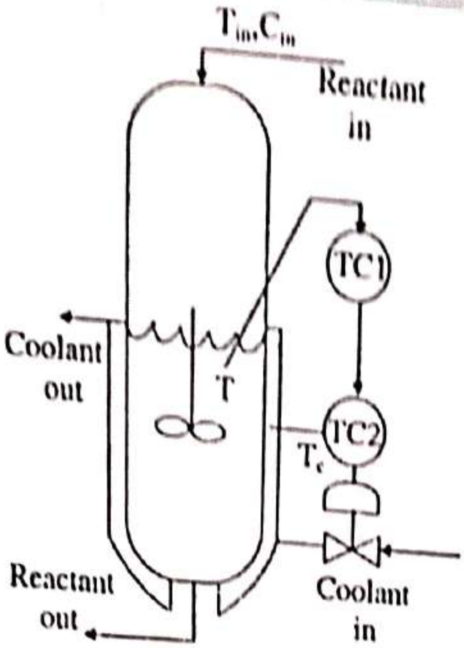
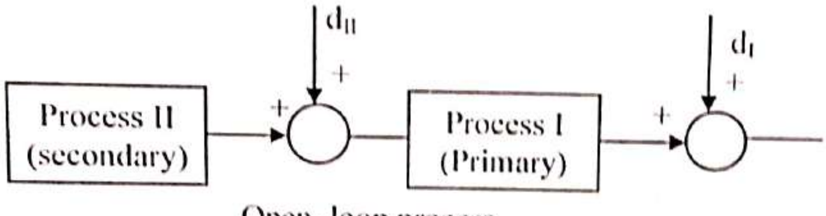


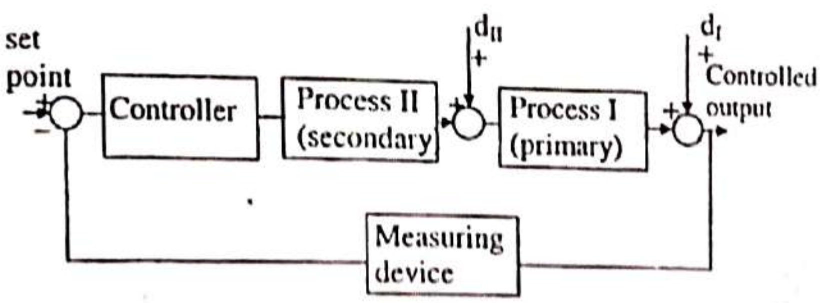
Cascaded control scheme on a CSTR

- The figure shown below the open loop block diagram representation of the jacketed CSTR system shown in figure above. For the CSTR, Process I is the reaction in the tank and its temperature T is the primary variable to be controlled. Process II is the jacket around CSTR and its output T_c is the secondary variable which affects Process I, and consequently T. The secondary process has an output 'which we are not interested in controlling but which affects the output we want to control.



Open-loop process

- For the jacketed CSTR; block diagram representation of simple feedback control loop and cascade control loop is shown in figures.



For above block diagrams

G_{c1} — Primary controller

G_{c2} - Secondary controller

G_{p1} - Primary process

G_{p2} - Secondary process

G_{l1} and G_{m1} - Measuring device

G_{l1} and G_{l2} - Disturbance gains

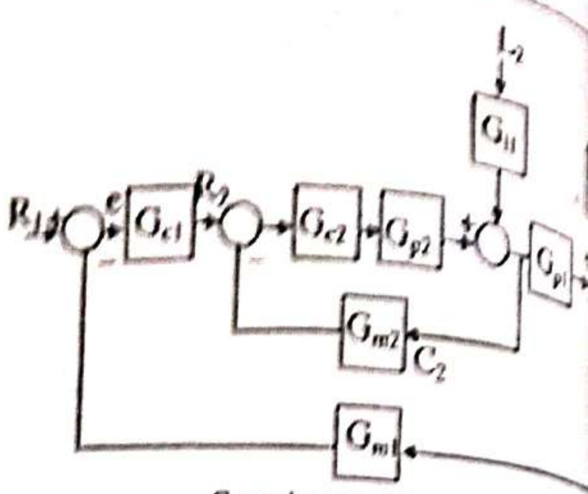
L_1 and L_2 - Disturbance inputs

R_1 - Set point of primary loop

R_2 - Set point of secondary loop

C_1 - Primary controlled variable

C_2 - Secondary variable



Cascade control loop

From the block diagram, we can calculate the transfer function by using the Mason's gain formula, the transfer function

$$\frac{Y}{X} = \frac{1}{\Delta}\sum_{k=1}^{N} P_k \Delta_k$$

Where Y is the output variable, and X is the input variable.

