

Part I

OVERVIEW OF PROCESS CONTROL

Contents

I	OVERVIEW OF PROCESS CONTROL	1
1	BAISIC LOW-LEVEL CONTROL	4
1.1	BASIC IDEA OF FEEDBACK/FEEDFORWARD CONTROL	4
1.2	MOTIVATION- WHY(NEGATIVE) FEEDBACK CONTROL ?	9
1.3	ELEMENTS OF A FEEDBACK SYSTEM	13
1.4	PID FORMULATIONS	20
1.4.1	INTEGRAL(I) CONTROL	20
1.4.2	PROPORTIONAL(P) CONTROL	21
1.4.3	PROPORTIONAL INTEGRAL(PI) CONTROL	24
1.4.4	PROPORTIONAL INTEGRAL DERIVATIVE(PID) CONTROL	25
1.4.5	DIGITAL IMPLEMENTATION	27
1.5	QUANTITIVE PID TUNING METHODS	29
1.5.1	CONTINUOUS CYCLING METHOD	29
1.5.2	REACTION-CURVE-BASED METHOD	38
1.5.3	FOPDT-BASED TUNING RULES	41
1.5.4	DIRECT SYNTHESIS METHOD - IMC TUNING	46
1.6	PRACTICAL CONSIDERATIONS	50

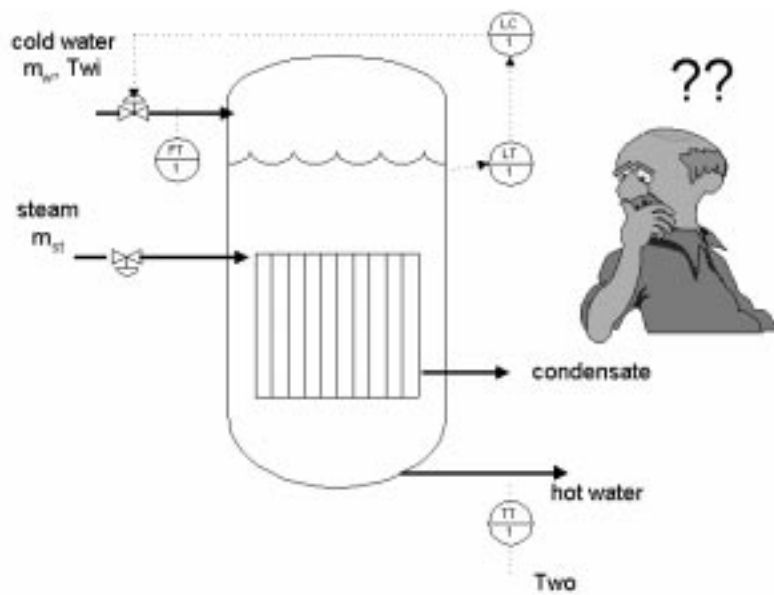
2	MULTI-LOOP CONTROL AND FURTHER PRACTICAL ISSUES	55
2.1	FEEDFORWARD-FEEDBACK CONTROL	55
2.2	CASCADE CONTROL	57
2.3	OVERRIDE CONTROL	61
3	CONTROL OF MULTI-INPUT MULTI-OUTPUT(MIMO) PROCESSES	62
3.1	MIMO PROCESS ?	62
3.2	INTERACTION AND I/O PAIRING	64
3.2.1	INTERACTION	64
3.2.2	I/O PAIRING	67
3.3	DECOUPLING	70
3.4	CURRENT TRENDS	74
3.4.1	COMPUTER INTEGRATED PROCESS MANAGEMENT	74
3.4.2	MODEL-BASED APPROACHES	75
3.4.3	COMPUTING ENVIRONMENT	77
3.4.4	COMPUTER CONTROL SYSTEM	78
3.4.5	SMART INSTRUMENT AND FIELD BUS	79

Chapter 1

BAISIC LOW-LEVEL CONTROL

1.1 BASIC IDEA OF FEEDBACK/FEEDFORWARD CONTROL

Example Process



Control Objective keep the water outlet temp(T_{wo}) at a desired set point(T_{sp}).

