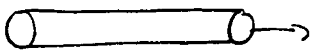
34 35 42

1, 2, 3, 4, 6, 7, 9, 10, 16, 17, 26, 27, 28, 30, 31, 43, 44, 47, 48, 49
53, 56, 64, 65, 72, 84, 88, 97

1.  1 kg/s $\quad Re = 2\cdot 10^4$

$\Delta p = 2\cdot 10^5\ N/m^2$

? wat is het vermogen P dat nodig is en wat is de temperatuurstijging ΔT als er geen warmte uitwisseling is met de omgeving

gebruik de energie balans: $\frac{dE}{dt} = \phi_{m,in} E_{in} - \phi_{m,uit} E_{uit} + \phi_A - \phi_W$

$E = u + p/\rho + \frac{1}{2}v^2 + gh$

$0 = \phi_m (u_i + p_i/\rho + \frac{1}{2}v_i^2 + gh_i) - \phi_m (u_u + p_u/\rho + \frac{1}{2}v_u^2 + gh_u)$

$h_u = h_i$ en $v_i = v_u$

$\Rightarrow 0 = u_i + p_i/\rho - u_u - p_u/\rho \qquad u = cT$

$c(T_u - T_i) = \frac{p_i - p_u}{\rho} \qquad \Rightarrow T_u - T_i = \Delta T = \frac{2.0\times10^5}{10^3\cdot 4.2\times10^3}$

$\phi_m (u_u - u_i) = \phi_A$ $\qquad$ water wordt opgewarmd door pomp

$= \phi_m \left(\frac{p_i - p_u}{\rho}\right) = \phi_A$

$\Rightarrow \phi_A = 1\cdot\frac{2,0\times10^5}{10^3} = 200 W$

a) waterstroom verdubbelen. $\qquad$? P en ΔT

$v' = 2v \qquad \Rightarrow Re' = 2Re$

frictie vergelijking van Fanning

① $p_1 - p_2 = 4f\ \frac{1}{2}\rho \langle v\rangle^2 \frac{x_2 - x_1}{D_i}$ $\qquad$ ② $p_1' - p_2' = 4f'\ \frac{1}{2}\rho\langle v'\rangle^2 \frac{x_2 - x_1}{D_i}$

$\frac{②}{①} \Rightarrow p_1' - p_2' = (p_1 - p_2)\frac{4f'}{4f}\frac{\langle v'\rangle^2}{\langle v\rangle}$

$Re = 2\cdot10^4 \qquad 4f = 0,020$

$Re' = 4\cdot10^4 \qquad 4f' = 0,022$

$\Rightarrow p_1' - p_2' = 2\cdot10^5\cdot\frac{0,022}{0,020}\cdot\frac{(2v)^2}{(v)^2} = 6,3\cdot10^5\ Pa$

$\Delta T = \frac{\Delta p}{\rho\cdot c} = \frac{6.3\times10^5}{10^3\cdot 4.2\times10^3} = 0,15\,°C \qquad P = \phi_A = \phi_m'\cdot\frac{p_1' - p_2'}{\rho} = 2\cdot\frac{6.3}{1}$

$= 1260 W$

②

b) $\phi_m'' = 1\,kg/s \quad D'' = {}^2/_3\,D$

zelfde vergelijking maar nu is D ook varierend ~~en v gelijk zodat~~

$P_1'' - P_2'' = (P_1 - P_2)\,\frac{4f''}{4f}\,\frac{\langle v''\rangle^2}{\langle v\rangle^2}\,\frac{D''}{D''}$

$\phi_m = \phi_v \cdot \ell = {}^1/_4\,\pi D^2 v \cdot \rho \quad \Rightarrow \quad v = \frac{4\phi_m}{\rho\pi D^2}$

