Exercise 1 : Axial Loads

a) 1. $F_A = (m_{ds}(h - h_{dc}) + m_{dc} h_{dc})\, g \left(1 - \frac{\rho_m}{\rho_s}\right)$

From tables: m_{ds}: 35,41 kg/m

m_{dc}: 181,7 kg/m

$\Rightarrow F_A = (35{,}41\,(2400 - 150) + 181{,}7 \cdot 150) \cdot 9{,}81 \cdot \left(1 - \frac{1210}{7850}\right) \cong 887{,}3\,kN$

2. $F_y = 1532\,kN$ (from tables)

$SF = \frac{F_y}{F_A} = \frac{1532}{887{,}3} \cong 1{,}73$ ok.

b) 1. $m_{dc} \frac{2}{3} h_{dc}\, g \left(1 - \frac{\rho_m}{\rho_s}\right) \geq F_B + F_N \Rightarrow F_B = m_{dc} \frac{2}{3} h_{dc}\, g \left(1 - \frac{\rho_m}{\rho_s}\right) - F_N$

$F_B = 181{,}7 \cdot \frac{2}{3} \cdot 150 \cdot 9{,}81 \left(1 - \frac{1210}{7850}\right) - 5000 \cong 145{,}8\,kN$

2. Compendium...

c) $\frac{1}{SF} = \sqrt{\left(\frac{P}{P_y}\right)^2 + \left(\frac{F}{F_y}\right)^2 + \left(\frac{M_F + M_R}{M_y}\right)^2}$

Tables: $P_y = 543$ bar

$F_y = 1532\,kN$

$M_y = 54\,kNm$

Solve for M_F.

$M_F = \sqrt{\left(\frac{1}{1{,}2}\right)^2 - \left(\frac{320}{543}\right)^2 - \left(\frac{887{,}3}{1532}\right)^2} \cdot 54\,kNm - 3\,kNm \cong 2{,}84\,kNm$

d) 1. $F_F = \frac{k_T - 1}{1 - k_T^{-n}} (M_g + F_x) = \frac{1{,}04 - 1}{1 - 1{,}04^{-12}} (3000 \cdot 9{,}81 + 887{,}3 \cdot 10^3) = 97679{,}6\,N \approx 97{,}68\,kN$

2. $v_F = \frac{\dot{E} \cdot \eta}{F_F} = \frac{750 \cdot 0{,}95 \cdot 10^3}{97679{,}6} \cong 7{,}29\,m/s$

3. $v = \frac{v_F}{n} = \frac{7{,}29\,m/s}{12} \cong 0{,}61\,m/s$

Exercise 2: Fluids and pumps

(21% + 4% multiple choice)
=> 25%

a) $\Delta P_F = \left(N_2(h - h_{dc}) + N_3 h_{dc}\right) \rho_R^{0.8} \mu_R^{0.2}$

$5\frac{1}{2}''$ → 21.90 lb/ft → ID = 4.778''

Tool joint ID = 101.6 mm = 4''

$\Rightarrow N_2 = 58$ kPa/100m

$N_3 = 497$ kPa/100m

$\Delta P_F = \underline{\underline{37,85 \text{ bar}}}$ (3%)

b) 1. $P_p = \Delta P_F + \Delta P_D + \Delta P_A + 0.9$

$\Rightarrow \Delta P_D = 320 - (37.85 + 11 + 0.9) = \underline{\underline{270.25}}$ bar (2%)

$\frac{270.25}{320} \approx 84\%$ (should be between 47% - 64%)

2. $F_D = \dot{m} v = \rho Q v = 1210 \cdot \frac{2000}{60000} \cdot 200.8 = \underline{\underline{8.1 \text{ kN}}}$ (3%)

↳ $v = 0.95 \sqrt{\frac{2 \cdot 270.25 \cdot 10^5}{1210}} = 200.8$ m/s

c) 1. $A_0 = \frac{Q}{v} = \frac{2000/60000}{200.8} = 166 \text{ mm}^2$

$A = \frac{A_0}{4} = 41.5 \text{ mm}^2$ (3%)

$D = \sqrt{\frac{4A}{\pi}} = 7.269$ mm => $\underline{\underline{\text{no. 11 : 7.731}}}$ mm

2. $v = \frac{F_D}{\rho Q} = \frac{7 \cdot 10^3}{1210 \cdot 2000/60000} = 173{,}6 \text{ m/s}$

$A_D = \frac{Q}{v} = 192 \text{ mm}^2$ (3%)

