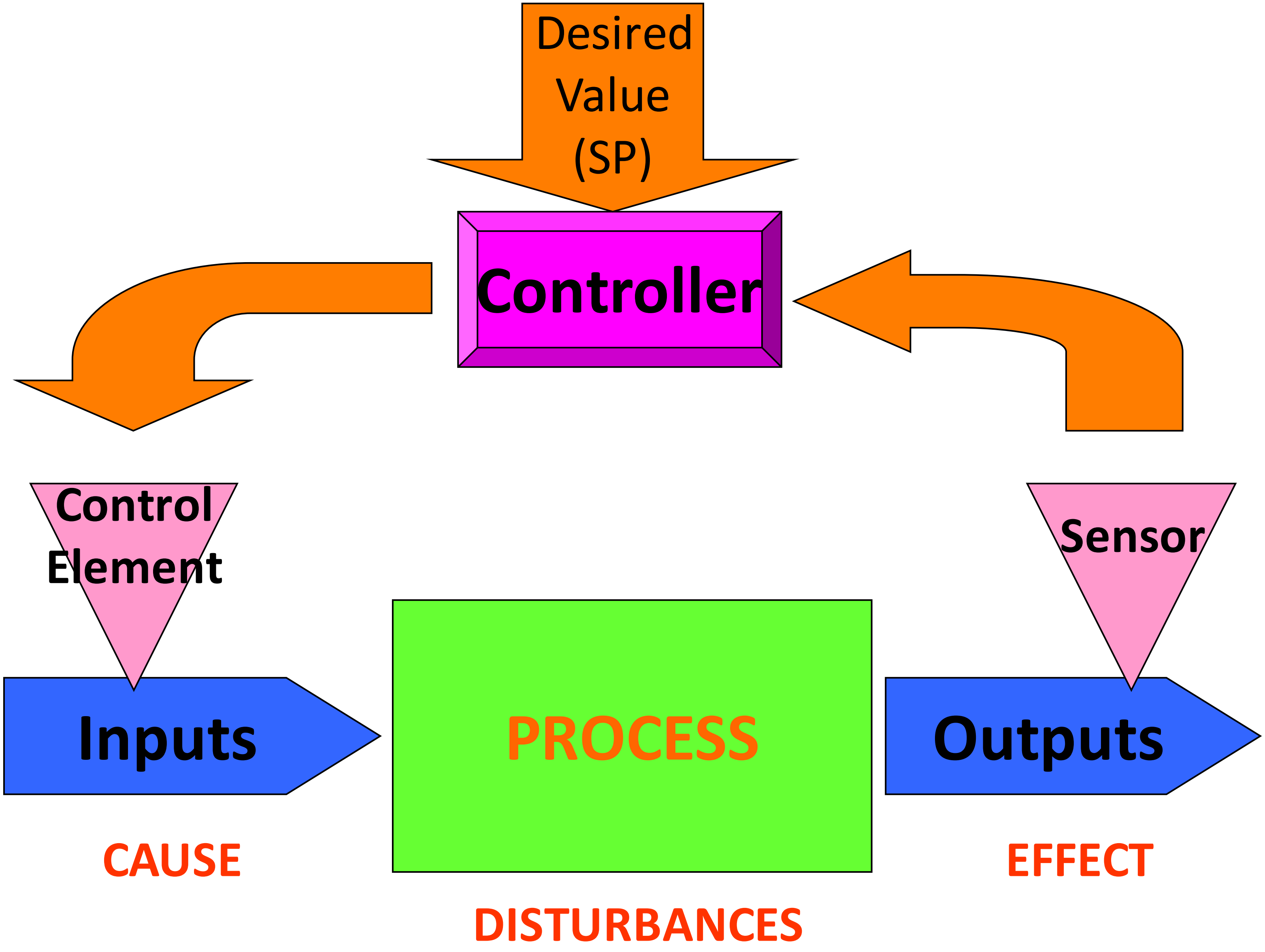
Basics On Process Control and PID’s


Desired Value (SP)
Controller
Control Element
Sensor
Inputs
PROCESS
Outputs
CAUSE
EFFECT
DISTURBANCES

