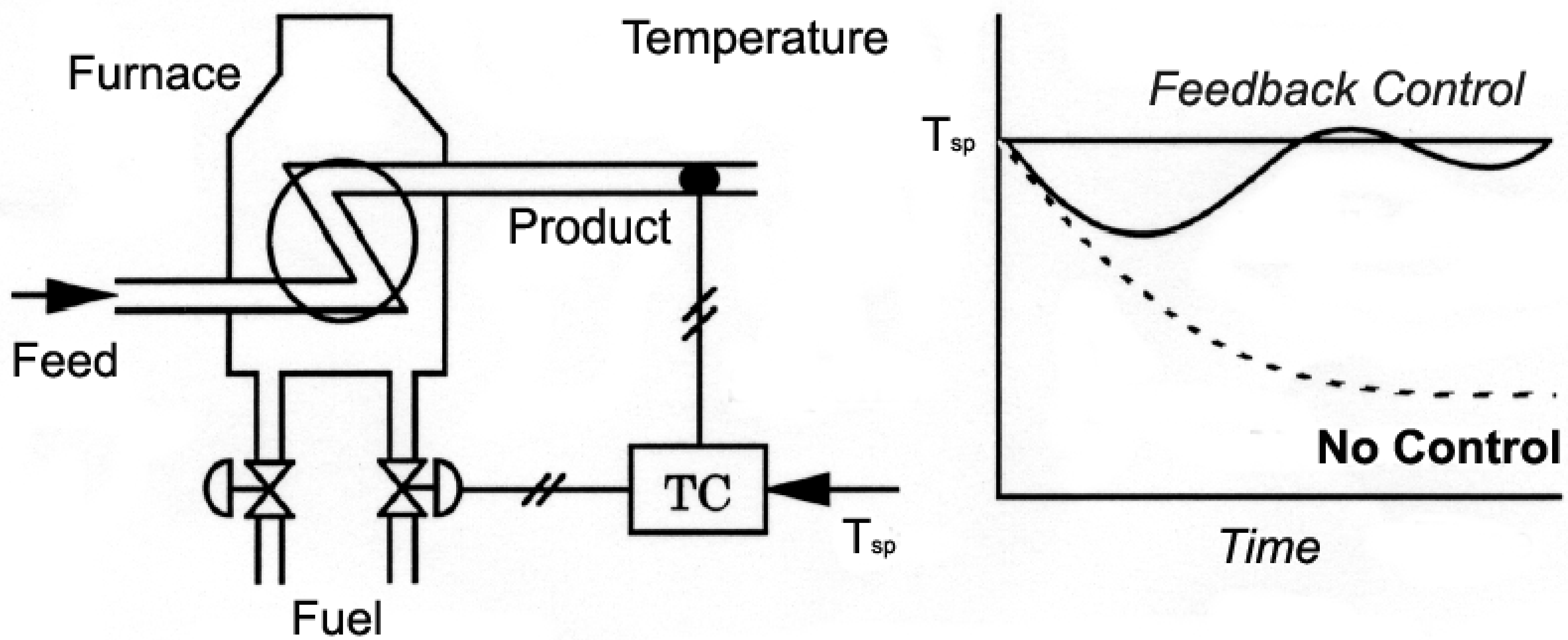
- On-Off Control - e.g., room thermostat
- Manual Control - Used by operators and based on more or less open loop responses
- PID control - Most commonly used controller. Control action based on error from setpoint
- Advanced PID - Enhancements of PID: ratio, cascade, feedforward
- Model-based Control - Uses model of the process directly for control

Manual control.