$Re = \frac{Re}{1,5} \qquad v''/v = {}^9/_4 \quad \swarrow D^2$

$\Rightarrow \quad P_1'' - P_2'' = 2 \cdot 10^5 \cdot \frac{0,025}{0,028} \cdot \frac{(9/4v)^2}{\langle v\rangle^2} \cdot D/D\,1,5 = 13,6 \cdot 10^5\,Pa$

$\Rightarrow \quad \Delta T = \frac{13,6 \times 10^5}{4.2 \times 10^3 \cdot 10^3} = 0,32\,^\circ C \qquad \Rightarrow \quad P = 1360\,W$

2. Reynolds moet gelijk blijven:

$\frac{\rho_\ell v_\ell D_\ell}{\eta_\ell} = \frac{\rho_w v_w D_w}{\eta_w}$

$\rho_\ell = 1,2\,kg/m^3 \qquad \eta_\ell = 1,6 \times 10^{-6}\,P.$

$\rho_w = 10^3\,kg/m^3 \qquad \eta_w = 10^{-3}\,Pa.s$

$D_\ell = {}^1/_{10}\,D_w \qquad v_w = 10\,m/s$

$v_\ell = \frac{\rho_w v_w \eta_\ell}{\rho_\ell\,\eta_w} \cdot \frac{D_w}{D_\ell}$

$= \frac{10^3 \cdot 10 \cdot 1,6 \times 10^{-6}}{1,2 \cdot 10^{-3}} \cdot 10 = 133,3\,m/s$

3. $P_o(\eta, \rho, D, d, N, g) = \eta^a \rho^b D^c d^d N^e g^f$

$P = [kg\,m^2/s^3]$ ① $1 = a + b$

$\eta = [kg/m.s]$ ② $2 = -a - 3b + c + d + f$

$\rho = [kg/m^3]$ ③ $-3 = -a - e - 2f$

$D = [m]$

$d = [m]$

$N = [1/s]$

$g = [m/s^2]$

alles proberen uit te drukken in f a en c
dan komt g mooi uit en in Re zitten η en D tot de macht 1

① $b = 1 - a$ ② $2 = -a - 3 + 3a + c + d + f \quad \Rightarrow \quad d = 5 - 2a - c - f$

③ $+e = 3 - a - 2f$

$$P_o = \eta^a \rho^{1-a} D^c d^{5-2a-c-f} N^{3-a-2f} q^f$$

$$\frac{P_o}{\rho d^5 N^3} = \left(\frac{\eta}{\rho d^2 N}\right)^a \left(\frac{D}{d}\right)^c \left(\frac{q}{N^2 d}\right)^f$$

$$\frac{P_o}{\rho d^5 N^3} = f\left\{\left(\frac{\eta}{\rho d^2 N}\right), \left(\frac{D}{d}\right), \left(\frac{q}{N^2 d}\right)\right\}$$

3 vergelijkingen 6 onbekende
dus houdt 3 kentallen over en 3 onb

4 In de kentallen komen de grootheden niet in/met dezelfde macht voor. Als je ze dimensieloos wilt houden geeft dit problemen bij $\frac{1}{d^2N}$ en $\frac{1}{N^2 d}$

6 $N = f(c, \rho_s, \rho_w, \eta, D, q, d) = c^a \rho_s^b \rho_w^c \eta^d D^e q^f d^g$

$N = \left[\frac{kmol}{m^2 s}\right]$ $c^a = \left[\frac{kmol}{m^3}\right]^a$ $\rho_s = \rho_w = \left[\frac{kg}{m^3}\right]$ $\eta^d = \left[\frac{kg}{ms}\right]^d$ $D^e = \left[\frac{m^2}{s}\right]^e$ $q^f = \left[m/s^2\right]^f$
$d^g = [m]^g$

mol $1 = a$
m $-2 = -3a - 3b - 3c - d + 2e + f + g$
s $-1 = -d - e - 2f$
kg $0 = b + c + d$

