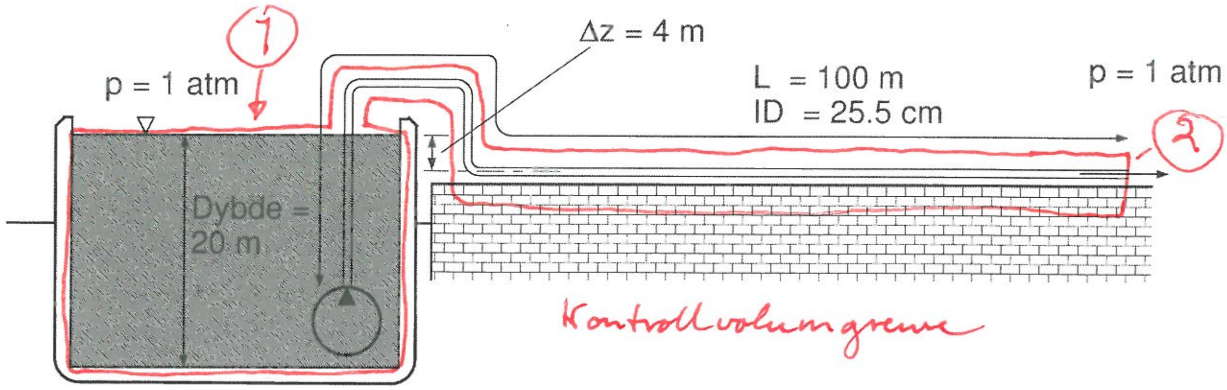
BIP 160 – Produksjon av Olje og Gass

ØVING 5 (2013)

LØSNINGSFORSLAG

Oppg. 1 (vannstrøm / pumpe)



a) ① velges v/ tankens overflate : $p_1 = 1$ atm, $u_1 = 0$

② — " — utløpet av røret : $p_2 = p_1 = 1$ atm, $u_2 = u = \frac{\dot{Q}}{A}$

Like (kansellere)

$$\cancel{\frac{p_1}{\rho g}} + \underbrace{\cancel{\frac{u_1^2}{2g}}}_{=0} + z_1 = \cancel{\frac{p_2}{\rho g}} + \frac{u_2^2}{2g} + z_2 + f_M \frac{L}{D}\frac{u^2}{2g}$$

$$\Rightarrow \underline{\underline{(z_1 - z_2) = \frac{u^2}{2g}\left(1 + f_M \frac{L}{D}\right)}}$$

b) $Re = \frac{D u \rho}{\mu}$ (11.79) $= \frac{0.255\,m \cdot 3.5\,m/s \cdot 673\,kg/m^3}{0.038\,Ns/m^2}$

$= 15806 \approx \underline{16000}$

$e = \frac{\varepsilon}{D} = \frac{0.05\,mm}{255\,mm} = 0.000196 \approx \underline{2 \cdot 10^{-4}}$

Moody diagrammet gir $\underline{\underline{f_m = 0.03}}$

(Colebrooklikningen løst numerisk gir $f_m = 0.0278$)

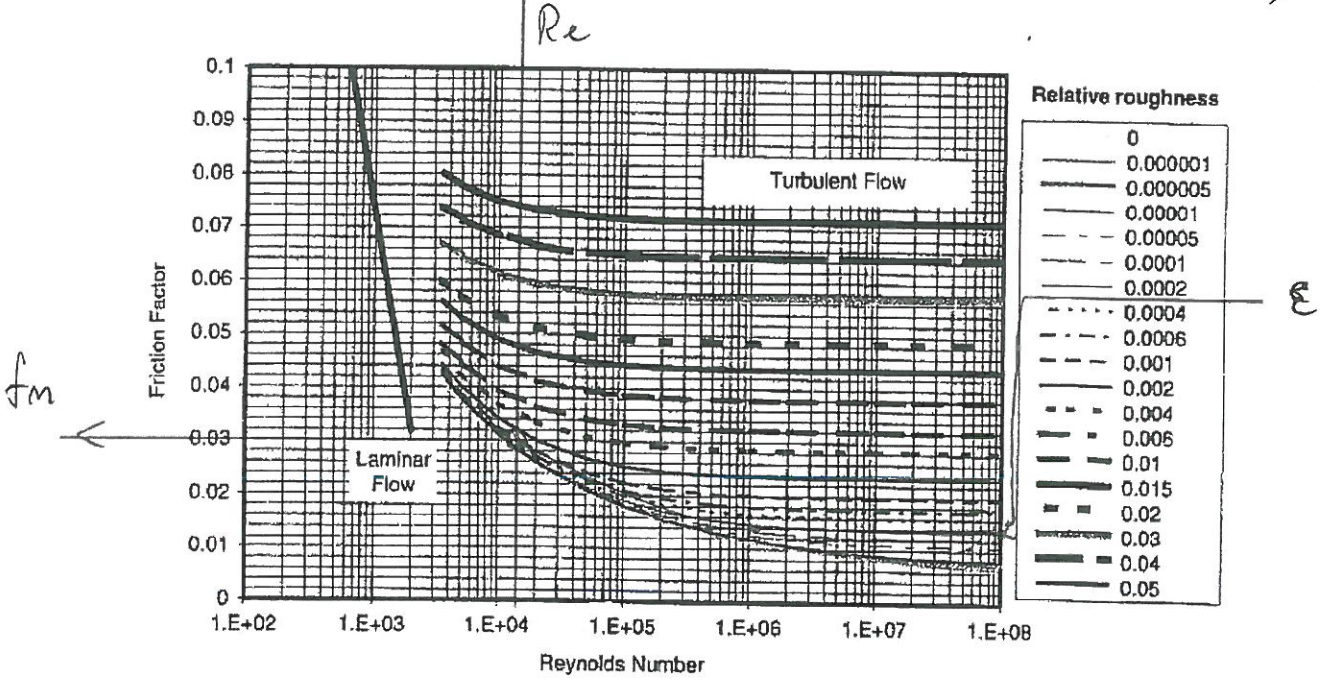


Figure 11.10 Darcy–Wiesbach friction factor chart (Moody, 1944).

c) $q = u \cdot A = \frac{\pi}{4} D^2 \cdot \sqrt{\frac{2g \cdot (z_1 - z_2)}{(1 + f_m L/D)}}$

$= \frac{\pi}{4} \cdot (0.255)^2 \cdot \sqrt{\frac{2 \cdot 9.81 \cdot 4}{\left(1 + 0.03 \cdot \frac{100}{0.255}\right)}} = \underline{\underline{0.127\,m^3/s}} = \underline{457.2\,m^3/h}$

d) Pumpens innløpstrykk gis av det hydrostatiske trykket:

$P_i = \rho g H = 673 \cdot 9.81 \cdot 20 = 132043\,Pa = \underline{1.32\,bar\,g}$

(= 2.33 bar abs.)

e) Systemkarakteristikken gis av trykkdifferansen mellom innløp og utløp:

$$\frac{P_1 - P_2}{\rho g} = \underset{\downarrow}{(z_2 - z_1)} + \underbrace{\frac{u^2 - u^2}{2g}}_{=0} + f_M \frac{L}{D} \frac{u^2}{2g}$$

