Introduction to Process control.

✓ Chemical process $\xrightarrow[\text{of}]{\text{consists}}$ reactor, heat exchanger, pumps distillation, evaporator, tank etc

✓ Objective : Raw mat. $\xrightarrow[\text{mical way}]{\text{Most econo-}}$ Desired products

Requirements.

1. safety : Primary requirement for the well-being of the people in the plant & for its continued contribution to the economic development.

   P, T, C — within allowable limits

   Ex : pressure vessel. How?

2. Production specifications : plant should produce desired quantity and quality of the pdts.

   Ex : 2000 tons of ethanol / day with 99.5 mol% purity. How?

3. Environmental regulations : Federal and state laws

   Ex (maintain) : conc. of chemicals (effluent)
   SO_2 ejected to the atmosphere
   waste water rejected to the river

   How?

Requirements (contd..)

4. operational constraints: Equipments have constraints

Ex (satisfy) :- Distillation should not be flooded

- catalytic reactor T should not exceed upper limit (catalyst destroyed).
- Tanks should not overflow or go dry
- Pumps should maintain NPSH How?

5. Economics: Min operating cost + Max profit.

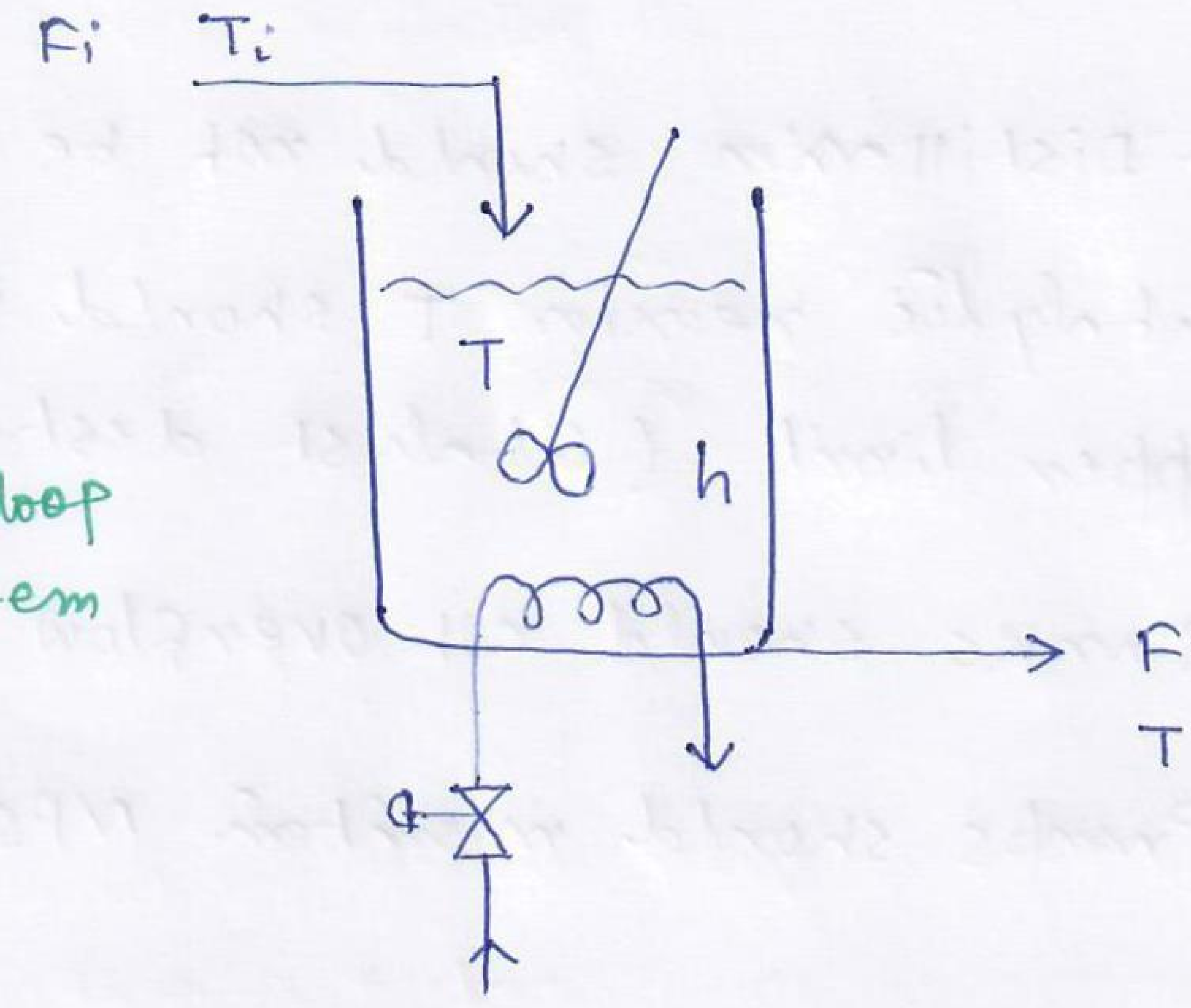
Raw mat. + Energy + capital + human labor

How?

Answer: Controller.

Controller

Ex : heating tank system.



