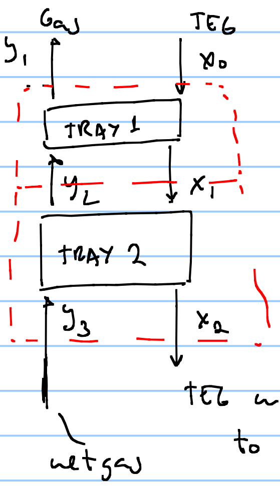
Cont. class exercise in excel → Gas dehydration with TEG
TEG regeneration

class exercise in Hysys → TEG column.

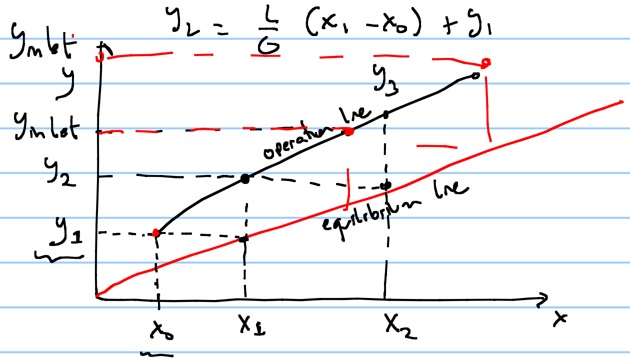
operation line equation

$$y_{i+1} = \frac{L}{G}(x_i - x_0) + y_1$$

$$y_2 = \frac{L}{G}(x_1 - x_0) + y_1$$



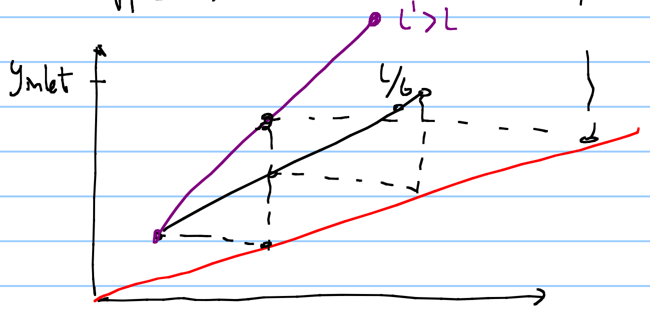
↳ i can measure y_{inlet}



if $y_{inlet} > y_3$ → NOT enough stages → increase stages

if $y_{inlet} < y_3$ → more than enough

what happens if L is increased?



$$y_{i+1} = \frac{L}{G}(x_i - x_0) + y_1$$

y_1: desired molar fraction of H_2O in gas

G: ↳ molar flow rate of gas

(4.a) calculate G

$q_g = 2.83\text{E}03\ \overline{Sm^3}/d$

↓ to

$[Kmol/d]$

EOS $\quad PV = ZnRT$

for standard conditions

$P_{sc} = 1.01325$ bara

$T_{sc} = 15.56\ °C$

$Z = 1$

molar density $\frac{n}{V} = \bar{\rho} = \left[\frac{Kmol}{Sm^3}\right]$

$$\frac{n}{V} = \frac{P_{sc}}{Z_{sc}\, R\, T_{sc}}$$

Gas dehydration exercise, TPG4135, Prof. Milan Stanko						
gas rate	2.83E+00	1E06 Sm3/d				
Gas γg	0.65					
p	68.95	bara				
T	37.8	C				
xo	0.1	[-]				
gas sc molar density	0.042	[Kmol/Sm3]				
MW water	18	kg/Kmol				
TEG concentration	33	l/kg H2O				
TEG density @ 25 C	1130	kg/m3				
TEG MW	150					
Desired dewpoint						
T	-10	C				
p	68.95	bara				
rsw_inlet	1005	[kg/1e06 Sm3]				
rsw_outlet	61.8	[kg/1e06 Sm3]				
m_water_to_remove	2.67E+03	[kg/d]				
y1		[-]				
yN+1		[-]				
G		[kmol/d]				
L		[kmol/d]				
xN		[-]				
					k	0.00062
Operation line					**Equilibrium**	
	x	y		x	y	