NB: $-4\,m$

$$H_S = -\Delta z + f_M \cdot \frac{L}{D} \cdot \frac{u^2}{2g} = -\Delta z + f_M \frac{L}{D} \frac{1}{2g} \left(\frac{4q}{\pi D^2} \right)^2$$

$$= -\Delta z + \frac{8 L f_M}{g \pi^2 D^5} \cdot \dot{q}^2$$

f) Sett inn tall:

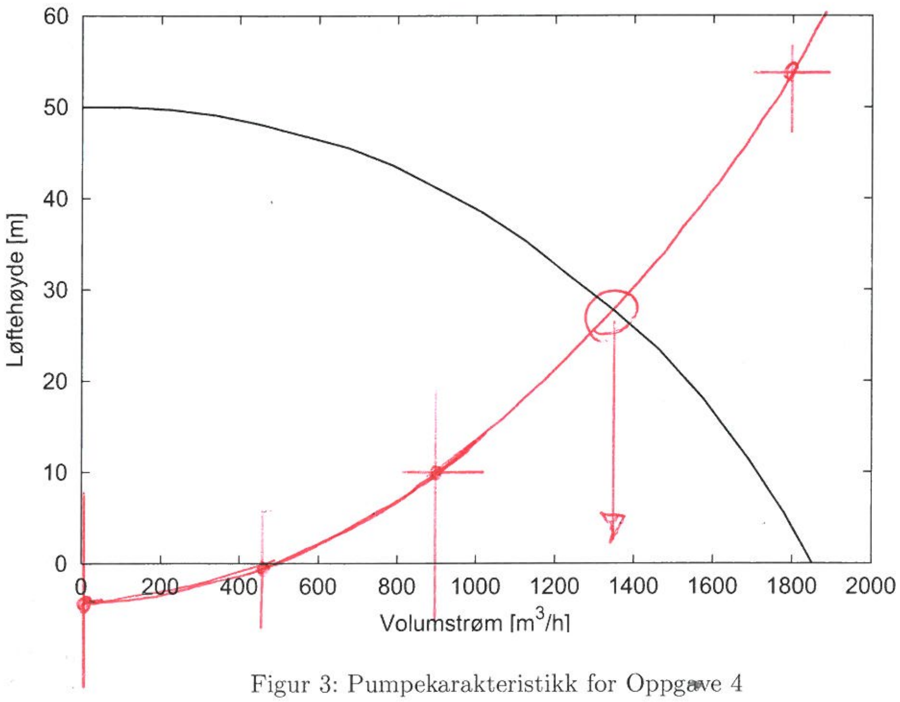
$$H_S = -4 + \frac{8 \cdot 100 \cdot 0.03}{9.81 \cdot \pi^2 \cdot (0.255)^5} \cdot q^2$$

$$= -4 + 229.9 \cdot \dot{q}^2$$

Beregn: (Velg verdier som er enkle å regne om til m^3/s)

$\dot{Q}\ [m^3/h]$	$q\ [m^3/s]$	$H\ [m]$
0	0	−4
450	0.125	−0.41
900	0.25	10.4
1800	0.5	53.5

④



Figur 3: Pumpekarakteristikk for Oppgave 4

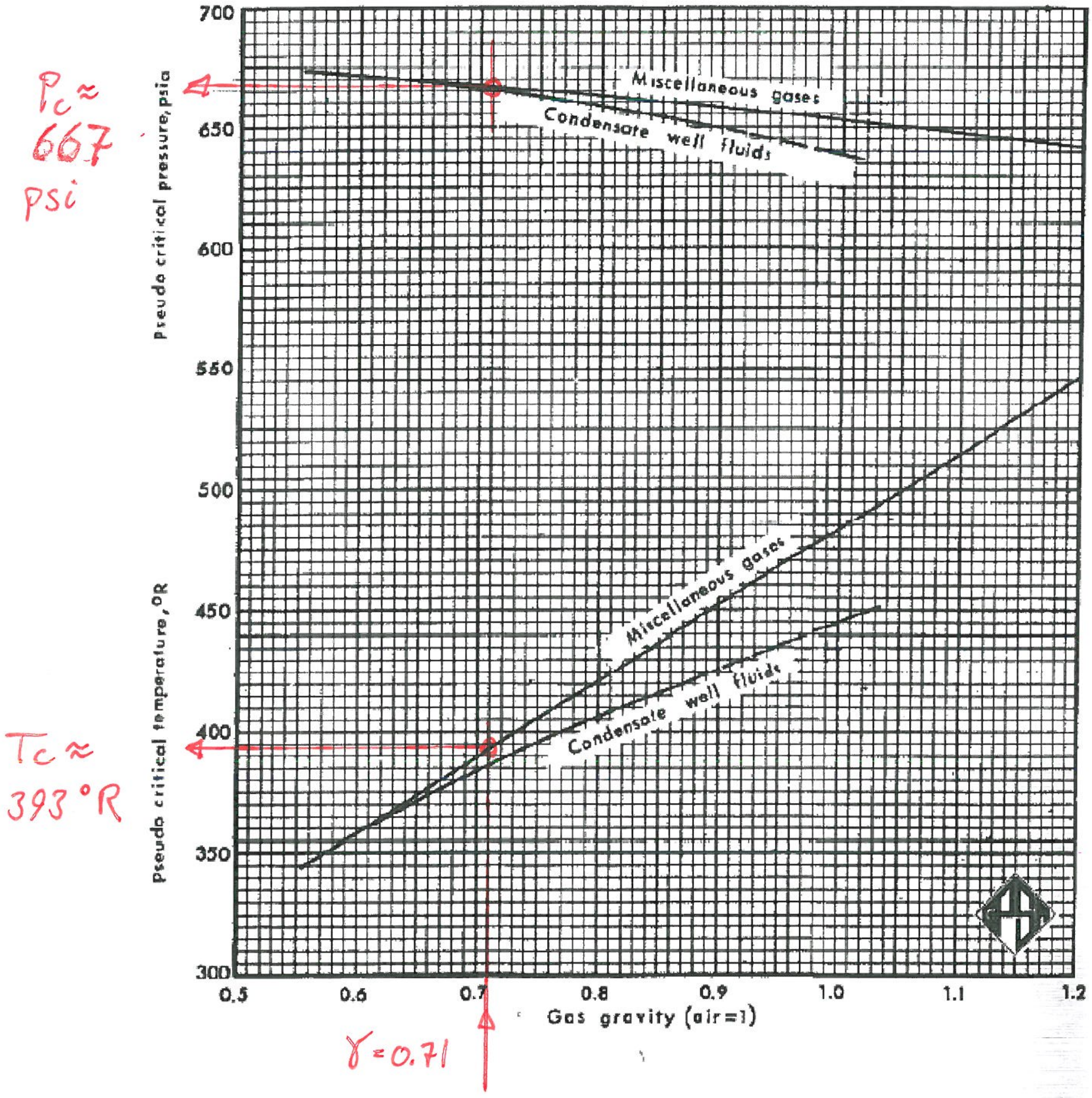
Tegnet inn på figuren får vi $q \approx 1350\ \mathrm{m^3/h} = \underline{\underline{0.375\ \mathrm{m^3/s}}}$