Seven Control Objectives

SAFETY

ENVIRONMENTAL PROTECTION

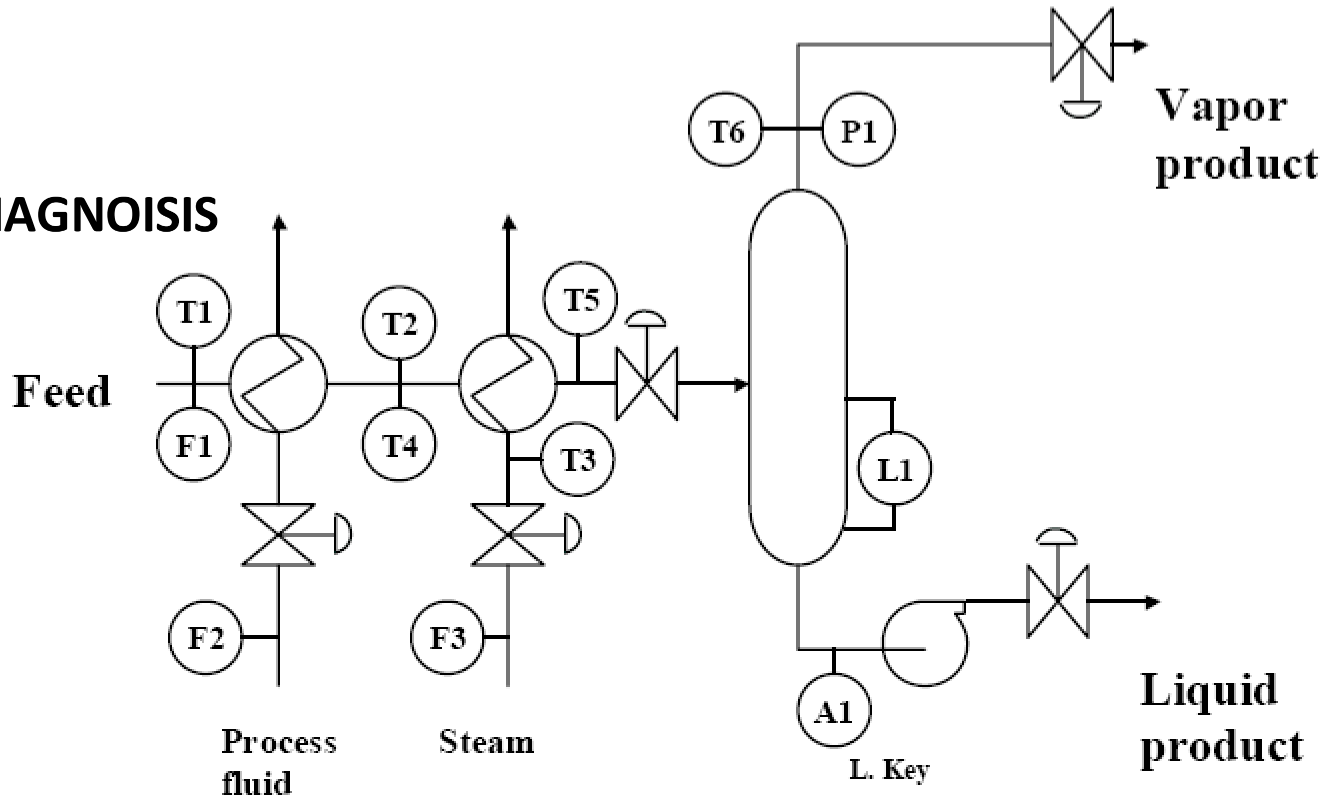
EQUIPMENT PROTECTION

SMOOTH OPERATION

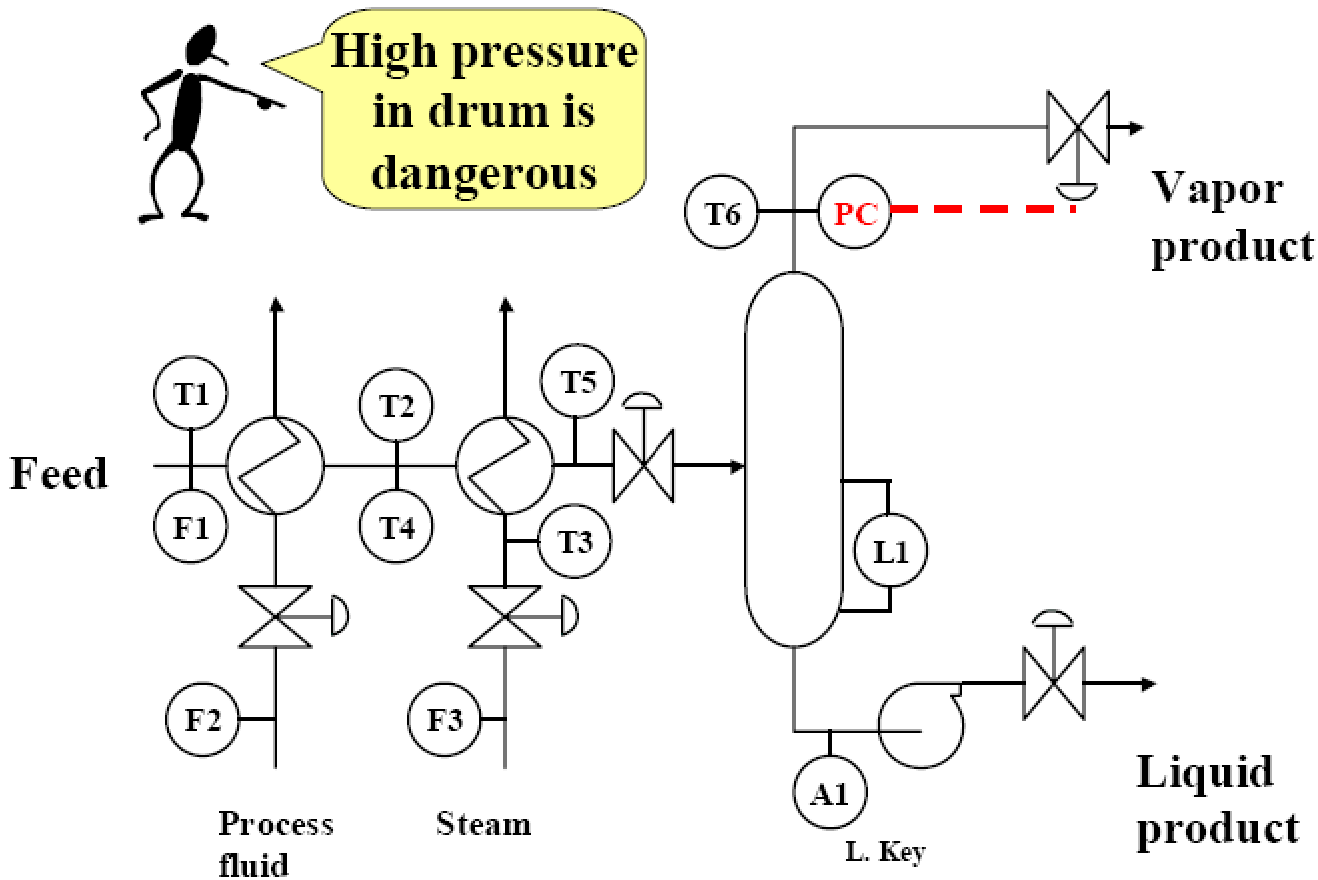
PRODUCT QUALITY

PROFIT

MONITORING AND DIAGNOISIS

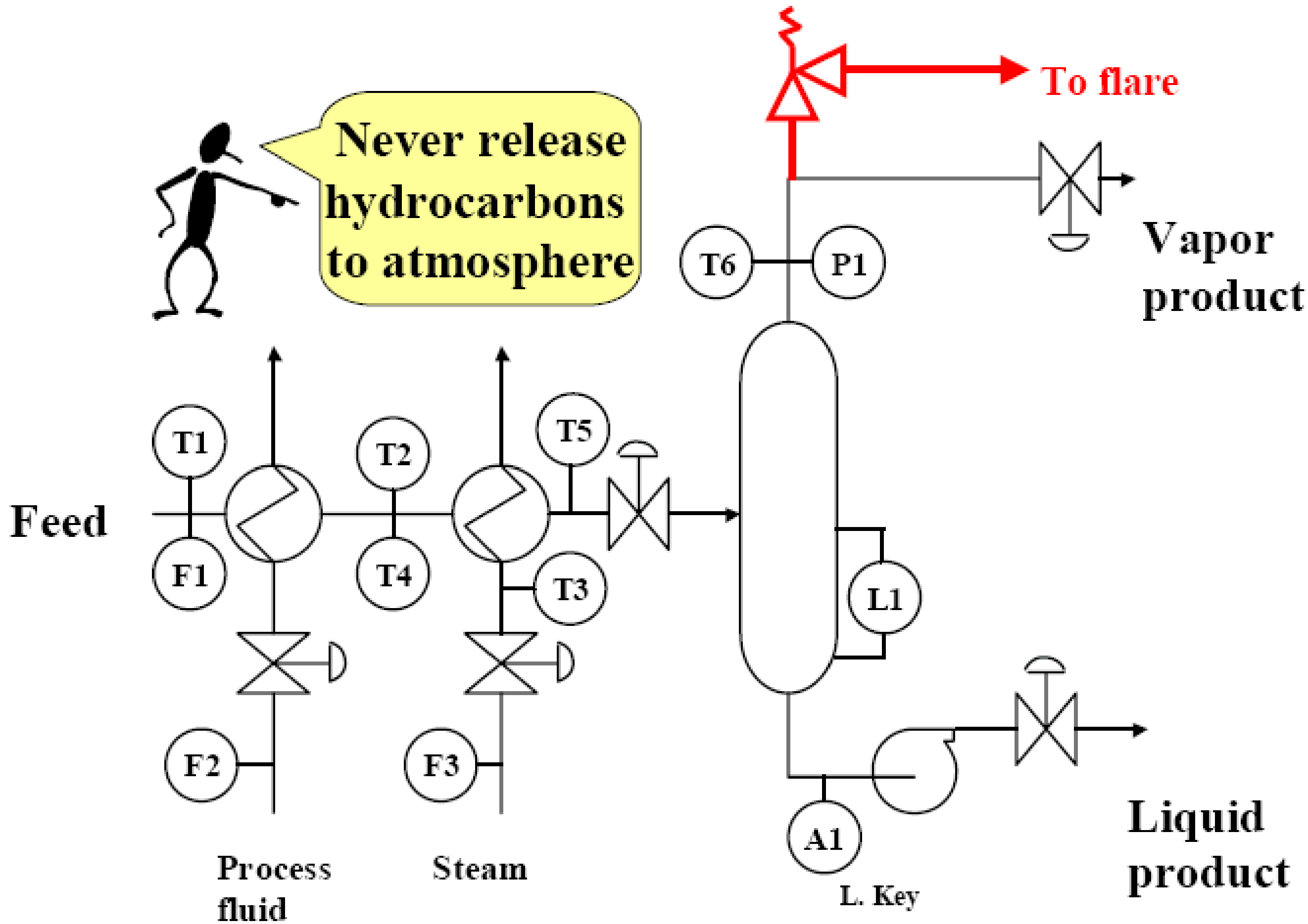


SAFETY

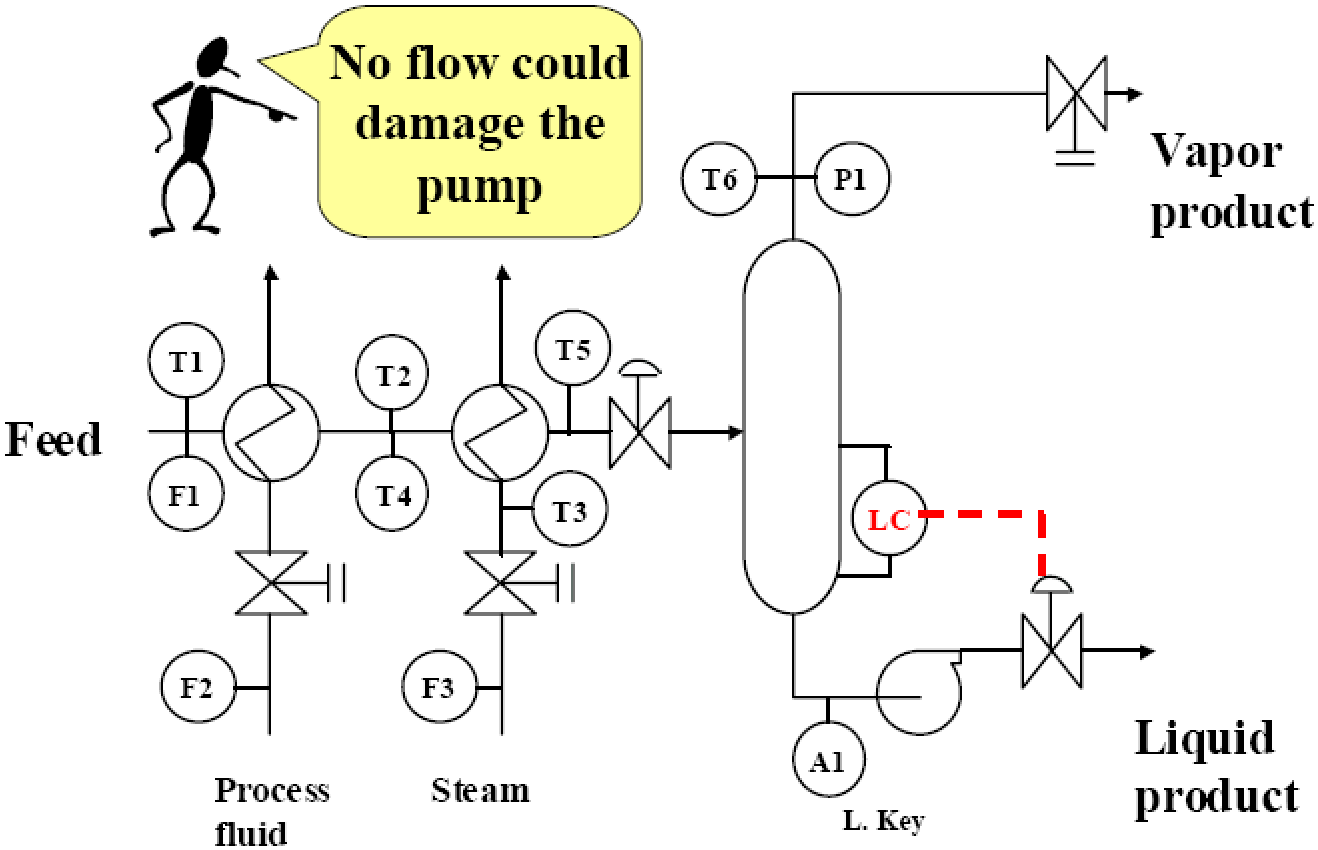


High pressure in drum is dangerous
Feed
T1
F1
T2
T4
T5
T3
F2
F3
T6
PC
L1
A1
L. Key
Vapor product
Liquid product
Process fluid
Steam

