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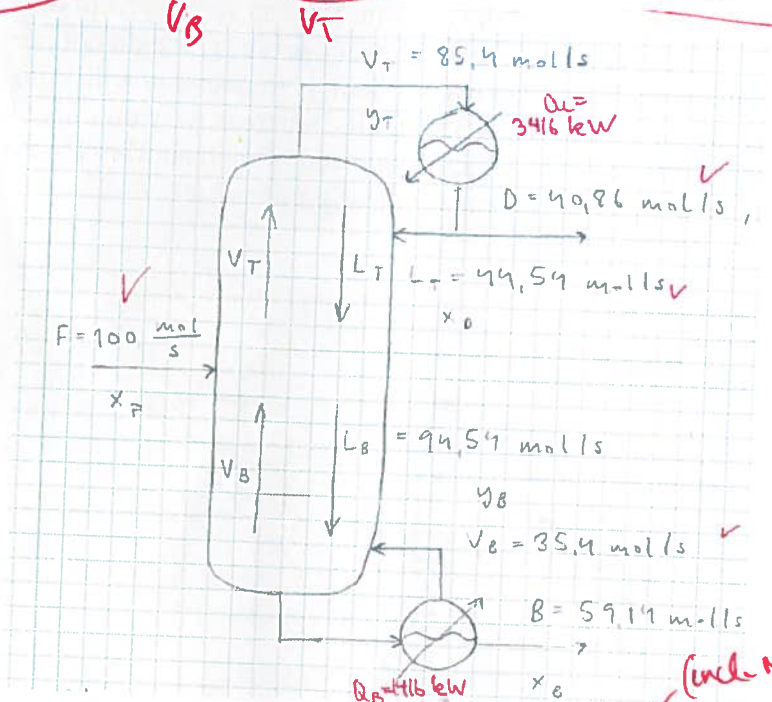
KEM 2018 SOLUTION

Problem 3- Distillation

(a) FzF = DxD + BxB
F = D + B
2 equations with 2 unknowns (D and B).
3 Get: D = F* (zF-xB) / (xD-xB) = 100*(0.4-0.02)/(0.95-0.02) = 40.86 mol/s
B = 59.14 mol/s

5 (b) Find in mol/s: VB=35.4, LB=94.54, VT=85.4, LT=44.54. See also Figure.
Heat reboiler: 35.4 mol/s * 40 kJ/mol = 1416 kW = 1.4 MW
(+ 2) Cooling condenser: 85.4 mol/s * 40 kJ/mol = 3416 kW = 3.4 MW



10 (c) From the McCabe-Thiele diagram we need Nbtm=3.3 and Ntop=4.1 (incl. reboiler) 3 4 ? Not clear from my figure

5 (d) Real ("new") column. We have excess stages (6 rather than 3.3) in the bottom, and since we keep the bottom composition unchanged we will get a "pinch" zone below the feed. In the top we have the same number of stages (4), but we get some benefit of the extra stages in the bottom, and we find that the top purity xD improves from 0.95 ("old") to about 0.97 ("new").

For details, see the McCabe Thiele diagram. The bottom operating line and the feed line is unchanged. We start the drawing of the "staircase" from the bottom and we must continue on the lower operating line for 6 stages, that is, we do not switch operating lines when we get to the feed line because the feed stage is not optimally located!

When we switch to the upper operating line, then we now "start" from a higher mole fraction, so we end up at a somewhat higher product composition xD (about 0.97). The left "starting" point of the upper operating line is unchanged. However, some iteration is required for the right starting point (xD,xD) which must be adjusted to fit in 4 stages.