open-loop system

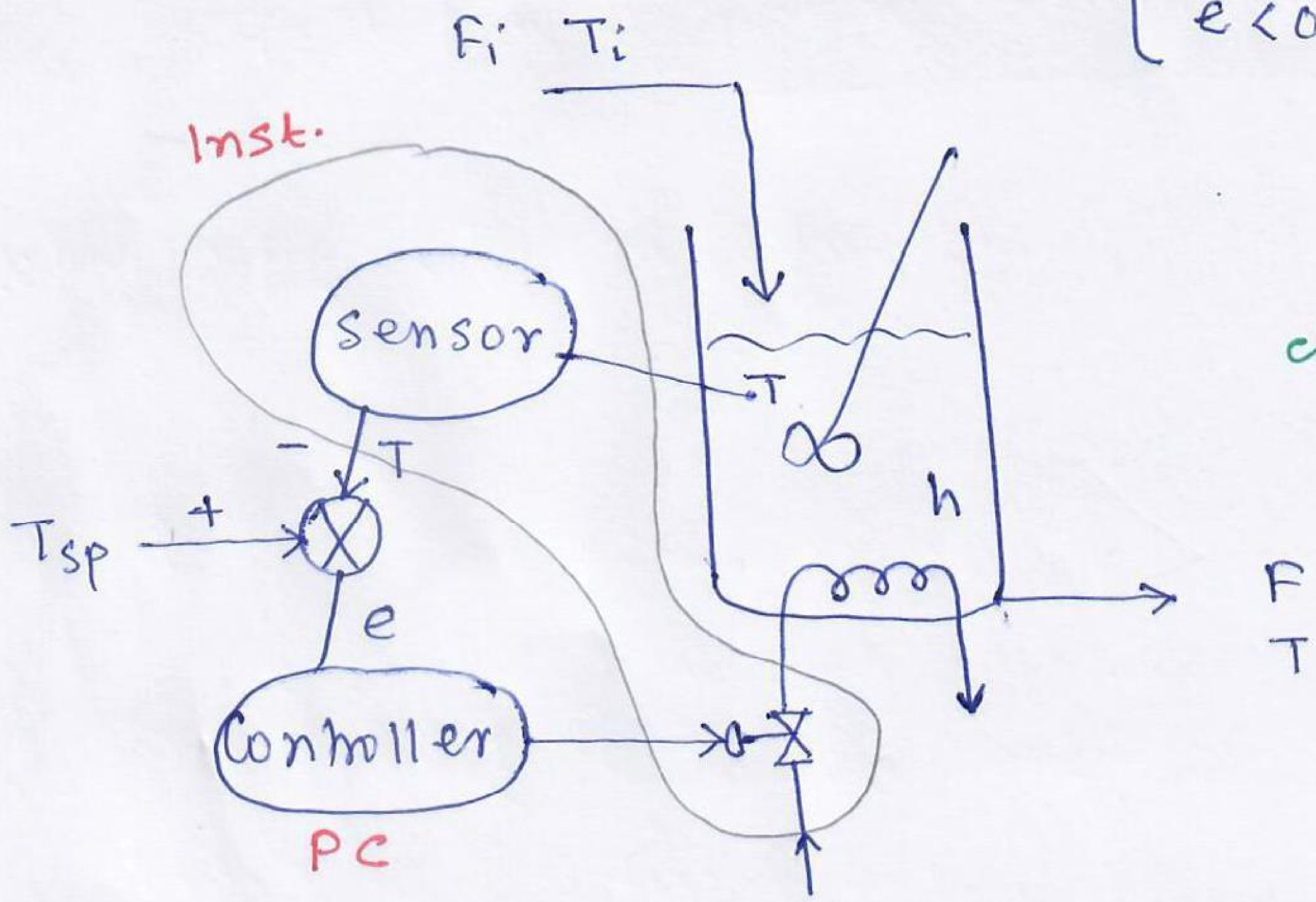
✓ Obj : $T = T_{sp}$

$h = h_{sp}$

✓ Startup ⟶ SS employ the controller

no disturbance @ no controller

✓ concept $e = T_{sp} - T$ $\begin{cases} e > 0 & T_{sp} > T & \text{more steam} \\ e < 0 & T_{sp} < T & \text{reduce steam} \end{cases}$



closed-loop system

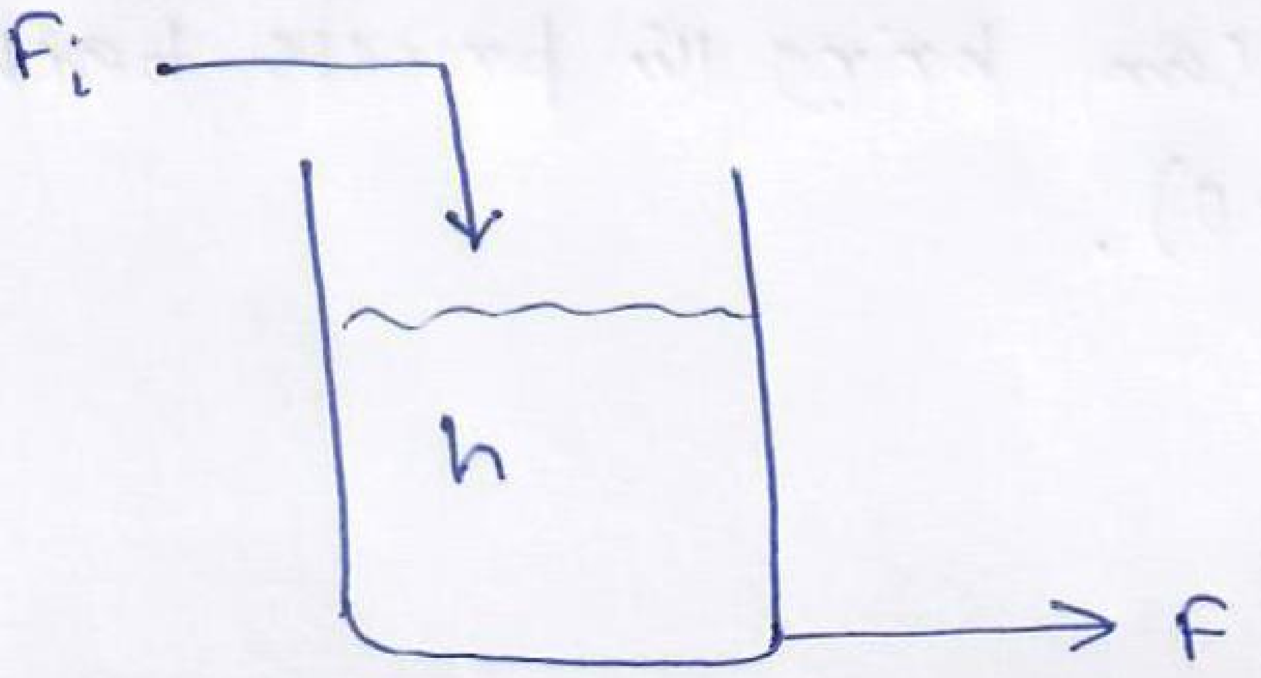
Controller (Contd..).

Why Controller?

- Suppressing the influence of external disturbances
- Ensuring the stability
- Optimizing the performance of a process.