$\bar{\rho} = 0.042 \left[\text{kmol}/\text{Sm}^3\right]$

$\dot{n}_g = q_{\bar{g}} \cdot \bar{\rho}_{sc} = 2.83\text{E}06\ \text{Sm}^3/d \cdot 0.042\ \frac{\text{kmol}}{\text{Sm}^3}$

$\dot{n} = 120000\ \text{kmol}/d$

(4.b) $y_1 = \dfrac{\dot{n}_{H_2O@out'}}{\dot{n}_{H_2O@out'} + \dot{n}_{gas\,out'}}$

$r_{sw@outlet} = 61.8 \left[\dfrac{\text{kg}}{1\text{E}06\ \text{Sm}^3}\right]$

$\dot{m}_{\bar{w}@outlet} = r_{sw@outlet} \cdot q_{\bar{g}}$

$= 2.83 \cdot 61.8 = 174.89\ \text{kg}/d$

$\dot{n}_{H_2O@outlet} = \dfrac{\dot{m}_{\bar{w}@outlet}}{MW_{H_2O}} = \dfrac{174.89\ \text{kg}/d}{18\ \text{kg}/\text{kmol}}$

$\dot{n}_{H_2O@outlet} = 9.78\ \text{kmol}/d$

$y_1 = \dfrac{\dot{n}_{H_2O\,outlet}}{\dot{n}_{H_2O\,outlet} + \dot{n}_{gas\,outlet}}$

$y_1 = 8.11\text{E}05\ [-]$

(4.c) calculate L rule of thumb TEG need 12 - 40 l/kg water

we will use 33 L TEG/kg water

$\dot{m}_{H_2O\_to\_remove} = 2670\ \text{kg}/d$

$q_{TEG} = 2670\ \text{kg}/d \cdot 33\ \text{L}/\text{kg} = 88110\ \ell/d$

$\dot{m}_{TEG} = q_{TEG} \cdot \rho_{TEG} = \dfrac{88110\ \cancel{\ell}\ \cancel{m^3}}{1000\ \cancel{\ell}\ d} \cdot 1130\ \dfrac{\text{kg}}{\cancel{m^3}}$

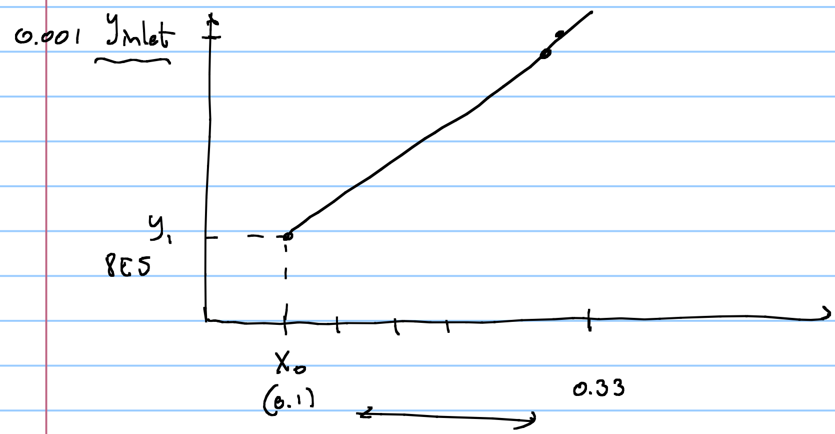
$\dot{m}_{TEG} = 99564\ \text{kg}/d$

$\dot{n}_{TEG} = L = \dfrac{\dot{m}_{TEG}}{MW} = \dfrac{99564}{150} = 664\ \text{kmol}/d$