N= total number of forward path

P_k = path gain of k^{th} forward path

Δ = 1- (sum of loop gains of all individual loops) + (sum of gain products of all possible combinations of two non-touching loops) —(sum of gain products of all possible combinations of three non-touching loops) +...

Δ_k = the value of Δ for that part of the graph not touching the kth forward path

$$\frac{C_2}{R_2} = \frac{G_{c2}G_{p2}}{1+G_{c2}G_{p2}G_{m2}}$$

$$\left(\frac{C_2}{R_2}\right)_{cascade} = \frac{G_{c1}G_{c2}G_{p1}G_{p2}}{1+G_{p2}G_{m2}G_{c2}+G_{p1}G_{p2}G_{c1}G_{c2}G_{m1}}$$

$$\left(\frac{C_1}{R_1}\right)_{\substack{simple\\feedback}} = \frac{G_{c1}G_{c2}G_{p1}G_{p2}}{1+G_{p1}G_{p2}G_{c1}G_{m1}}$$

$$G_{c2} = 1,\ G_{m2} = 0$$

Assuming that major disturbances enter the secondary loop:

$$\left(\frac{c}{L_2}\right)_{cascade} = \frac{-G_{l2}G_{p1}G_{m1}}{1+G_{p1}G_{p2}G_{c1}G_{m1}}$$

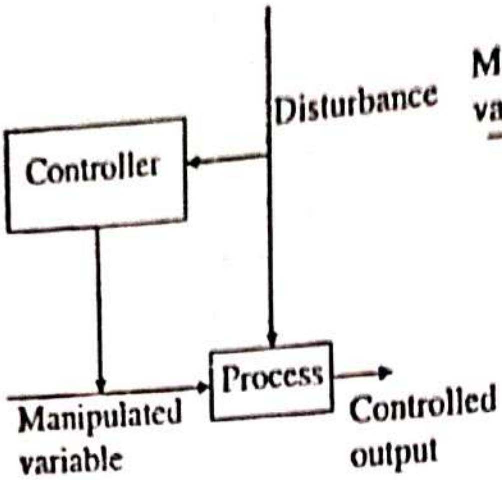
- These expression can be used to analyse the effect of adding a secondary loop to the basic feedback loop in terms of performance, such as steady state error and speed of response.

...rules for designing and tuning cascade control:

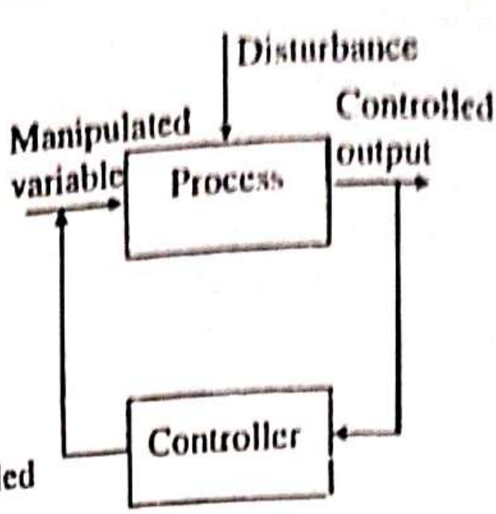
- Let the secondary loop he the input point of the most serious disturbance. Secondary loop should reduce the effect of one or more disturbances.
- Make the secondary loop fast by including only minor lags of complete control system. The secondary loop must be at least 3 times faster than the master loop.
- Choose a secondary variable which will provide stable performance with narrow proportional band. The correct sequence of operations while tuning the controllers that work in cascade is:
- Set the primary controller to manual Tune the secondary controller
- Put the secondary controller in automatic mode
- Tune the primary controller.