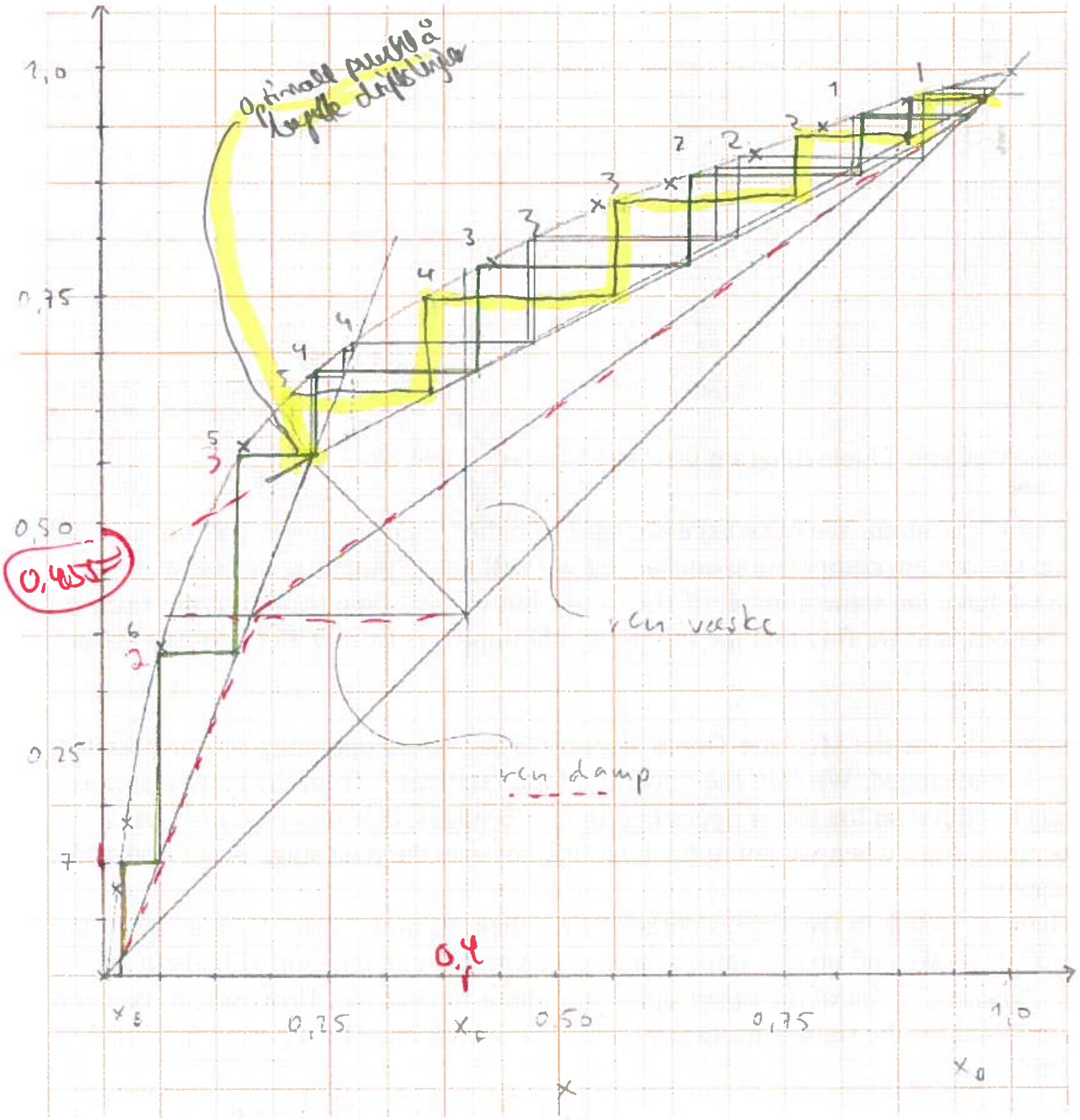
Operating line, new: $y \cdot V_T = x \cdot L_T + D x_D$

$y = \frac{L_T}{V_T} x + \frac{D x_D - 0.95}{V_T}$

Comment: The bottom operating line will also change somewhat. The ratio LB/VB in the bottom is equal to (VB+B)/VB, and although VB is constant, B will change somewhat because the purity in the top changes. However, the effect is small as long as the top product is reasonably pure because B should contain mainly the heavy component (which is fixed at 60 mol/s).

(e) With vapor feed the purity xD will improve. McCabe-Thiele: The lower operating line will be unchanged, but the upper operating line will start further down, so the top purity will be better, maybe around xD=0.99.