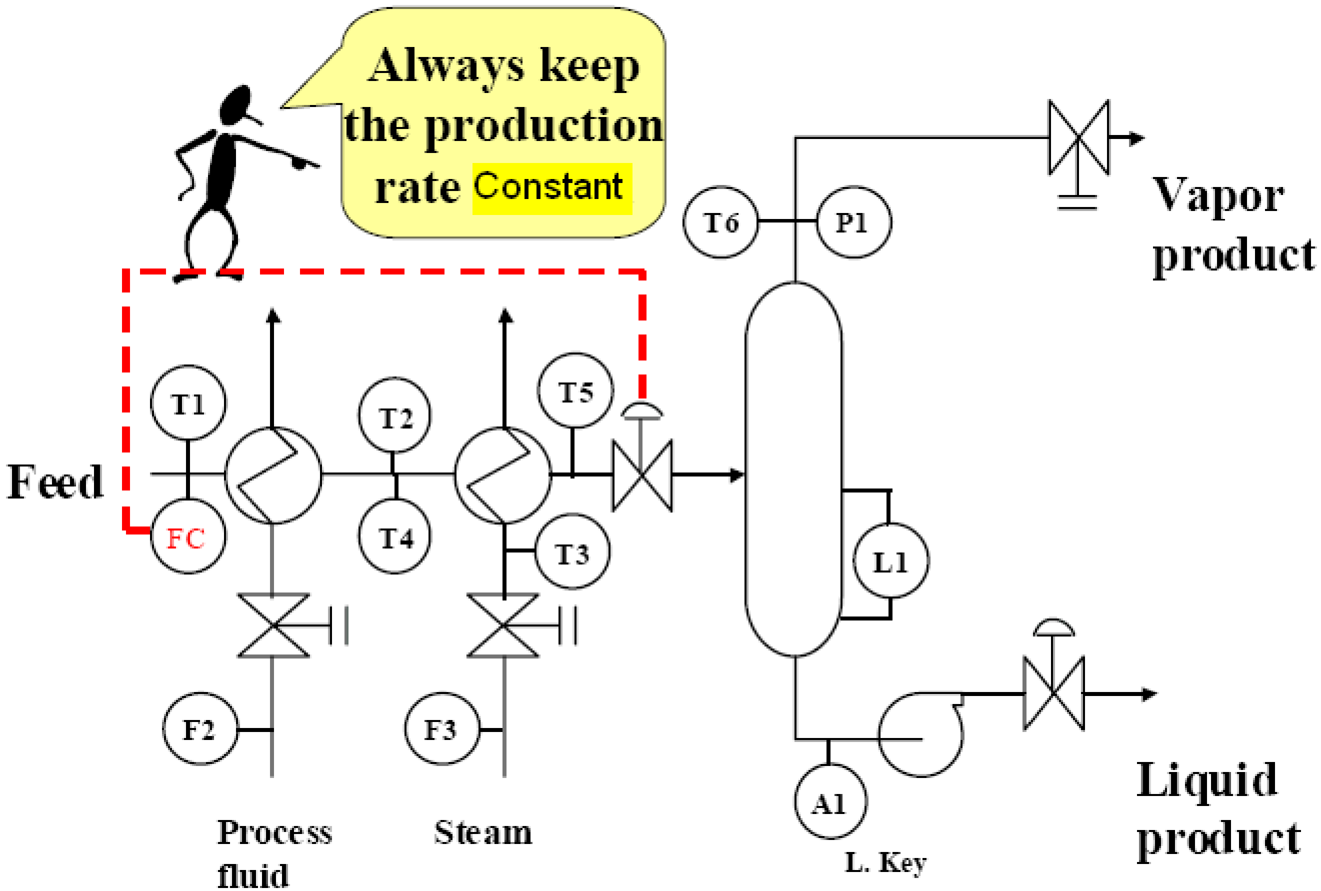
ENVIRONMENTAL PROTECTION



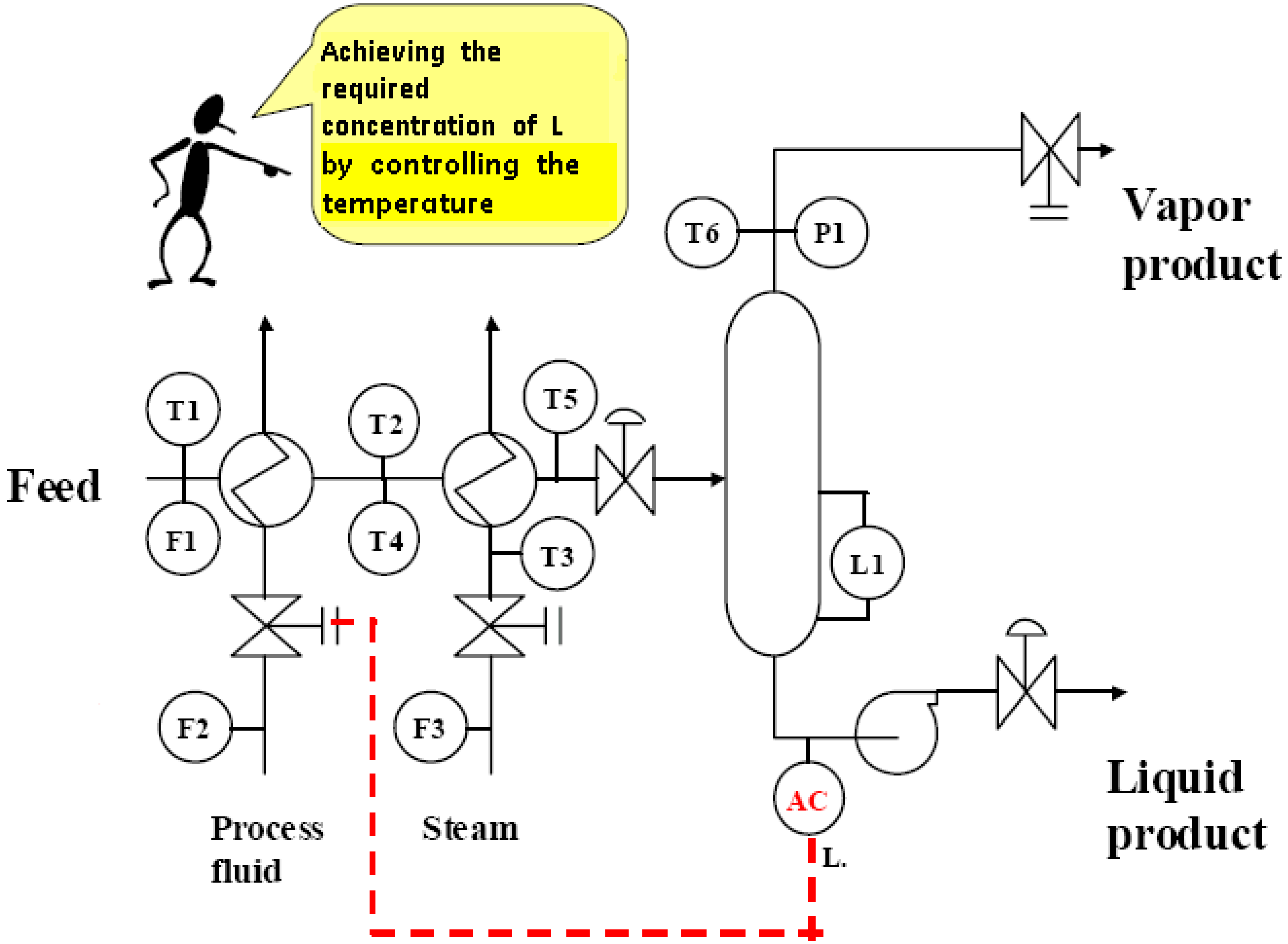
EQUIPMENT PROTECTION



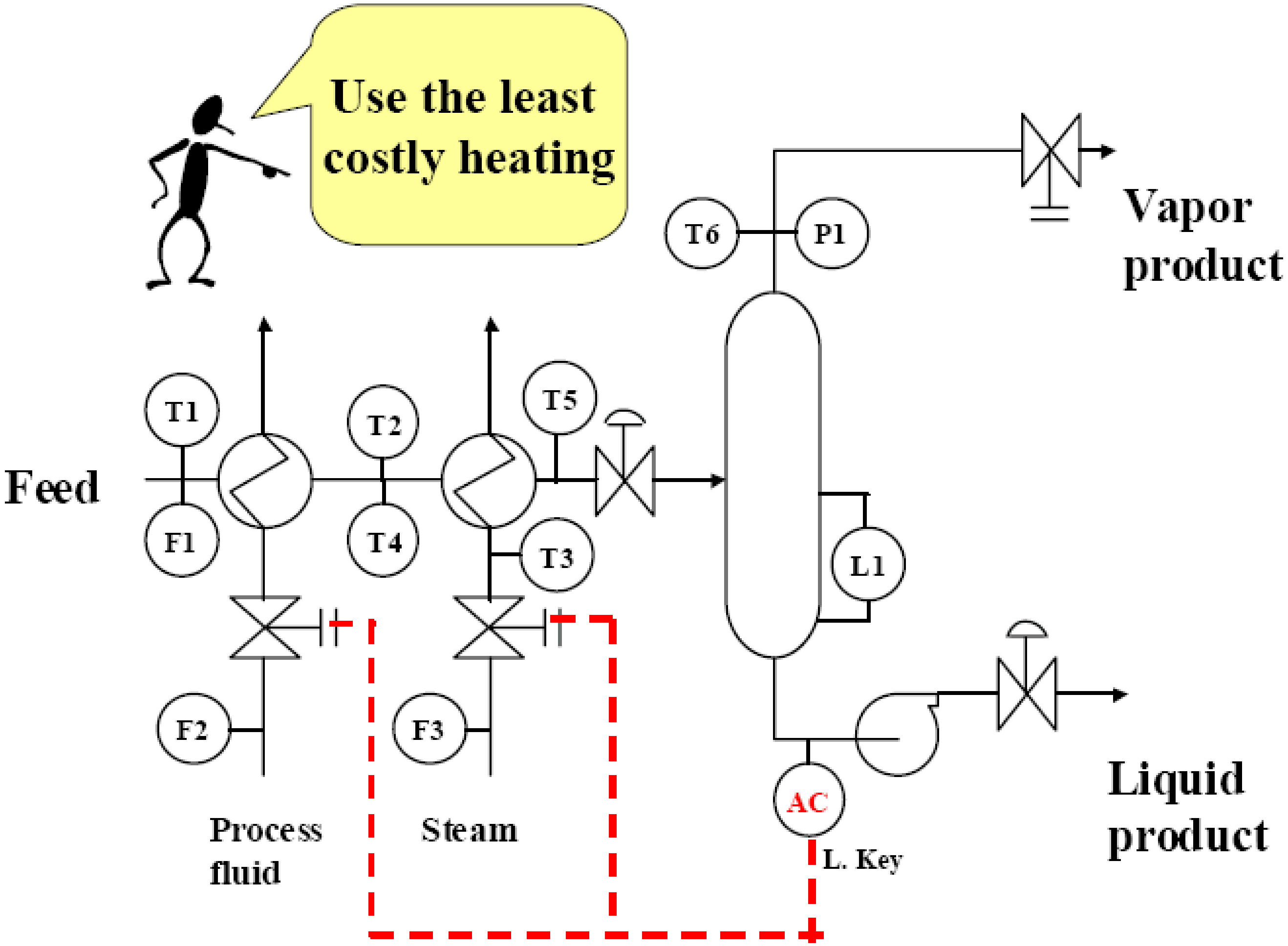
SMOOTH OPERATION



PRODUCT QUALITY

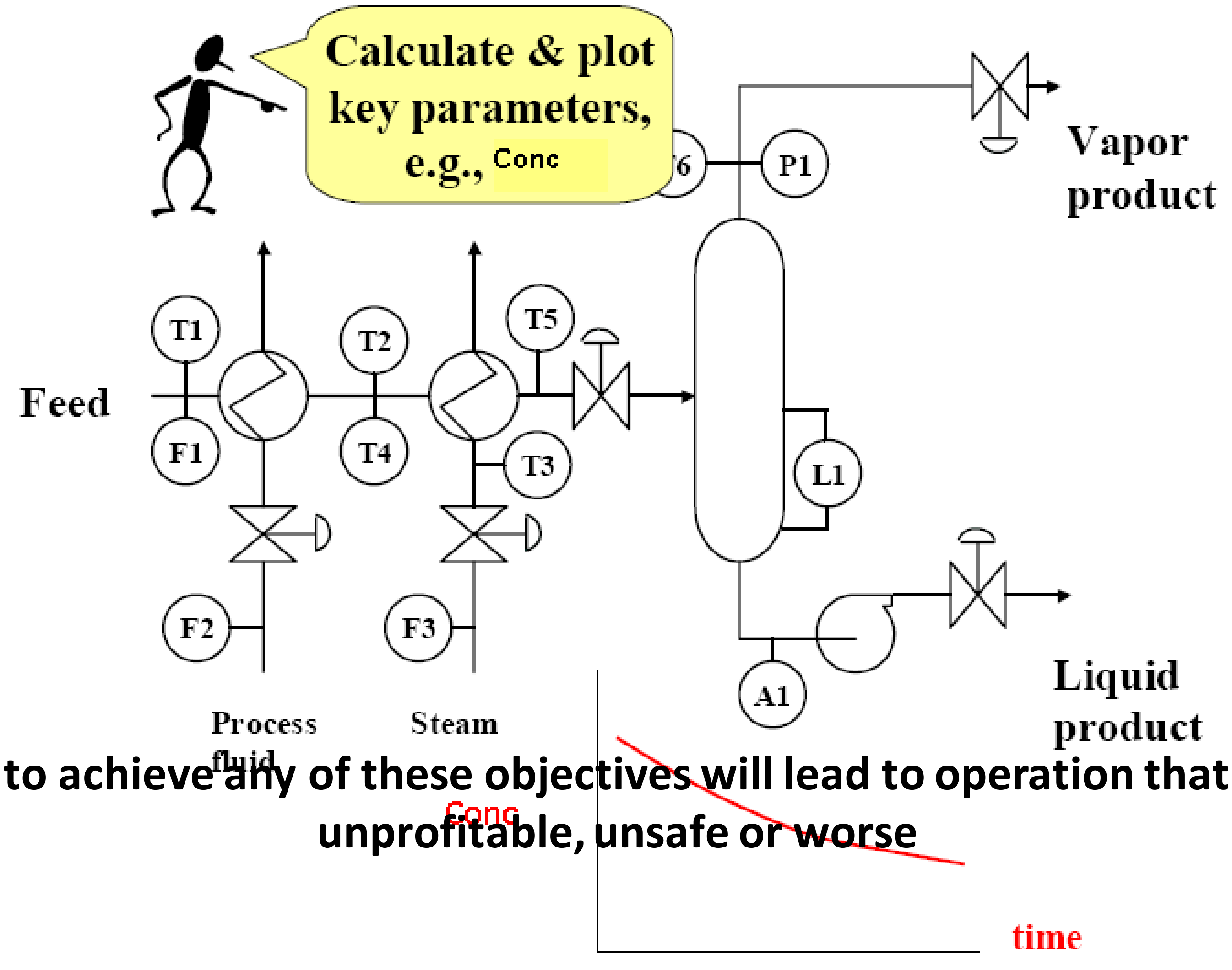


PROFIT



Use the least costly heating
Vapor product
T6
P1
Feed
T1
F1
T2
T4
T5
T3
L1
F2
F3
Process fluid
Steam
AC
L. Key
Liquid product

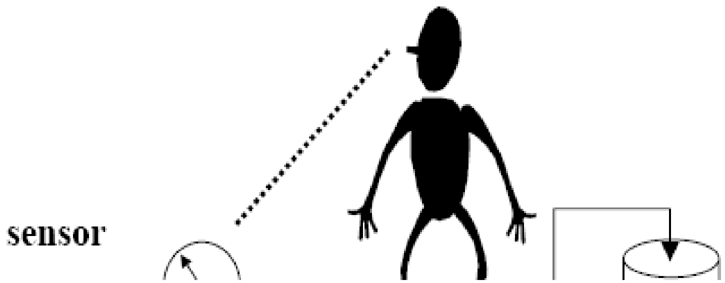
MONITORING AND DIAGNOISIS

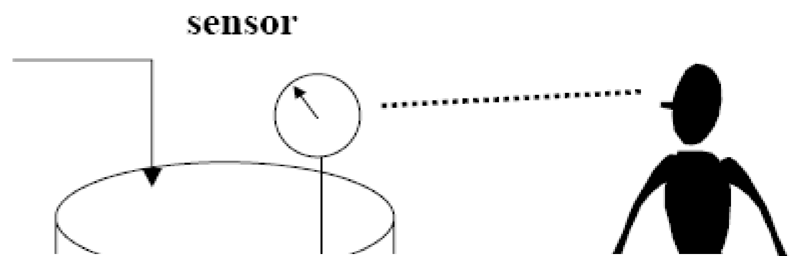


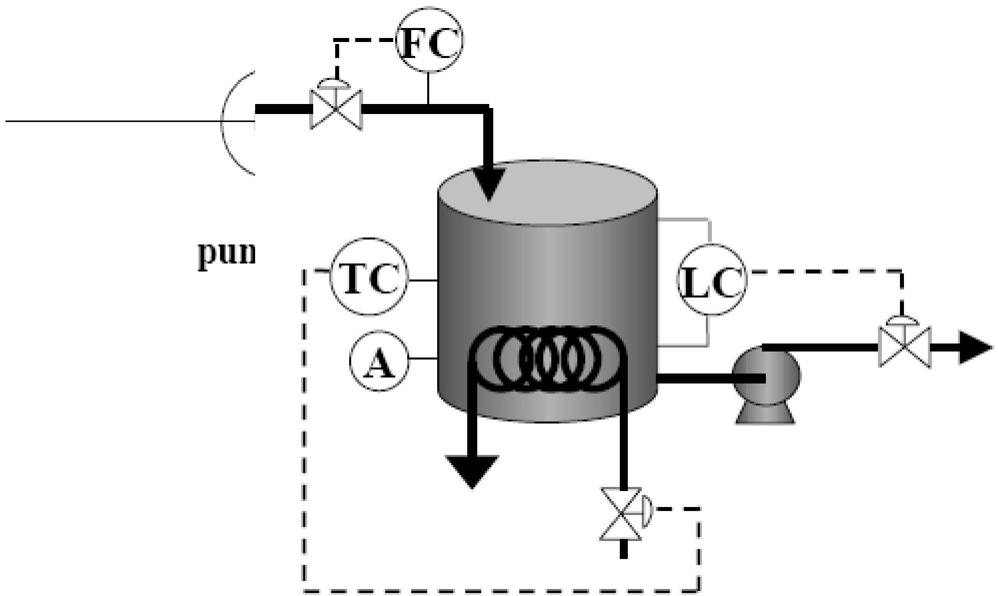
Failing to achieve any of these objectives will lead to operation that will be unprofitable, unsafe or worse

