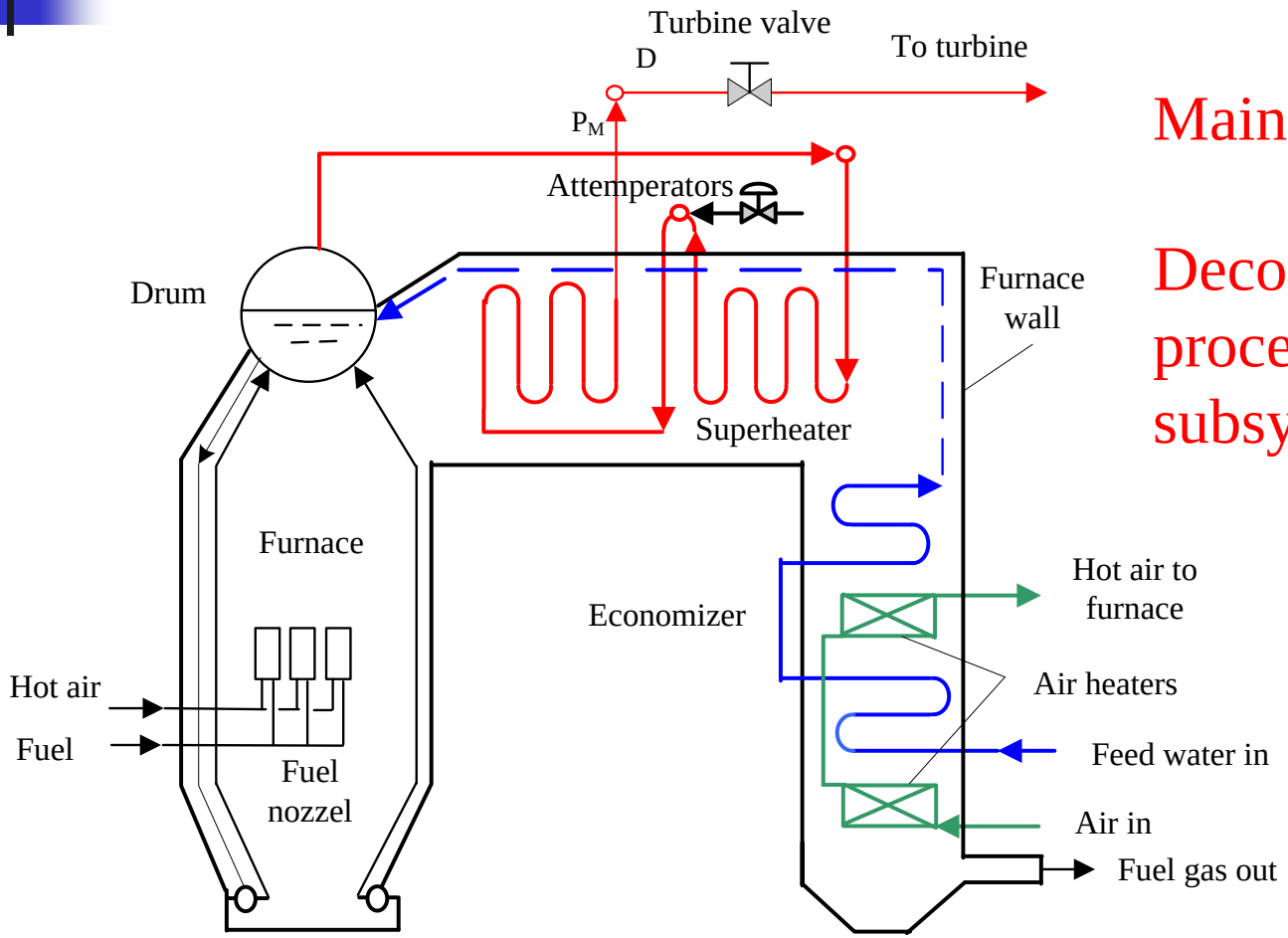
Boiler Control
(Instrumentation & Process Automation)

By:

Brajesh Singh
Technical Officer (Instrumentation Engg.)
National Sugar Institute
Kanpur, India