Major Disturbance hot water demand(m_w)

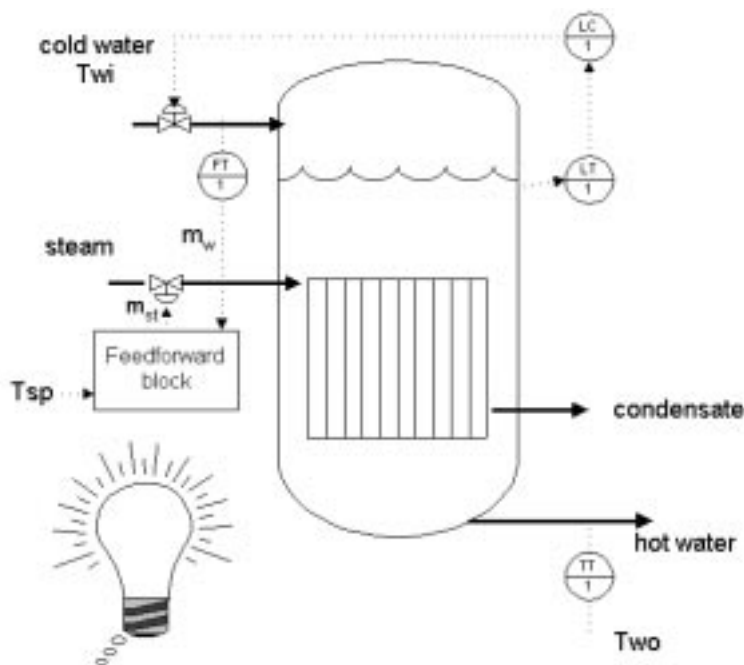
Manipulated Input steam flow rate(m_{st})

◇ **APPROACH 1 : FEEDFORWARD CONTROL**

- Measure m_w
- Calculate m_{st} needed to maintain T_{wo} for given m_w . For example,

$$\lambda_{st} m_{st} = m_w C p_w (T_{wo} - T_{wi}) \rightarrow m_{st} = \frac{m_w C p_w (T_{sp} - T_{wi})}{\lambda_{st}}$$

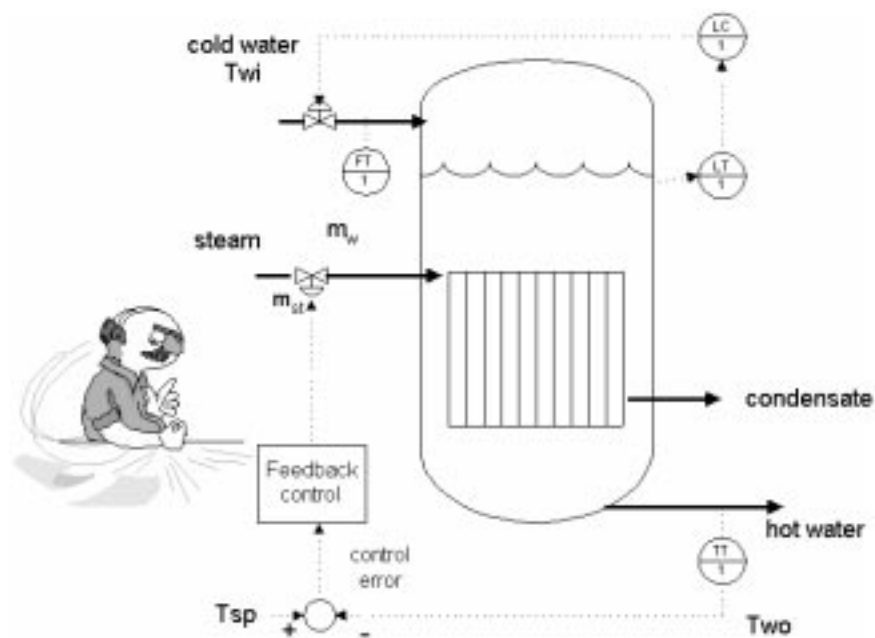
- Apply m_{st} .



No guarantee that $T_{wo} \rightarrow T_{sp}$ because of various *uncertainties* which come from the model description, measurements, and signal implementation, etc.