Flow Control

Level Control







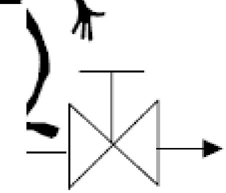
F = flow

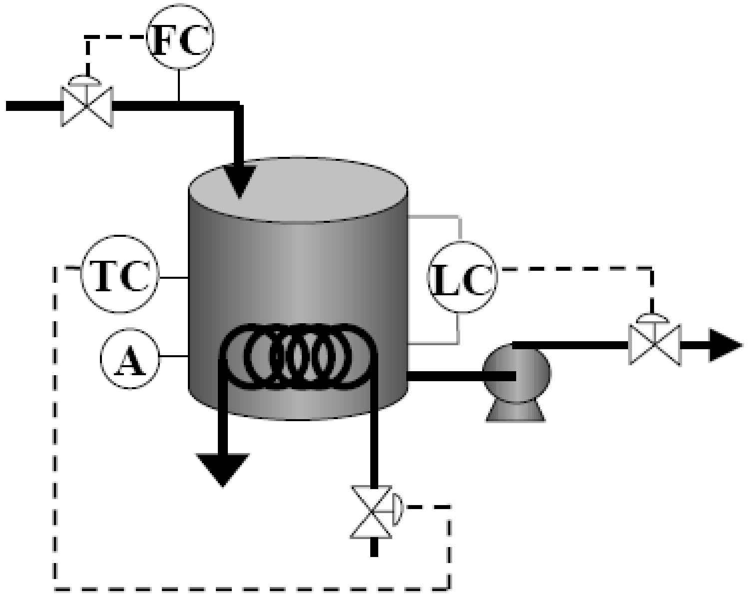
L = level

P = pressure

T = temperature

.....





F = flow

L = level

P = pressure

T = temperature

.....

Input Variables

-**Manipulated (or adjustable) Variables**

if their values can be adjusted freely by the human operator or a control mechanism

-**Disturbances**

if their values are not the result of adjustment by an operator or a control system

Output Variables

-**Measured O/P Variables**

if their values are known by directly measuring them

-**Unmeasured O/P Variables**

if they are not or cannot be measured directly

Types Of Controllers

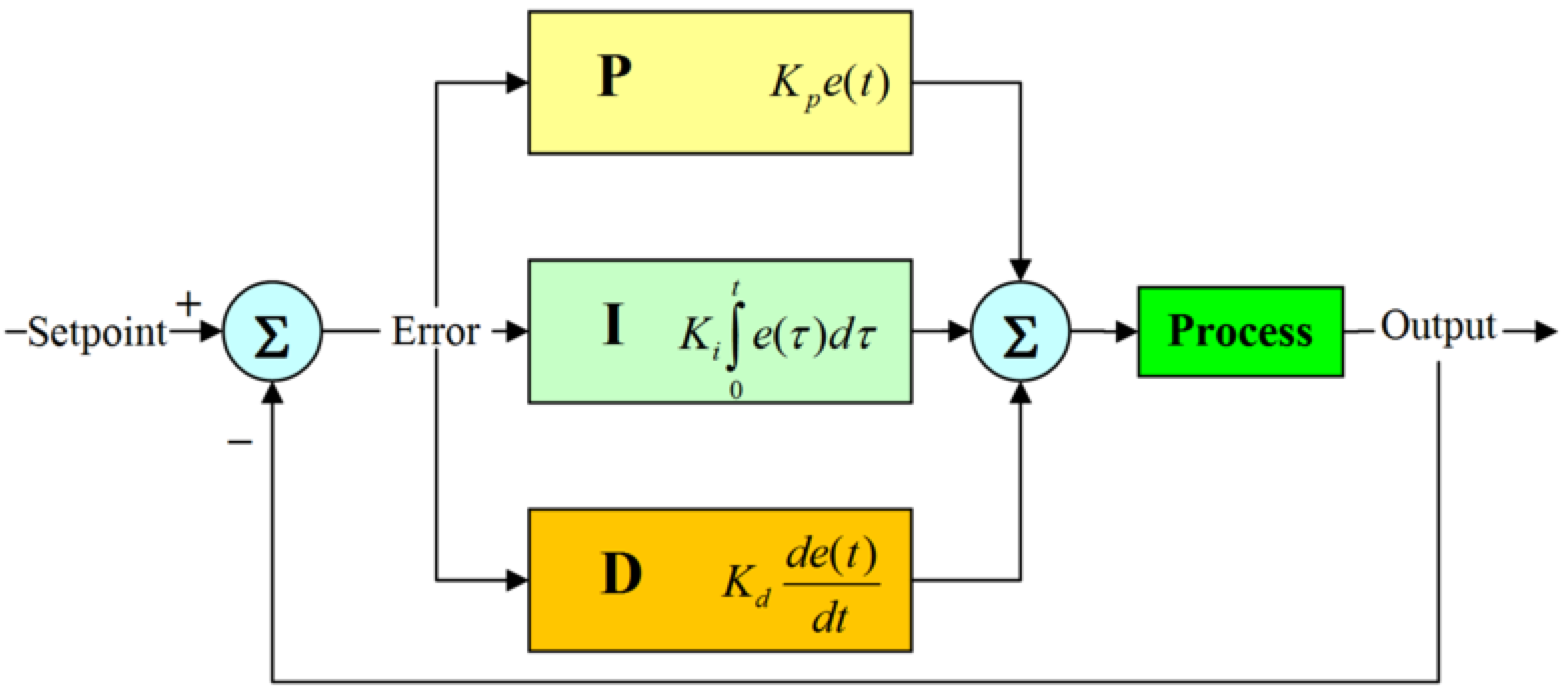
On-Off Controller

Proportional Controller

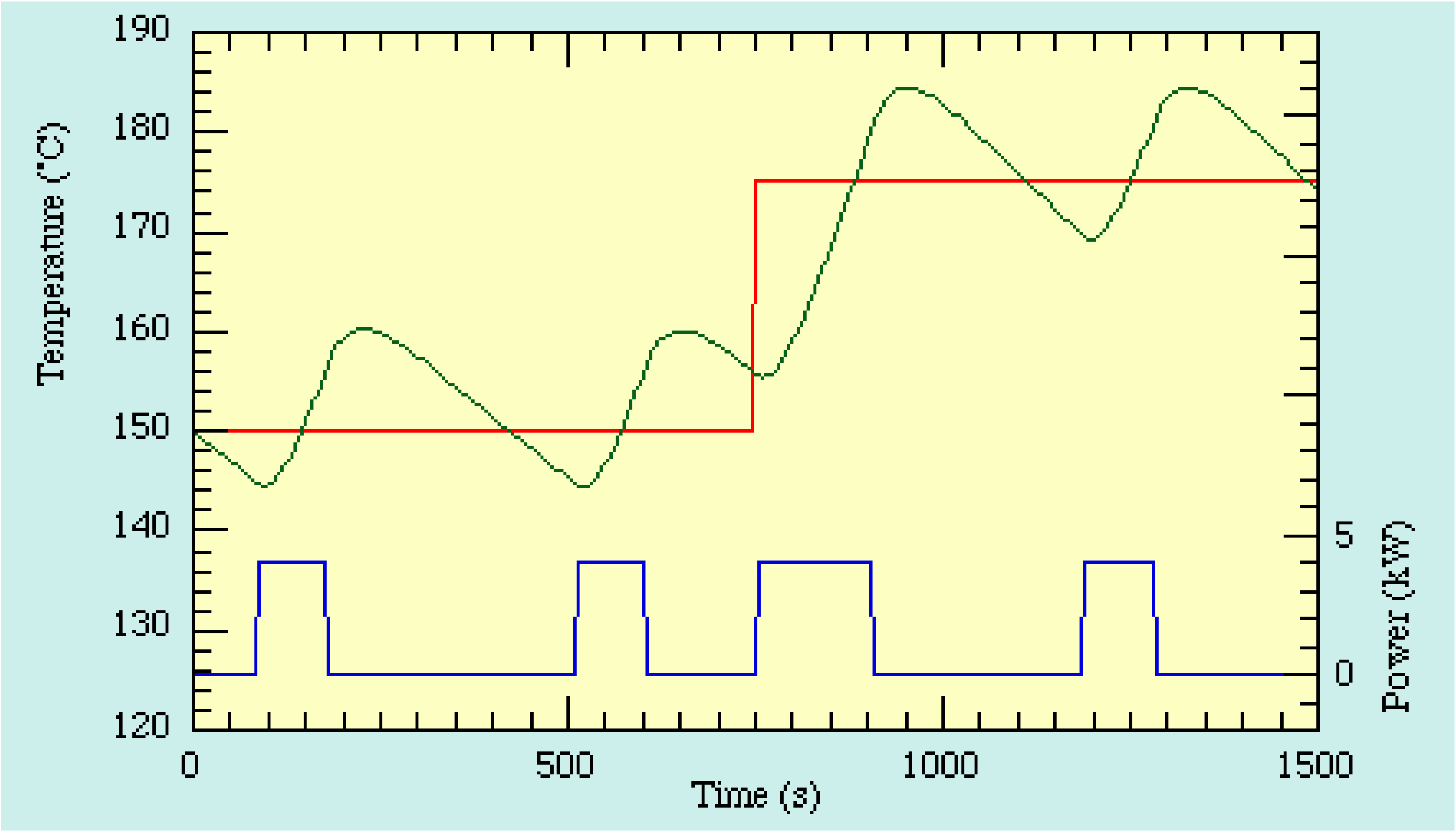
Proportional Integral Controller

Proportional Derivative Controller

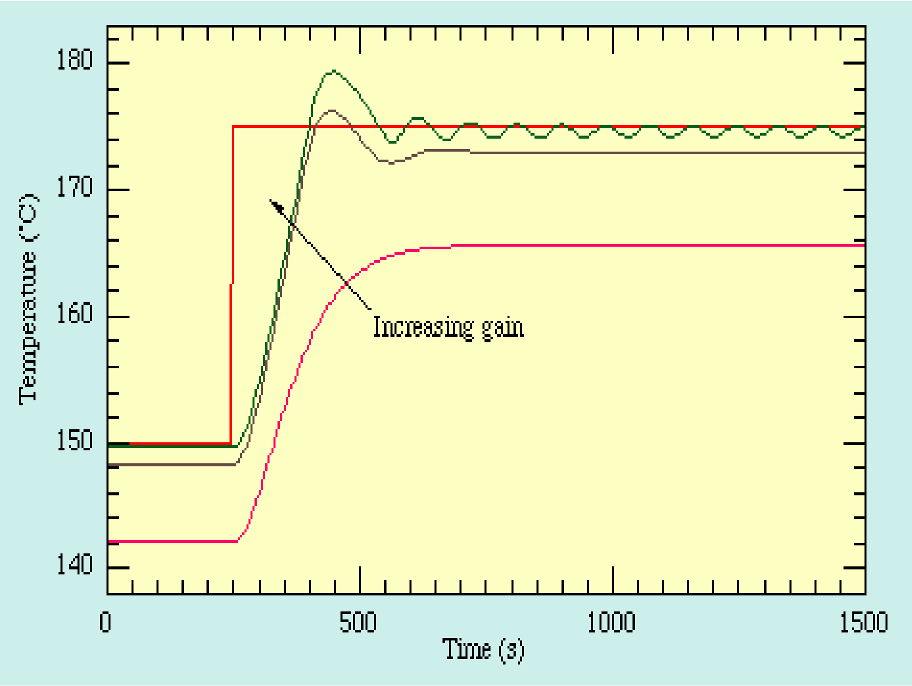
Proportional Derivative Integral Controller



On-Off Controller



Proportional Controller



A high proportional gain results in a large change in the output for a given change in the error.

In contrast, a small gain results in a small output response to a large input error, and a less responsive (or sensitive) controller.

If the proportional gain is too high, the system can become unstable.

If the proportional gain is too low, the control action may be too small when responding to system disturbances.