Influence of external disturbance

Ex. Liquid tank system



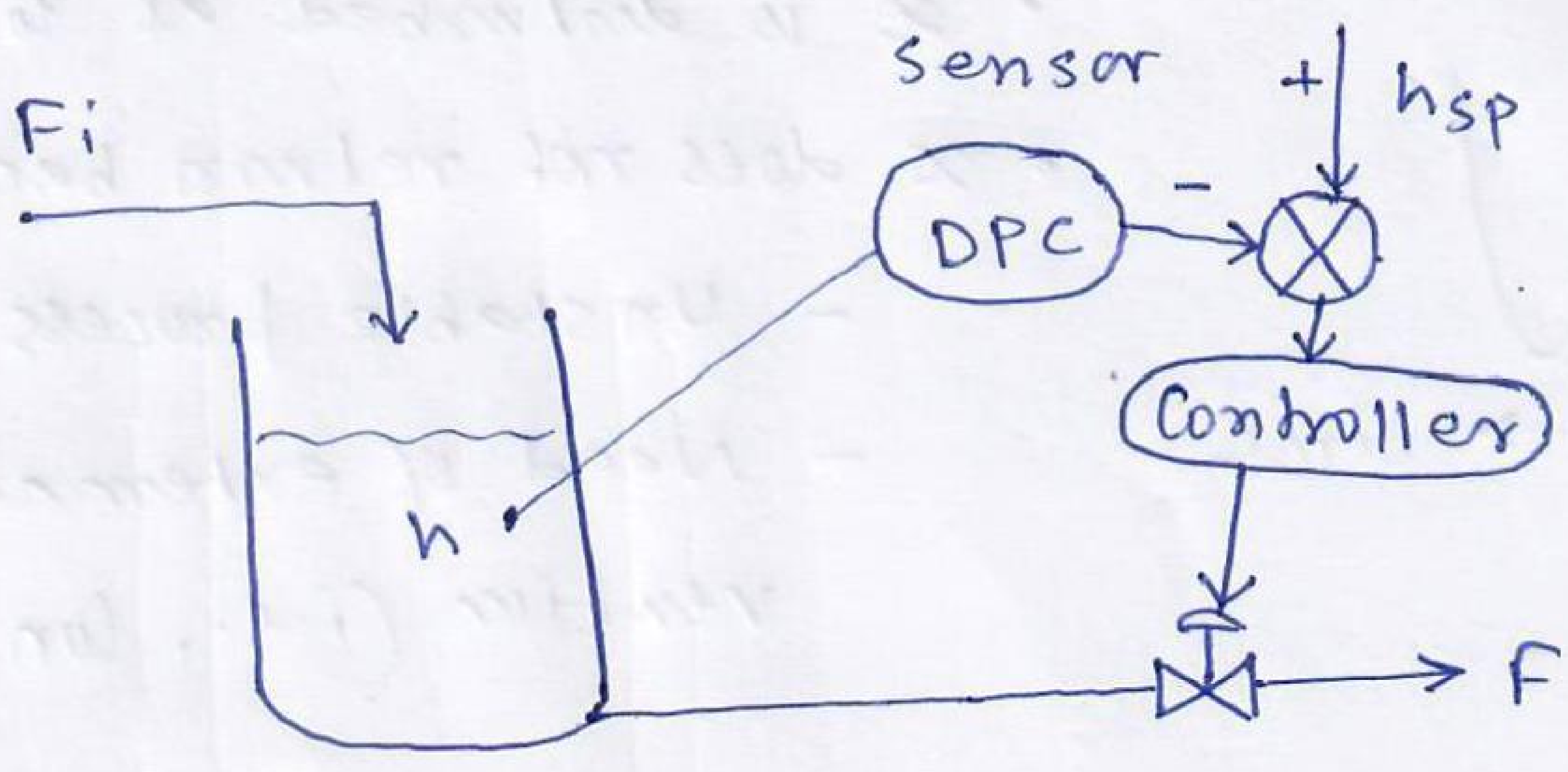
F_i, F → liq flow rates

F_i → disturbance variable

If $F_i \uparrow$ $h \uparrow$ $h_{sp} < h$

$F_i \downarrow$ $h \downarrow$ $h_{sp} > h$

Undesired



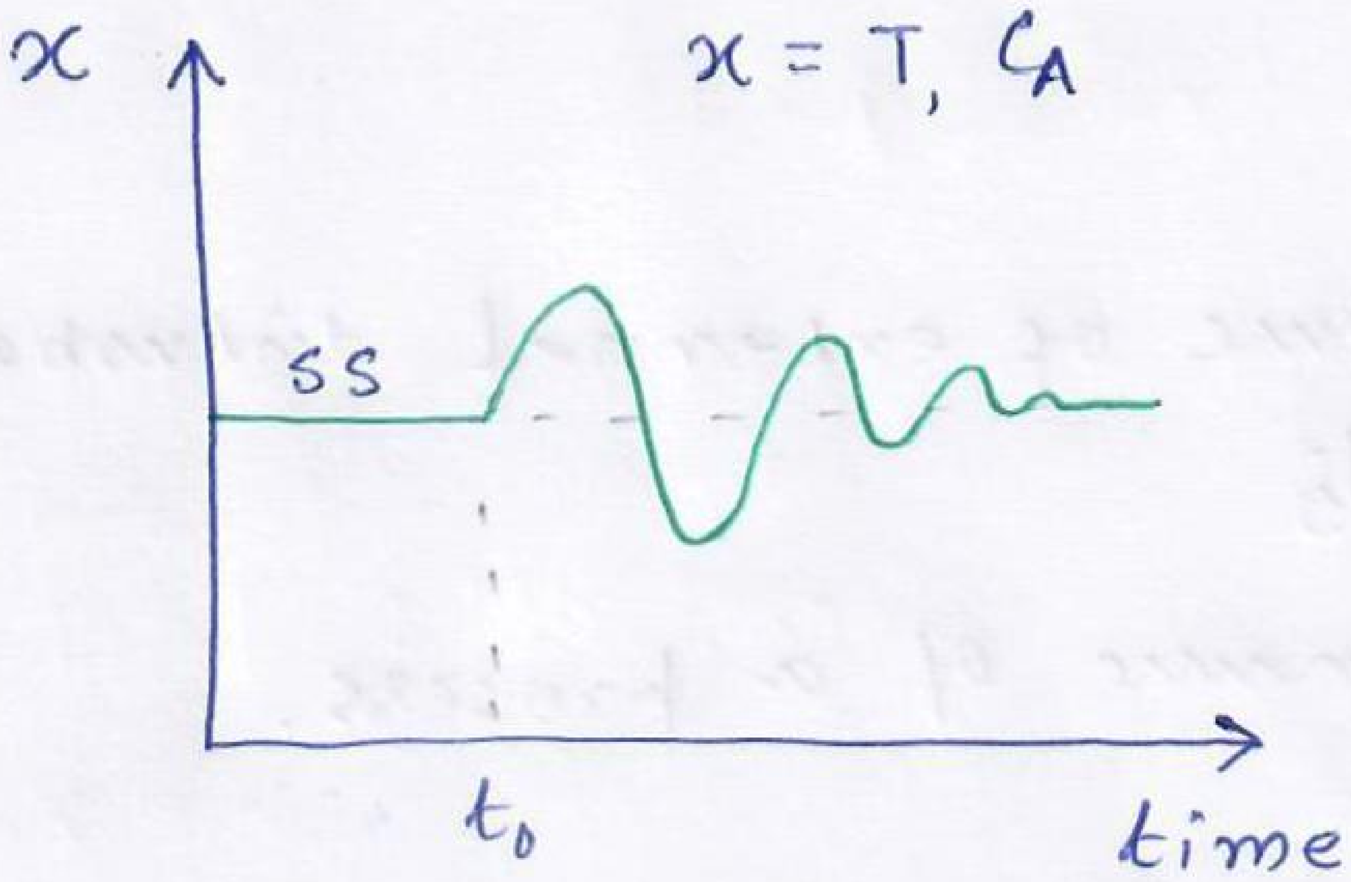
If $F_i \uparrow$ $h \uparrow$ $h_{sp} < h$ $F \uparrow$ to keep $h_{sp} = h$

$F_i \downarrow$ $h \downarrow$ $h_{sp} > h$ $F \downarrow$ to keep $h_{sp} = h$

Control action.