◇ **APPROACH 2 : FEEDBACK CONTROL**

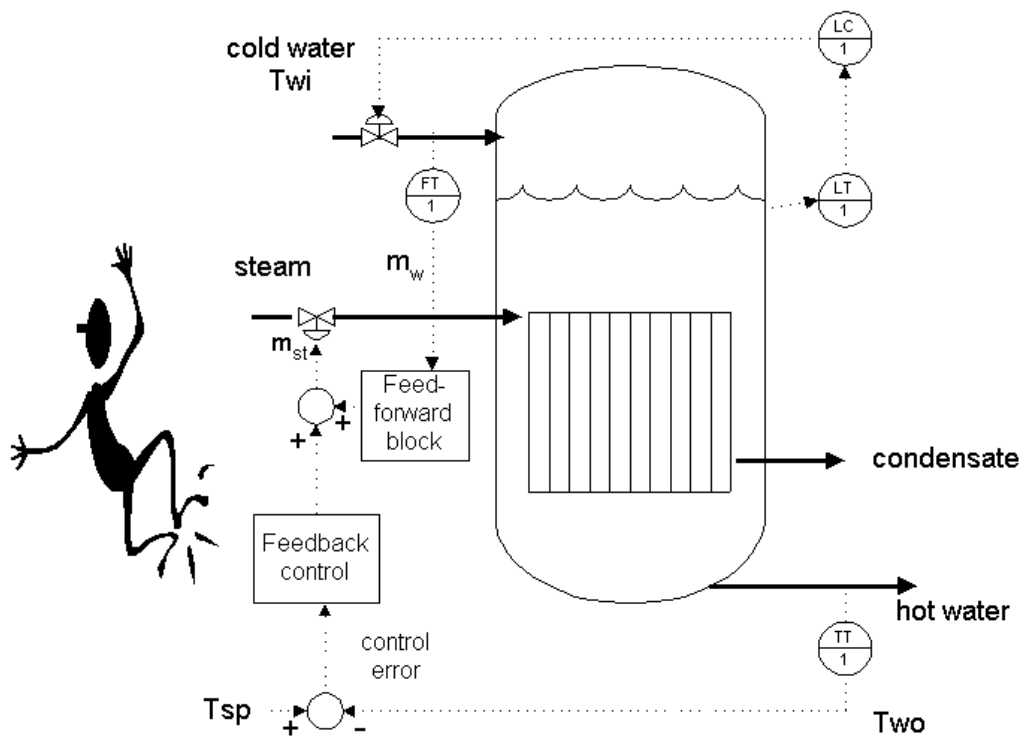
- Measure T_{wo}
- Compare with T_{sp}
- Take appropriate action to eliminate the observed error.



T_{wo} can be steered to T_{sp} . But T_{wo} may undergo a long transient period, frequently with oscillation, due to the trial and error nature of the feedback action. If the feedback controller is designed based on a *process model*, however, the transient can be adjusted as desired (with some limitations).

◇ **APPROACH 3 : FEEDFORWARD-FEEDBACK CONTROL**

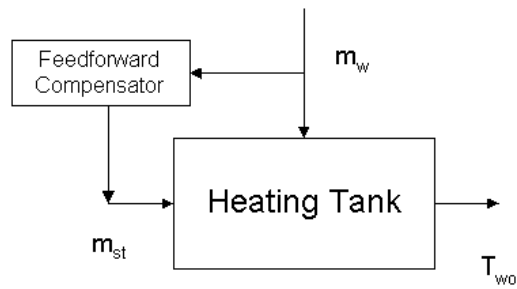
- Apply m_{st} from the feedforward block to the process.
- Provide additional corrective signal through feedback control when there is control error.



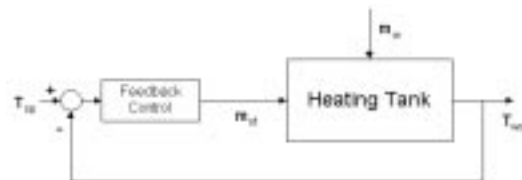
Better control performance can be expected than with feedback or feedforward-only control.

Block Diagram Representations

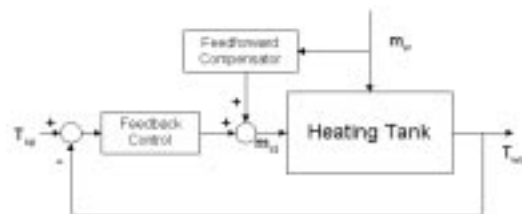
Feedforward Control



Feedback Control

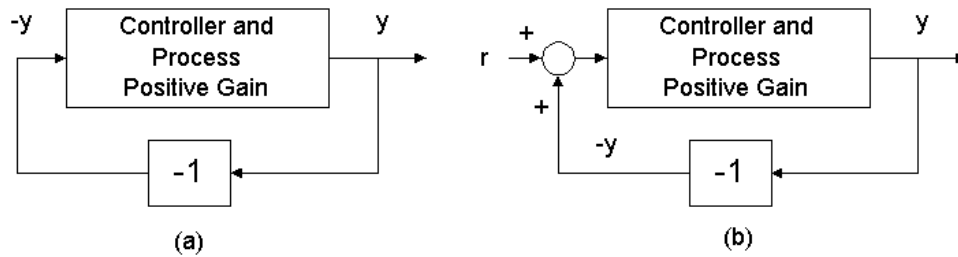


Feedforward-Feedback Control



1.2 MOTIVATION- WHY(NEGATIVE) FEEDBACK CONTROL ?

Some Comments on Negative Feedback



- In (a), as y deviates from zero, it is pulled back toward zero. Hence, negative feedback has self-stabilizing tendency.
- If an external r is put as in (b), y will tend to r .
- When the positive signal is fed back (positive feedback), it adds to itself and will tend to diverge.

What Can We Gain Through Feedback Control in Process Control Problems ?