...forward Control

- The feedback control loops can never achieve perfect control. It is difficult for the conventional loops to keep the process output continuously at the desired set point value in the presence of load or set point changes. This is because a feedback controller reacts only after it has detected a deviation in the value of the output from the desired set point. Unlike feedback systems, a feed forward control configuration measures the disturbance directly and takes control action to eliminate its impact on the process output. Feed forward controllers have the theoretical potential for perfect control.
- In teed forward control strategy, information concerning one or more conditions that might disturb the control variable is converted into corrective action to minimize deviation of controlled variable. The signal which have the potential to upset the process are transmitted to the controller. The controller makes appropriate computation on these signals, and calculates new values for the manipulated signals and sends those to the find control element, therefore, the control variable remains unaffected in spite of load changes. The generalized block diagram of a feed forward control system and a feedback control system are shown in figures respectively.



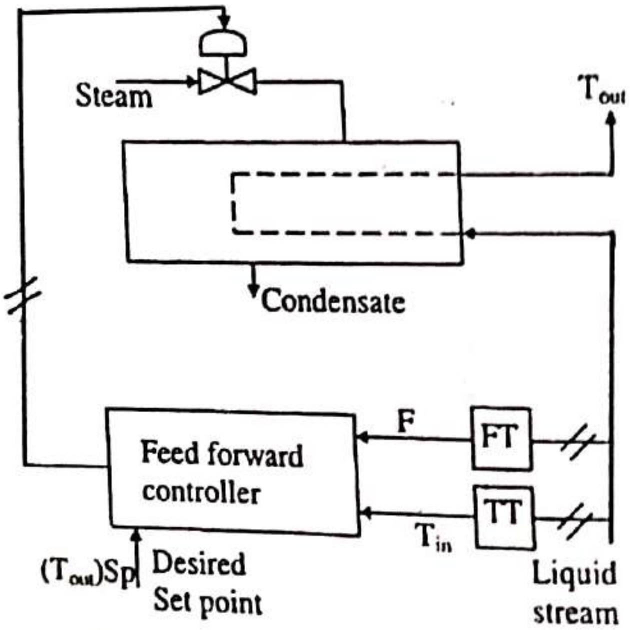
Basic block diagram
of feed forward control



Basic block diagram
of feedback control

Feed forward Control of a Heat Exchonger:

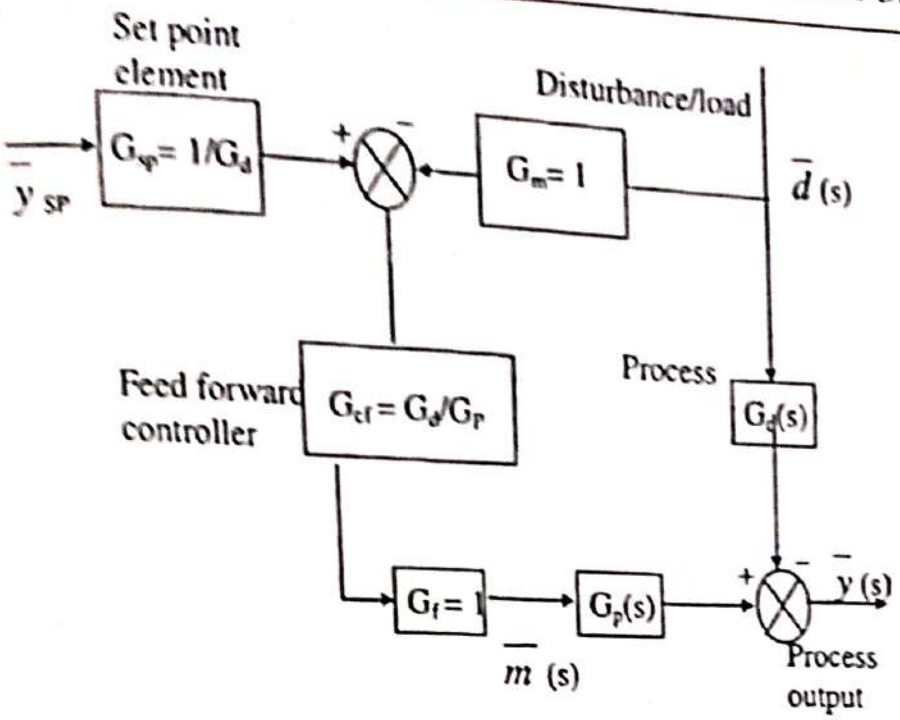
- The figure shown below describes the use of feed forward control in heat exchanger. The objecti keep the exit temperature of the liquid constant by manipulating the steam flow rate. There a principal disturbances (loads) that are measured for implementing feed forward control: liquid fl and liquid inlet temperature. Measurement of these disturbances manipulations the stream flow



Feedforward control of heat exchanger

Generalized design procedure for feed forward control:

- The block diagram of feed forward control system is shown in the figure below.