Opps. 2 [Bruk vedleggene fra Øving 1]

a) 1. Pseudo P_c og T_c:

FIG.16-6

Pseudocritical properties of natural gases



2. Pseudoreduserte egenskaper:

$p = 50$ bar $= 5000$ kPa $\cdot 0.145$ $= \underline{725 \text{ psi}}$

$T = 34°C = 1.8 \cdot 34 + 32 = 93.2°F$

$= 93.2 + 460 = 553.2\ °R$

$$P_r = \frac{725 \text{ psi}}{667 \text{ psi}} = \underline{1.09}$$

$$T_r = \frac{553.2\ °R}{393\ °R} = \underline{1.4}$$

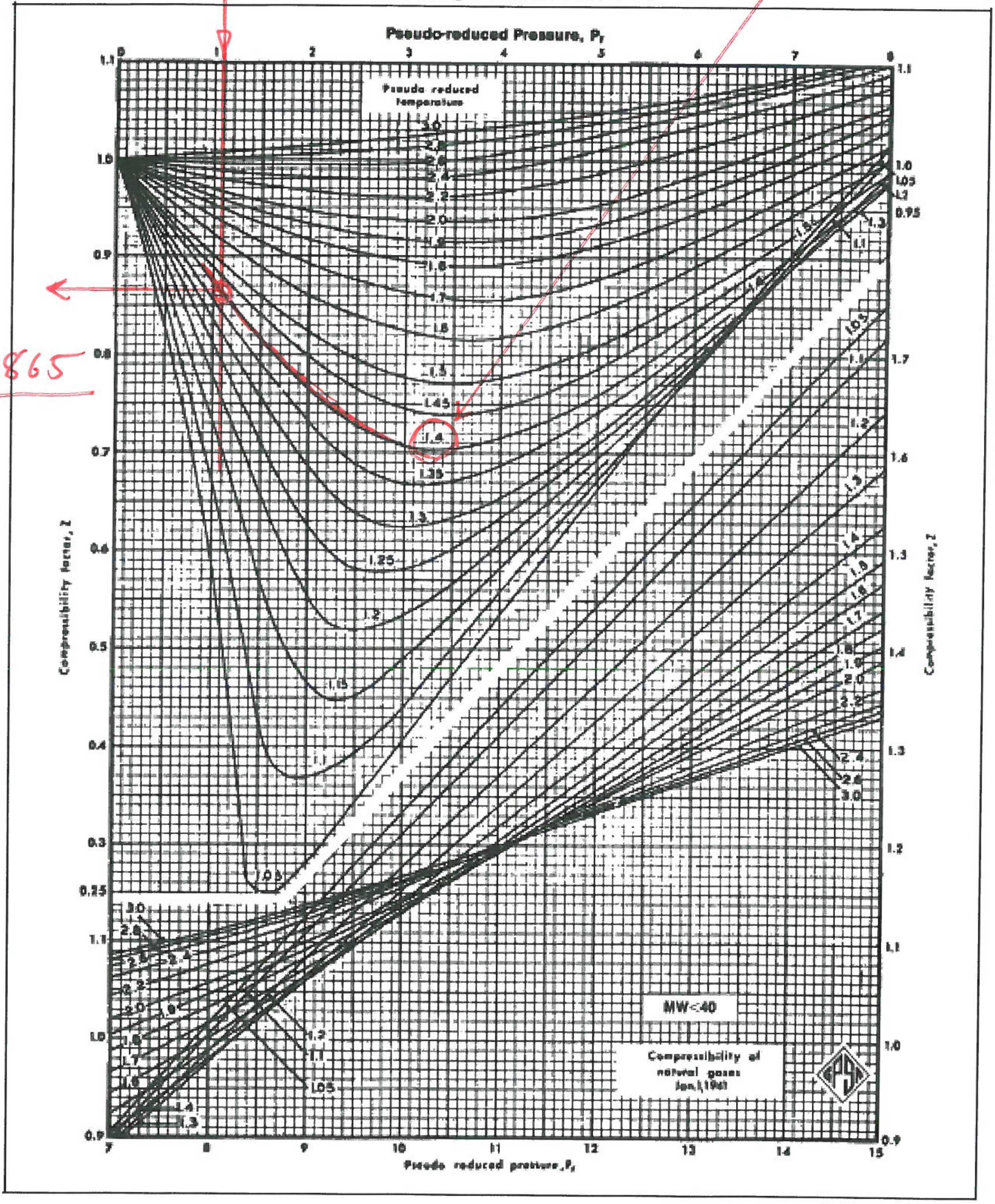
3. Finn gasskompressibilitet, Z

$P_r = 1.09$

$T_r = 1.4$

FIG. 23-4

Compressibility Factors for Natural Gas[1]



Z

≈ 0.865

4: Gasstetthet : $\rho_g \equiv \frac{1}{v_g} = \frac{P}{ZRT} = \frac{PM}{ZR_oT}$

R_o = Universell gasskonstant = $\underline{8.3144\ J/mol\,K}$

M = Molvekt = $\gamma \cdot M_{Luft} = 0.71 \cdot 28.97\ g/mol$

$= 20.57\ g/mol$

Brukt grunnenheter, bortsett fra g

$$\rho_g = \frac{50 \cdot 10^5\ N/m^2 \cdot 20.57\ g/mol}{0.865 \cdot 8.3144\ Nm/mol\,K \cdot \underbrace{307.15\ K}_{(34+273.15)}}$$

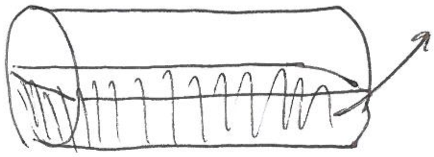
$= 46559\ g/m^3$

$$\underline{\underline{= 46.56\ kg/m^3}}$$

5. Oljetetthet fra °API : $\rho_L = \gamma_{API} \cdot 1000\ kg/m^3$

$= 1000 \cdot \frac{141.5}{131.5 + 80°API} = \underline{\underline{669\ kg/m^3}}$

b) Max oljerate : $q_{L,max} = \frac{V_L}{\tau_{ret}}$



V_L – "settling volume"

V_L v/ ½ full separator : $V_L = \frac{1}{2} \cdot \frac{\pi}{4} D^2 L$

$= \frac{1}{2} \cdot \frac{\pi}{4} \cdot (1.524\ m)^2 \cdot 4.572\ m = \underline{4.17\ m^3}$