Contents

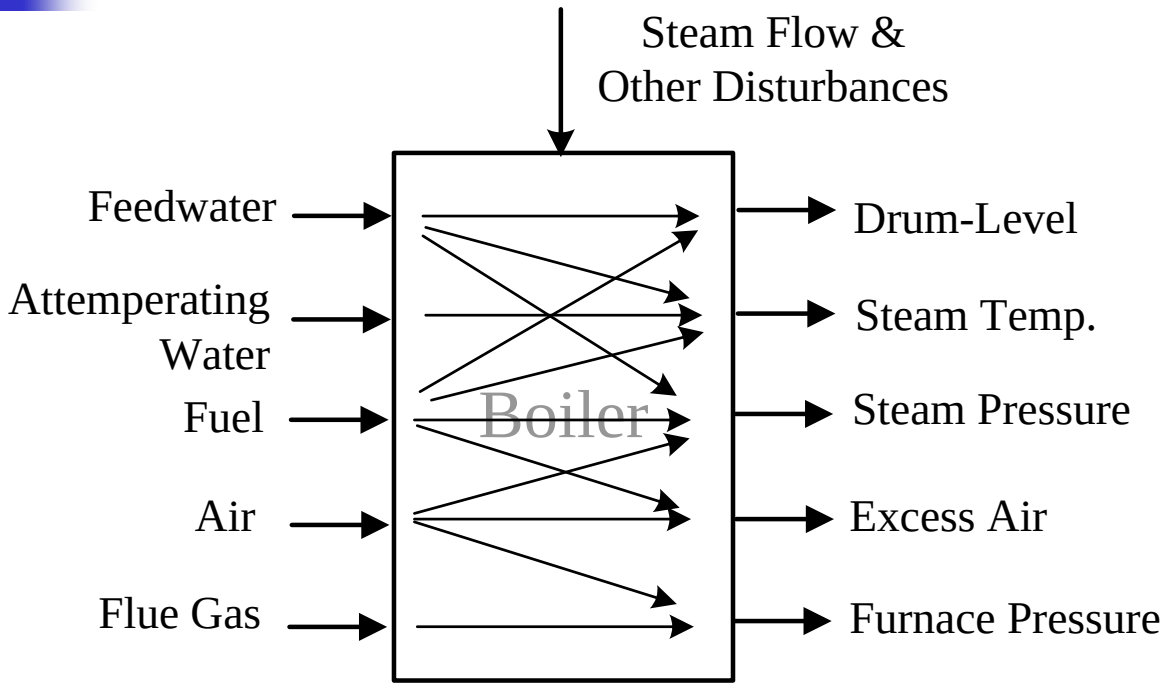
Simplified Process Diagram of a Boiler



Main equipments ?

Decompose the process into several subsystems ?

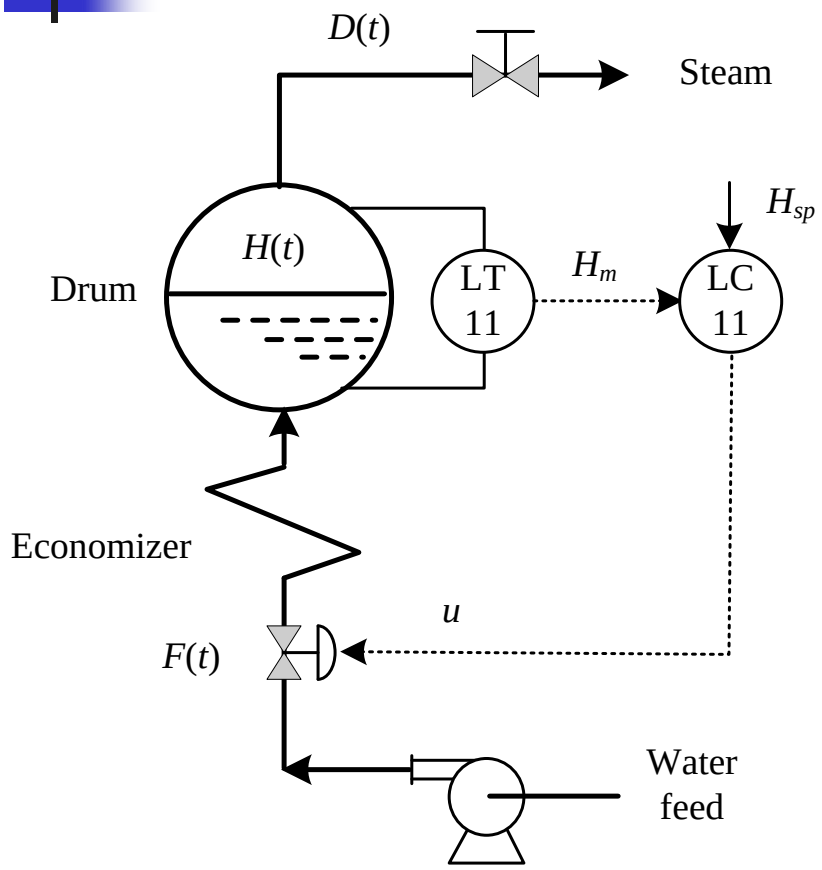
Boiler Control Problem



Select the best pairing of MVs & CVs ?

System decomposition: (1) drum-level control;
(2) combustion control; (3) steam-temperature control.

Drum-level Control Problem

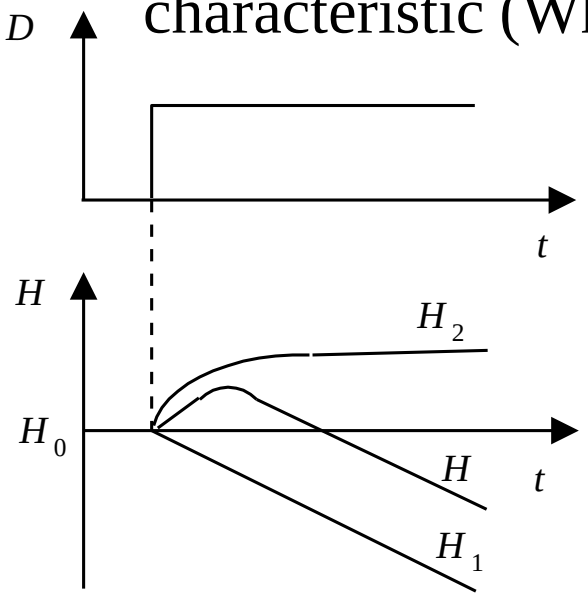


- Controlled variable: drum level, in $H(s)$
- Manipulated variable: feedwater flow, in $F(s)$
- Main disturbances: Steam flow, in $D(s)$