$A = \frac{A_D}{4} = 48 \text{ mm}^2$

$D = \sqrt{\frac{4A}{\pi}} = 7.818 \text{ mm} \Rightarrow$ no. 12: 8.525 mm

d). $D = \sqrt{\frac{4 \cdot \eta_p \cdot \eta_T \cdot \eta_E \cdot \dot{E}}{3\pi L n P_p}} \Rightarrow D = 5.04'' \Rightarrow 5''$ (2%)

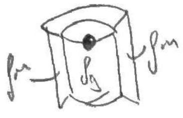
e) 1. $P_p = \frac{4 \eta_p \eta_T \eta_E \cdot \dot{E}}{3\pi L n D^2} = 325.33 \text{ bar}$ (2%)

2. $Q = \frac{3\pi D^2 L \cdot \eta_v \cdot n}{4} = 0.02029 \text{ m}^3/\text{s} = 1217{,}2 \text{ l/min}$

$\frac{2000}{1217.2} = 1.64 \Rightarrow$ 2 pumps needed (3%)

Exercise 3 : Casing

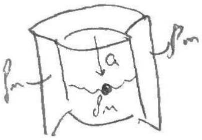
a) 1.



$\Delta P_B = P_i - P_o$
$= (P_F - \rho_g g h) - 0$
$= 320 \cdot 10^5 - 170 \cdot 9{,}81 \cdot 2400$
$\cong$ **280 bar**

2. At the top

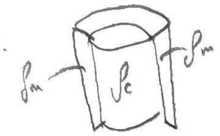
3.



$\Delta P_c = P_o - P_i$
$= 0{,}4 \cdot 2400 \cdot 1210 \cdot 9{,}81 - 0$
$= 113{,}95$ bar $\approx$ **114 bar**

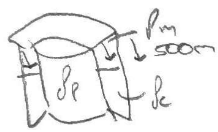
4. At a·h and down

b) 1. Burst :



$\Delta P_B = P_i - P_o$
$= 1525 \cdot 9{,}81 \cdot 2400 - 1210 \cdot 9{,}81 \cdot 2400$
$\cong$ **74,2 bar**

collapse :



$\Delta P_c = P_o - P_i$
$= [1525 \cdot 9{,}81 (2400-500) + 1210 \cdot 9{,}81 \cdot 500]$
$-$
$[1035 \cdot 9{,}81 \cdot 2400]$
$\cong$ **100 bar** (99,9)

2. At the bottom

c) 1. Dimensioning burst : $1{,}5 \cdot 280 = 420$ bar
Dimensioning collapse : $1{,}2 \cdot 114 = 136{,}8$ bar

2. **13 3/8" 68 lb/ft P110**

3. $SF_B = \frac{476}{420} = 1{,}13$ (ok) $\qquad SF_c = \frac{161}{136{,}8} = 1{,}18$ (ok)

d) 1. Degenerated : $F_{AD} = m \cdot h \cdot (1 - \frac{\rho_{md}}{\rho_s}) g = 992 \cdot 2400 \cdot (1 - \frac{1060}{7850}) =$ **2059,3 kN**

(m: 992 N/m (from tables))

cementing : $F_{AC} = m \cdot h (1 - \frac{\rho_m}{\rho_s}) g + A_i h (\rho_c - \rho_m) g$

(A_i: $78{,}10 \cdot 10^{-3}$ (from tables))

$= 992 \cdot 2400 (1 - \frac{1210}{7850}) + 78{,}10 \cdot 10^{-3} \cdot 2400 (1525 - 1210) \cdot 9{,}81 =$ **2593 kN**

(F_j from tables : 9510 kN)

2. $SF_D = \frac{9510}{2059{,}3} = 4{,}62$ (ok) $\qquad SF_C = \frac{9510}{2593} = 3{,}67$ (ok)

3. The axial load during cementing is dimensioning.

Exercise 4: Kick calculations

(21% + 4% multiple choice ⇒ 25%)

a) 1. $P_f = SIDPP + \rho_m g h = 22 \cdot 10^5 + 1210 \cdot 9.81 \cdot 2400 = \underline{\underline{306.88 \text{ bar}}}$ (2%)