Kan også bruke Table 10.5 : ½ Full (60" × 15') = 26.68 bbl

$= 26.68 \cdot 0.15899 = \underline{4.24\ m^3}$

Bruker $V_L = 4.2\ m^3 \Rightarrow q_{L,max} = \frac{4.2\ m^3}{60\ s} = \underline{\underline{0.07\ m^3/s}}$

c) Max. gassrate: $q_g = A \cdot v_{max}$

$A = \frac{\pi}{4} \cdot D^2 = \frac{\pi}{4} \cdot (1.524\,m)^2 = 1.82\,m^2$

Hele arealet legges til grunn

Gj.snitts K fra tabell 10.1 : K = 0.45

Siden enheten for v er innbakt i konstanten, vil svaret komme i ft/s

$v_{max} = 0.45 \cdot \sqrt{\frac{669 - 46.56}{46.56}} = 1.64\ ft/s \cdot 0.3048\ m/ft = \underline{0.501\ m/s}$

$\rightarrow q_{g\,max} = 1.82\,m^2 \cdot 0.501\ m/s = \underline{0.912\ m^3/s}$

Omregning til Std. m^3/d:

$T_{st} = 60°F = 5/9(60-32) = 15.56°C = \underline{288.71\ K}$

$P_{st} = 14.7\ psi \cdot 6.89\ \frac{kPa}{psi} = 101.283\ kPa = \underline{101325\ Pa}$

Disse benyttes senere også

Denne omregningen stemmer ikke, fordi 14.7 er en avrundet størrelse

Via massestrøm:

$\dot{m} = q_g \cdot \rho_g = \dot{Q}_{st.} \cdot \rho_{st.}$

$\Rightarrow \dot{Q}_{st} = q_g \cdot \frac{\rho}{\rho_{st.}} = q_g \cdot \frac{P}{ZRT} \cdot \frac{RT_{st.}}{P_{st.}} = q_g \cdot \frac{P}{P_{st.}} \cdot \frac{T_{st.}}{T} \cdot \frac{1}{Z}$

$\dot{Q}_{st.} = 0.912 \cdot \frac{50 \cdot 10^5 \cdot 288.71}{101325 \cdot 307.15 \cdot 0.865} = 48.90\ Sm^3/s$

$= 48.9 \cdot 86400\ s/d = 4224960\ Sm^3/d = \underline{4.22\ MMSm^3/d}$

$\frac{5.1}{4.22} \approx \underline{\underline{1.2}}$ QED

d) Sjekke oljeraten: $q_L = 500 \frac{m^3}{MMSm^3} \cdot 4.22\ Sm^3/d = \underline{2110\ m^3/d}$

$q_{L,max} = 0.07\ m^3/s = \underline{6048\ m^3/d}$ (Godt under max)

Fasehastighet for gassen; må regne om fra Sm^3/s til m^3/s

$$\dot m = \dot q_g \rho_g = \dot Q_{ST}\rho_{ST} \Rightarrow \dot q_g = \dot Q_{ST}\cdot\frac{\rho_{ST}}{\rho_g}$$

$$= \dot Q_{ST}\cdot\frac{p_{ST}}{\cancel{R}T_{ST}}\cdot\frac{Z\cancel{R}T}{p}$$

Kan velge enhete nokså "fritt", da det e snakk om forholdstall

$$\Rightarrow \dot q_g = 5.1\cdot\frac{14.7\cdot 0.865\cdot 307.15}{288.71\cdot 725} = 0.0951\cdot 10^6\ m^3/d$$

$$\underline{= 1.1\ m^3/s}$$

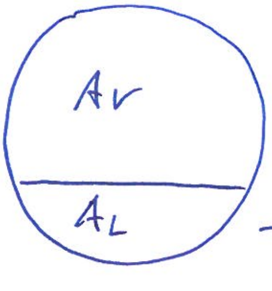
$$A_{1/2} = \frac{1}{2}\cdot 1.82\ m^2 = 0.91\ m^2 \leftarrow$$

$$\Rightarrow v_{ph} = \frac{1.1\ m^3/s}{0.91\ m^2} = \underline{1.2\ m/s}$$

Kan bruke Tabell 5.1 igjen:

$$A_{1/2} \approx \frac{V_{1/2}}{L} = \frac{4.2\ m^3}{4.572\ m} = 0.92\ m^2 \quad (\text{ok})$$

$$V_{1/4} = 10.21\ bbl = 1.62\ m^3 \Rightarrow A_{1/4} = \frac{1.62}{4.572} = 0.35\ m^2$$



$$A_V = 2\cdot 0.92 - 0.35 = \underline{1.49\ m^2}$$

$$\rightarrow A_L = 0.35\ m^2$$

$$\downarrow$$

gir $v_{ph} = \frac{1.1}{1.49} = \underline{0.74\ m/s}$

$\frac{0.74}{1.2} = 0.62$ – Fasehastigheten senkes til 62% av det den var.

Oppg. 3 (Dehydrering)

a) All gass regnes som ideell ved std. betingelser.

I molare enheter er spesifikt volum i gasslikningen gitt i m^3/mol :

$$pv = RT \Rightarrow p\underset{\underset{\text{Totalt vol}}{\uparrow}}{V} = \underset{\llcorner\text{ Antall mol}}{N}\overset{\ulcorner\rightarrow 8.3144\ J/mol\,K}{R}T$$

$$V = 1\,cf = 1\,ft^3 = (0.3048\,m)^3 = 0.0283\,m^3$$

$$p = 14.7\,psia = 101325\,\frac{N}{m^2} \quad \text{(Pr. def)}$$

$$T = 60°F = 0.5556(60-32)+273.15 = 288.7\,K$$

$$N = \frac{101325\,\frac{N}{m^2}\cdot 0.0283\,m^3}{8.3144\,\frac{Nm}{mol\,K}\cdot 288.7\,K} = \underline{1.195\,mol}$$

b) $50 \text{ bar} = 50 \cdot 14.\cancel{5}7 \text{ psi/bar} = \underline{725 \text{ psi}}$