Assumption L is constant in the column

$\dot{m}_{H_2O\,remove} = 2670\ \text{kg}/d$

$\dot{n}_{H_2O\,remove} = 148\ \text{kmol}/d$



(4.d) Calculate $y_{inlet} = y_{N+1}$

$$r_{sw@inlet} = 1005 \ kg / 1E06 Sm^3$$

$$\dot{m}_{H_2O@inlet} = 1005 \cdot 2.83 =$$

$$\dot{n}_{H_2O@inlet} = \frac{\dot{m}_{H_2O\,inlet}}{MW_{H_2O}}$$

$$y_{inlet} = \frac{\dot{n}_{H_2O@inlet}}{\dot{n}_{H_2O@inlet} + \dot{n}_{gas\,inlet}} = 0.00132$$

$$y_{inlet} \longrightarrow y_1 \,(y_{outlet})$$

0.00132 → 0.0000811

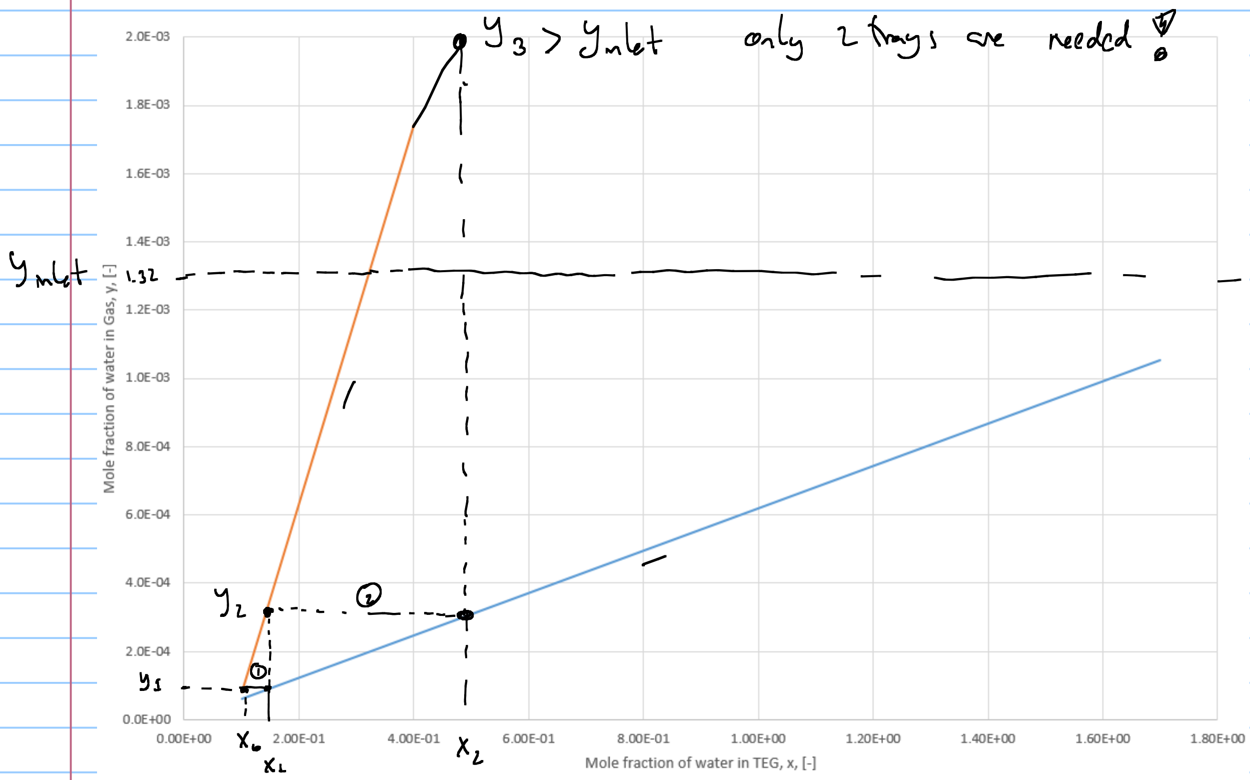
(4.e) what is X_N (molar fraction of water in the TEG exiting the colum)