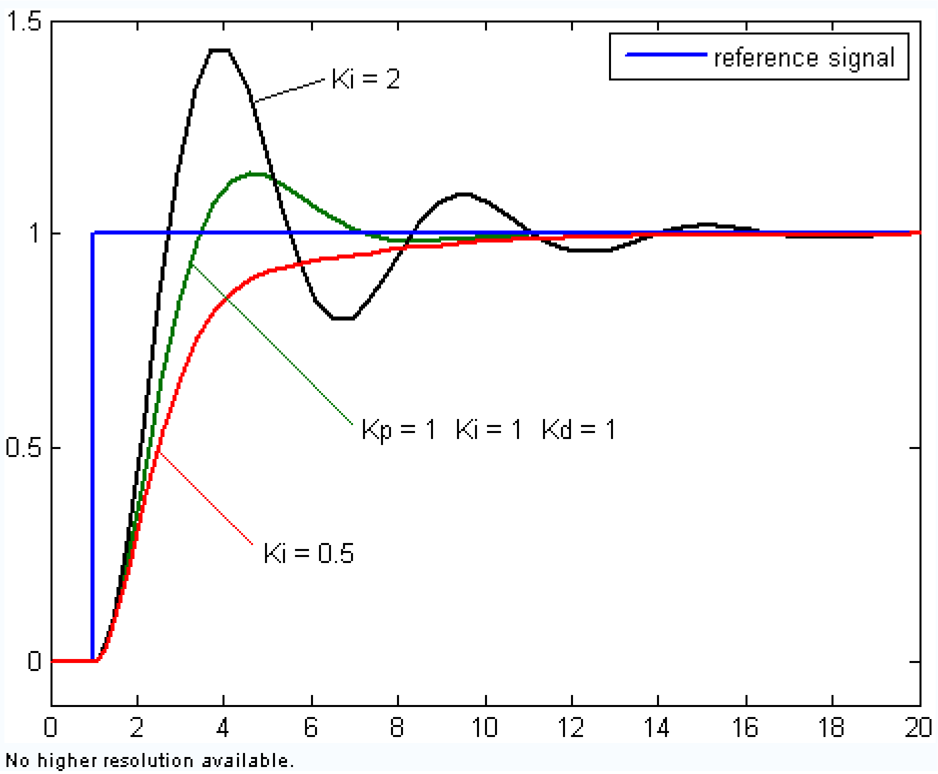
$$P_{\mathrm{out}} = K_p \, e(t)$$

M V(t) = P_{out}

Where

- P_{out}: **Proportional output**
- K_p: **Proportional Gain, a tuning parameter**
- e: **Error** = $SP - PV$
- t: **Time or instantaneous time (the present)**

Proportional Integral Controller



The integral term (when added to the proportional term) accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a proportional only controller.

However, since the integral term is responding to accumulated errors from the past, it can cause the present value to overshoot the setpoint value (cross over the setpoint and then create a deviation in the other direction).

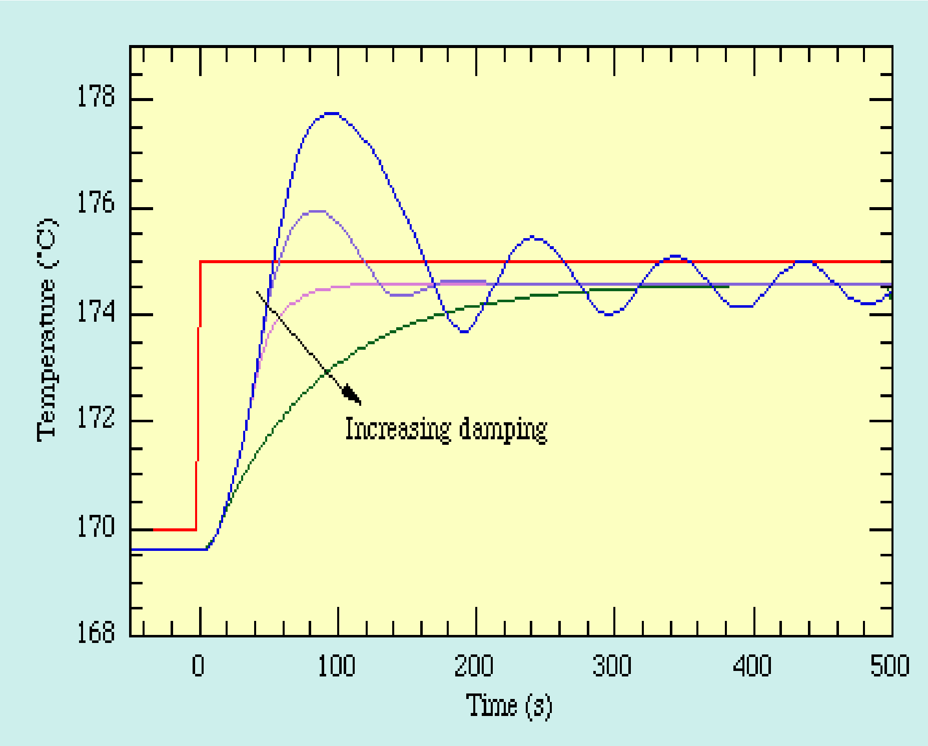
$$I_{\text{out}} = K_i \int_0^t e(\tau)\, d\tau$$

M V(t) = P_{out} + I_{out}

Where

- I_{out}: **Integral output**
- K_i: **Integral Gain, a tuning parameter**
- e: **Error** = $SP - PV$
- τ: **Time in the past contributing to the integral response**

Proportional Derivative Controller



The derivative term slows the rate of change of the controller output and this effect is most noticeable close to the controller setpoint. Hence, derivative control is used to reduce the magnitude of the overshoot produced by the integral/proportional component and to improve the combined controller-process stability.

However, differentiation of a signal amplifies noise in the signal. Hence, this term in the controller is highly sensitive to noise in the error term. If the noise and the derivative gain are sufficiently large then the process becomes unstable.

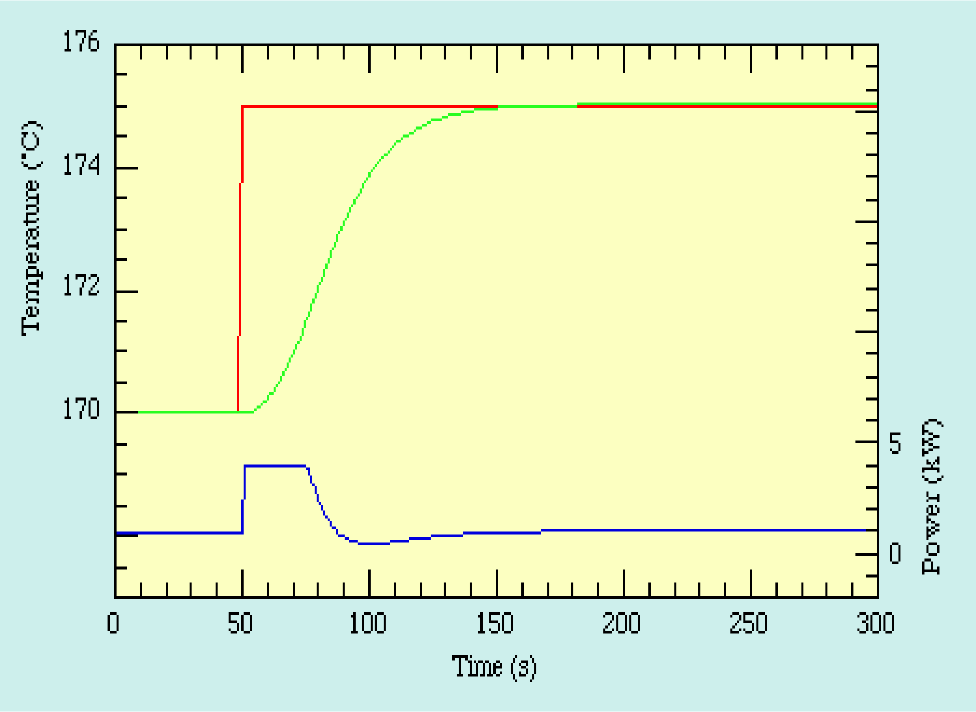
$$D_{\text{out}} = K_d \frac{de}{dt}$$

$MV(t) = P_{out} + D_{out}$

Where

- D_{out}: **Derivative output**
- K_d: **Derivative Gain, a tuning parameter**
- e: **Error** = $SP - PV$
- t: **Time or instantaneous time (the present)**

Proportional Derivative Integral Controller



$MV(t) = P_{out} + D_{out} + I_{out}$

$$\mathrm{MV}(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de}{dt}$$

Effects of *increasing* parameters				
Parameter	**Rise Time**	**Overshoot**	**Settling Time**	**S.S. Error**
K_p	Decrease	Increase	Small Change	Decrease
K_i	Decrease	Increase	Increase	Eliminate
K_d	Small Change	Decrease	Decrease	None

Proportional Gain - Larger K_p typically means faster response since the larger the error, the larger the feedback to compensate. An excessively large proportional gain will lead to process instability.

Integral Gain - Larger K_i implies steady state errors are eliminated quicker. The trade-off is larger overshoot: any negative error integrated during transient response must be integrated away by positive error before we reach steady state.

Derivative Gain - Larger K_d decreases overshoot, but slows down transient response and may lead to instability.

Different Types Of Control Systems

Feedback Control System

Feedforward Control System

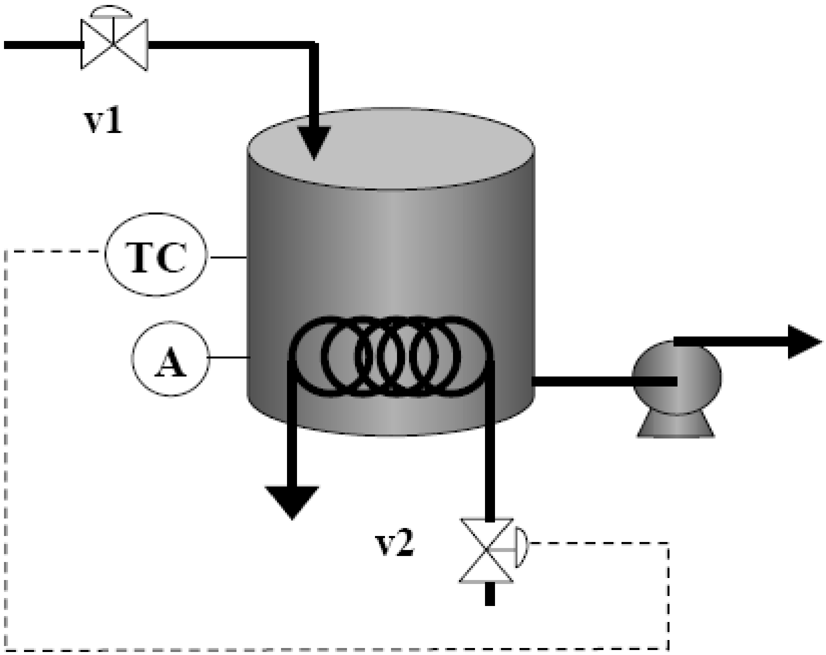
Cascade Control System

Ratio Control System

Split Control System

Feedback Control System

Controller acts after the effect of disturbance has been felt by the system



Advantages:

•Corrective action occurs regardless of the source and type of disturbances.

•Requires little knowledge about the process (For example, a process model is not necessary).

•Versatile and robust (Conditions change? May have to re-tune controller).

Disadvantages:

•FB control takes no corrective action until a deviation in the controlled variable occurs.

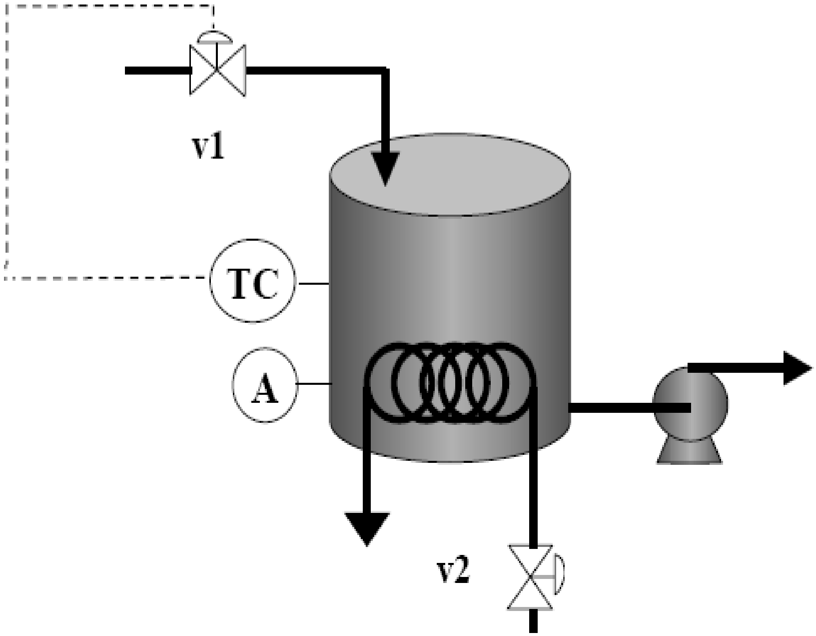
•FB control is incapable of correcting a deviation from set point at the time of its detection.