Please explain the reason why it is a difficult problem

Drum-level Characteristics

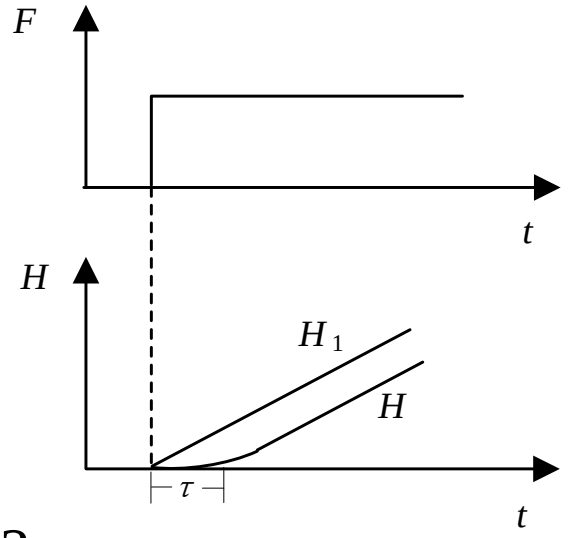
Disturbance path characteristic (Why?)



$$\frac{H(s)}{D(s)} = -\frac{K_1}{s} + \frac{K_2}{T_2 s + 1}$$

Models ?

Control path characteristic (Why?)



$$\frac{H(s)}{F(s)} = \frac{K_0}{s} e^{-\tau s}$$

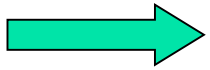
Non-minimum phase Characteristics

$$\frac{H(s)}{D(s)} = -\frac{K_1}{s} + \frac{K_2}{T_2 s + 1}$$

$$\frac{H(s)}{D(s)} = \frac{(K_2 - K_1 T_2)s - K_1}{s(T_2 s + 1)} = \frac{-K_1(-T_0 s + 1)}{s(T_2 s + 1)}, \quad T_0 = \frac{K_2}{K_1} - T_2$$

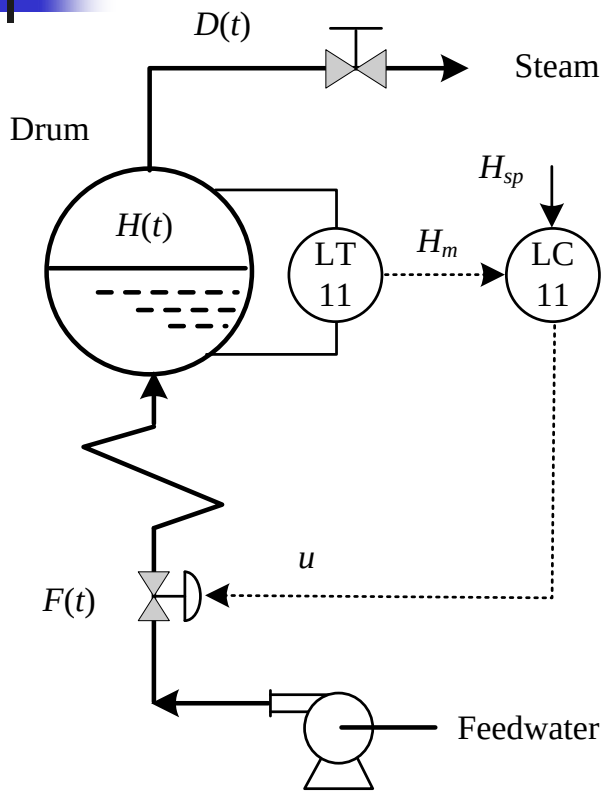
There will be a zero in right side of the complex plane if

$$T_0 = \frac{K_2}{K_1} - T_2 > 0$$

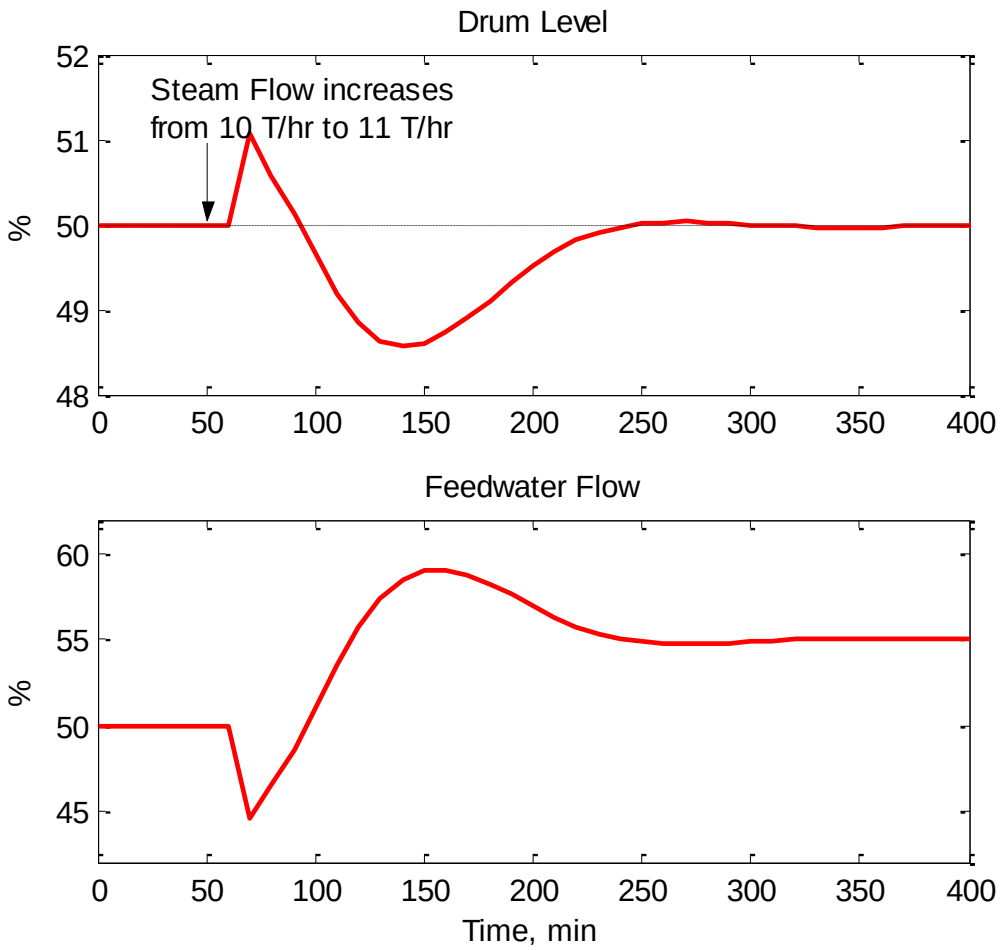


The process will be called "non-minimum phase system (非最小相位系统)"