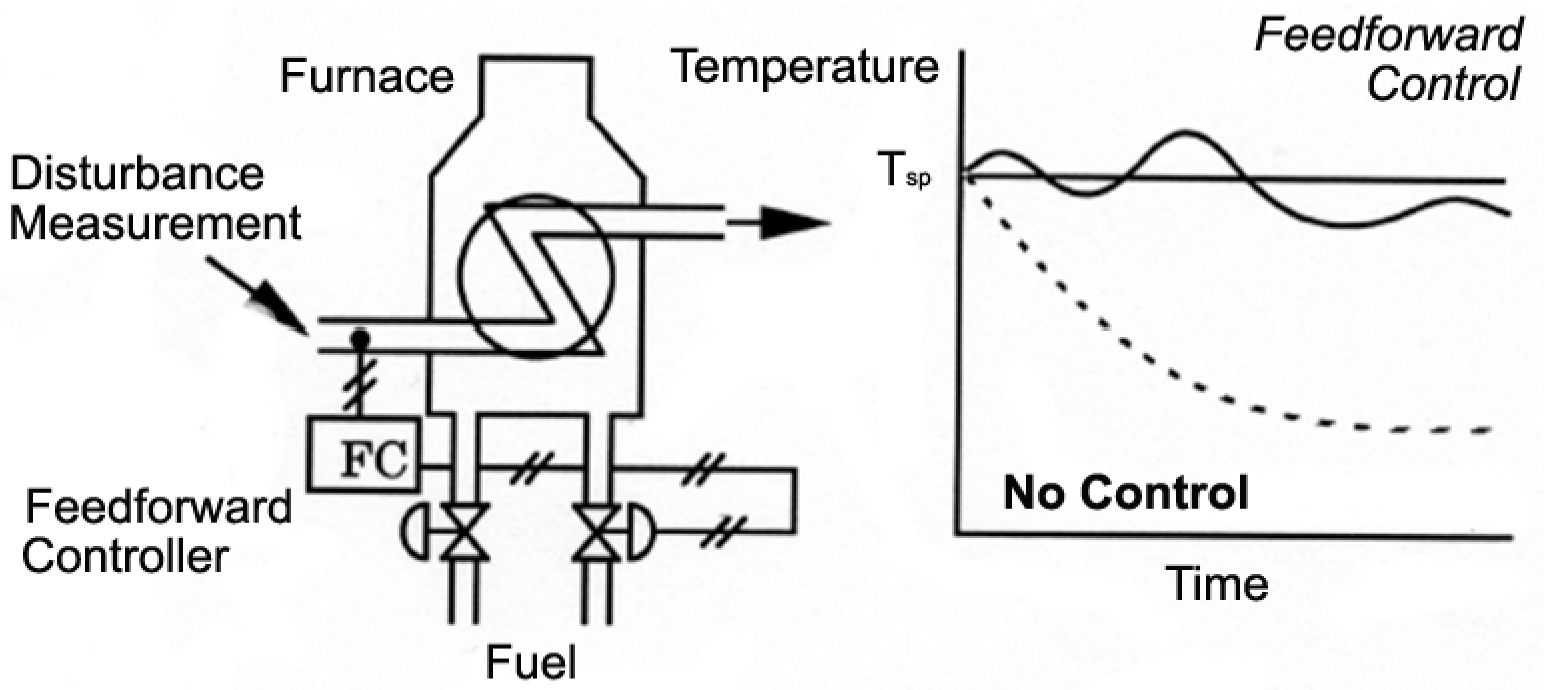
- Operator adjustments of the two valves based on his observations and prior experience
  - Overadjustment: Intolerant and impatient
  - Inconsistency

Feedback control.