4 vergel. 7 onbek.
$\Rightarrow$ 3 kentallen ~~met~~ en 3 onbek

uitdrukken in ~~d f g~~ b e f

① $a = 1$
③ $d = 1 - e - 2f$
④ $c = -b - 1 + e + 2f$
② $1 = -3b - 3(-b - 1 + e + 2f) - 1 + e + 2f + 2e + f + g$
$g = 3f + 1$

$$\Rightarrow \frac{N \rho_w}{c \eta d} = f\left(\frac{\rho_s}{\rho_w}, \underbrace{\frac{D \rho_w}{\eta}}_{= \frac{1}{Sc}}, \underbrace{\frac{q \rho_w^3 d^3}{\eta^2}}_{Ga}\right)$$

④

7 $H = f(D, N, \rho, \nu, Q)$

$\left[\frac{s^2}{m^2}\right] = [m]^a \, [1/s]^b \, \left[\frac{kg}{m^3}\right]^c \, \left[\frac{m^2}{s}\right]^d \, \left[\frac{m^3}{s}\right]^e$

m $-2 = a - 3c + 2d + 3e$

s $2 = -b + d - e$ 5 onbekende 3 vergel ⇒ 2 kentallen

kg $0 = c$

$c = 0$ $b = -e - d - 2$ m/s

$a = -2 + 3c - 2d - 3e = -2 - 2d - 3e$

$\frac{s^2}{m^2}$

$H = D^{-2-2d-3e} \, N^{-e-d-2} \, \rho^0 \, \nu^d \, Q^e$

$\frac{m^2}{s^2}$ $\frac{m^2}{s}$

$\frac{H}{N^2 D^2} = \left(\frac{\nu}{N D^2}\right)^d \left(\frac{Q D^{-3}}{N}\right)^e$ $a = 2 - 3e + 2b$

$c = 0$

$\frac{s^2}{m^2}$ $d = -1$

7. $H = f(D, N, \rho, \nu, Q)$ e

$\left[\frac{s^2}{m^2}\right]^{-1} = [m]^a \, [1/s]^b \, \left[\frac{kg}{m^3}\right]^c \, \left[\frac{m^2}{s^1}\right]^d \, \left[m^3/s^1\right]^e$

s $-2 = -b + d + e$ $b = +d + e - 2$

m $+2 = a - 3c - 2d - 3e$ $a = $ [illegible] $-2 - 2d + 3e$

kg $0 = c$ $c = 0$

$H = D^{-2-2d+3e} \, N^{+d+e-2} \, \rho^0 \, \nu^d \, Q^e$

=

7 kn want antwoord bevat $\frac{D^2 N}{\nu}$

ν = viscositeit = m^2/s

s =

7 $H = f(D, N, \rho, \nu, Q)$

$\left[\frac{m^2}{s^2}\right] = [m]^a \, [1/s]^b \, \left[\frac{kg}{m^3}\right]^c \, \left[\frac{m^2}{s}\right]^d \, \left[\frac{s}{m^3}\right]^e$

s $-2 = -b - d + e$ $\qquad$ $b = 2 - d + e$

m $2 = a - 3c + 2d - 3e$ $\qquad$ $a = 2 - 2d + 3e$

kg $0 = c$ $\qquad$ $c = 0$

$$H = D^{2-2d+3e} \, N^{-d+e+2} \, \rho^0 \, \nu^d \, Q^e$$

$$\frac{H}{D^2 N^2} = \left(\frac{\nu}{D^2 N}\right)^d \left(\frac{Q}{N D^3}\right)^e$$

b. $H = 15 m$

$N = 400/min$

$D_1 = D/4$

$g = 9.81$

$\frac{Hg}{N^2 D^2} = \frac{Hg}{D_1^2 N_1^2}$

$D_1 = D/4$

$\Rightarrow \quad N_1 = 4 \times N \quad = 1600/min$

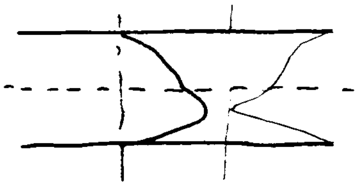
$\frac{Q}{ND^3} = \frac{Q_1}{N_1 D_1^3}$