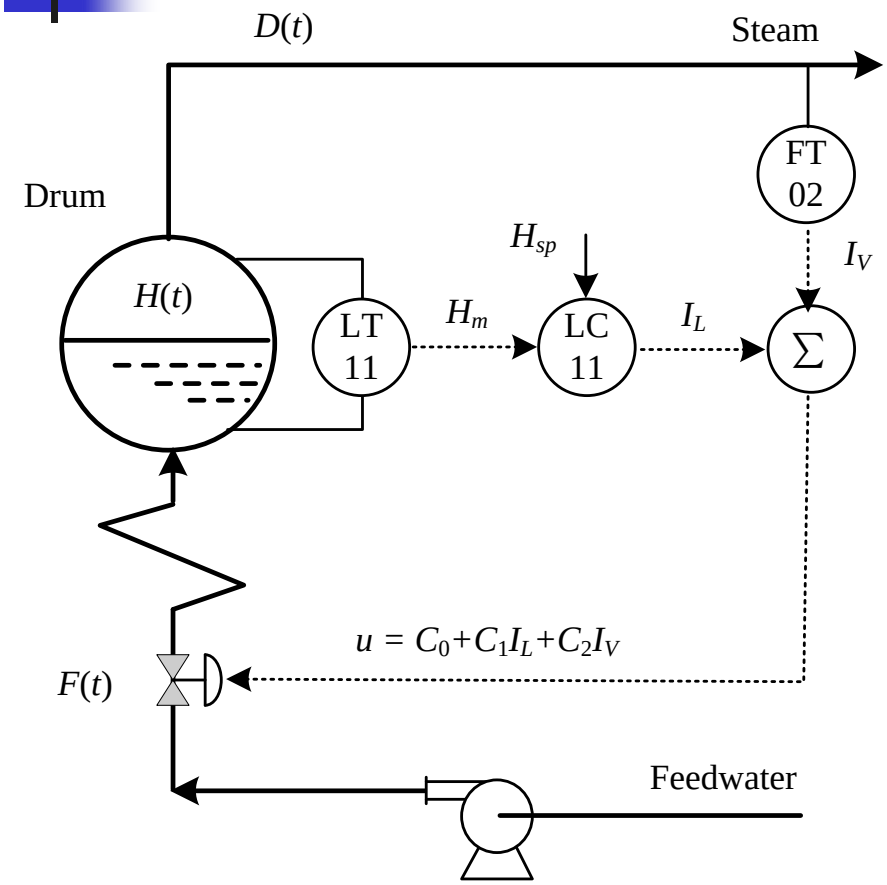
One-element Control



Simple PID Control



Two-element Control



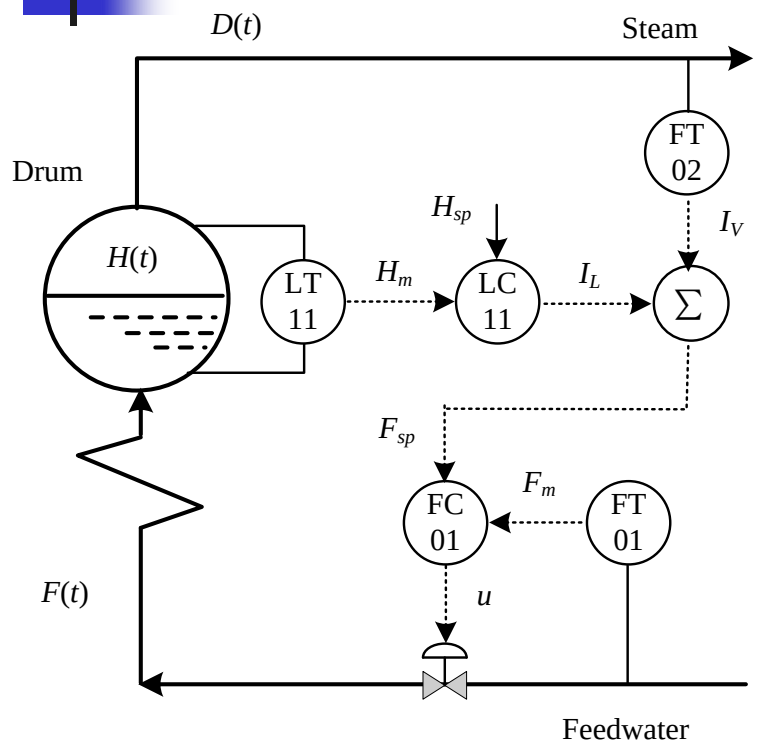
Problem discussion:

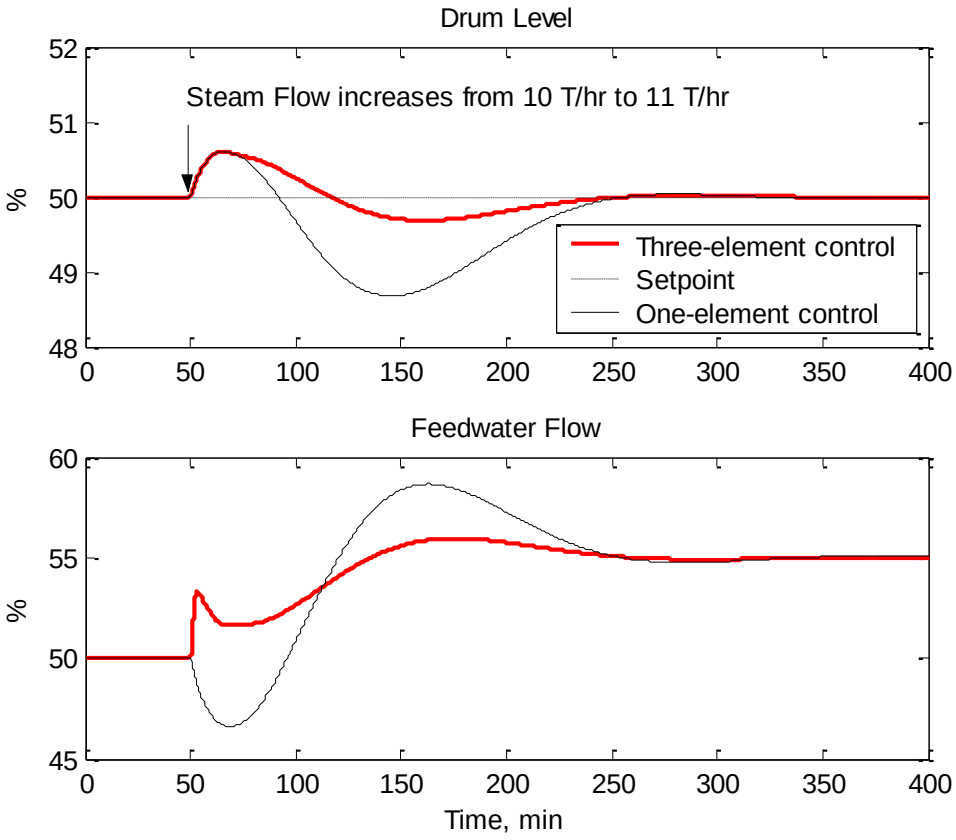
(1) Point out the kind of control methods ?

(2) Obtain control diagram of the scheme.

(3) Select the controller action, the symbol and the value of C_2, if the valve is a fail-open valve and C_1=1.

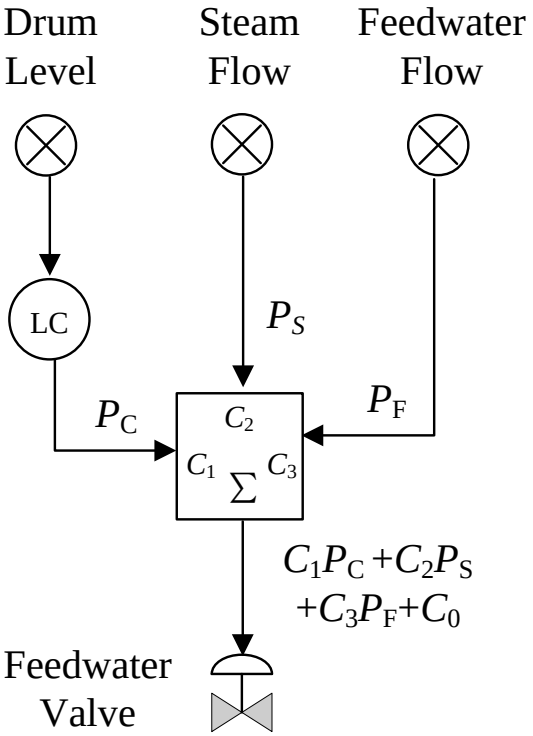
Three-element Control

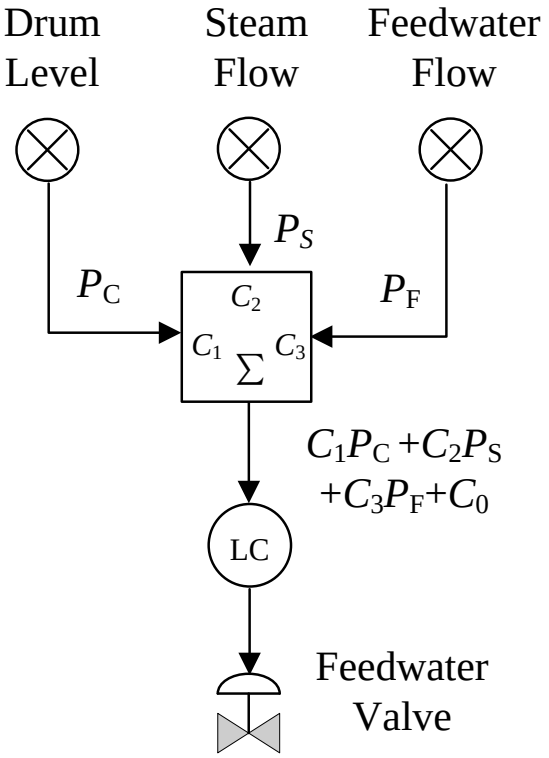




Control Diagram ?