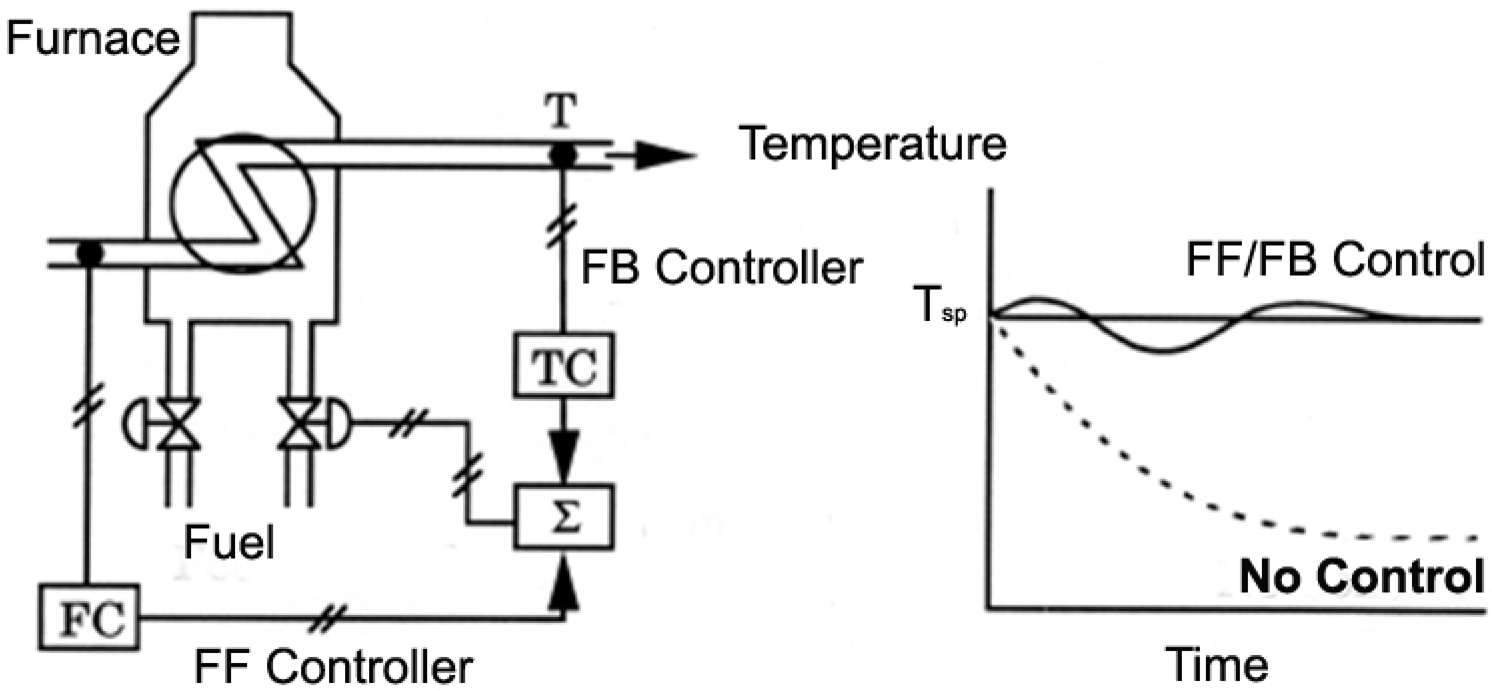
- Perfect end-result (no offset) but adjustment takes place only after the temperature is affected significantly.

Feedforward control.