•Theoretically not capable of achieving "perfect control."

•For frequent and severe disturbances, process may not settle out.

Feedforward Control System

Controller acts even before the effect of disturbance has been felt by the system



Advantages:

•Takes corrective action before the process is upset (cf. FB control.)

•Theoretically capable of "perfect control"

•Does not affect system stability

Disadvantages:

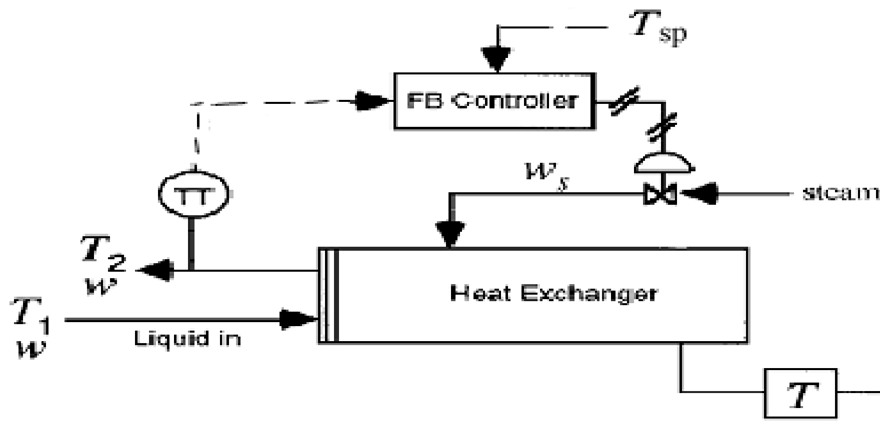
•Disturbance must be measured (capital, operating costs)

•Requires more knowledge of the process to be controlled (process model)

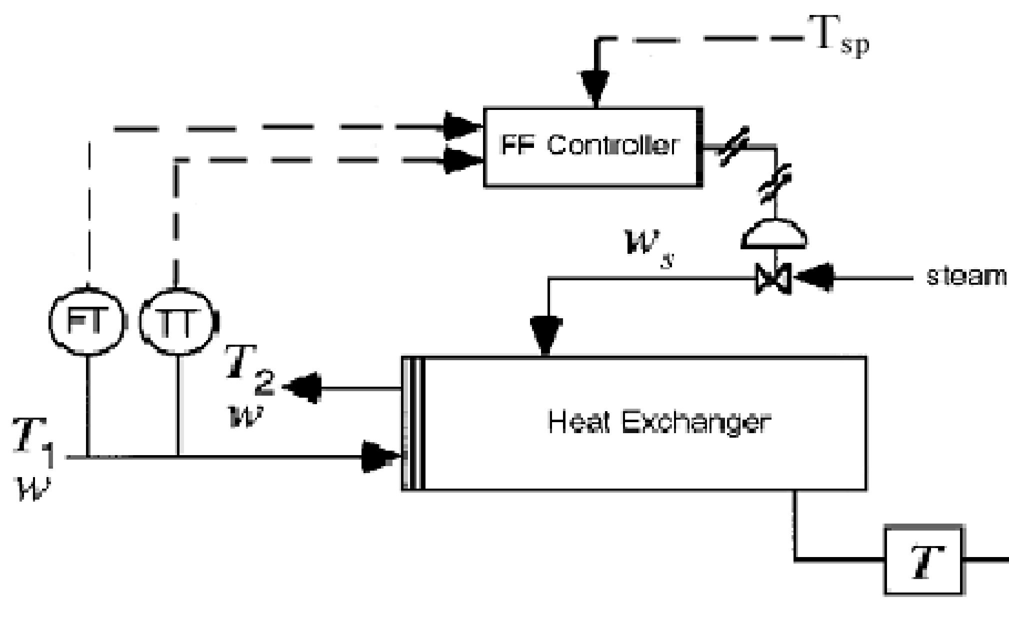
•Ideal controllers that result in "perfect control": may be physically unrealizable. Use practical controllers such as lead-lag units

Comparison

Feedback Control



Feedforward Control



Feedw

Figur
drum.

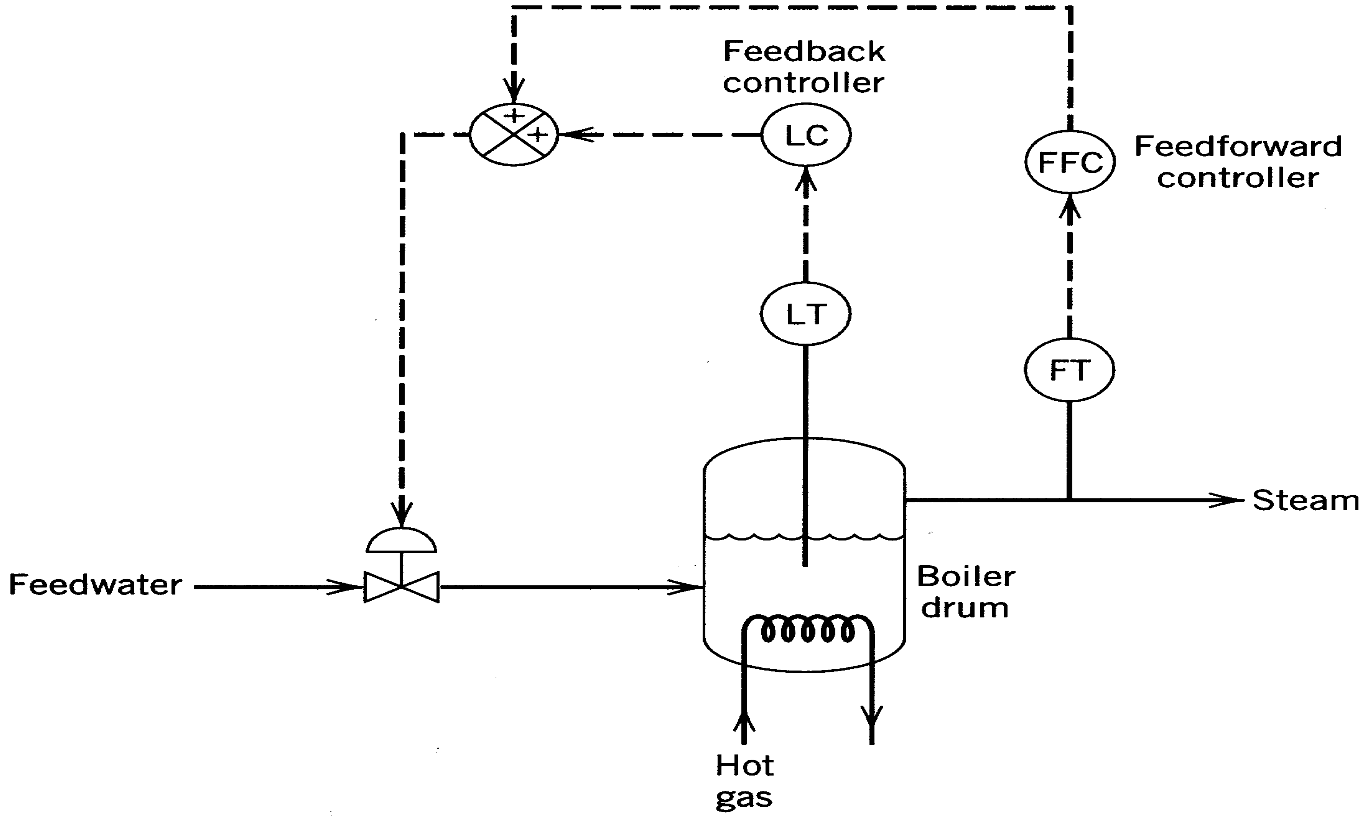


Figure 15.4 Feedforward–feedback control of the boiler drum level.

FF Control

- Attempts to eliminate the effects of measurable disturbances.

FB Control

- Corrects for unmeasurable disturbances, modeling errors, etc. (FB trim)

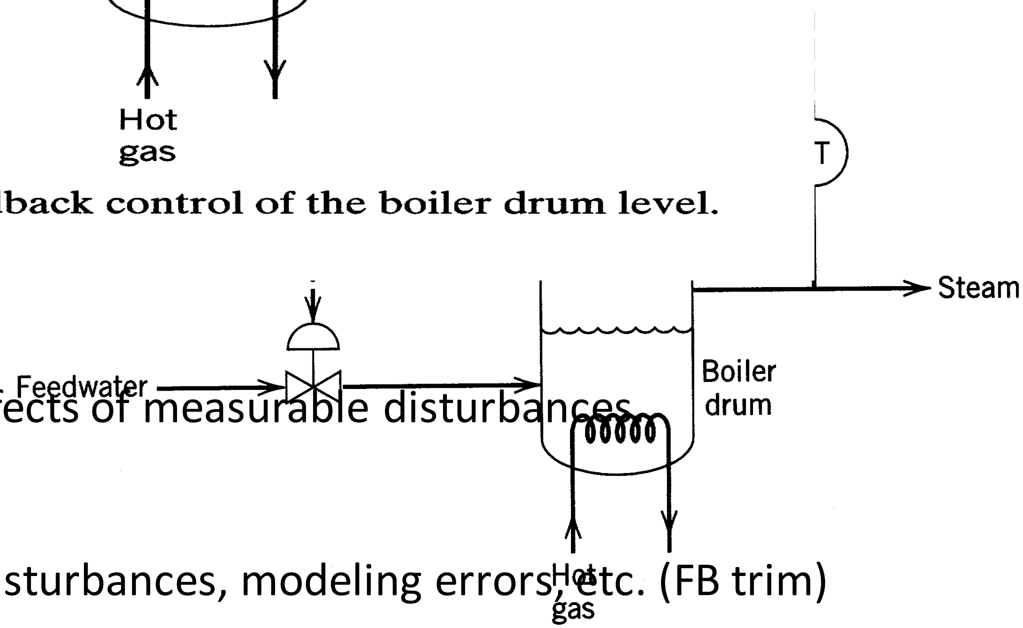
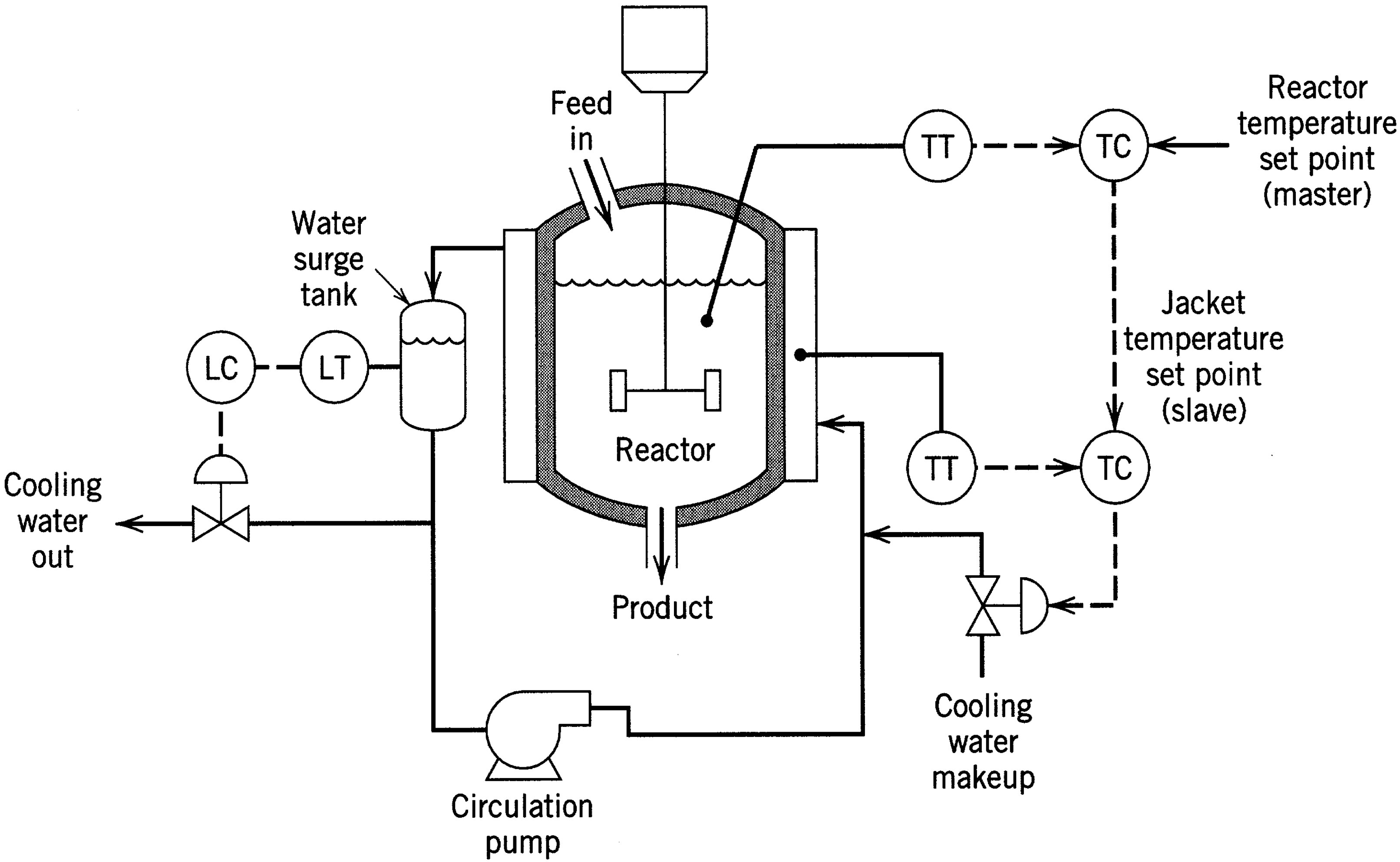


Figure 15.3 Feedforward control of the liquid level in a boiler drum.

