Formic acid Process

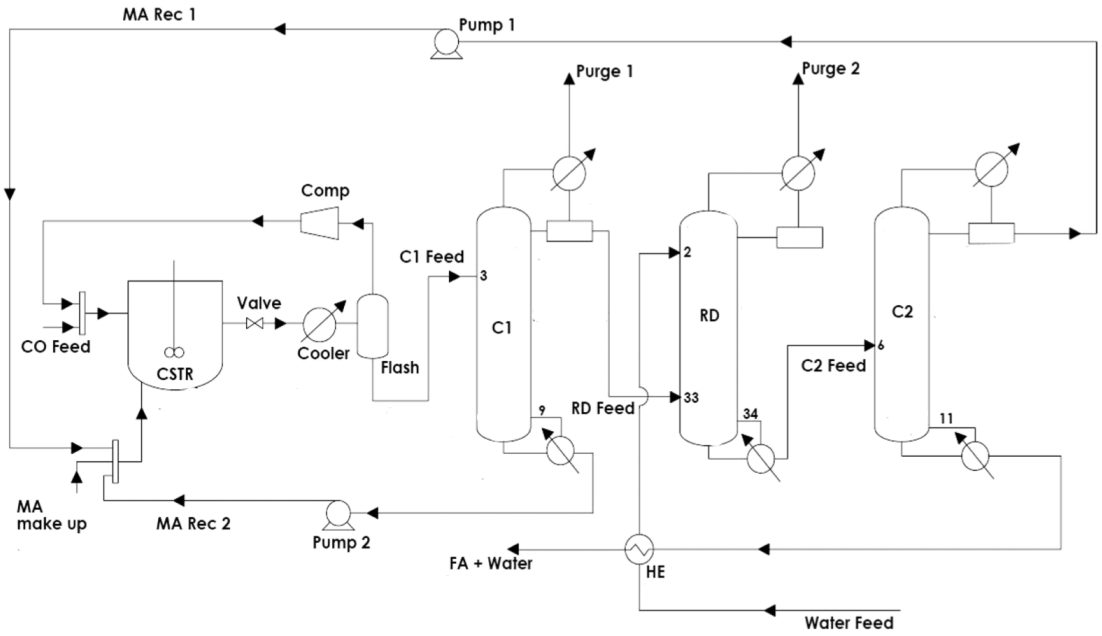
The process includes a reactor for carbonyl reaction, one RD column for MF(Methyl Formate/Formic acid) hydrolysis, and two distillation columns for the separation of hydrolysis products.
Fresh CO is given to the CSTR, recycled MA(Methyl alcohol) along with a small amount of makeup is also fed to this adiabatic CSTR. In this reactor, MF is produced from MA and CO by the carbonyl reaction:

$$CH_3OH + CO \rightarrow HCOOCH_3$$

Unconverted CO is recovered in the flash and is recycled to the CSTR via a compressor, in the vapour state. On the other hand, MA is partly recovered in the bottoms of the C1 column for recycling to the CSTR in the liquid state. Purge-1 from C1 is small and mainly contains CO.
FA and MA production by the hydrolysis of MF is carried out in the RD. Freshwater is fed to this column on the second stage and MF from the C1 column.

$$HCOOCH_3 + H_2O \rightarrow HCOOH + CH_3OH$$

The reactants (MF and water) are separated from the products (FA and MA) simultaneously with FA and MA production in the RD. Distillate of RD is small and mostly contains CO, whereas the bottoms stream contains MA, FA, and unreacted water, which is sent to C2 for further separation. MA is separated as the distillate of C2 for recycling to the CSTR, whereas C2 bottoms are the desired product.