✓ Influence of disturbance is reduced

Ensuring stability



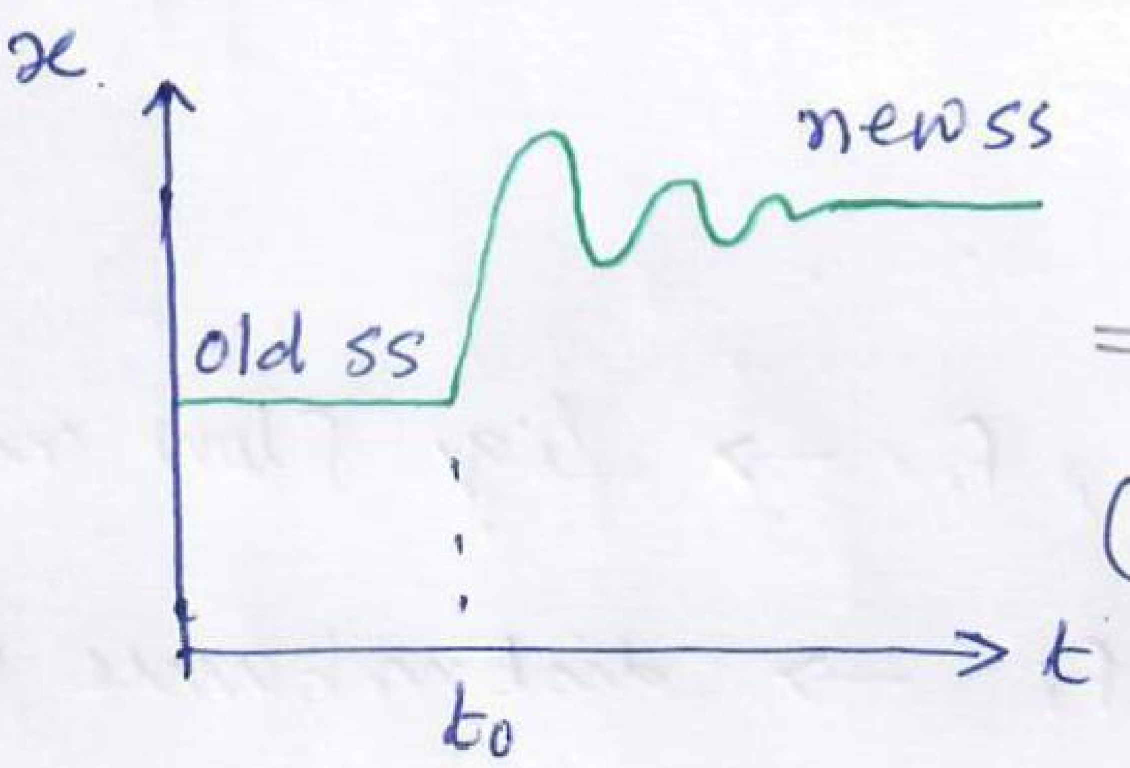
stable process

Stable process

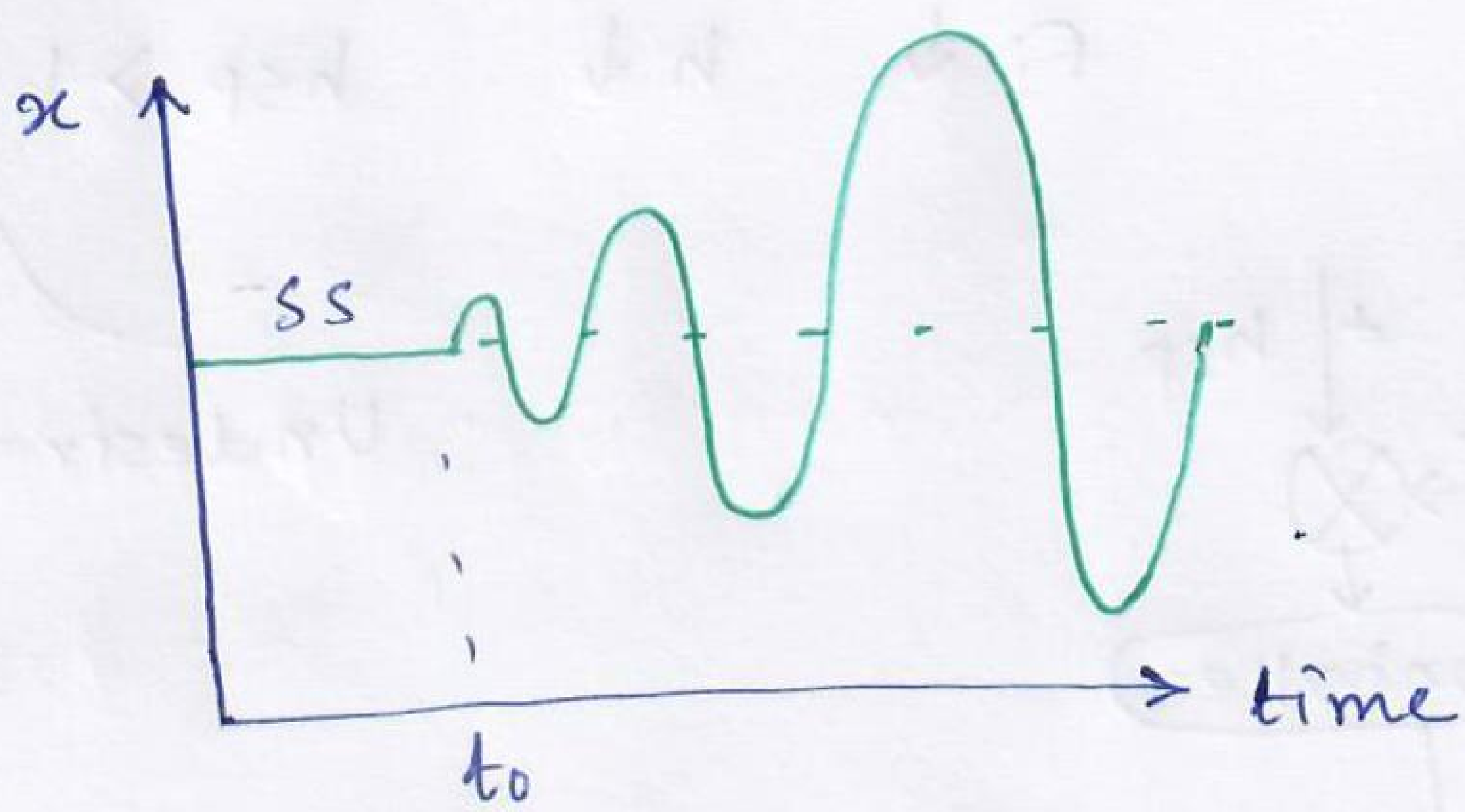
- x is disturbed at t_0
- x returns automatically to ss
  - stable / self-regulating process
  - No need of any external intervention (i.e., controller) if stability is the sole concern.

Any role of controller ?

- controller leads to reach the process to ss with a shorter time



- If x reaches a new ss ($e \neq 0$), controller can bring the process back to ss (old) ($e = 0$).



Unstable process

Unstable process

- x is disturbed at t_0
- x does not return back to ss
  - Unstable process
  - Need of external intervention (i.e., controller).

Optimizing the performance

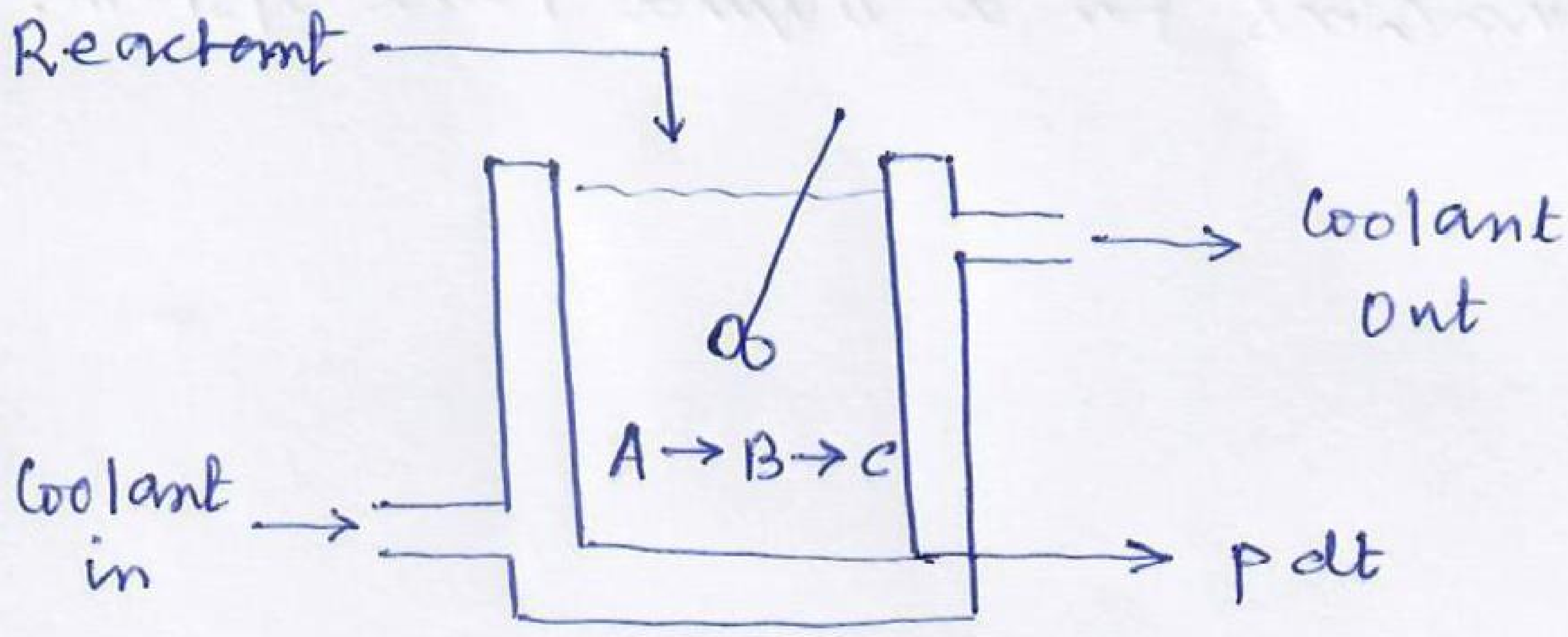
- Safety
- Production specification

} Main requirements

↓

Next goal is to make the opⁿ more profitable.