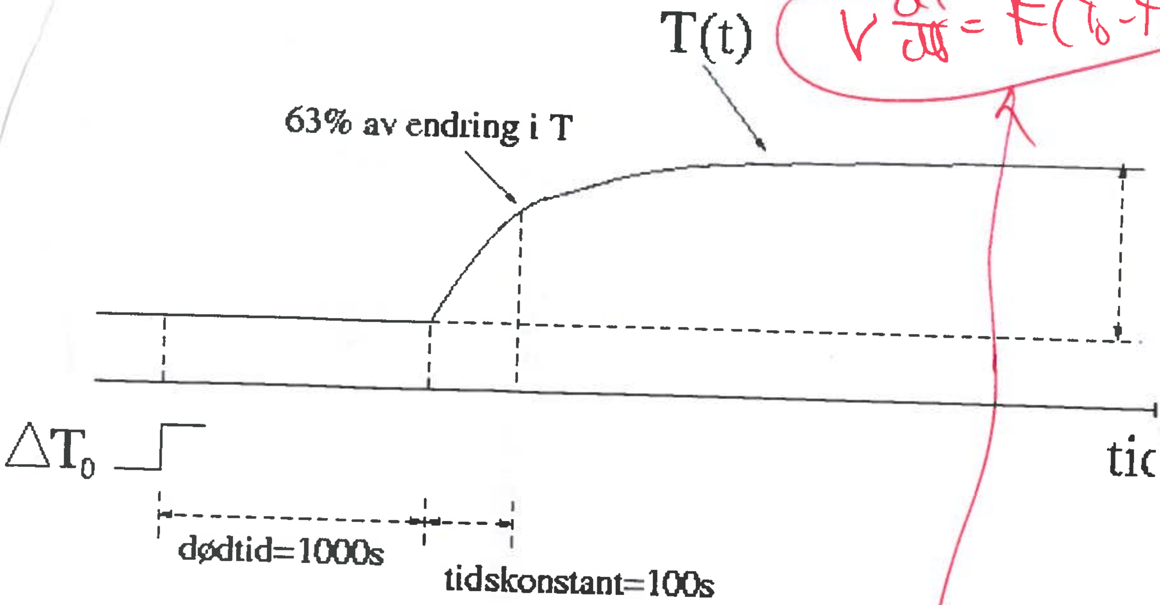
With liquid feed it is NOT possible to achieve the desired purity in the bottom; we simply do not have enough vapor flow in the column. We can see this from the McCabe-Thiele diagram where the feed line and lower operating line do not cross each other. Another way to see that we have a problem, is to note that with pure liquid feed, the vapor flow in the top is VT=VB = 35.4 mol/s, whereas we would like to take out about 40 mol/s of distillate product (which is the feed of methanol)- which is larger than what we have of vapor to condense – clearly infeasible!



Poor diagram!

Problem 4. Control

(b)



Strømningshastighet i røret:
$v=F/(\rho A)=1\ kg/s\ /\ (1000m^3\ 0.01m^2)=0.1m/s$

(c) Dødtid:
$\theta=L/v=100m\ /\ 0.1m/s=1000s$

(a) Energibalansen for vannet i tanken:
$d(mc_p(T-T_r))/dt=h_0F-hF=Fc_p(T_0-T_r)-Fc_p(T-T_r)$

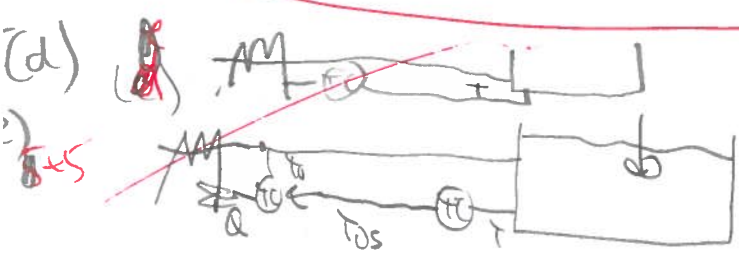
(c) Omskriver når c_p og m er konstant:
$m/F\ dT/dt=-T+T_0$

Tidskonstant fra sammenlikning med standardform ($\tau\ dy/dt=-y+ku$)
$tau=m/F=\rho V/F=1000kg/m^3\ 0.1m^3\ /\ 1kg/s=100\ s$

(Alternativt til å sette opp energibalansen, kan en argumenter med at tidskonstanten (τ) er ofte lik oppholdstiden (m/F) i et system der netto tilført på annen måte er lik null).

Forsterkning:
$k=\Delta T(t\to\infty)/\Delta T_0(t\to\infty)=1$ pga $\Delta T\to\Delta T_0$ når $t\to\infty$

(d)



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