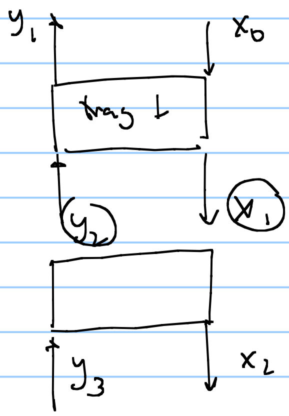
$$G \cdot y_1 + L X_N = y_{N+1} \cdot G + L X_0$$

clearing X_M

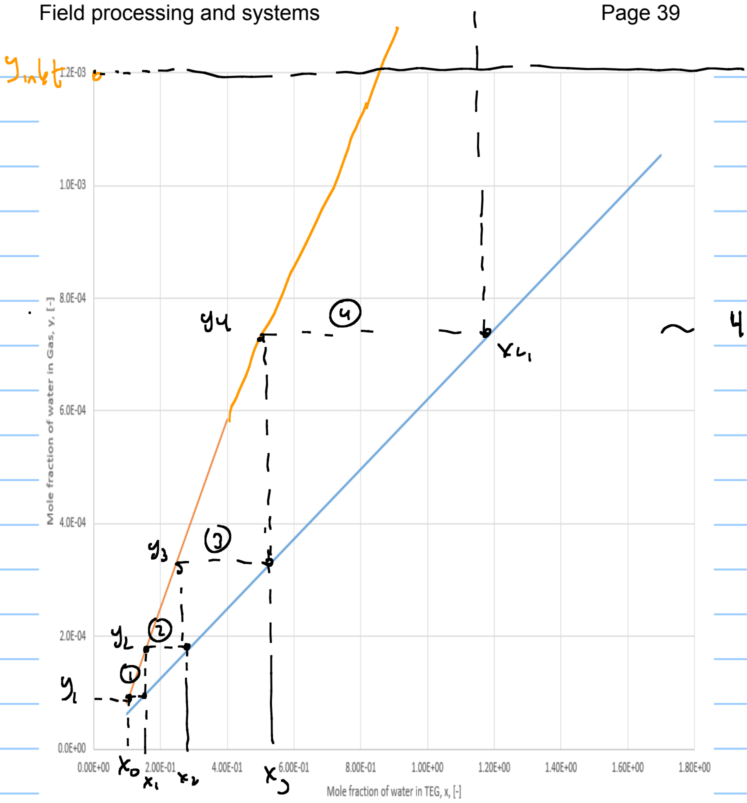
$$X_N = \frac{(y_{N+1} \cdot G + L X_0 - G \cdot y_1)}{L}$$

$$X_M = 0.323$$



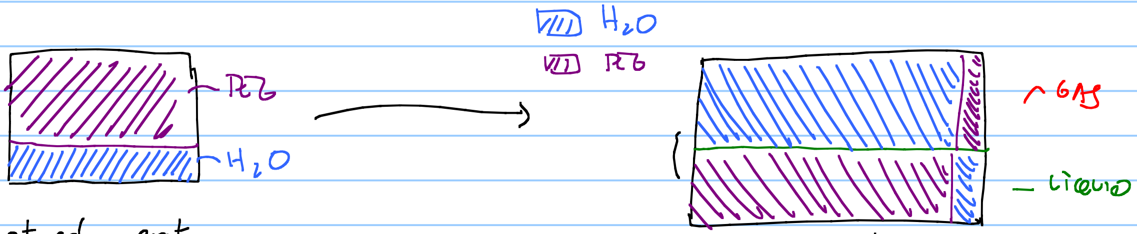


what happens if L is reduced (90 L TEG/kg H_2O)



~ 4 trays are needed

TEG regeneration (removing water from TEG leaving the TEG column)



at column exit
69 bara
38 °C

at regenerator
1.01325 bara
T= 200 °C

mechanically separate liquid from gas
- vapour mostly water vapour
- liquid mostly TEG