Cascade Control System



Cascade control of an exothermic chemical reactor.

Distinguishing features:

-Two FB controllers but only a single control valve (or other -final control element).

-Output signal of the "master" controller is the set-point for “slave" controller.

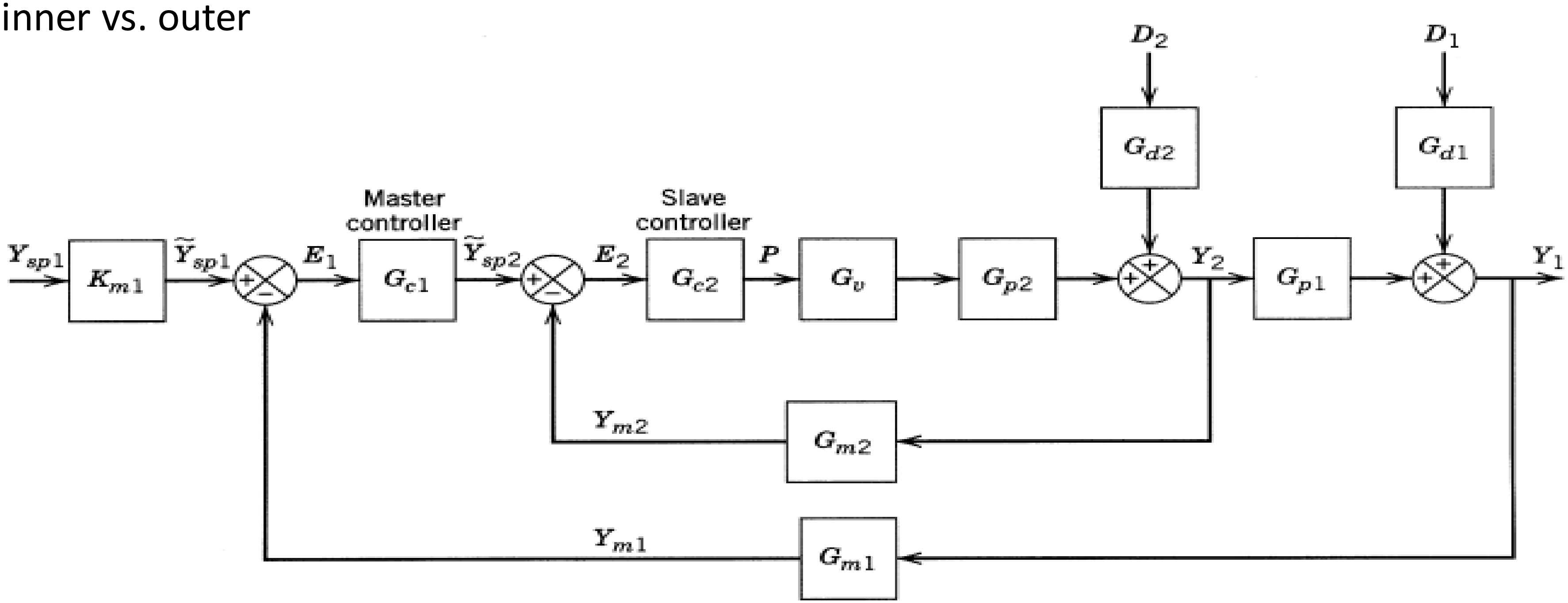
-Two FB control loops are "nested" with the "slave" (or "secondary") control loop inside the "master" (or "primary") control loop.

Terminology

-slave vs. master

-secondary vs. primary

-inner vs. outer



Block diagram of the cascade control system.

Ratio Control System

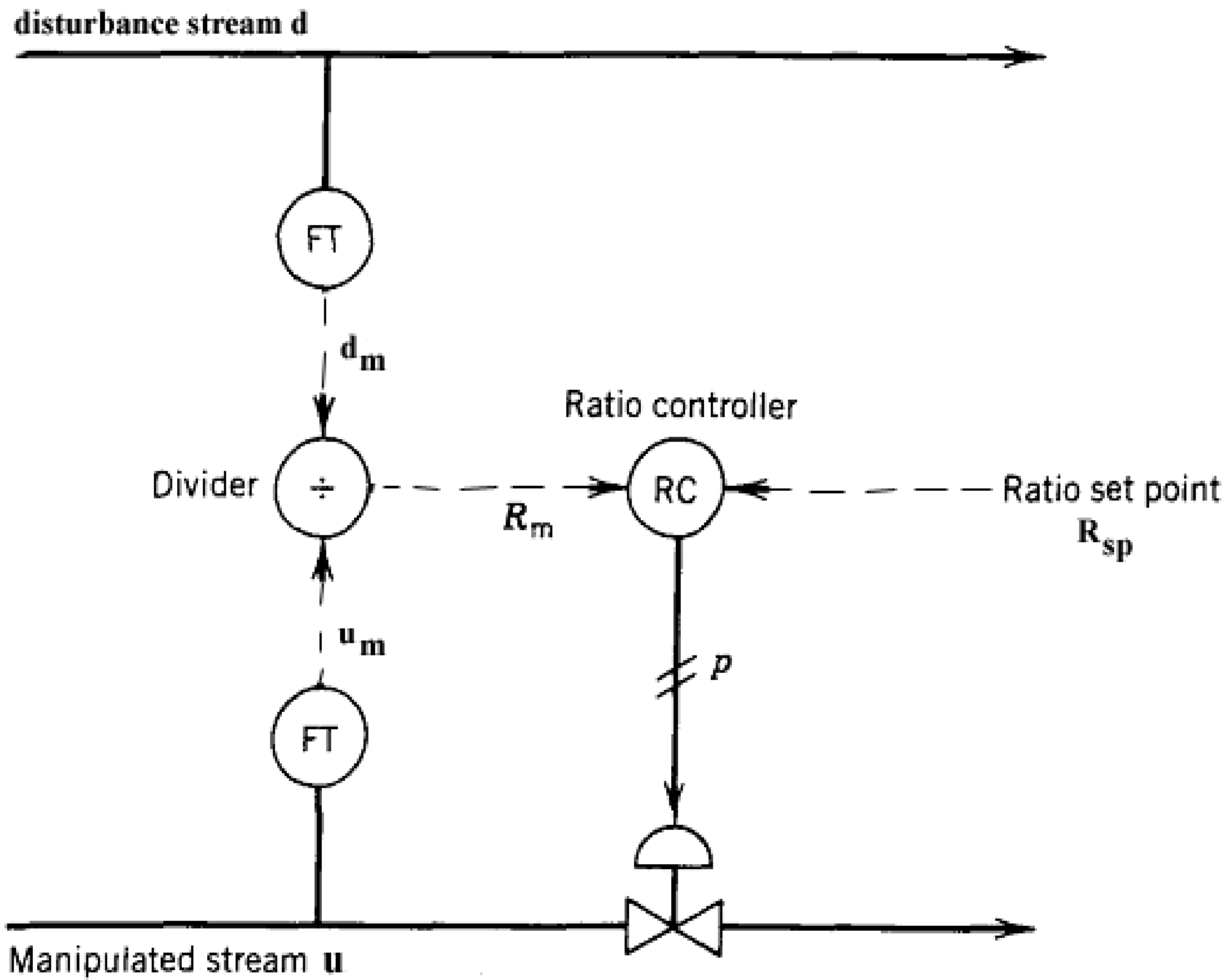


Figure 17.5. Ratio control, Method I.

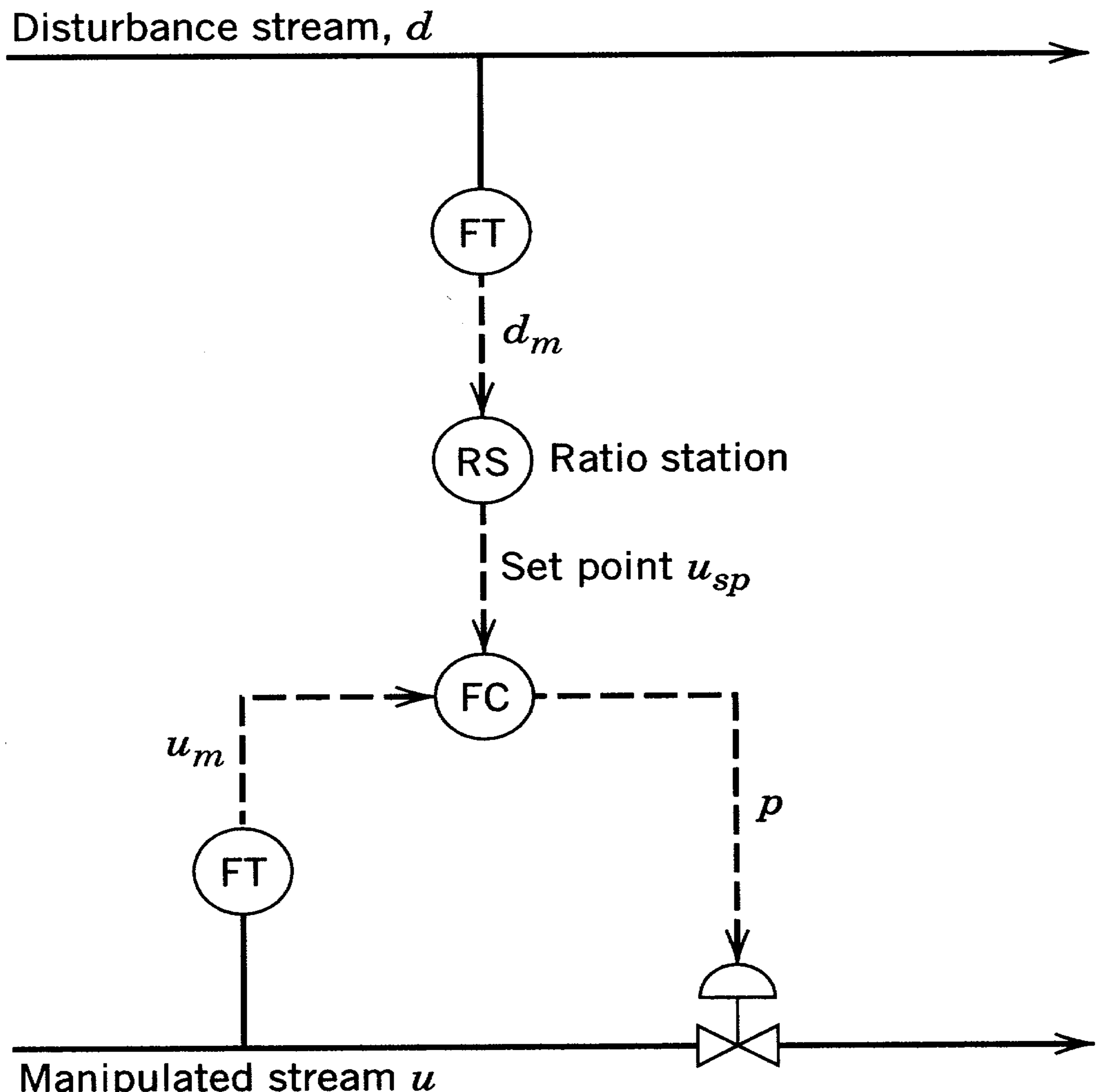


Figure 15.6 Ratio control, Method II.