$\frac{Q}{N \cdot D^3} = \frac{Q_1}{4N(\frac{1}{4})^3 D^3} \Rightarrow Q_1 = 1/16 \, Q$

$= 1{,}25 \, m^3/min$

9. maximaal aan de wand en in het midden nul

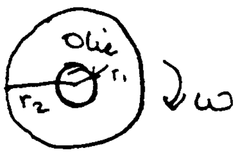
10)



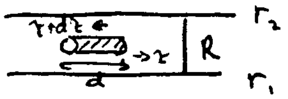
= goede snelheidsverdeling

$\tau = -\eta \frac{dv}{dy}$

16.



ga uit van vlakke plaat benadering



$\Sigma F = 0$

$\tau 2\pi R - (\tau + d\tau) 2\pi R_1 = 0$

$\tau 2\pi R - (\tau + \frac{d\tau}{dR} dR) 2\pi R = 0$

$\tau 2\pi R = \tau 2\pi R + \frac{\partial \tau}{\partial R} \partial R \, 2\pi R \quad \Rightarrow \quad \frac{\partial \tau}{\partial R} dR \, 2\pi R = 0$

$\Rightarrow \frac{\partial \tau}{\partial R} = 0$

$\tau_{xy} = -\eta \frac{\partial v_y}{\partial x} \Rightarrow \frac{\partial \tau}{\partial r} = 0 = -\eta \frac{\partial}{\partial r}\frac{\partial v}{\partial r} \Rightarrow \frac{\partial^2 v}{\partial r^2} = 0$

dus $\frac{\partial v}{\partial R}$ = een constante en dus is v een rechte lijn

$v = c_1 R + c_2$ als $R = r_1$ dan $v = \omega r_1$ $\qquad \omega R_1 = c_1 R_1 + c_2$

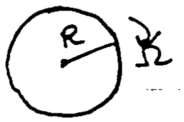
$\qquad\qquad R = r_2$ dan $v = 0$ $\qquad 0 = c_1 R_2 + c_2$

$\qquad \omega R_1 = c_1 (R_1 - R_2)$

$c_2 = -c_1 R_2 = \frac{-\omega R_1 R_2}{R_1 - R_2}$ en $c_1 = \frac{\omega R_1}{R_1 - R_2}$

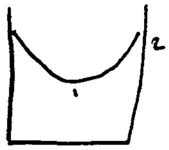
$\Rightarrow v = \frac{\omega R_1}{R_1 - R_2}(R - R_2)$

7.



v in midden 0 en aan rand het grootst

$V = \Omega \cdot r = \frac{2\pi r}{2\pi/\Omega}$



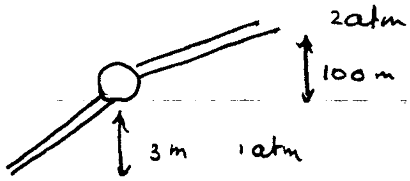
$0 = p_2 - p_1 + \rho g(h_2 - h_1) + \frac{1}{2}\rho(\langle v_2\rangle^2 - \cancel{\langle v_1\rangle^2})$

$p_1 = p_2 \qquad v_1 = 0$

$\rho g \Delta h = \frac{1}{2}\rho \langle v_2\rangle^2$

$\Rightarrow \Delta h = \frac{1}{2}\Omega^2 R^2 / g \qquad \Rightarrow h = h_1 + \frac{\Omega^2 r^2}{2g}$ = parabool

24.