$34°C = 1.8 \cdot 34 + 32 = \underline{93.2 °F}$

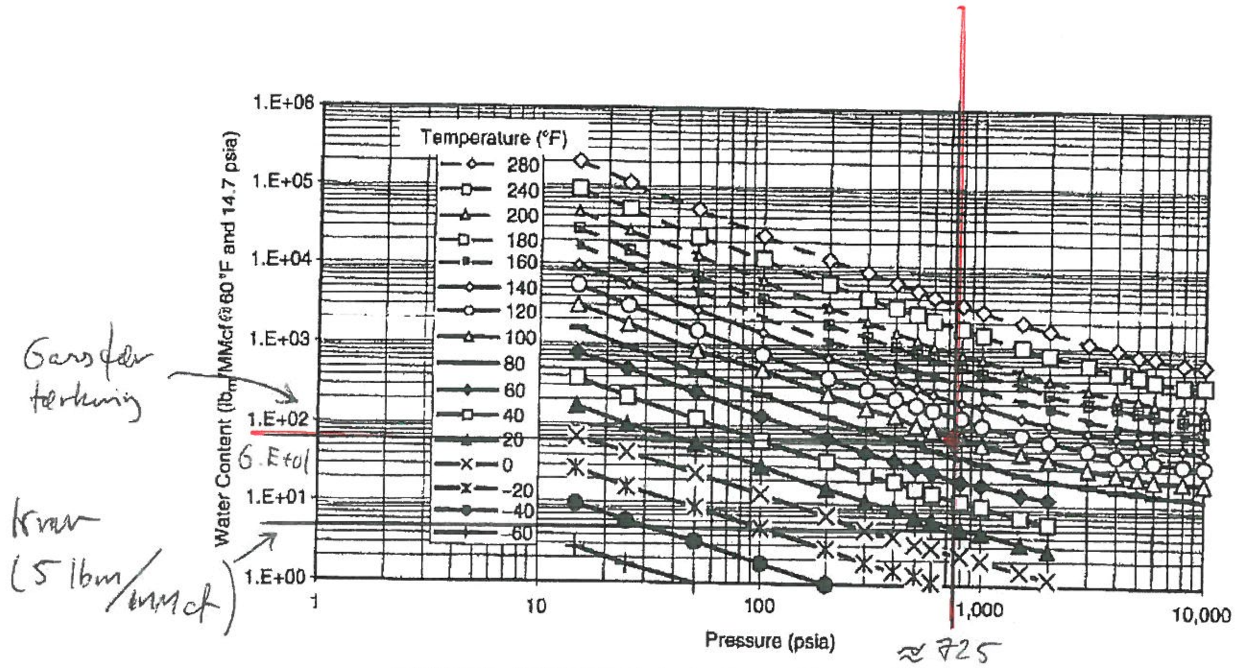


Figure 10.6 Water content of natural gases (Guo and Ghalambor, 2005).

Vanninnhold ≈ 60 lbm/MMScf

Dette diagrammet tillater ikke mer nøyaktig avlesning enn dette

$$1 \text{ lbm} = 0.454 \text{ kg} = \frac{454 \text{ g}}{18.02 \text{ g/mol}} = 25.19 \text{ mol } H_2O / \text{lbm } H_2O$$

Molfraksjon: $$X = \frac{60 \text{ lbm } H_2O/\text{MMScf} \cdot 25.19 \frac{\text{mol } H_2O}{\text{lbm } H_2O}}{1.195 \cdot 10^6 \text{ mol gass/MMScf}}$$

(Vannet antas som en del av gassen) →

$$= 0.00126 \frac{\text{mol } (H_2O)}{\text{mol (gass)}} = \underline{1260 \text{ ppm}}$$

C) Her må man strengt tatt interpolere i tabellene:

Table 10.9 *Temperature Correction Factors for Trayed Glycol Contactors*

Operating temperature (°F)	*Correction factor* (C_t)
40	1.07
50	1.06
60	1.05
70	1.04
80	1.02
90	1.01
100	1.00
110	0.99
120	0.98

Source: Used, with permission, from Sivalls, 1977.

Table 10.10 *Specific Gravity Correction Factors for Trayed Glycol Contactors*

Gas-specific gravity (air = 1)	*Correction factor* (C_g)
0.55	1.14
0.60	1.08
0.65	1.04
0.70	1.00
0.75	0.97
0.80	0.93
0.85	0.90
0.90	0.88

Source: Used, with permission, from Sivalls, 1977.

Tabell 10.9: $C_t = 1.00 - \frac{100 - 93.2}{100 - 90} \cdot (1.00 - 1.01) = \underline{1.0068}$

Tabell 10.10: $C_g = 0.97 - \frac{0.75 - 0.71}{0.75 - 0.7} \cdot (0.97 - 1.00) = \underline{0.994}$

$$\Rightarrow q_s = \frac{2.55\ MMSm^3/d}{1.0068 \cdot 0.994} = 2.548 \cdot 35.32\ ft^3/m^3 = \underline{89.9\ MMscfd}$$

<u>OD = 72 in</u>

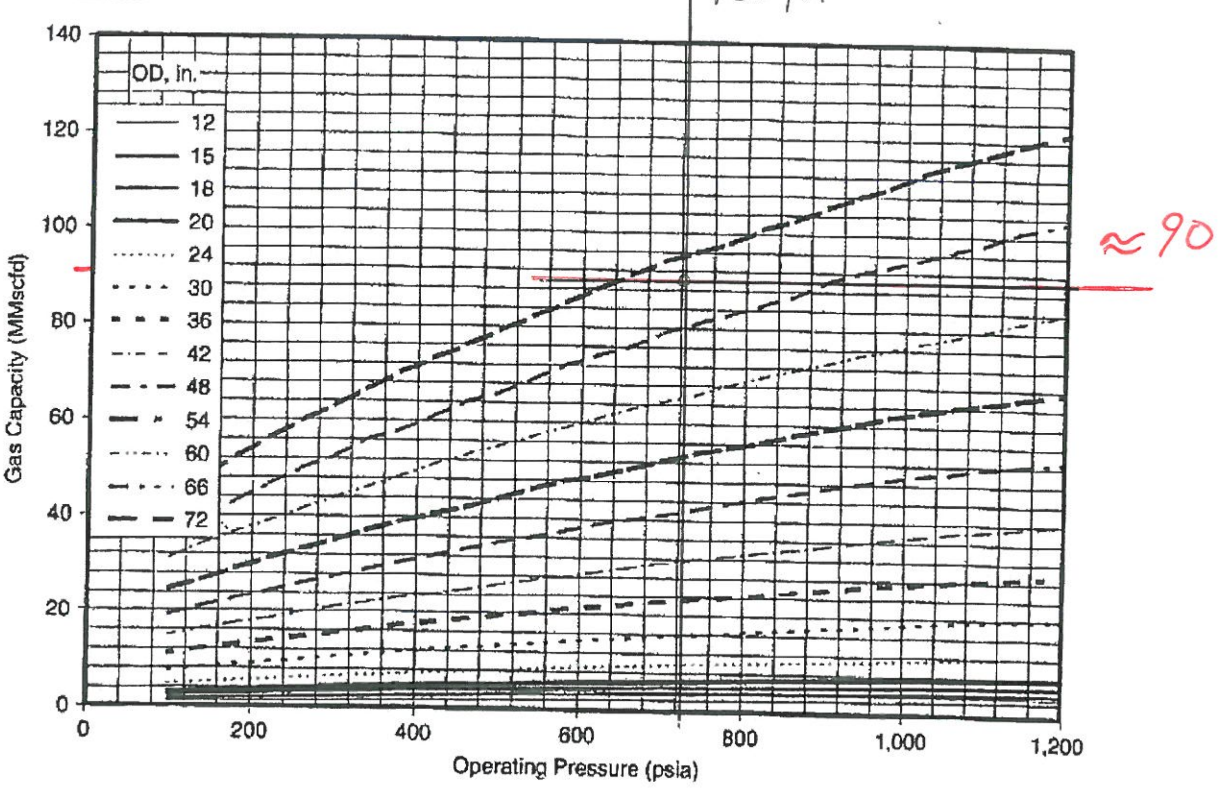


Figure 10.10 *Gas capacity for trayed glycol contactors based on 0.7-specific gravity at 100 °F (Sivalls, 1977).*

d) Fig 10.6: Tørket gass får et duggpunkt på i underkant av 20°F ⇒ $T_{DP} = 18°F = -7.8°C$ (v/ 725 psi)

e) Duggpunktet før tørking er pr. def gassens temperatur, når den er mettet på vann.