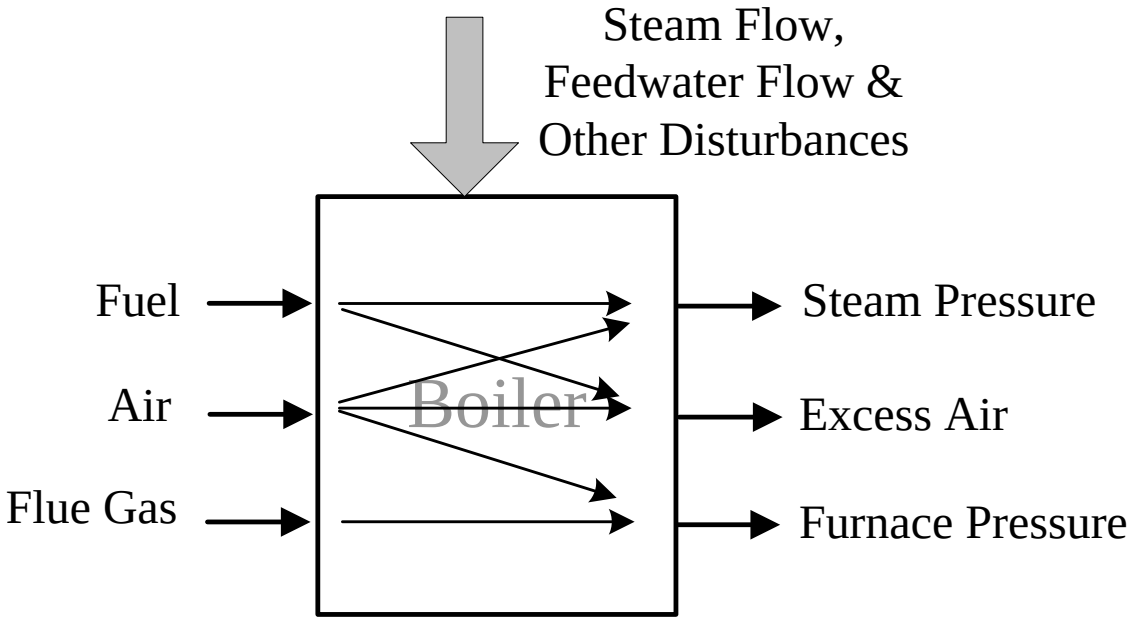
Two Simplified Connections of Three-element Systems





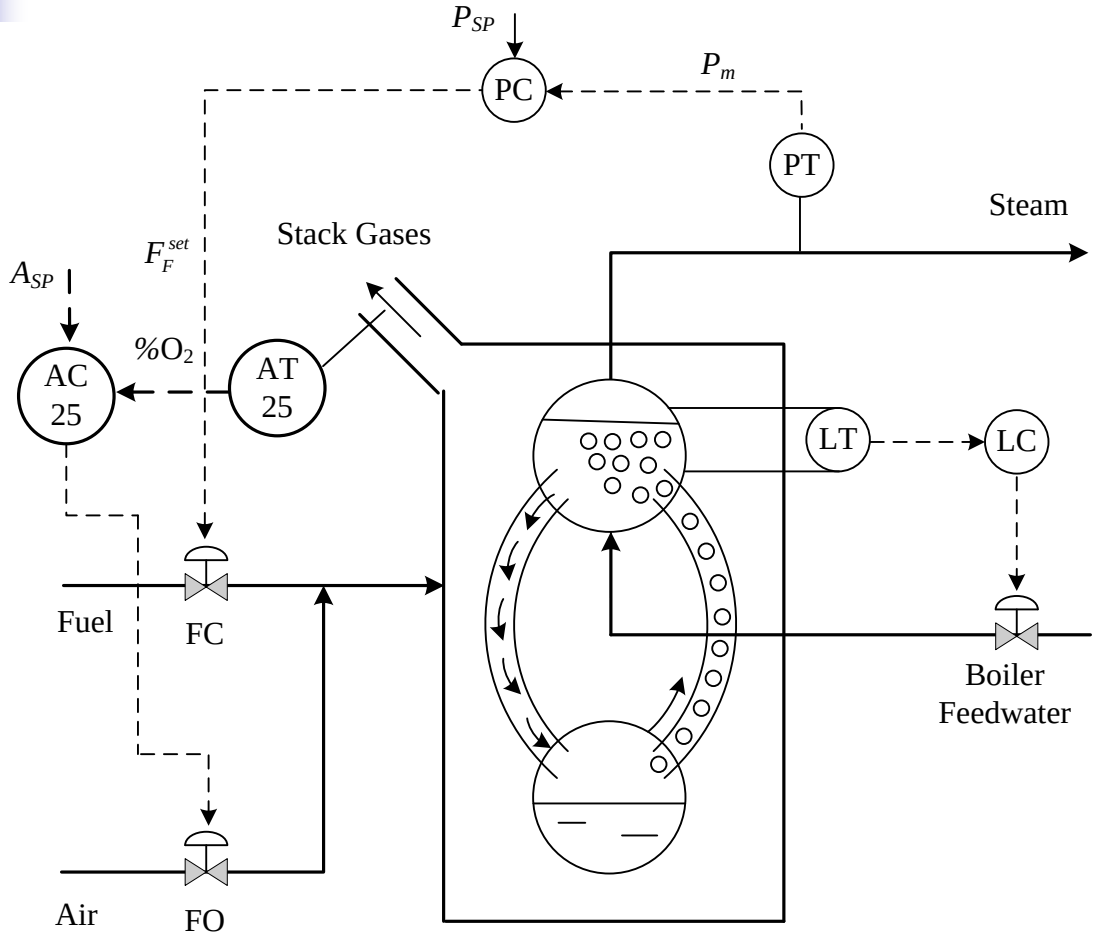
Which differences between two connections ?