ϕ_w = 3600 ton/uur

ϕ_A = 1000 Pk

$0 = \phi_m\left\{\frac{p_2 - p_1}{\rho} + g(h_2 - h_1) + \frac{1}{2}(\langle v_2\rangle^2 - \langle v_1\rangle^2)\right\} - \phi_A/0{,}9 - \phi_m A_{wr}$

$v_2 = v_1$

door wrijving gaat verloren $\phi_m A_{wr} = \phi_{wr}$

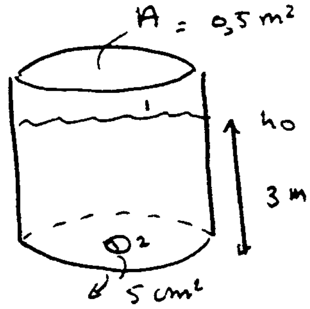
$0 = \phi_m\left\{\frac{10^5}{10^3} + g(103)\right\} - \phi_A/0{,}9 - \phi_{wr}$

$= \phi_v \cdot 10^3\left\{\frac{10^5}{10^3} + 10(103)\right\} - \frac{736 \times 10^3}{0{,}9} = \phi_{wr}$

b $\quad \phi_m \, c_p \, \Delta T = \phi_{wr} + (1-\eta)\, \phi_A / \eta$

$= \quad + (0{,}1)\, 736 \times 10^3 / 0{,}9$

28



bernoulli $0 = \Delta\left(\tfrac{1}{2}\rho v^2\right) + \Delta(\rho g h) + \Delta P\} \cancel{+ \phi_{h}} - \cancel{A_{wr} \phi_m}$

$\tfrac{1}{2}\rho\,\{\langle v_2\rangle^2 - \langle v_1\rangle^2\} + \rho g(h_2 - h_1) + P_1 - P_2 = 0$

$P_1 = P_2$

stel situatie is stationair $\quad v_1 = 0 \quad h_2 = 0$ $\quad \cancel{h_1 - h_2 = h_0}$

$\tfrac{1}{2}\rho \, v_2^2 - \rho g h_0 = 0$

$\Rightarrow \quad v_2 = \sqrt{2 g h_0}$

. stop eruit

$\langle v \rangle = \phi_v / opp \qquad \Rightarrow \phi_v = \sqrt{2gh_0} \cdot A_{2\,eff} = \sqrt{2gh_0} \cdot 0{,}5 \times 10^{-4} \cdot c$

en $\phi_v = v_1 . A_1 \qquad \Rightarrow \phi_v = \frac{\partial h}{\partial t} A_1$

$\frac{\partial h}{\partial t} A_1 = \sqrt{2gh_t}\; A_2 \cdot c$

$-\int_{h_0}^{h_t} A_1 \frac{1}{\sqrt{h}} \partial h = \int_0^t \sqrt{2g}\, A_2\, c\, dt \qquad - 2\sqrt{h}\,\Big|_{h_0}^{h_t} = - \frac{\sqrt{2g}}{A_1} c A_2 \cdot t$

$2(\sqrt{h_t} - \sqrt{h_0}) = - \ldots$

$+2A_1(\sqrt{h_0} - \sqrt{h}) = \sqrt{2g}\, A_2 c t \qquad\qquad c = 0{,}63$

invullen $\sqrt{h} = \sqrt{3} - 1{,}408 \cdot 10^{-3}\, t \qquad$ als $h = 0 \Rightarrow t = 1230\,sec$

$= 20$ min.

$\phi_v = F_2' \cdot v(t) = c . C_c \cdot F_2 \sqrt{2gh(t)} \qquad C_0 =$ doorstroom coeff. $= 0{,}63$

$C_c =$ contractie factor $=$

(30). $\Delta h = 10\,m$

. rel. ruwh $= e/D = 0{,}02$

. $L_{sl} = 25\,m$

. $\phi_{sl.} = 50\,mm$

. $\phi_{mond} = 15\,mm$

. $c_c = 0{,}7$

$P_1 = 4\,atm$

$P_2 = 760\,mmHg$

$\rho = 1000\,kg/m^3$

$\mu_w = 1{,}0\,cP$

Bern. $= \phi_m \{ P_1 - P_2 + g\rho(h_2 - h_1) + \tfrac{1}{2}\rho(\langle v_2\rangle^2 - v_1^2)\}$