From the figure we can write the process equation as

$$\bar{y}(s) = G_p(s)\bar{m}(s) + G_d(s)\bar{d}(s)$$

If $\bar{y}_{sp}(s)$ be the desired set point for the process output. Then, we can write the above equation as

By interchanging terms in the above equation, we have:

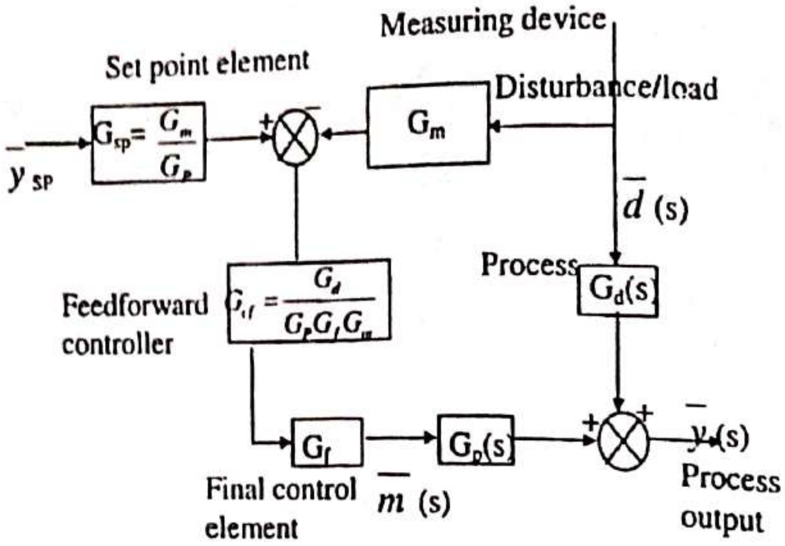
$$\bar{m}(s) = \left[\frac{1}{G_d}\bar{y}_{sp}(s) - \bar{d}(s)\right]\frac{G_d(s)}{G_p(s)}$$

From the above figure

$$G_{cf}(s) = \frac{G_d(s)}{G_p(s)}$$ = transfer function of the main feed forward controller.

$$G_{SP}(s) = \frac{1}{G_d(s)}$$ = transfer function of the set point element.

- From the equations, we came to know that fedd forward controller is different from the conventional feedback controllers.
- A more general feed forward control system which includes a final control element and a sensor that measure the disturbance is shown in the figure below.



- From figure,

  $\bar{y} = [G_p G_f G_{cf} G_{SP}]\bar{y}_{SP} + [G_d - G_p G_f G_{cf} G_m]\bar{d}$

  In this control action we have to make the disturbance d = 0

  Therefore, $G_d - G_p G_f G_{cf} G_m = 0$

  $$= G_{cf} = \frac{G_d}{G_p G_f G_m}$$

  We know, $G_{SP} G_{cf} G_p = 1 \Rightarrow \frac{1}{G_f G_p G_{cf}} s$

  By substituting the value of G_{cf} from equations

  $$G_{SP} = \frac{G_m}{G_d}$$

Ratio Control:

- Ratio control is used to ensure that two or more flows are kept at a constant ratio even if the flows are changing. Ratio control is a special type of feed forward control where two disturbances are measured and held at constant ratio with each other.
- To keep a constant ratio between the feed flow-rate and the steam in the re boiler of distillation column.
- To hold the reflux ratio constant in s distillation column.
- To control the ratio of two reactants entering a reactor at a desired ratio.
- To hold the ratio of two blended streams constant, in order to maintain the composition of the blend at a desired value.
- To maintain correct air and fuel mixture for optimal combustion.