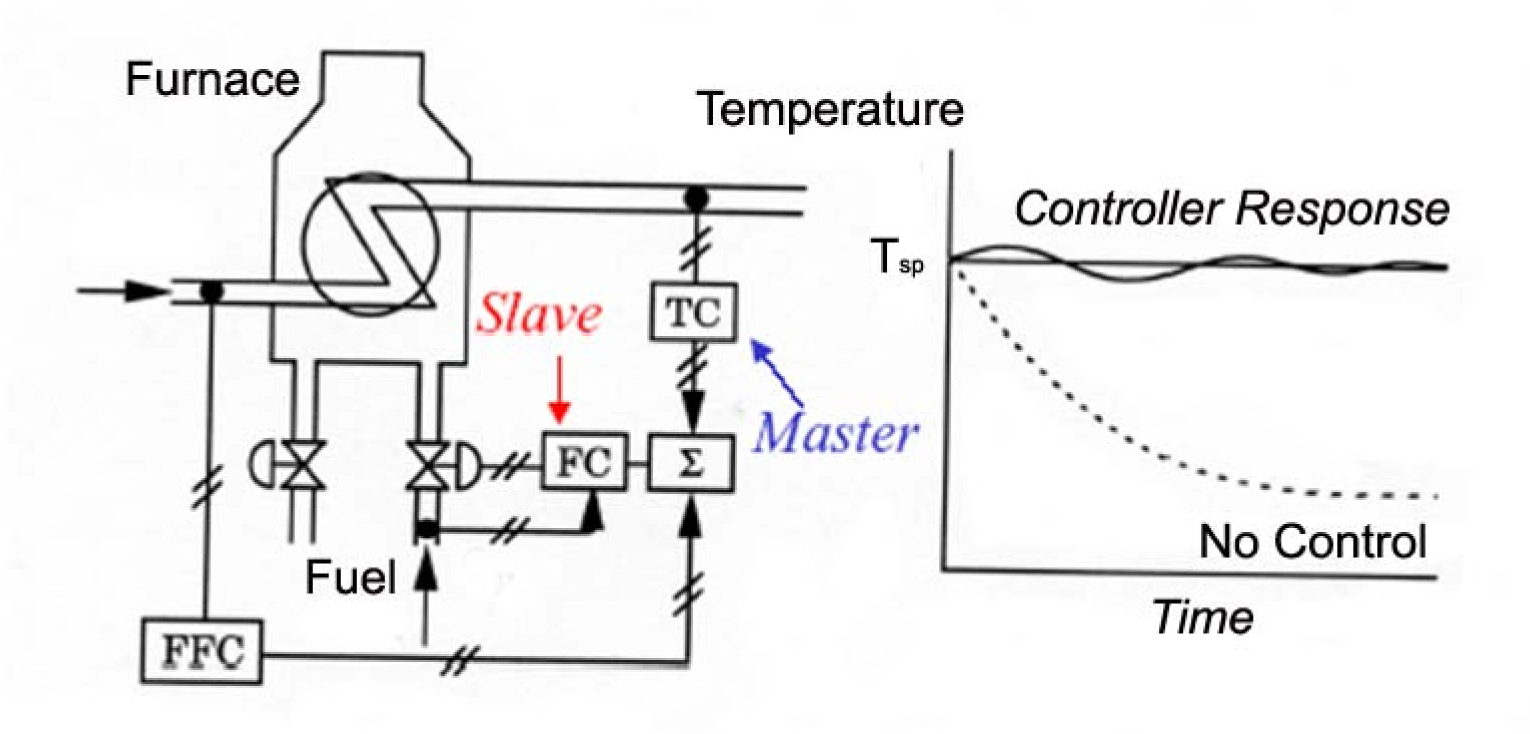
- Faster response to disturbances in the feed.
- Adjustment is not perfect and offset results.

Feedforward/feedback control.



- Combines the advantage of both FB (no offset) and FF control (fast response to disturbances in the feed).
- Still slow to respond to disturbances in the fuel pressure.

FB/FF + Cascade control.



- Best configuration.
- Responds fast to disturbances in the fuel pressure as well as feed.
- No offset.

Commonly found control loops.

Discussion: Liquid level control.

Discussion: Liquid level control - Strategy 1.

Discussion: Liquid level control - Strategy 2.