1. To steer the process variables to desired steady states

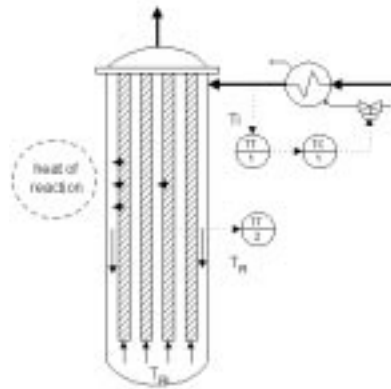
- Even when there is no disturbance, it is hard to manually drive PVs to desired states.
- With the aid of *integral action*, the feedback controller continues the corrective action until PVs reach their respective SPs.

2. Disturbance Rejection

- Try to keep the PVs at their SPs against various disturbances.

3. Stabilization

- Some processes are intrinsically unstable.

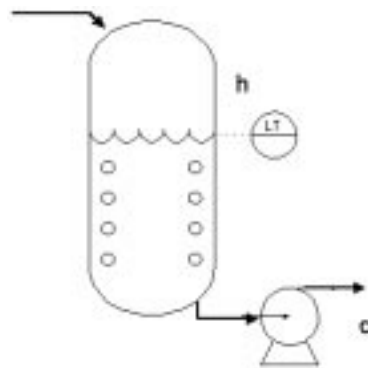


Autothermal Reactor

- (a) When T_i is perturbed to increase, T_{Ri} is increased.
- (b) This accelerates reaction rate and induces more heat of reaction.
- (c) This again increases T_{Ri} and boosts up (b).

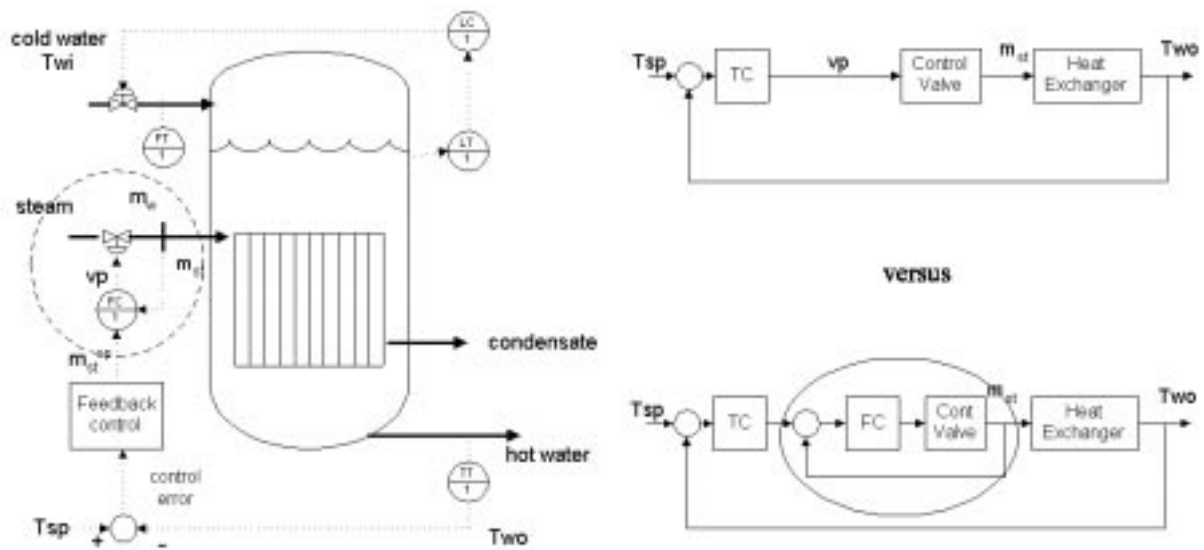
Positive feedback path exists between T_R and T_{Ri} .

- There are processes with integrating dynamics.



Surge Tank - Level is not self-stabilizable.

4. Linearization



- Usually, m_{st} (steam flow rate) changes nonlinearly with vp (valve position).
- When TC is configured to directly manipulate vp , the process seen by TC includes a nonlinear control valve block.
- In the cascade configuration, $m_{st} \approx m_{st}^{sp}$ if the slave controller is tightly tuned. Thus, the nonlinearity by the control valve block can be removed.

5. Improving Dynamics

- The dynamics of the slave loop in the cascade configuration can be adjusted to have a faster response than the control valve block has.
- Suppose T_{wo} is to be changed to another value. If the change in m_{st} is made manually, the settling time is set by the intrinsic process

time constant. On the other hand, putting a feedback loop (TC) can speed up the response time.

- Thus, TC in the cascade configuration controls a faster process than the one in the direct configuration.