Combustion Control Problem



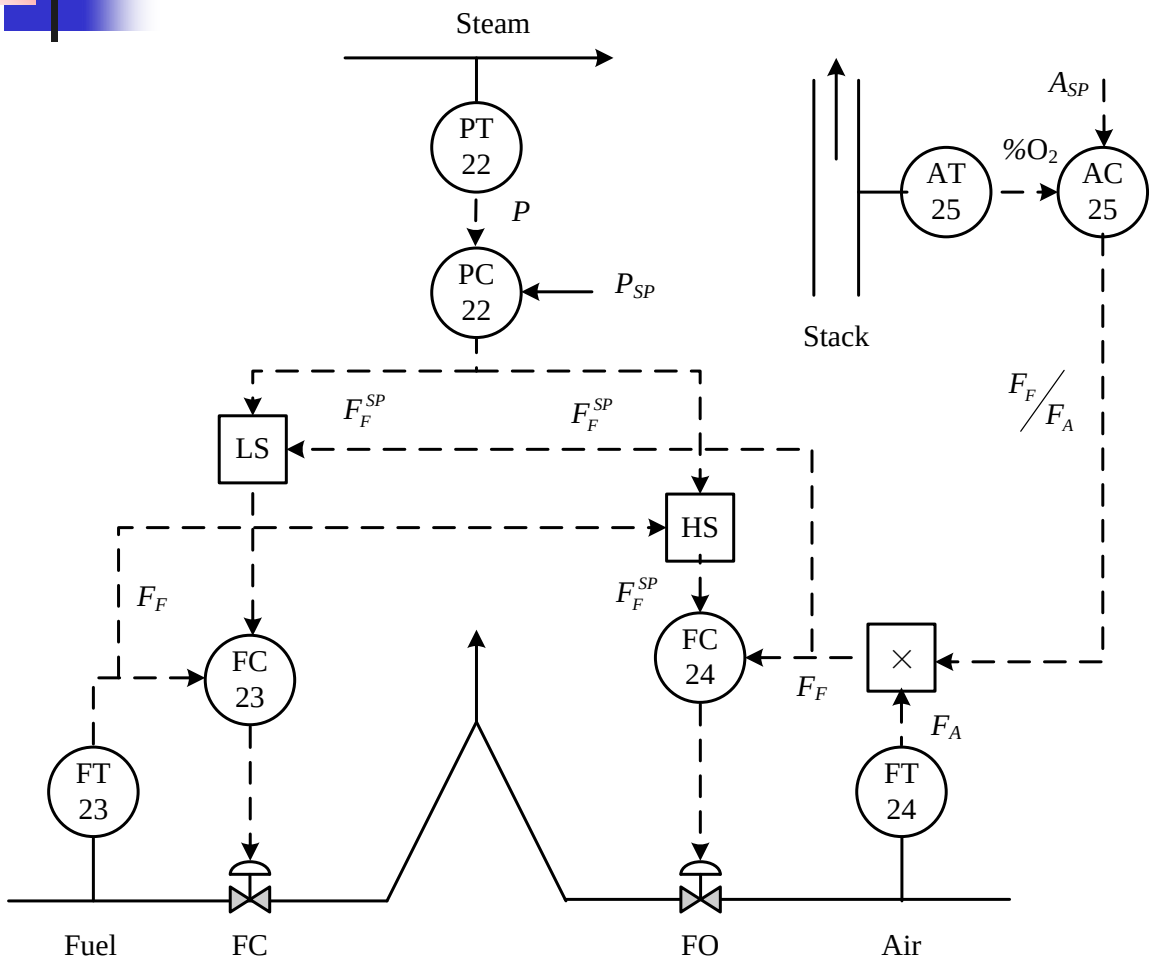
MVs and CVs Pairings: Flue gas →Furnace pressure, Air → Excess Air (O_2% in flue gas), Fuel → Steam pressure

Simple Control Scheme for Combustion Control



Existing main problem ?