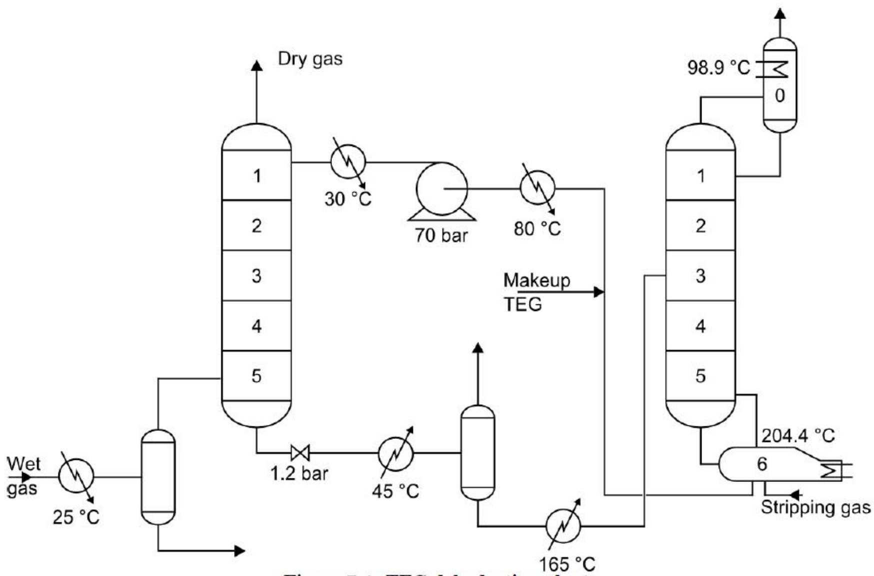


Figure 7-1: TEG dehydration plant.

to calculate the splitting @ $T = 200\,C$, $p = 1.01325$ bara

calculate y_{H_2O}, x_{H_2O}, y_{TEG}, x_{TEG}

Use Rachford Rice

T	472.15	K									
p	101.325	Kpa									
Only TEG and Water											
Fv											
				pv	Z	K	RR_term	xi	yi	MW	Mass fraction
	A	B	C	[Kpa]	[-]	[-]		[-]	[-]		
H20	3.55959	643.748	-198.043		0.56						
TEG	6.7568	3715.222	-1.299		0.44						
			sum=		1	SUM=					

composition of liquid stream leaving column x_N

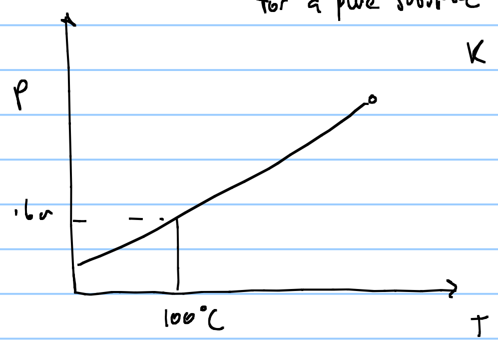
$K = f(p, T)$

Raoult's law

$p_v\, x_i = \underbrace{P \cdot y_i}_{\text{partial pressure}}$

for a pure substance

$K = \frac{p_v}{P} = \frac{y_i}{x_i}$



Antoine $P_v = f(T)$

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Function pvap_antoine(T, A, B, C)
'T in K
'p in Kpa
pvap_antoine = (10 ^ (A - (B / (T + C)))) * 100
End Function
```

A, B, C are constant for each pure substance

T	472.15	K									
p	101.325	Kpa									
Only TEG and Water											
Fv	0.303										
				pv	Z	K	RR_term	xi	yi	MW	Mass fraction
	A	B	C	[Kpa]	[-]	[-]		[-]	[-]		
H20	3.55959	643.748	-198.043	1625.78	0.323	16.045	0.874	0.0581	0.9317		
TEG	6.7568	3715.222	-1.299	7.35	0.677	0.073	-0.874	0.9419	0.0683		
			sum=		1	SUM=	0.000				

liquid

water vapour (back to atmosphere)

$\dot{n} \rightarrow \begin{cases} \rightarrow \dot{n}_v \\ \rightarrow \dot{n}_L \end{cases}$ how much TEG am I losing to atmosphere?

$\dot{n}_v = \dot{n} \cdot F_v \qquad \dot{n}_{v\_TEG} = \dot{n} \cdot F_v \cdot y_{TEG}$

$\dot{n} = L + W = 664 \frac{kmol}{d} + 148 \frac{kmol}{d} = 812\ kmol/d \qquad \dot{n}_v = 812 \cdot 0.303 = 246\ kmol/d$

make-up TEG $\dot{n}_{v_{TEG}} = 246 \cdot 0.0581 = 14 \text{ kmol/d}$

$\dot{m}_{v_{TEG}} = 14 \text{ kmol/d} \cdot 150 \frac{kg}{kmol}$

$= 2141 \text{ kg/d}$

Hysys example