Ex. Jacketed CSTR



Consecutive EXO Reaction

$$A \longrightarrow \underset{\text{desired pdt}}{B} \longrightarrow \underset{\text{Undesired waste}}{C}$$

✓ Economic objective

$$\text{Maximize } \phi = \int_0^{t_R} [\text{revenue from the sales of pdt B} - \text{cost of raw mat (A)} - \text{other op. cost}]\, dt$$

↑ Coolant, labor, etc

t_R = run time.

Maximize profit

Questions.

1. What are the various requirements a plant must satisfy?

2. Why and when we need a controller? Discuss with examples.

3. Develop control configurations for a liquid tank system.

Controller

Why controller ?

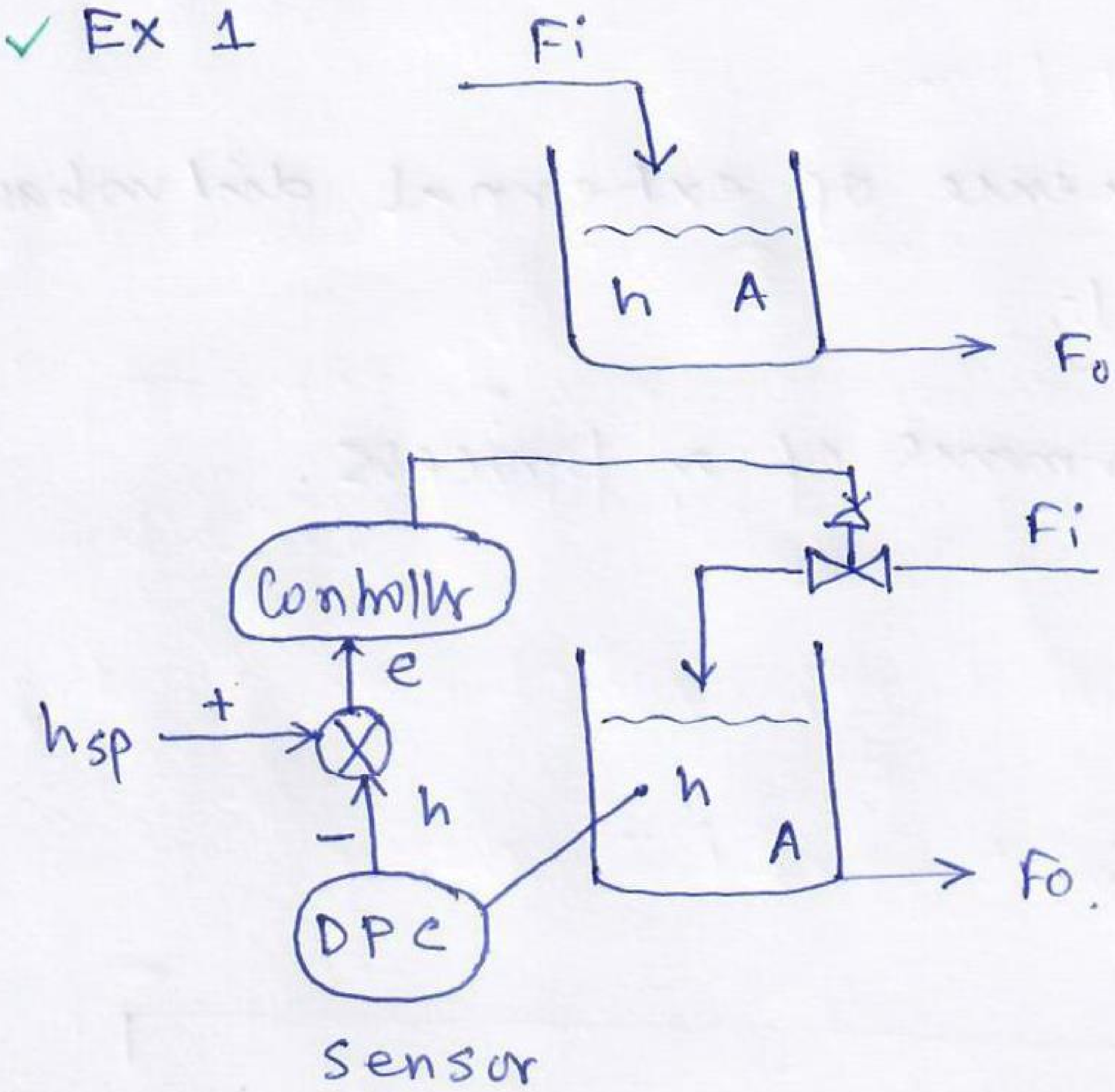
- suppressing the influence of external disturbances
- Ensuring the stability
- optimizing the performance of a process.

Variables

- Input variables
  - MV / control variable
  - LV / disturbance
    - Measured LV
    - Unmeasured LV
- Out-put variables
  - Measured
    - Primary meast. (Controlled variable (CV))
    - Secondary meast.
  - Unmeasm.

Variables (contd..).