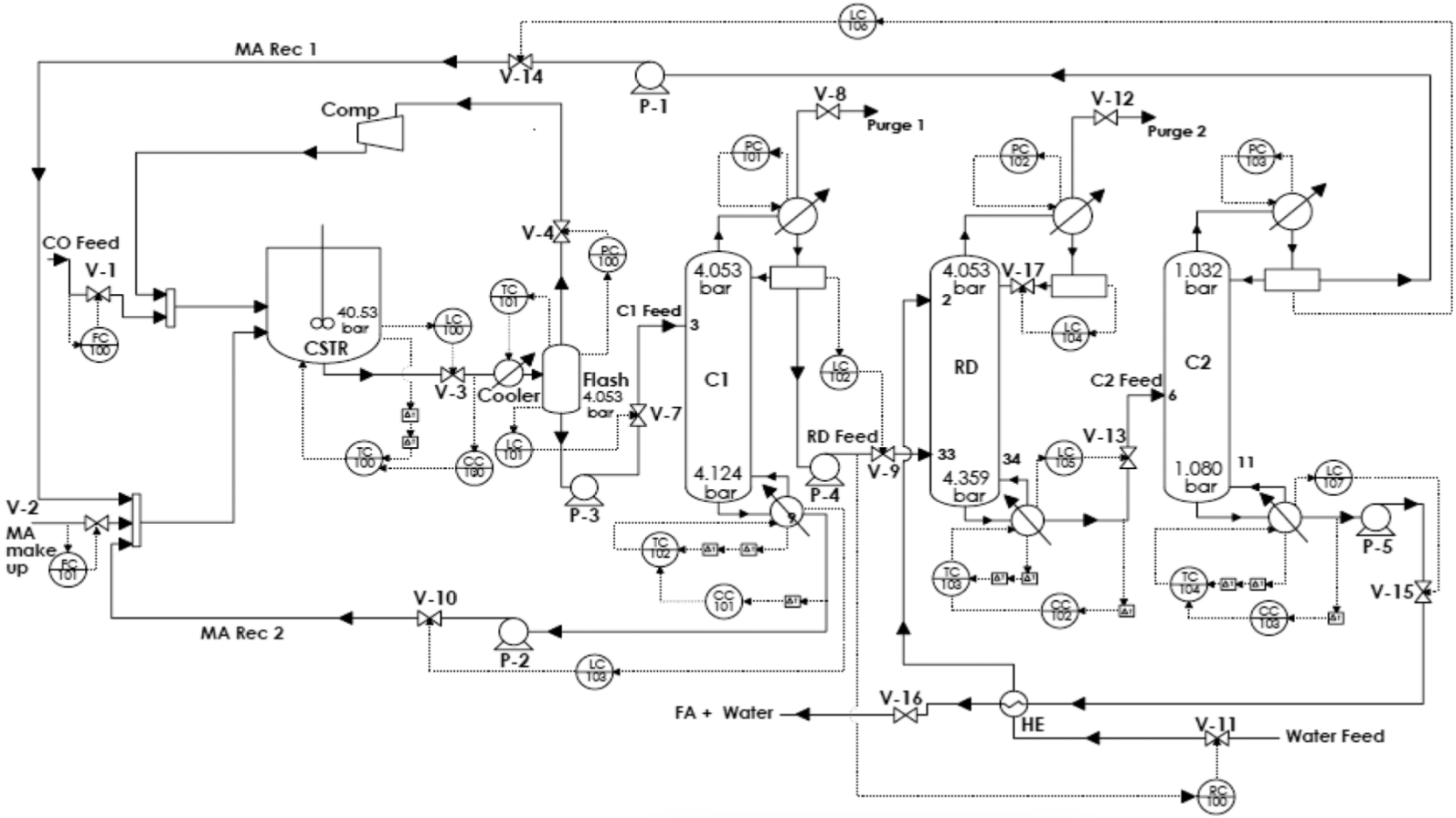
Q.1) Draw a neat flowsheet clearly showing all the unit operations and material/energy streams as described in the process described above.
Q.2) Clearly show all the control valves on the flow sheet.
Q.3) What is the control and steady-state degrees of freedom for the process.
Q.4) What are reasonable specification variables corresponding to the steady-state degrees of freedom.
Q.5) Draw a plantwide regulatory control system with the flowrate of CO as the throughput manipulator.

Ans.) Control degree of freedom = 26, Steady-state degree of freedom = 13

S. No.	Controller	Controlled variable (CV)	Manipulated Variable (MV)	SS DOF
1	FC100	CO flow rate (TPM)	CO flow [V-1]	y
2	FC101	MA flow rate	Fresh MA [V-2]	y
3	FC102	Reflux flow rate	Valve in Reflux line	y
4	FC103	Reflux flow rate	Valve in Reflux line	y
5	RC100	Water flow rate to the RD	Inlet water flow [V-11]	n
6	PC100	Flash pressure	Flash Top flow rate [V-4]	n
7	PC101	Condenser pressure in C1	Condenser duty in C1	n
8	PC102	Condenser pressure in RD	Condenser duty in RD	n
9	PC103	Condenser pressure in C2	Condenser duty in C2	n
10	TC100	Temperature in CSTR	CSTR cooling	y
11	TC101	Temperature in Flash	Cooler duty	y
12	TC102	Bottom stage temperature in C1	Reboiler duty in C1	y
13	TC103	Bottom stage temperature in RD	Reboiler duty in RD	y
14	TC104	Bottom stage temperature in C2	Reboiler duty in C2	y
15	LC100	Level in CSTR	Liquid outlet flow [V-3]	n
16	LC101	Level in flash	Liquid outlet flow [V-7]	n
17	LC102	Reflux drum level in C1	Distillate flow [V-9]	n
18	LC103	Sump level in C1	Bottom flow [V-10]	n

19	LC104	Reflux drum level in RD	Reflux flow in RD [V-17]	n
20	LC105	Sump level in RD	Bottom flow [V-13]	n
21	LC105	Reflux drum level in C2	Distillate flow [V-14]	n
22	LC107	Sump level in C2	Bottom flow [V-15]	n
23	CC100	MF composition in CSTR outlet	Temperature of CSTR	y
24	CC101	MF composition in C1 bottoms stream	Temperature in C1 reboiler	y
25	CC102	MF composition in RD bottoms stream	Temperature in RD reboiler	y
26	CC103	FA purity in C2 bottoms stream	Temperature in C2 reboiler	y

P.T.O.


MA Rec 1
V-14
P-1
Comp
V-8
Purge 1
V-12
Purge 2
CO Feed
V-1
FC 100
CSTR
40.53 bar
LC 100
TC 101
V-4
PC 100
V-3
Cooler
Flash
4.053 bar
V-7
C1 Feed
C1
4.053 bar
4.124 bar
RD
4.053 bar
4.359 bar
V-17
LC 104
C2
1.032 bar
1.080 bar
C2 Feed
RD Feed
V-9
V-13
LC 105
P-3
P-4
P-5
V-2
MA make up
FC 101
V-10
MA Rec 2
P-2
LC 103
V-15
V-16
FA + Water
HE
V-11
Water Feed
RC 100