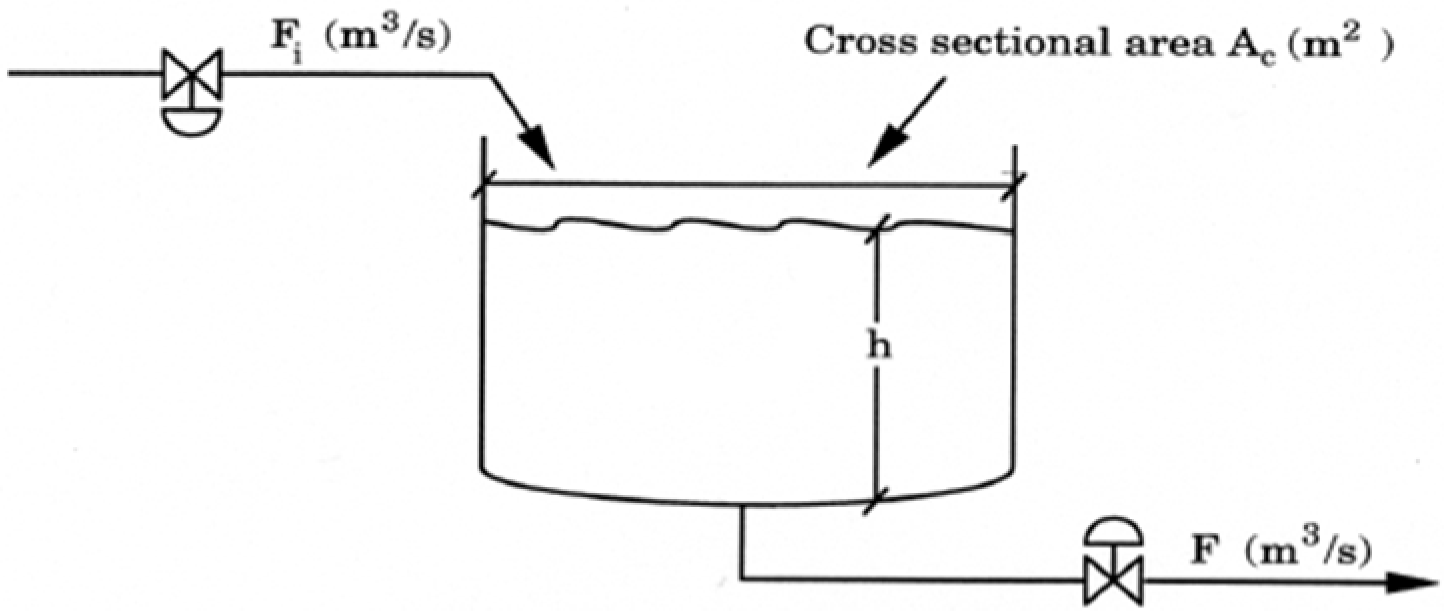
Discussion: Liquid level control - Strategy 3.

TYPICAL CONTROL LOOPS

Commonly found control loops.