$$\Rightarrow \Delta T_{DP} = 93.2 - 18 = \underline{75.2\ °F}$$

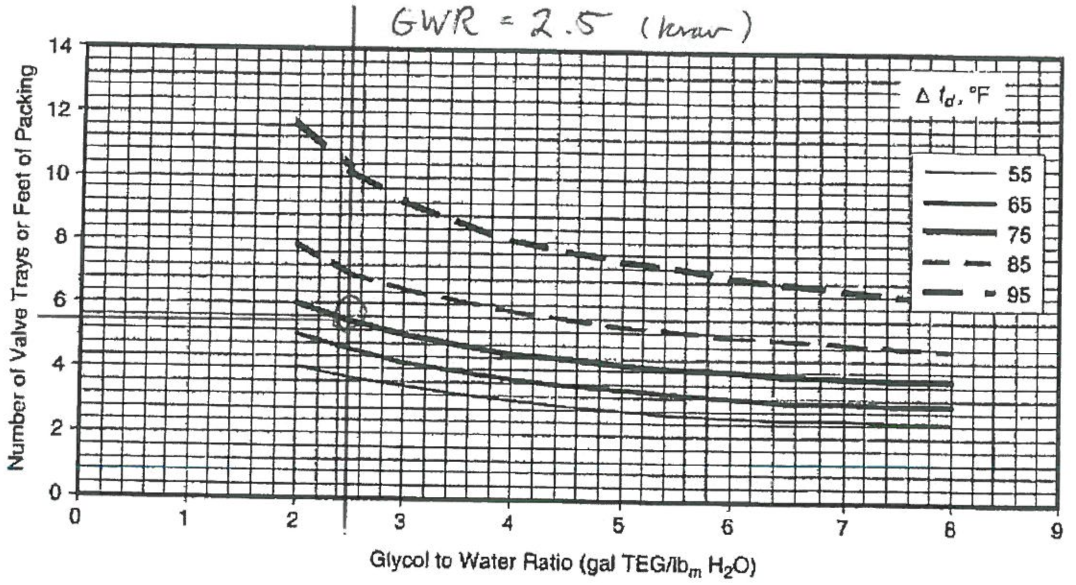


Figure 10.12 The required minimum height of packing of a packed contactor, or the minimum number of trays of a trayed contactor (Sivalls, 1977).

Fig. 10.12: Kontaktoren må ha 6 trinn.

f) Fra ligning. 10.8:

$$q_G = 2.5 \frac{\text{gal TEG}}{\text{lbm } H_2O} \cdot 60 \frac{\text{lbm } H_2O}{\text{MMScf}} \cdot 2.54 \text{ MMSm}^3/d \cdot 35.32 \frac{ft^3}{m^3}$$

$$= 13456.92 \text{ gal}/d = \underline{\underline{560.7 \text{ gal}/h = 2.1 \ m^3/h}}$$

(pr. enhet)

Oppg 4 – Varmeveksler

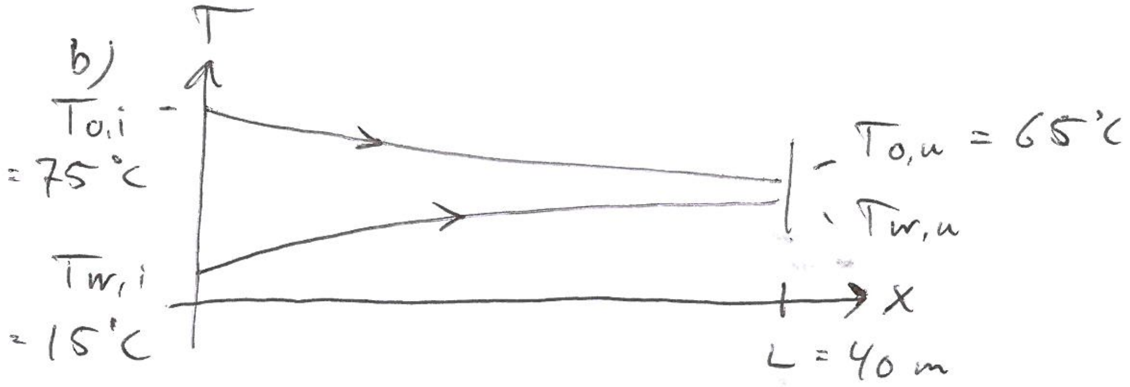
a) Uendelig lang varmeveksler vil gi samme temperatur på begge væskene:

$$\dot{q} = \dot{m}_o \cdot c_o \cdot (T_{o,i} - T) = \dot{m}_w \cdot c_w \cdot (T - T_{w,i})$$

$$T = \frac{\dot{m}_o \cdot c_o \cdot T_{o,i} + \dot{m}_w \cdot c_w \cdot T_{w,i}}{\dot{m}_o c_o + \dot{m}_w c_w}$$

$$= \frac{3.5 \cdot 2131 \cdot 75 + 1.5 \cdot 4200 \cdot 15}{3.5 \cdot 2131 + 1.5 \cdot 4200} = \underline{\underline{47.53\,^\circ C}}$$

b)



$$I: \dot{q} = \dot{m}_o \cdot c_o \cdot (T_{o,i} - T_{o,u}) = 3.5\,\frac{kg}{s} \cdot 2131\,\frac{J}{kg\,K}$$

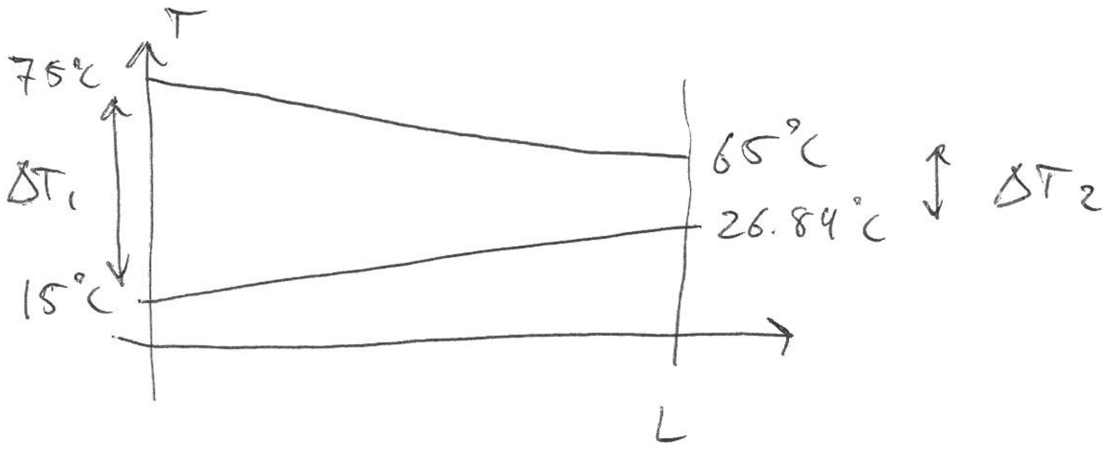
$$\cdot (75 - 65)\,K = \underline{74585\,W}$$