2. $\rho_{km} g h = (306.88 + 10) \cdot 10^5$

$$\Rightarrow \rho_{km} = \frac{316.88 \cdot 10^5}{9.81 \cdot 2400} = \underline{\underline{1345.9 \text{ kg/m}^3}} \quad (2\%)$$

b)
$$\underline{\underline{h_k}} = \frac{(P_{ann} - P_{dp})\left(1 + \frac{Q_m \Delta t}{V_i}\right)}{(\rho_m - \rho_i) g}$$

$$= \frac{(28-22) \cdot 10^5 \cdot \left(1 + \frac{2000/60000 \cdot 54}{9.2}\right)}{(1210 - 725) \cdot 9.81} = \underline{\underline{150.78 \text{ m}}} \quad (4\%)$$

c) 1. $\Delta t_{string} = \frac{15.5}{650/60000} = 1430.8 \text{ s} \approx \underline{\underline{23 \text{ min } 50 \text{ s}}}$ (2%)

2. $\Delta t_{annulus} = \frac{152}{650/60000} = 14030.8 \text{ s} = \underline{\underline{3 \text{ h } 53 \text{ min } 49 \text{ s}}}$ (2%)

3. $\Delta t_{tot} = \Delta t_{string} + 2 \cdot \Delta t_{annulus} = \underline{\underline{8 \text{ h } 11 \text{ min}}}$ (2%)

d) 1. $\Delta P_{Fm2} = \frac{Q_{km}^{1.8}}{Q_m^{1.8}} \Delta P_{Fm1} = \left(\frac{650}{2000}\right)^{1.8} \cdot 37.85 = \underline{\underline{5 \text{ bar}}}$ (1%)

2. $\Delta P_{Om2} = \left(\frac{Q_{km}}{Q_m}\right)^2 \cdot \Delta P_{Om1} = \left(\frac{650}{2000}\right)^2 \cdot 270.25 = \underline{\underline{28.6 \text{ bar}}}$ (1%)

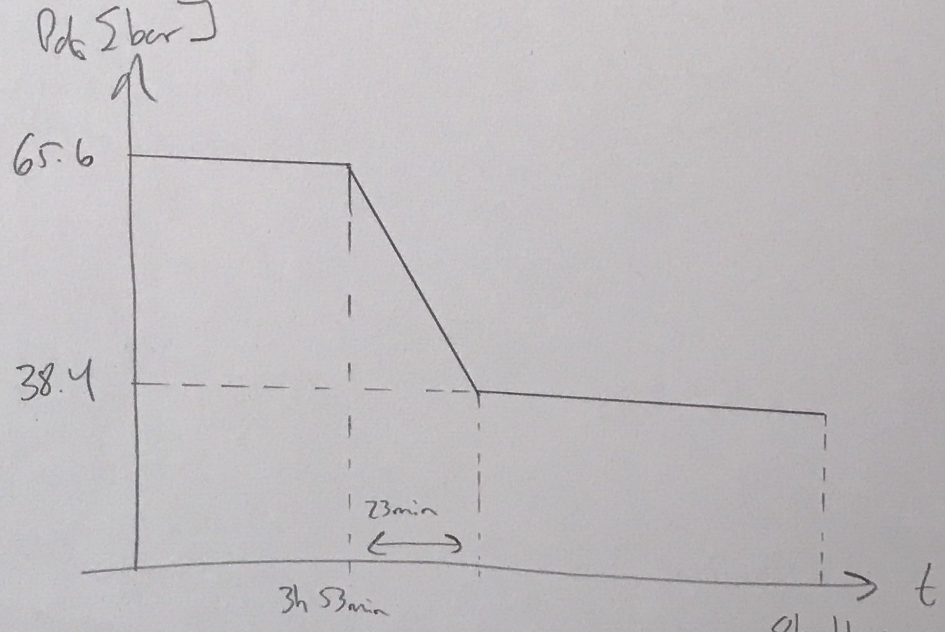
3. $\Delta P_{F,km} = \left(\frac{1345.9}{1210}\right)^{0.8} \cdot \left(\frac{26}{10}\right)^{0.2} \cdot 5 = \underline{\underline{6.6 \text{ bar}}}$ (1%)

4. $\Delta P_{O,km} = \frac{\rho_{km}}{\rho_m} \Delta P_{Om2} = \frac{1345.9}{1210} \cdot 28.6 = \underline{\underline{31.8 \text{ bar}}}$ (1%)

5. $P_{c1} = \Delta P_{Fm2} + \Delta P_{Om2} + \Delta P_S = \underline{43.6 \text{ bar}}$

$P_{c2} = \Delta P_{F,km} + \Delta P_{O,km} = \underline{38.4 \text{ bar}}$

$P_{dp} + P_{c1} = 65.6 \text{ bar}$



(3%)