Part I

OVERVIEW OF PROCESS CONTROL

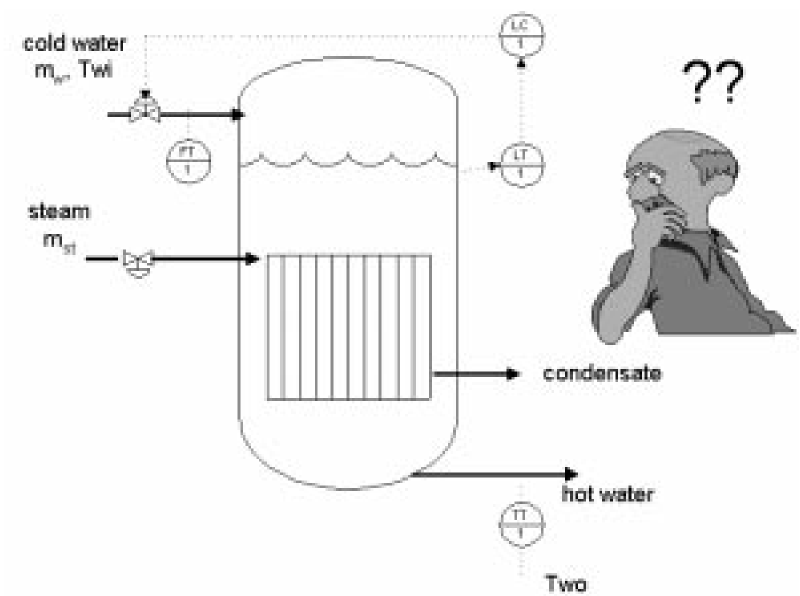
Contents

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)

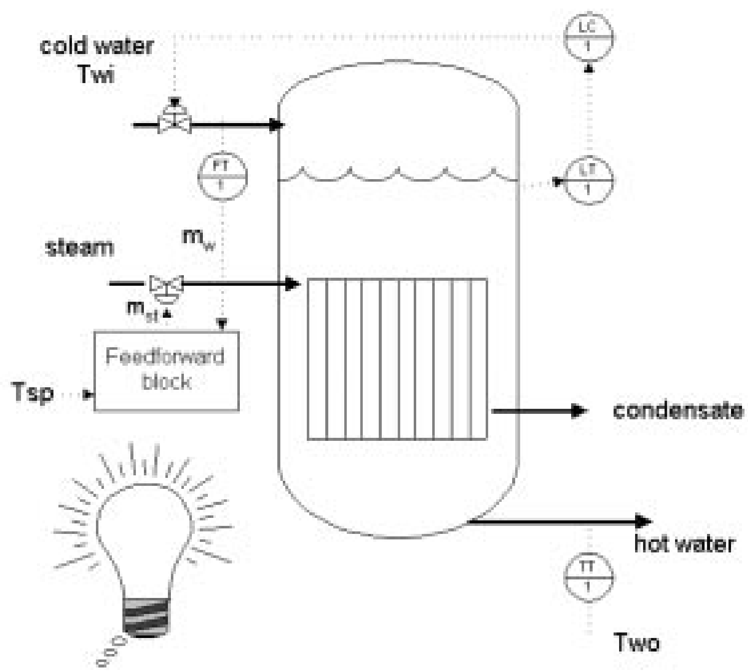
Manipulated Input steam flow rate(m_{st})

◇ **APPROACH 1 :** FEEDFORWARD CONTROL

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

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

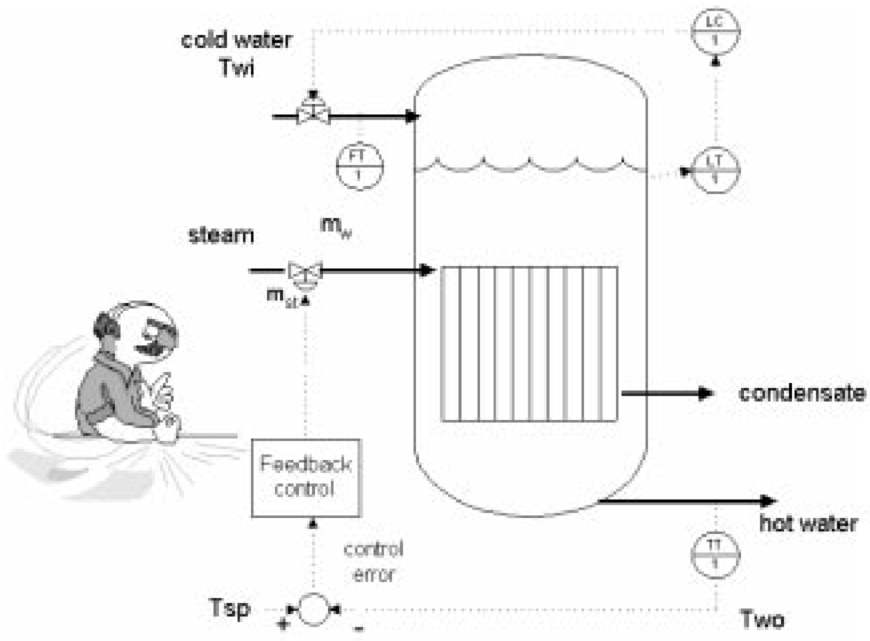
- Apply m_{st}.