$$II: \dot{q} = \dot{m}_w \cdot c_w \cdot (T_{w,u} - T_{w,i})$$

$$\Rightarrow T_{w,u} = \frac{\dot{q} + \dot{m}_w c_w \cdot T_{w,i}}{\dot{m}_w \cdot c_w} = \frac{74585 + 1.5 \cdot 4200 \cdot 15}{1.5 \cdot 4200}$$

$$= \underline{26.84\,^\circ C}$$

III: $\dot{q} = U \cdot A \cdot LMTD$



$\Delta T_1 = 75 - 15 = 60\ K$

$\Delta T_2 = 65 - 26.84 = 38.16\ K$

$$LMTD = \frac{60 - 38.16}{\ln\left(\frac{60}{38.16}\right)} = \underline{48.26\ K}$$

$$A = \pi D_2 \cdot L = \pi \cdot 0.058\ m \cdot 40\ m = \underline{7.29\ m^2}$$

$$\Rightarrow U = \frac{\dot{q}}{A \cdot LMTD} = \frac{74585\ W}{7.29\ m^2 \cdot 48.26\ K} = \underline{\underline{213\ W/m^2K}}$$

c)

$$\frac{1}{U_{th}} = \frac{r_2}{r_1}\frac{1}{h_I} + \frac{r_2}{k} \cdot \ln\left(\frac{r_2}{r_1}\right) + \frac{1}{h_Y}$$

$$= \frac{58}{50} \cdot \frac{1}{360} + \frac{0.029}{47} \cdot \ln\left(\frac{58}{50}\right) + \frac{1}{2650} = 3.691 \cdot 10^{-3}$$

Forholdstall, så man kan sette inn diameteren i hvilken enhet man ønsker

$$\Rightarrow \underline{\underline{U_{th} = 271\ W/m^2K}}$$

d) ① Sette inn for nytt varmeovergangstall:

$$\dot{q} = 271\ \mathrm{W/m^2K} \cdot 7.29\ \mathrm{m^2} \cdot 48.26\ \mathrm{K} = \underline{95342\ \mathrm{W}}$$

② Beregne nye ut-temperaturer for ny verdi av $\dot{q}$:

$$T_{w,u} = \frac{95342 + 1.5 \cdot 4200 \cdot 15}{1.5 \cdot 4200} = \underline{30.13\ ^\circ C}$$

$$T_{o,u} = \frac{3.5 \cdot 2131 \cdot 75 - 95342}{3.5 \cdot 2131} = \underline{62.22\ ^\circ C}$$

③ Beregne ny ΔT_2 (ΔT_1 vil være konstant i medstrømsarrangement)

$$\Delta T_2 = 62.22 - 30.13 = \underline{32.09\ K}$$

④ Beregne ny LMTD

$$LMTD = \frac{60 - 32.09}{\ln\left(\frac{60}{32.09}\right)} = \underline{44.60\ K}$$

⑤ Gjenta fra ①:

$$\dot{q} = 271 \cdot 7.29 \cdot 44.60 = \underline{88111\ W}$$

Dette er en enkel form for numerisk beregning som kalles direkte substitusjon. Som det fremgår av Excel beregningen på neste side, slutter LMTD å endre seg (i 2. desimal) etter 6 gjentagelser. Vi sier da at beregningen har konvergert

Numerisk løsning:					
LMTD_0	48.26	K			
ΔT1	60				
U	271	W/m2K			
A	7.29	m2			
Iterasjon	q	Twu	Tou	ΔT2	LMTD
0	95342	30.13	62.22	32.08	44.59
1	88101	28.98	63.19	34.20	45.90
2	90679	29.39	62.84	33.45	45.44
3	89768	29.25	62.96	33.72	45.60
4	90091	29.30	62.92	33.62	45.54
5	89977	29.28	62.94	33.65	45.56
6	90017	29.29	62.93	33.64	45.56

e) Kobber ; $k = 400\ W/mK$:

$$\frac{1}{U_{th,2}} = \frac{58}{50}\,\frac{1}{360} + \frac{0.029}{400}\cdot \ln\left(\frac{58}{50}\right) + \frac{1}{2650} = 3.610\cdot 10^{-3}$$

$$\rightarrow \underline{U_{th,2} = 277\ W/m^2K}$$

$$\%\text{-vis økning} : \frac{277-271}{271}\cdot 100\% = \underline{\underline{2.2\%}}$$

– Neppe verdt prisen; det er ikke i rørveggen den største motstanden mot varmeovergang ligger. Selv med et materiale med uendelig stor termisk konduktivitet, ville U blitt ca. 277.8.

Varmeovergangen ved konveksjon, samt fouling utgjør de største barrierene mot varmestrømmen.

Oppg. 5, Kompresjon

a) Lign. 11.49: $W_s = RT_1 \frac{\varkappa}{\varkappa-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\varkappa-1}{\varkappa}} - 1\right]$

Dersom T_1 er lik, blir arbeidet pr. trinn det samme dersom P_2/P_1 e likt for hvert trinn.

$$\frac{P_2}{P_1} = \frac{P_3}{P_2} \Rightarrow P_2^2 = P_1 \cdot P_3 \Rightarrow P_2 = \sqrt{P_1 \cdot P_3} = \sqrt{5 \cdot 45} = \underline{\underline{15\text{ bar}}}$$

b) Beregne teoretisk arbeid pr. mol først:

$$P_2/P_1 = P_3/P_2 = \underline{3}$$

$$W_s = 8.3144\,\text{J/mol K} \cdot \overbrace{(35+273.15)}^{=308.15}\,\text{K} \cdot \frac{1.24}{(1.24-1)} \cdot \left[3^{\frac{1.24-1}{1.24}} - 1\right] = \underline{3136.4\text{ J/mol}}$$

Antall mol i 1 Sm^3 (Jfr. Oppg. 3): ($pV = NRT$)

$$N_{Sm^3} = \frac{101325 \cdot 1}{8.3144 \cdot 288.71} = \underline{42.2\text{ mol}}$$

$$\Rightarrow W = 3136.4\,\text{J/mol} \cdot 42.2\,\text{mol/Sm}^3 \cdot 2500\,\text{Sm}^3\text{/h} \cdot \frac{1}{3600}\,\frac{\text{h}}{\text{s}}$$

$$= 91914\,\text{J/s} = \underline{\underline{91.9\text{ kW}}}$$

c) Lign. 11.40: $T_{ut} = T_{inn} \cdot \left(\frac{P_2}{P_1}\right)^{\frac{\varkappa-1}{\varkappa}} = 308.15 \cdot 3^{\frac{0.24}{1.24}}$

$$\underline{\underline{= 381.16\text{ K} = 108\text{ °C}}}$$

d) 2. trinn: $P_1 = 15$ bar $T_1 = 35\,°C = 308.15\,K$

1: $r = P_2/P_1 = \underline{3}$

2: $$q = \frac{101238}{15\cdot 10^5}\cdot\frac{308.15}{288.71}\cdot 2500\ Sm^3/h = \underline{180\ m^3/h}$$

3: Anta $E_p = \underline{0.7}$ (konstant)

4: $$R_p = \frac{1.24-1}{1.24}\cdot\frac{1}{0.7} = \underline{0.276} \quad \left(=\frac{n-1}{n}\right)$$

5: $$T_2 = 308.15\cdot 3^{0.276} = \underline{417.5\ K} = \underline{144.4\,°C}$$

6: Bruke regnearket:

$Z_1(35°C,\ 1.5\ MPa) = \underline{0.970}$

$Z_2(144.4°C,\ 4.5\ MPa) = \underline{0.968}$

7: $$q = \frac{0.970}{0.968}\cdot\frac{101238}{15\cdot 10^5}\cdot\frac{308.15}{288.71}\cdot 2500 = \underline{180\ m^3/h}$$

8: Med så like z-verdier vil denne endre seg minimalt.