✓ Ex 1



Liquid tank system

Input : F_i

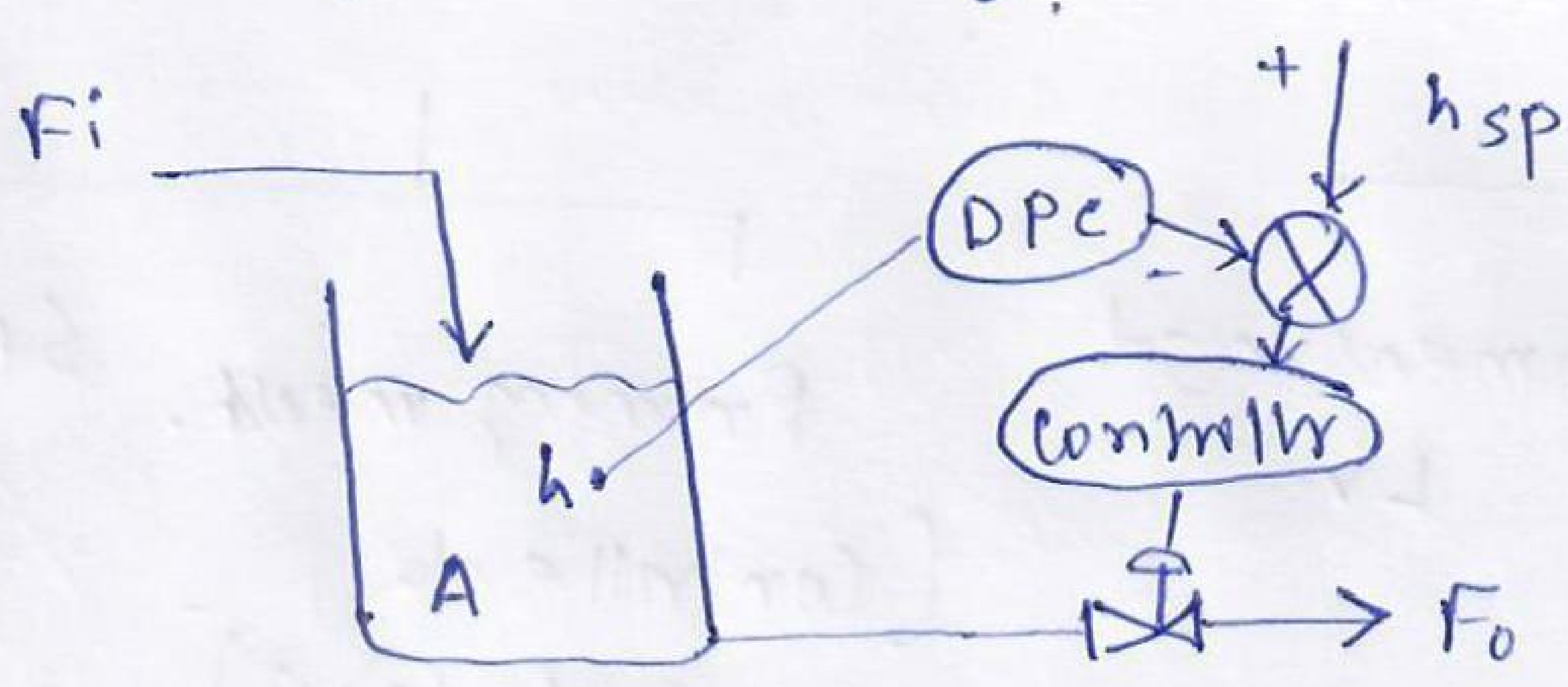
Outputs : h, F_o

Liquid tank with controller

Control obj : $h = h_{sp}$.

CV	MV
h	Fi

✓ Ex 1 (Alternative).



Liquid tank with controller

Control obj : $h = h_{sp}$

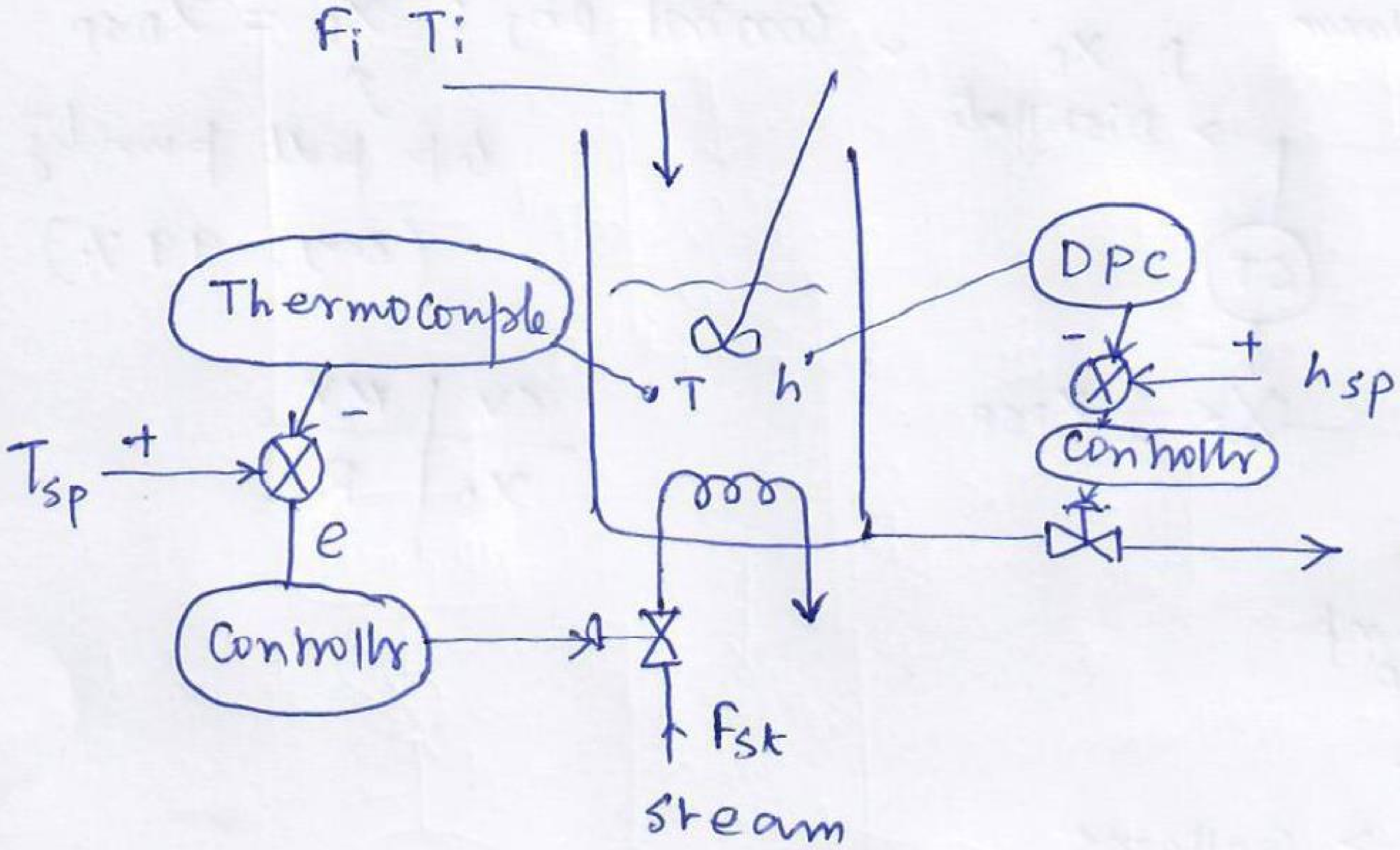
CV	MV
h	Fo

Inputs : F_i, F_o

Outputs : h.

Variables (contd..)

Ex 2. Heating tank system (revisited)