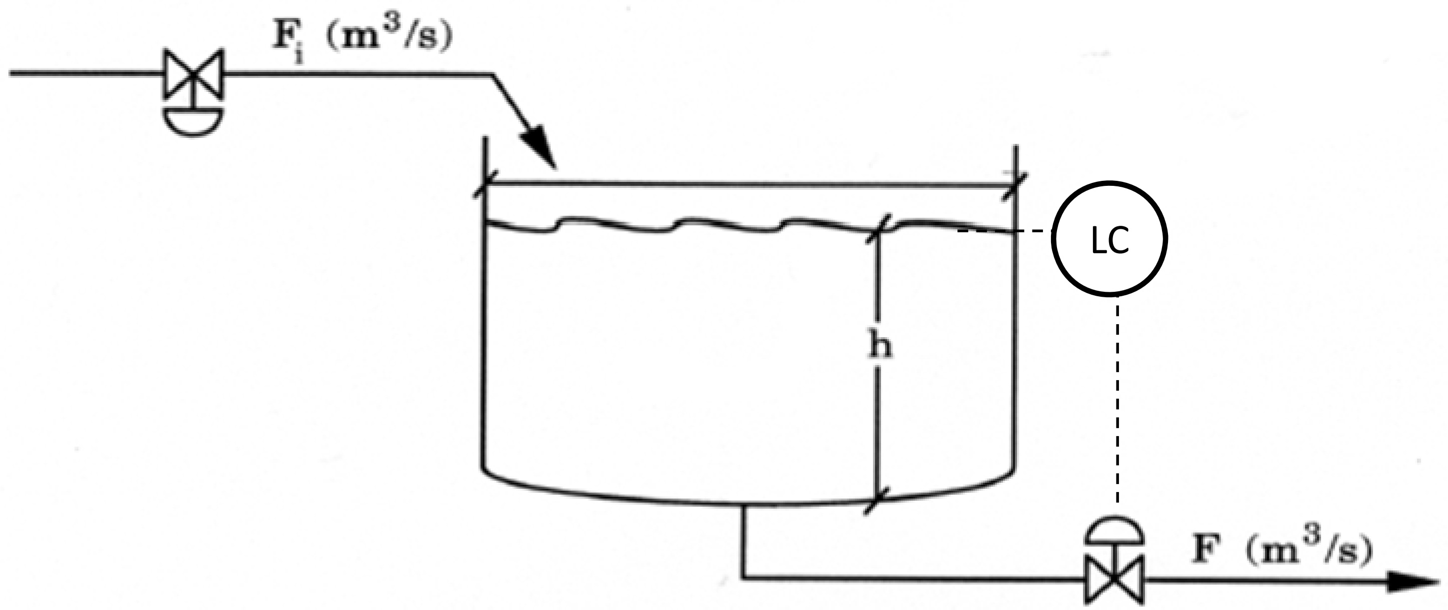
- Flow Loops
  - Orifice meter, Proportional Control
- Level Loops
  - Differential Pressure Sensor, Proportional Control
- Pressure Loops
  - Pressure Sensor, P or PI Control
- Temperature Loops
  - Thermocouple or RTD, PID Control
- Composition Loops
  - Gas Chromatograph, Statistical Process Control

Discussion: Liquid level control.



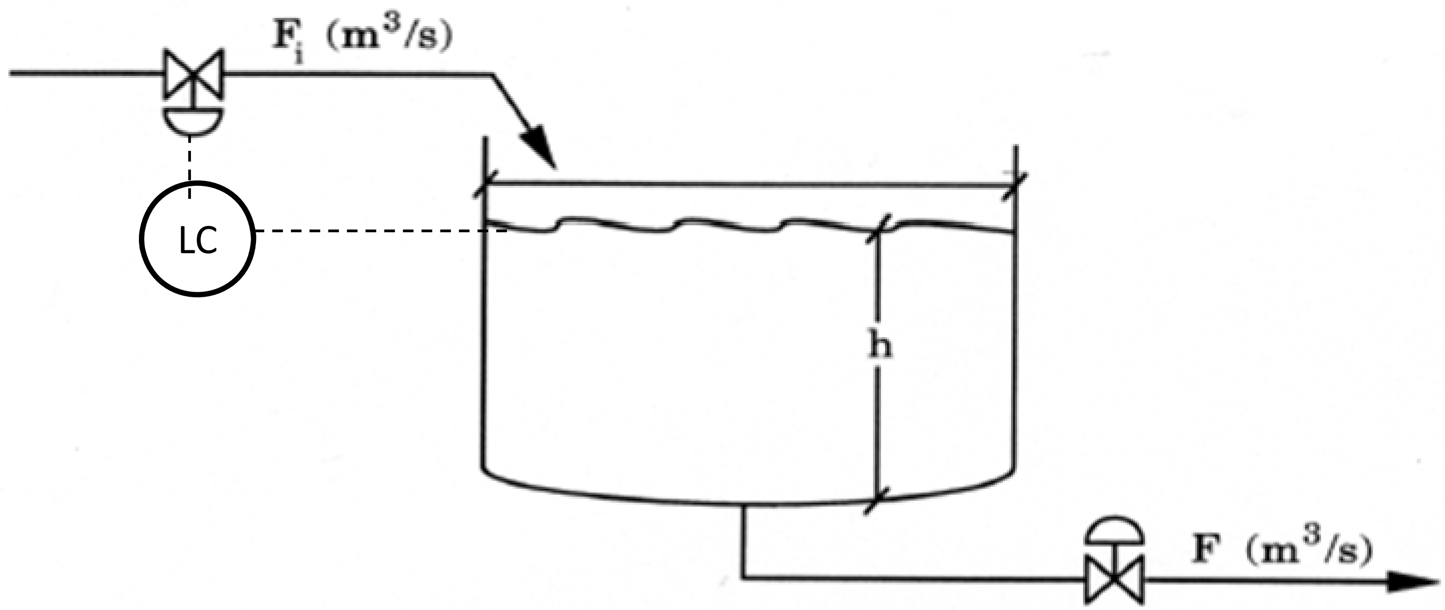
Control the level (h) to a desired value