9: Polytropisk (NB! teoretisk ytelse) arbeid pr. mol, korrigert for reell gass vha. z:

$$W_p = \underbrace{RT_1\cdot\left(\frac{Z_1+Z_2}{2}\right)}_{P_1v_1 = \bar{Z}RT_1}\cdot\underbrace{\frac{n}{n-1}}_{\frac{1}{R_p}}\cdot\left[\left(\underbrace{\frac{P_2}{P_1}}_{r}\right)^{\overbrace{\frac{n-1}{n}}^{R_p}} - 1\right]$$

$$= 8.3144\,\frac{J}{mol\,K}\cdot 308.15\,K\cdot\left(\frac{0.97+0.968}{2}\right)\cdot\frac{1}{0.276}\cdot\left(3^{0.276}-1\right)$$

$$= \underline{3192.8\ J/mol}$$

Korrigert mhp. virkningsgrad, og omregnet til kW:

$$W = \frac{3192.8 \ \mathrm{J/mol}}{0.7} \cdot 42.2 \ \mathrm{mol/Sm^3} \cdot 2500 \ \mathrm{Sm^3/h} \cdot \frac{1}{3600} \ \frac{\mathrm{h}}{\mathrm{s}}$$

$$= 133667 \ \mathrm{J/s} = \underline{\underline{133.7 \ \mathrm{kW}}} \qquad (= 179.3 \ \mathrm{Hp})$$

Lign. 11.74 forutsetter at q_1 oppgis i $\mathrm{ft^3/min}$ og at P_1 oppgis i psi(a): $180 \ \mathrm{m^3/h} = 105.9 \ \mathrm{ft^3/min}$, $15 \ \mathrm{bar} = 217.6 \ \mathrm{psi}$

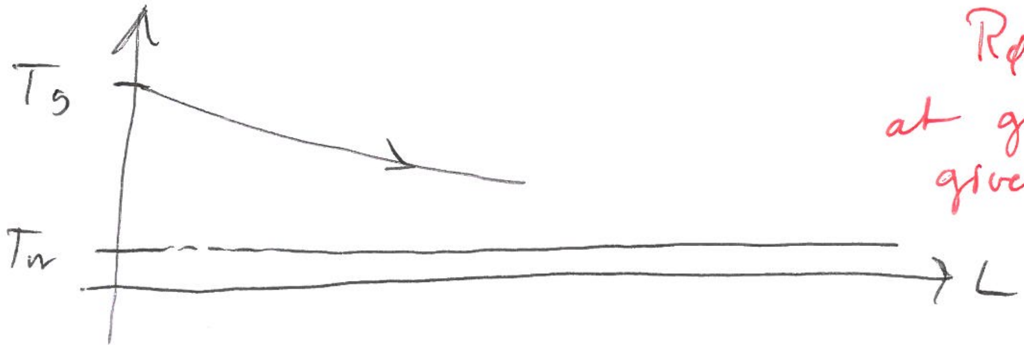
$$H_{pg} = \frac{105.9 \cdot 217.6}{229 \cdot 0.7} \cdot \left(\frac{0.97 + 0.968}{2 \cdot \underline{0.97}}\right) \cdot \left(\frac{3^{0.276} - 1}{0.276}\right) = 184.3 \ \mathrm{Hp}$$

$$(184.3 \cdot 0.97 = 178.7 \ \mathrm{Hp})$$

Dette behøver ikke bety at 11.47 er feil, men Z-verdiens rolle er ikke forklart utifra ligningen

Oppg. 6 – Gassrørledninger

a) Røret kan tenkes som en varmeveksler, hvor gassen kjøles mot vann som har konstant temp. hele tiden, og det er 658 000 m langt



Røret er så langt at gassen vil få omgivelses temperatur etter en kort "tur"

Det var opprinnelig ikke meningen at man skulle regne på dette, men siden varmeveksleren har blitt tatt inn i pensum kan vi gjøre et overslag:

70 MSm³/d v/ 90 bar og 4°C har $C_p \approx 50\ J/mol\,K$

$$\dot N = 70\cdot 10^6\ \frac{Sm^3}{d}\cdot 42.2\ \frac{mol}{Sm^3} = 2.954\cdot 10^9\ \frac{mol}{d} = 34190\ mol/s$$

Hvis vi antar $T = 50°C$ inn : LMTD ≈ [illegible]

$U = 100\ W/m^2K$ (ganske lavt) $\quad \frac{46-1}{\ln 46} = 11.7\ K$

Må ha utg. punkt i en lav verdi her

$$\dot q = \dot N\cdot C_p\cdot(50-5) = UA\ LMTD$$

$$A = \frac{34190\ mol/s\cdot 50\ J/mol\,K\cdot 45K}{100\ W/m^2K\cdot 11.7K} = 65750\ m^2$$

$$A = \pi\cdot D\cdot L \Rightarrow L = \frac{65750\ m^2}{\pi\cdot 1.07\ m} = \underline{19560\ m}$$

Med disse antagelsen vil gassen holde 5°C etter 19.6 km

c) Weymouth i SI - enheter:

$$q_{st} = 137.2 \cdot \left(\frac{288.71}{101283}\right) \cdot \sqrt{\frac{(19 \cdot 10^6)^2 - (9 \cdot 10^6)^2}{0.736 \cdot 0.61 \cdot 277.15 \cdot 658 \cdot 10^3}} \cdot (1.07)^{8/3}$$

$$= 866.2 \ Sm^3/s \cdot 86400 \ s/d = 74839680 \ Sm^3/d$$

$$\underline{\underline{\approx 74.8 \ MMSm^3/d}}$$

Det største anslaget stemmer m/ Weymouth-lign.

d) (Viser ikke alle omregninger her:)

$$q_{st} = 18.062 \cdot \left(\frac{520\,°R}{14.7\,psi}\right) \cdot \sqrt{\frac{(2756\,psi)^2 - (1305\,psi)^2}{0.736 \cdot 0.61 \cdot 499\,°R \cdot 409\,mi}} \cdot (42\,in)^{8/3}$$

$$\underline{\underline{= 109207149 \ sft^3/h}} = \underline{74.2 \ MMSm^3/d}$$