Control obj : $T = T_{sp}$

$h = h_{sp}$

CV	MV
h	F
T	F_{st}

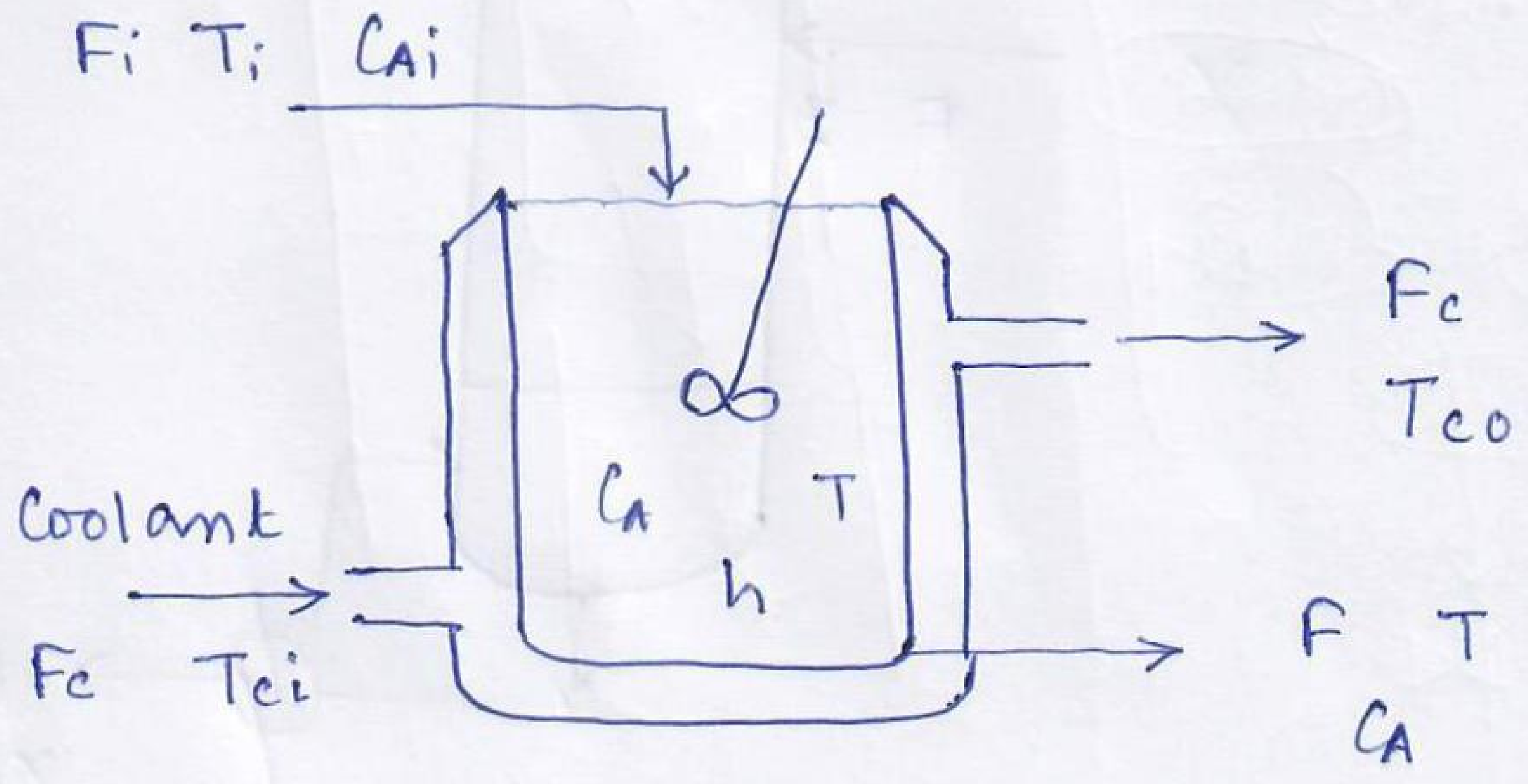
closed-loop | Inputs : F_i, T_i, F, F_{st}

Outputs : T, h

open-loop | Inputs : F_i, T_i, F_{st}

Outputs : F, T, h

Ex 3. Jacketed CSTR (exothermic reaction)



Control obj : $T = T_{sp}$

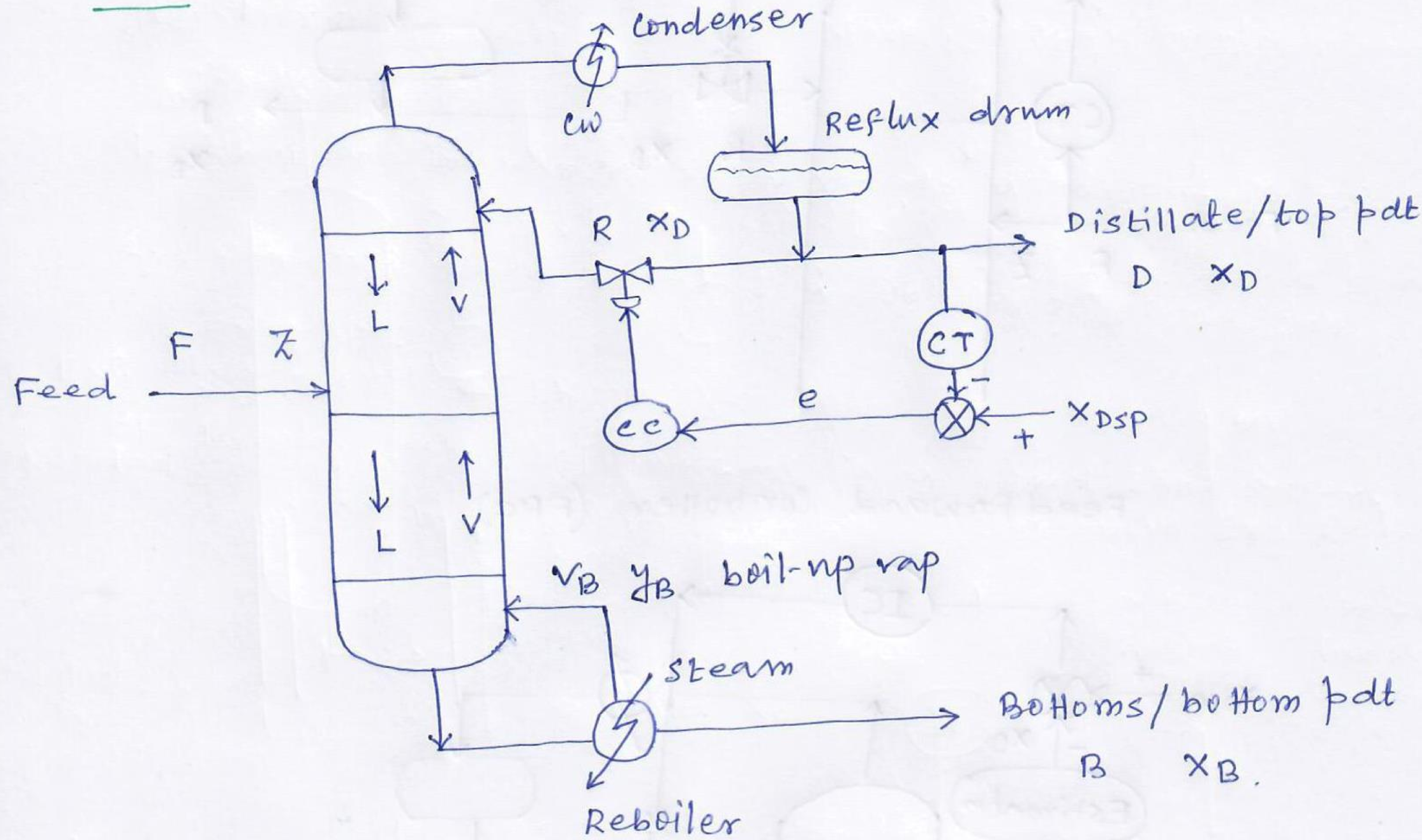
$h = h_{sp}$

CV	MV
T (or C_A)	F_c
h	F_i (or F)

Inputs : F_i, T_i, C_{Ai}, F_c, T_{ci} (F)