$+ \cancel{\phi_A} - \phi_m A_{wr} = 0$

$v = \frac{\phi_v}{\frac{1}{4}\pi D^2}$

$0 = \{P_1 - P_2 + g\rho(10) + \frac{8\phi_v^2 \rho}{\pi^2}\left(\frac{1}{D_2^4} - \frac{1}{(0{,}7 D_2)^2}\right)\} - A_w$

$P_1 - P_2/\rho = \tfrac{1}{2}\langle v_0\rangle^2 \cdot \frac{L}{D_i} \cdot 4f = 4f\, \frac{8\phi_v^2}{\pi^2 D_i^4}\, \frac{L}{D_i}$

$4f\; C \cdot \phi_v^2 = g\, 10 + \frac{8}{\pi^2}\left(\frac{1}{D_1^4} - \frac{1}{(0{,}7 D)^2}\right)\phi_v^2$

$4f C\, \phi_v^2 = A + B\, \phi_v^2$

$\phi_v^2 = \dfrac{A}{4f.C - B}$ trial en error . kies f... bereken ϕ_v...

$Re = \dfrac{4\rho\phi_v}{\pi D\mu}$ ⇒ bepaal Re lees bijbehorende f af

bereken ϕ_v ⇒ Re enz tot const Re af

$A = 100$

$B = -32{,}5 \times 10^6$

$C = 25{,}9 \times 10^6$

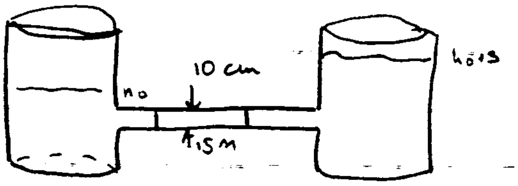
$f = 0{,}012 \Rightarrow \phi_v = 1{,}7 \times 10^{-3}$ $Re = 43{,}9 \times 10^3$

$f = 0{,}014 \Rightarrow \phi_v = 1{,}7 \times 10^{-3}$ $Re = 43{,}7$ ...

$\Rightarrow 4f \approx 0{,}05$

$\phi_v = 6{,}86 \; m^3/h$

31



$\rho = 1000 kg/m^3 = 1 kg/l$.

$k_{w\,in} = 0{,}2$ $k_{w\,uit} = 1{,}0$ $k_{w\,bocht} = 1{,}4$ $\eta = 1 \times 10^{-3}$ P

B.V. $0 = -\phi_m \left\{ \dfrac{p_1 - p_2}{\rho} + g(h_2 - h_1) + \tfrac{1}{2}(\cancel{\langle v_2\rangle^2} - \langle v_1\rangle^2) \right\} - A_{wr}\phi_m + \phi_A$

$\phi_m = \phi_v . \rho = 20 \cdot 1000 = 20.000$

$p_1 = p_2$ $h_2 - h_1 = 3$

$A_{wr} = \sum k_w \cdot \tfrac{1}{2}\langle v\rangle^2 + 4f\dfrac{L}{D}\cdot\tfrac{1}{2}\langle v\rangle^2 = 0.2 + 1 + 1{,}4 + 1{,}4 \cdot \tfrac{1}{2}v^2 = 4 \cdot \tfrac{1}{2}v^2 = 12{,}9 + ...$ $= 19{,}7$

$2{,}5$ m/s

$-\phi_A = -\{g \cdot 3 + \tfrac{1}{2} - (2{,}5)^2\}\, 20 - 19{,}7 \cdot 20$

$-\phi_A = -\{600 - 6{,}5\} - 394$

$\phi_A = 535 + 394 = 929$

$Re = \dfrac{4\rho\langle v\rangle D}{\eta} = \dfrac{4 \cdot 10^3 \cdot 1{,}275 \cdot 0{,}05}{1 \cdot 10^{-3}} = 2{,}53 \times 10^5$