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

◇ **APPROACH 2 :** FEEDBACK CONTROL

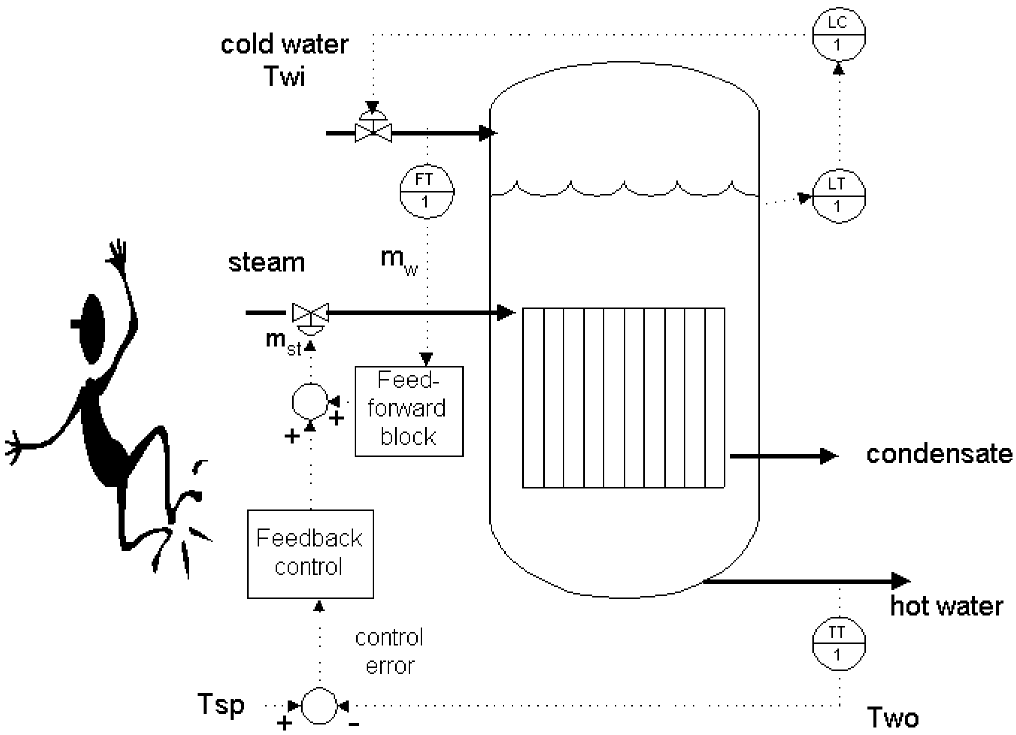
- Measure T_{wo}
- Compare with T_{sp}
- Take approriate action to elimiate the observed error.



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 :** FEEDFOWARD-FEEDBACK CONTROL

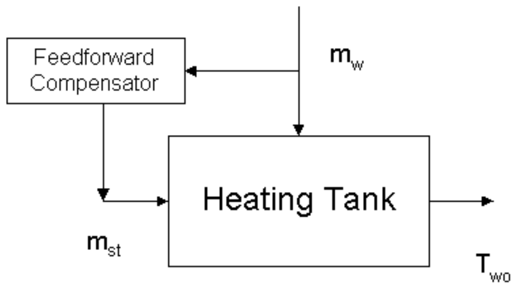
- Apply m_{st} from the feedforward block to the process.
- Provide additional corrective signal through feedback control when there is control error.



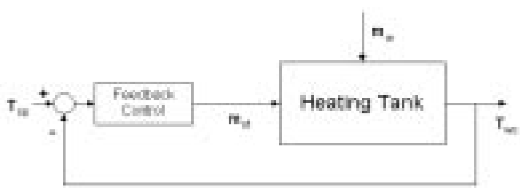
Better control performance can be expected than with feedback or feedforward-only control.