Outputs ; F, T, C_A, T_{co}, h

Ex 4. Distillation column



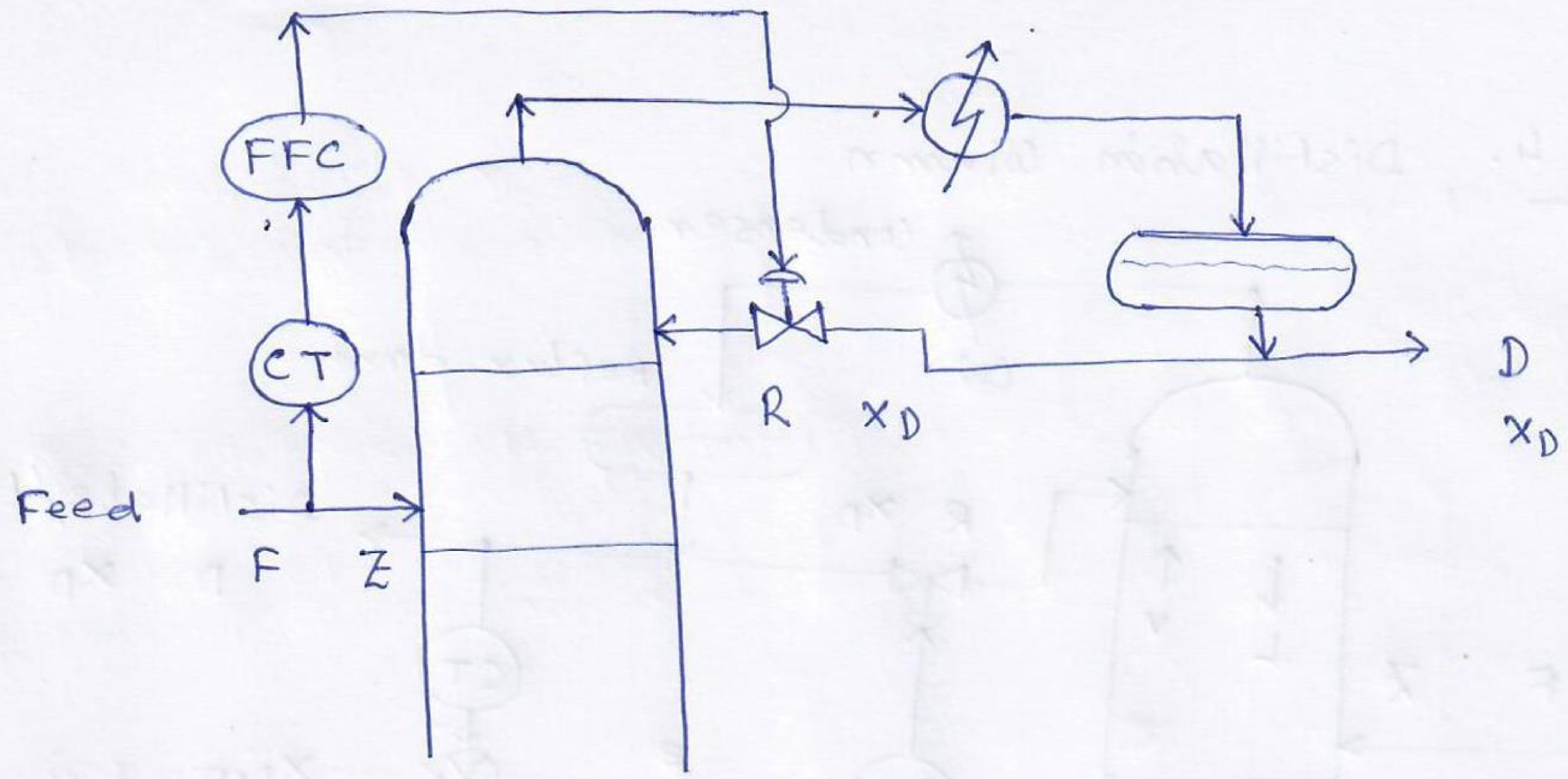
Feedback controller (FBC)

Notation : $x, y, z \rightarrow$ composition (mol. fract.)

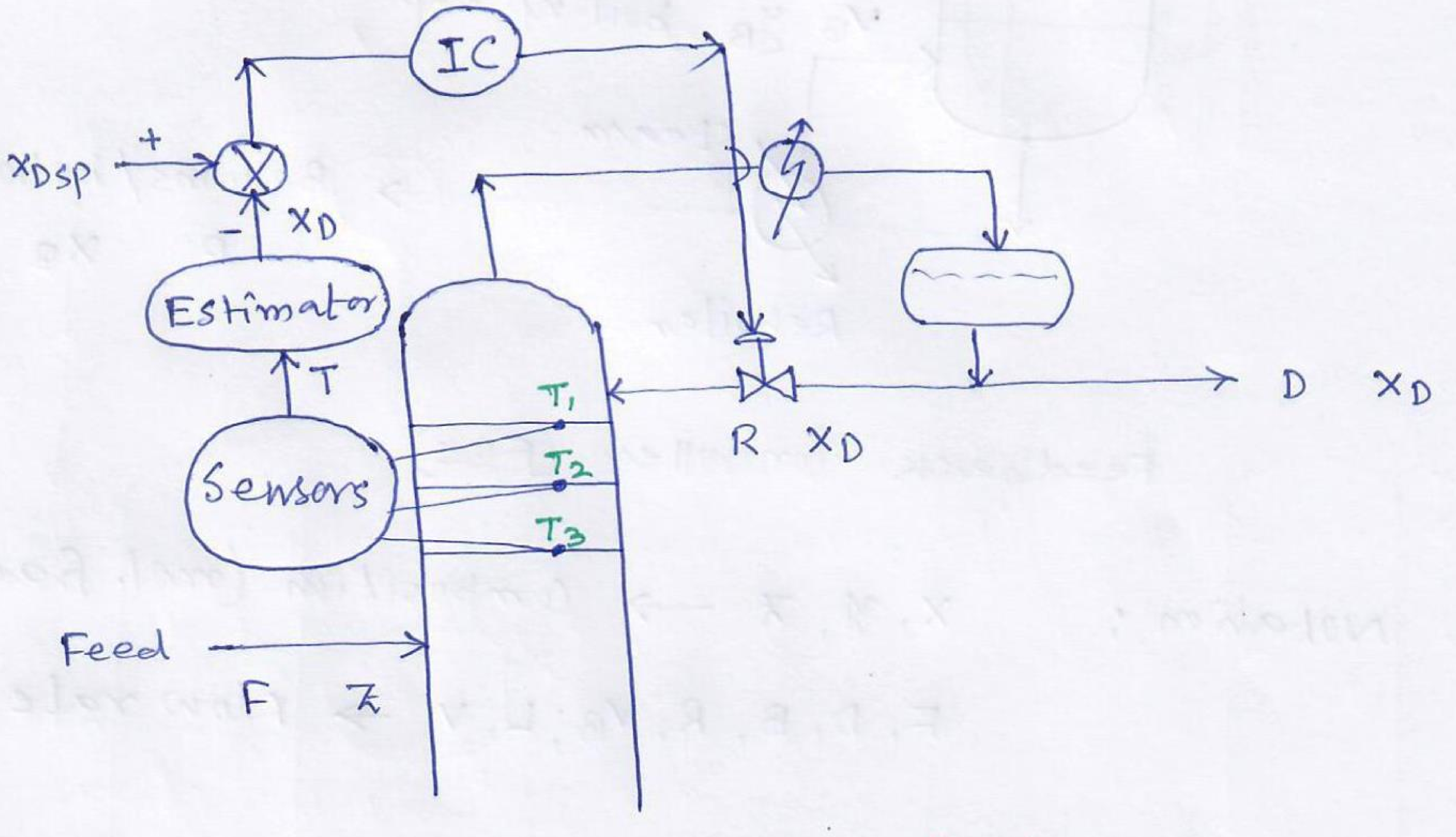
$F, D, B, R, V_B, L, V \rightarrow$ flow rate

control obj : $x_D = x_{DSP} \equiv 99\%$ purity

CV	MV
x_D	R
x_B	V_B



Feedforward Controller (FFC)



Inferential Controller (IC).

✓ Estimator: $x_D = f(T_i)$ $\quad$ $i \rightarrow$ tray index

✓ Measurements: x_D = primary meast. (CV)

T = secondary meast.

≡ measured and used to infer x_D

(thus inferential controller)

Questions

1. Develop the FB and FF control configurations for
   - a heat exchanger
   - distillation bottom section

2. In the inferential control of a distillation column, x_D is considred primary measurement. Why it is called so when no continuous measurement is shown for x_D ?

3. Develope the inferential control configuration for a jacketed CSTR, in which, an ~~exo~~ endothermic reaction occurs.