Cross-limiting Air/Fuel Ratio Combustion Control



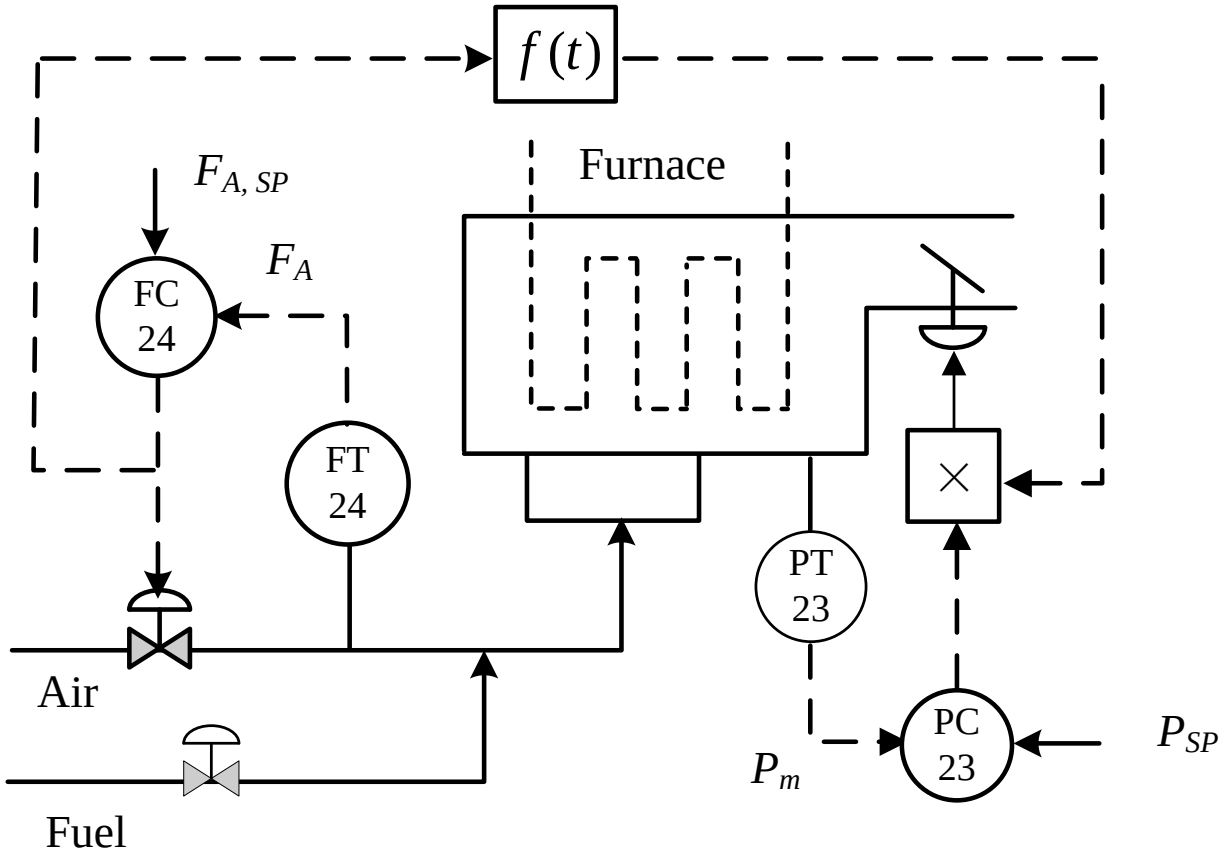
Analyze the control scheme

Advantage:

(1) Decoupling design

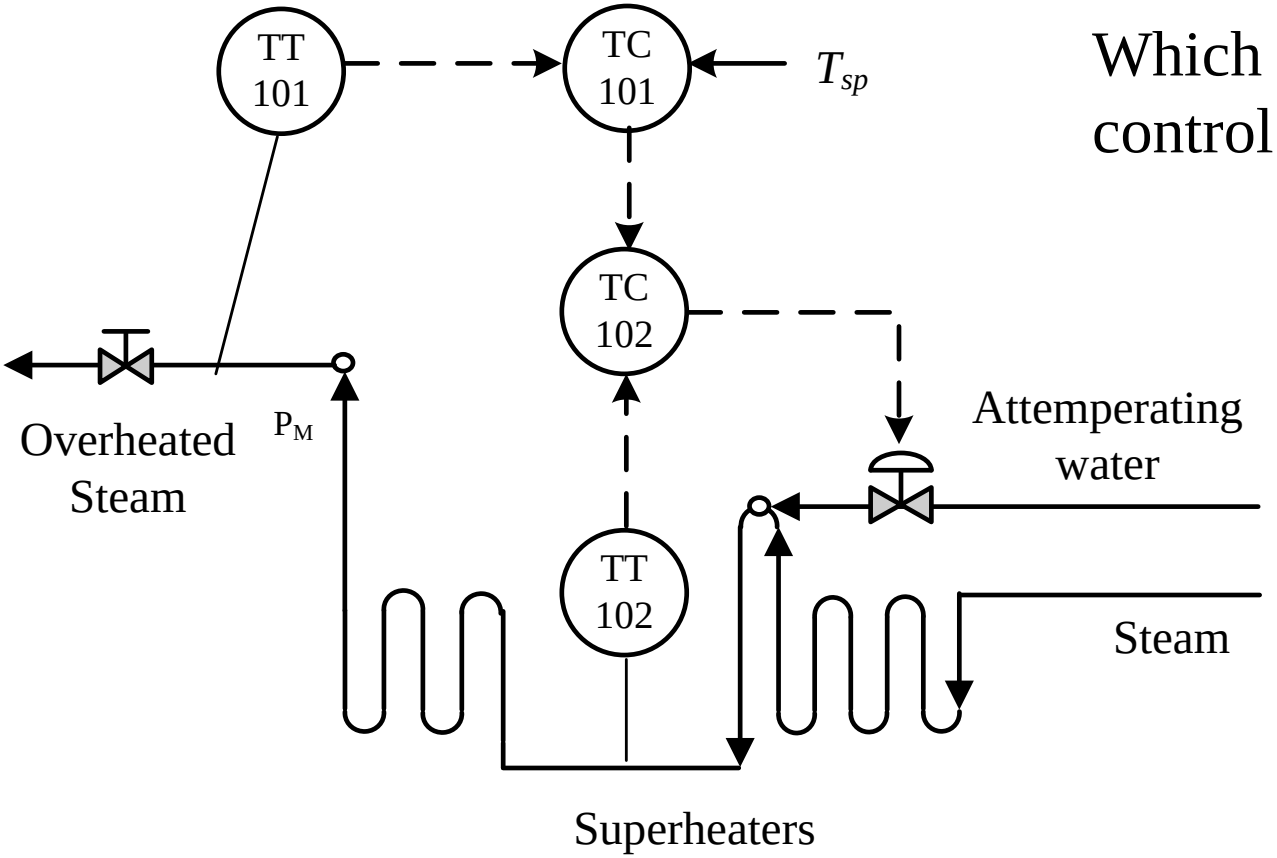
(2) Protect against excess of fuel under all conditions

Feedforward/Feedback Control for Furnace Pressure



Analyze its design principle

Steam-temperature Control Scheme



Which kind of control methods ?