Block Diagram Representations

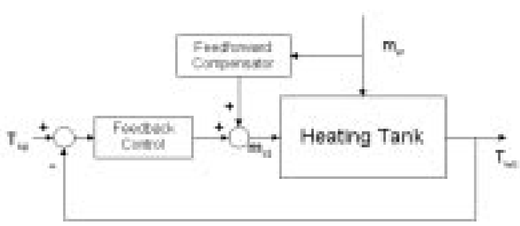
Feedforward Control



Feedback Control

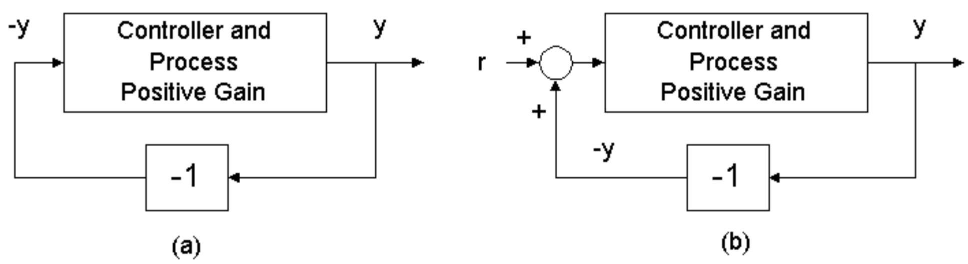


Feedforward-Feedback Control



1.2 MOTIVATION- WHY(NEGATIVE) FEEDBACK CONTROL ?

Some Comments on Negative Feedback



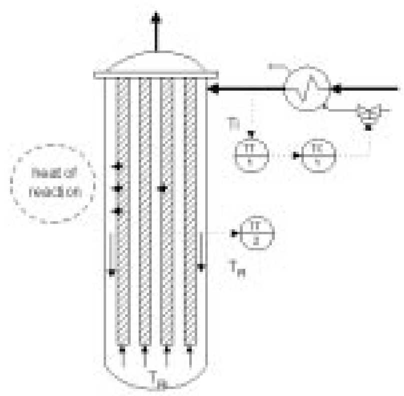
- In (a), as y deviates from zero, it is pulled back toward zero. Hence, negative feedback has self-stabilizing tendency.
- If an external r is put as in (b), y will tend to r.
- When the positive signal is fed back (positive feedback), it adds to itself and will tend to diverge.

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 manulally 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

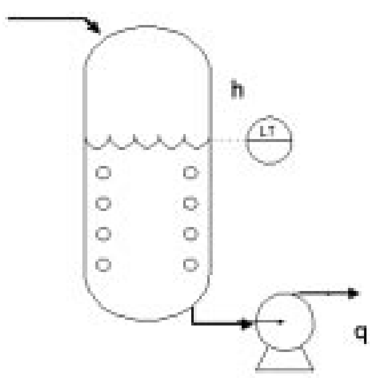
(a) When T_i is perturbed to increase, T_{Ri} is increased.

(b) This accelerates reaction rate and induces more heat of reaction.

(c) This again increases T_{Ri} and boosts up (b).

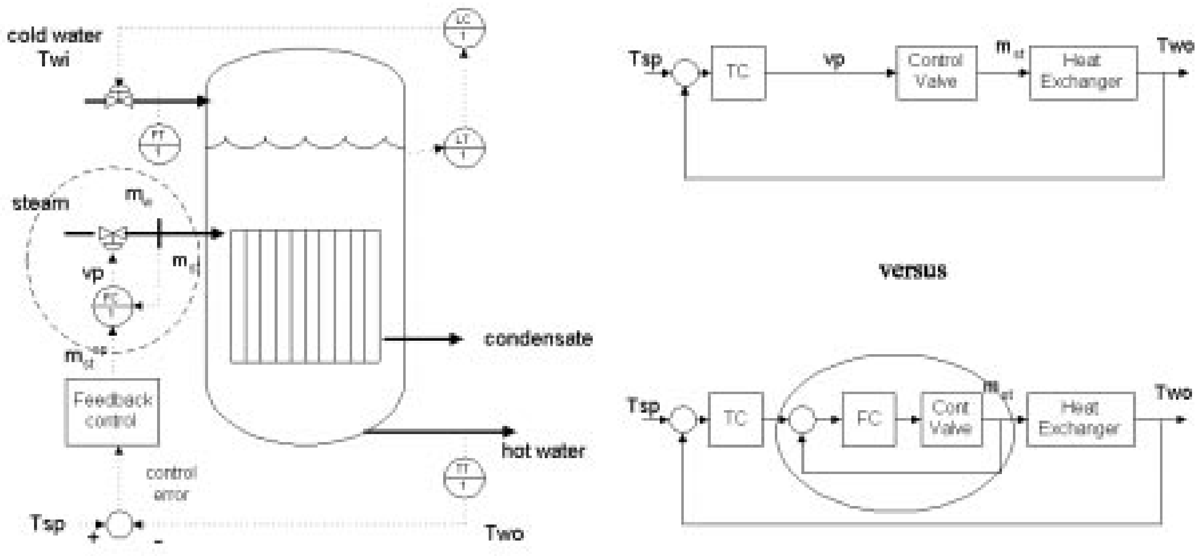
Positive feedback path exists between T_R and T_{Ri}.

- 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 manipluate 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.