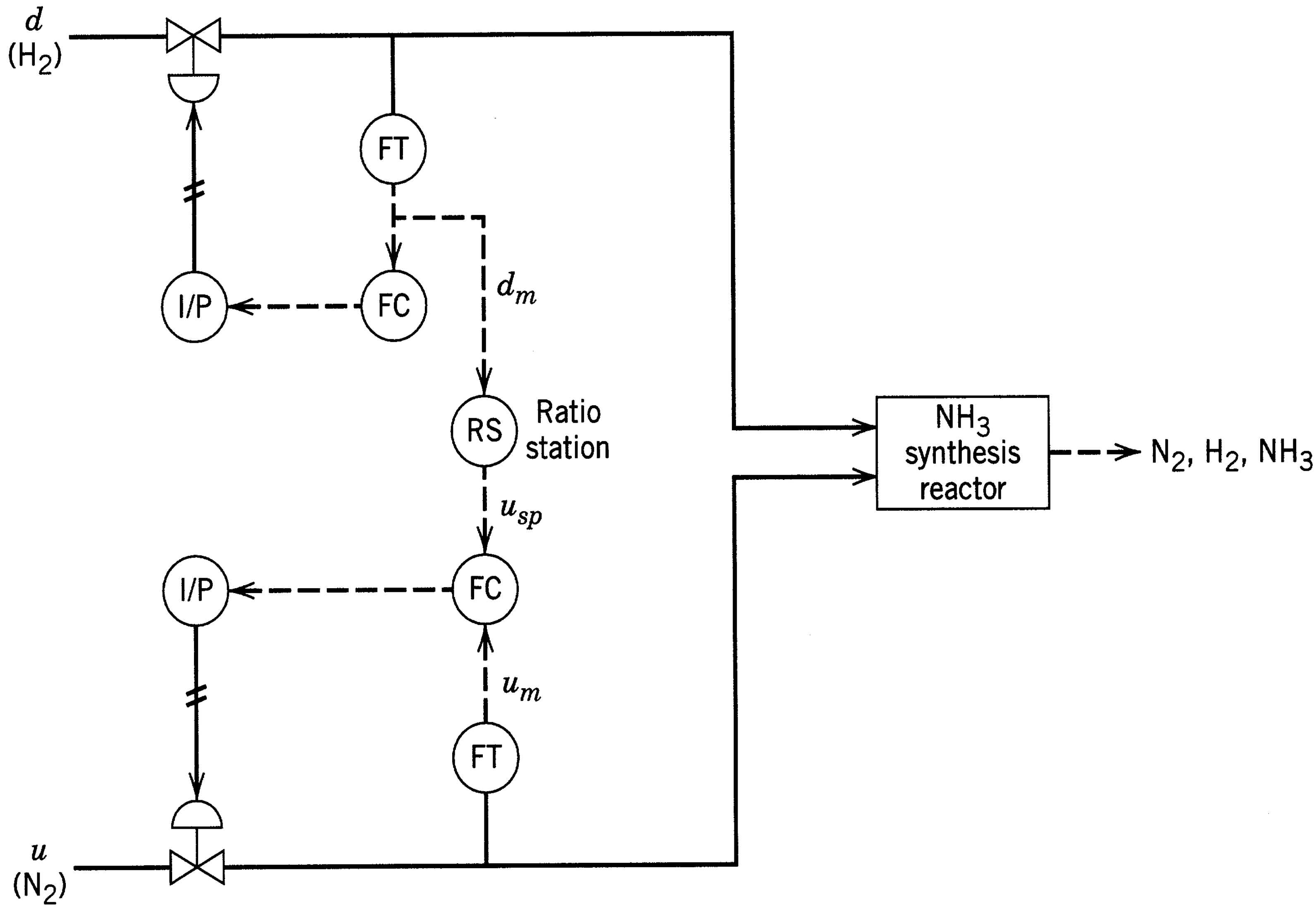
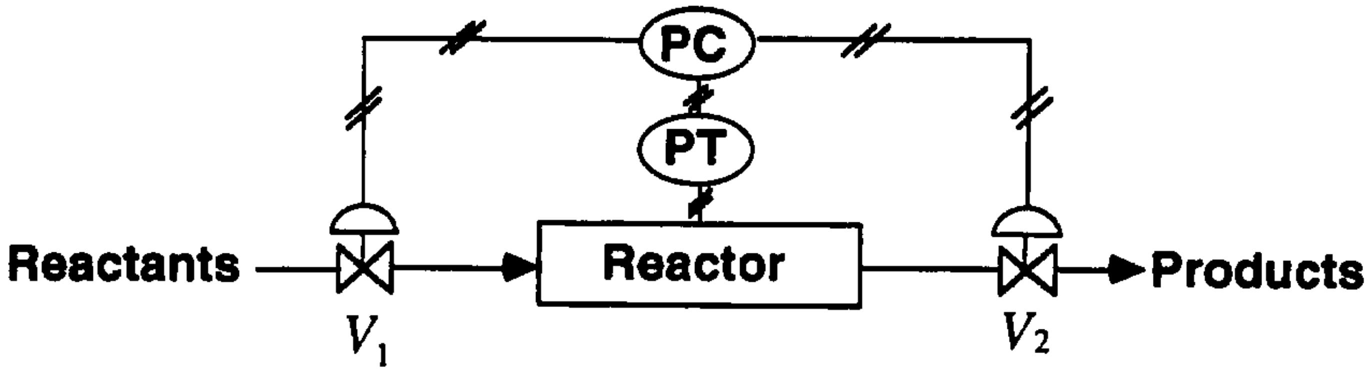
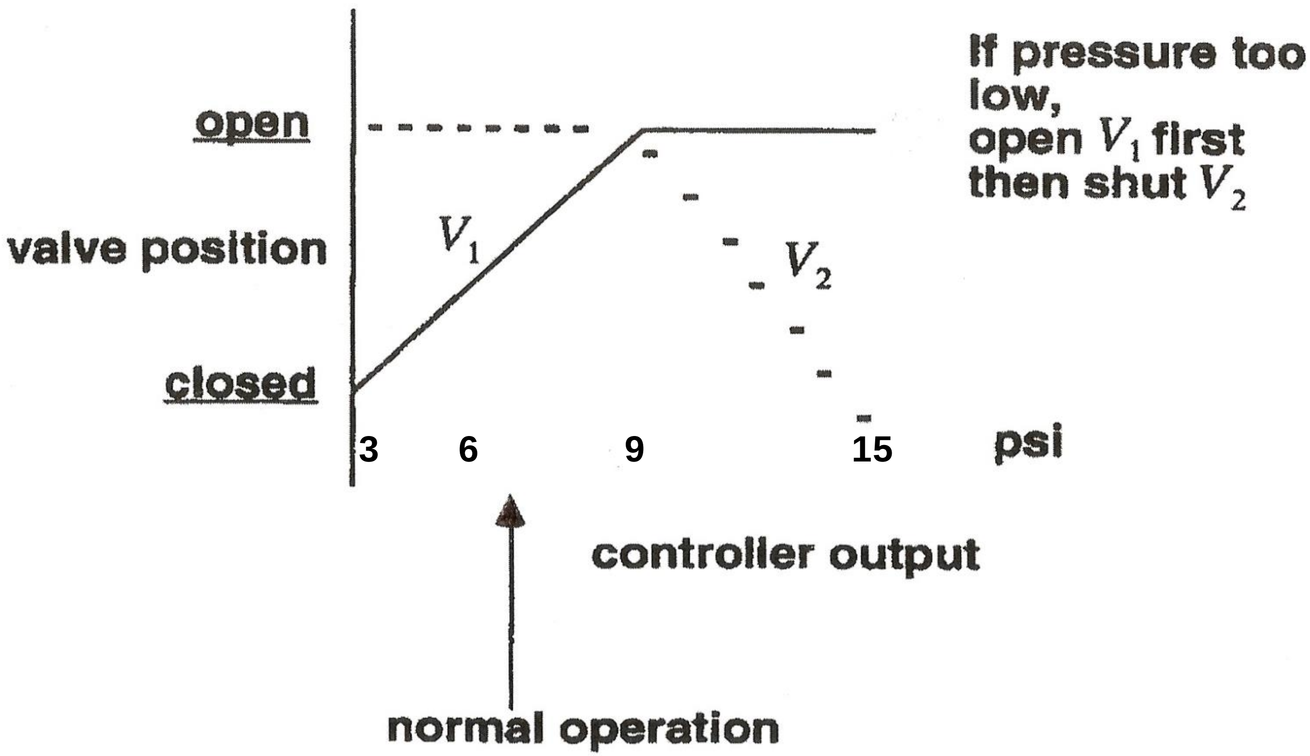


Figure 15.7 Ratio control scheme for an ammonia synthesis reactor of Example 15.1.

Split Control System



2 Manipulated Vars.: | 1 Controlled Var.:



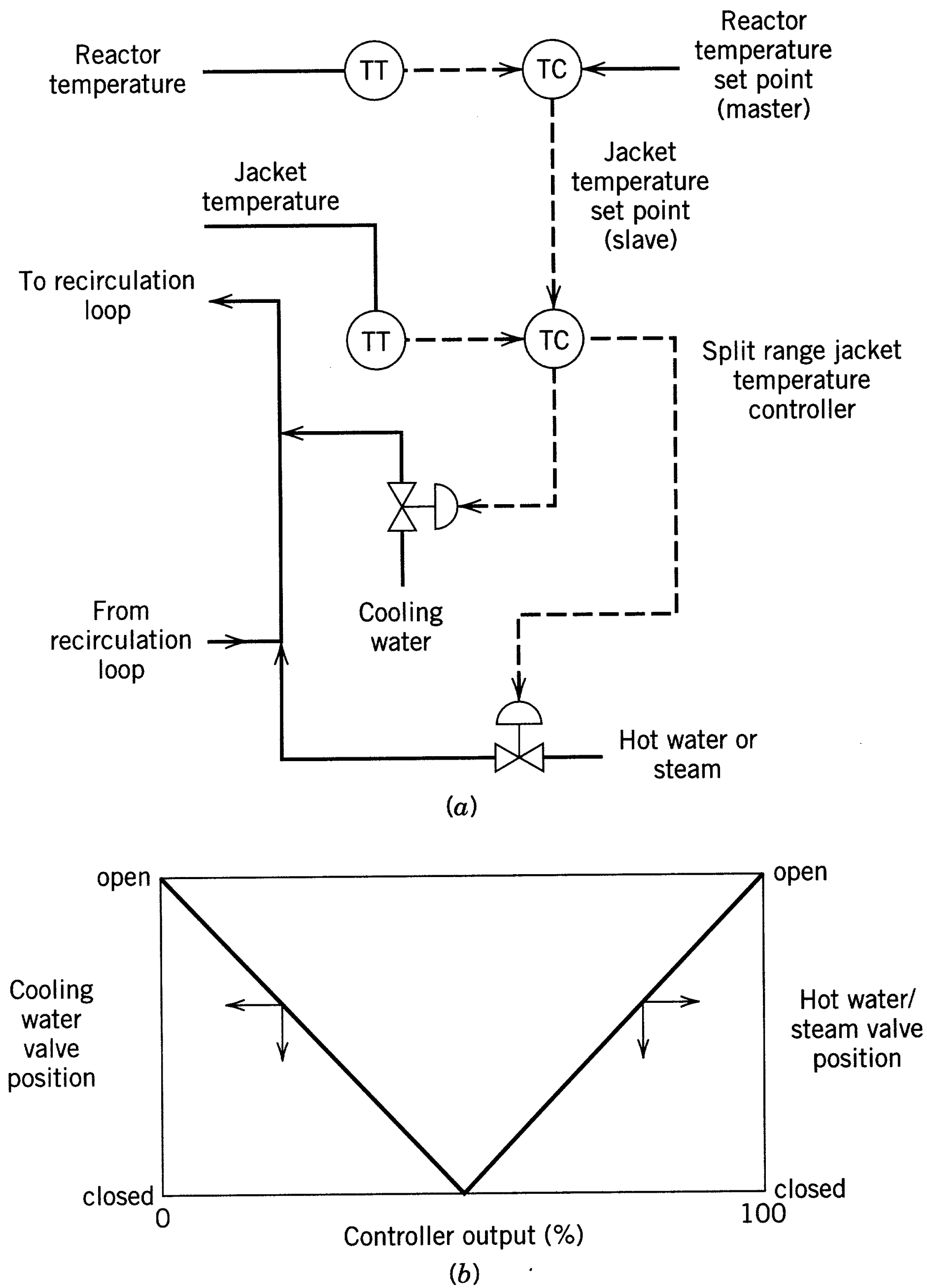


Figure 16.14 Split range control: (*a*) control loop configuration, (*b*) valve position–controller output relationship.