Discussion: Liquid level control - Strategy 1.



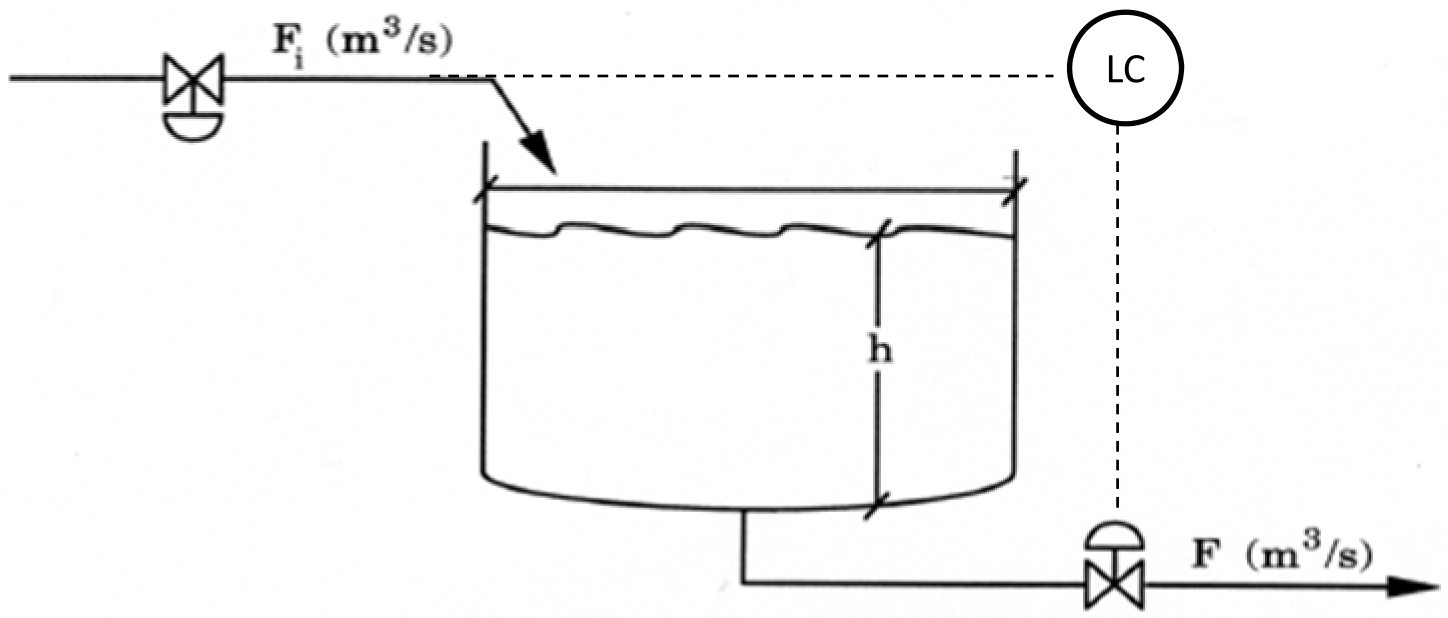
What type of control is this?

Discussion: Liquid level control - Strategy 2.



What type of control is this?

Discussion: Liquid level control - Strategy 3.



What type of control is this?

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