ENP100 - Prosess og produksjon

Øving 6 - Løsningsforslag

Oppgave 1

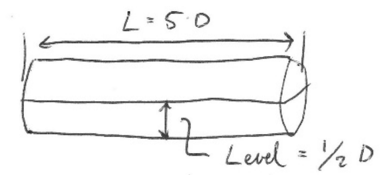
a) Note that the spec's are given in metric units, thereby some unit conversion is needed in order to use the formulas in the text book (Guo et.al., Chp. 10)

T = 34 °C = 307.15 K = 552.87 °R ≈ 553 °R (T = 93.2 °F)
P = 50 bar = $50 \cdot 10^5$ Pa = 725.19 psi ≈ 725 psi

Liquid capacity (10.29) – units are irrelevant; 1440 is just how many minutes there are in a day (24 hr).

Retention time for plain oil/gas separation is 1 min (Table 10.2)

Cylindrical shape:



$$V_L = \frac{\pi}{4} D^2 \cdot 5 \cdot D \cdot \frac{1}{2} = \frac{q_L \cdot t}{1440}$$

$$\Rightarrow D = \sqrt[3]{\frac{2 \cdot 4 \cdot 12000\ m^3/d \cdot 1\ min}{1440\ min/d \cdot 5 \cdot \pi}} = \boxed{1.619\ m}$$

Vapour capacity (10.28) – need to calculate the oil- and gas densities, and find a value for K first. We also need to find the gas flow rate in MMscfd (10^6 std. ft^3/d)

K = 0.45 ft/s (average value for horizontal separator from Table 10.1) Note that K has the same dimension as the superficial gas velocity.

$$\rho_L = \gamma_L \cdot \rho_w = 0.6508 \cdot 1000\ kg/m^3 = 650.8\ kg/m^3 \quad (2.4)$$

$$\rho_g = \frac{M_w \cdot p}{zRT} = \frac{\gamma_g \cdot 29\ g/mol \cdot p\,[Pa]}{z\ R\,[J/mol\,K] \cdot T\,[K]} \quad (2.60)$$

$$= \frac{0.628 \cdot 29 \cdot 50 \cdot 10^5}{0.9 \cdot 8.314 \cdot 307.15} = 39621\ g/m^3 = 39.6\ kg/m^3$$

$$v = 0.45 \cdot \sqrt{\frac{650.8 - 39.6}{39.6}} = 1.77\ ft/s$$

$$q_{st} = q_o \cdot GOR = 12000\ m^3/d \cdot 183\ Sm^3/m^3 = 2.196.000\ Sm^3/d$$

$$\times\ 35.3147\ ft^3/m^3 = 77.551.081\ Sft^3/d = 77.6\ MMscfd$$

Eqn. (10.28):

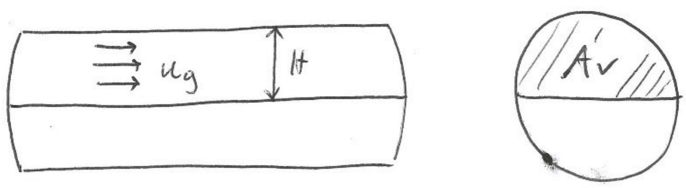
$$q_{st} = \frac{2.4\, D^2\, p[psi]}{Z\, T[°R]} \cdot \underbrace{K\sqrt{\frac{\rho_L - \rho_g}{\rho_g}}}_{v}$$

$$\Rightarrow D = \sqrt{\frac{77.6 \cdot 0.9 \cdot 553}{2.4 \cdot 725 \cdot 1.77}} = 3.54\ ft \times 0.3048\ m/ft = \boxed{1.08\ m}$$

In this case, the liquid capacity gives the largest diameter and must therefore be chosen as the dimensioning criterion.

<u>D = 1.619 m</u>

b)



I Phase velocity: $u_g = \frac{q_g(\text{real})}{A_v}$

$$q_{st} \cdot \rho_{st} = q_g \cdot \rho \quad \Rightarrow \quad q_g = q_{st} \frac{\rho_{st}}{\rho}$$

By (2.60): $$\frac{\rho_{st}}{\rho} = \frac{\not{M_w} \cdot p_{std}}{Z_{std}\, \not{R}\, T_{std}} \cdot \frac{Z\, \not{R}\, T}{\not{M_w}\, p}$$

R and Mw cancel, $Z_{std} \equiv 1$ (assume ideal gas)

$$\rightarrow q_g = q_{st} \cdot \underbrace{\frac{p_{std}}{p} \cdot \frac{T}{T_{std}} \cdot \frac{Z}{1}}_{} = 2.196.000 \cdot \frac{1.01325}{50} \cdot \frac{307.15}{288.15} \cdot 0.9$$

All ratio's so units are optional

$$= 42693\ m^3/d = 0.494\ m^3/s$$

$$A_v = \frac{\pi}{4}(2.4\ m)^2 \cdot \frac{1}{2} = 2.26\ m^2$$

$$u_g = \frac{0.494}{2.26} = 0.219\ m/s$$

II

$q_L = 12000\ m^3/d = 0.139\ m^3/s$

$V_L = A_L \cdot L = 2.26 \cdot 12.2 = 27.57\ m^3$

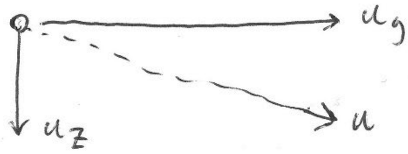
(= A_r)

$t = \frac{27.57}{0.139} = \underline{\underline{198\,s}}$

(3 min, 18 s)

III Terminal velocity:

$$u_Z = \sqrt{\frac{4}{3} \cdot \frac{g\,d}{C_D} \cdot \frac{(\rho_L - \rho_g)}{\rho_g}}$$



Vector-sum of velocities

Drops will reach the vapour outlet if $\frac{H}{u_Z} > \frac{L}{u_g}$

– In the limit $u_Z = \frac{H}{L} u_g$

$$\rightarrow d = \frac{3}{4} \cdot \frac{C_D}{g} \cdot \frac{\rho_g}{(\rho_L - \rho_g)} \cdot \Big(\underbrace{\frac{H}{L} u_g}_{u_Z}\Big)^2$$

$$= \frac{3}{4} \cdot \frac{7}{9.81\ m/s^2} \cdot \frac{39.6}{(850.8 - 39.6)} \cdot \left(\frac{1.2}{12.2} \cdot 0.219\ m/s\right)^2$$

$$= 2.29 \cdot 10^{-6}\ m = \underline{\underline{2.29\ \mu m}}$$

Drops smaller than this may entrain the gas flow

Oppgave 2:

Ex. 2 requires that the spread sheet "`LP-flash.xls`" is downloaded and activated (i.e. editing and content enabled)

a) For control; The result for nv (green number in cell C51) should be 0.6959 after pressing the "Solution" button, with the default composition from Example problem 10.1

b) Entering new values; T = 93.2 °F / p = 725 psi a (same as Ex. 1); Result for nv should now be 0.5237

c) See spreadsheet "`øving6_LF_oppg_2c.xlsx`" for suggested solution (nv should be 0.5687 upon solution)