$4f = 0{,}316\, Re^{-1/4} = 0{,}014$

b) $\phi_m\, c_p\, \Delta T = A_{wr}\,\phi_m + \dfrac{1-\eta\,\phi_A}{\eta}$

$\Rightarrow \Delta T = 0{,}04\,°C$

34. $\rho = 1{,}27\ \mathrm{kg/m^3}$ $\eta = 15{,}6 \cdot 10^{-6}\ \mathrm{kg/ms}$

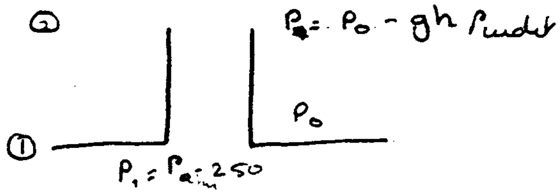
$P_s = 250\ \mathrm{N/m^2}$

$P_0 = 1000\ \mathrm{mbar}$ 15 t/h afgevoerd.

$T_s = 260°C$

$T_0 = 21°C$

$d = 2 \times 1{,}60$



alleen gassen uit de schoorsteen als $P_2 < P_0 - 250$

$$\frac{P_1 - P_2}{\rho_g} = gh \qquad \rho = \frac{MP}{RT} \text{, verwaarloos je} =$$

$$\rho_g = 1{,}27\ T_0/T$$

$$\frac{\rho_L}{\rho_g} = \frac{RT_g}{RT_L} \qquad \rho_g = \rho_L \cdot \frac{T_L}{T} = 1{,}27 \cdot \qquad = 0{,}7\ \frac{\mathrm{kg}}{\mathrm{m^3}}$$

$$\Rightarrow h = \frac{P_1 - P_2}{\rho g} = 44{,}0\ \mathrm{m}$$

35. $P_1 = P_{atm} - 250$

$P_2 = P_{atm} - \rho g h = 1 \cdot 10^5 - 1{,}2\cdot 9{,}81 \cdot H = 1{,}10^5 - 11{,}77H$

$$P_2 - P_1 = 250 - 11{,}77\,H$$

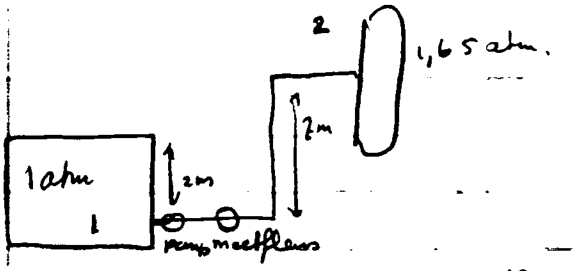
$$0 = \frac{250 - 11{,}77H}{\rho} + gH + 4f\ \tfrac{1}{2}\,v^2\,\frac{H}{D}$$

$$-250 = -11{,}77H + \rho g H + \rho\, 4f\ \tfrac{1}{2}\,v^2\,\frac{H}{D}$$

$$H = \frac{-250}{-11{,}77 + \rho g + \rho 4 f \cdot \tfrac{1}{2} v^2 / D} = \frac{-250}{-11{,}77 + 0{,}7 \cdot 9{,}8 + 0{,}7 \cdot 0{,}02 \cdot \tfrac{1}{2}\ 10}$$

$$= 51\ \mathrm{m}.$$

35



ϕ buis 5 cm

L buis 20 m

$$BV: \; 0 = -\phi_m \left\{ \frac{p_1 - p_2}{\rho} + g(h_2 - h_1) + \tfrac{1}{2}\langle v \rangle^2 - \langle v \rangle^2 \right. - A_{wr}\,\phi_m + \phi_A$$

$$\phi_A = +\phi_m \left\{ \frac{p_1 - p_2}{\rho} + g(h_2 - h_1) \right\} + A_{wr}\,\phi_m$$

$$= +\phi_v \rho \left\{ \frac{p_1 - p_2}{\rho} + g(h_2 - h_1) \right\} + \tfrac{1}{2}\langle v \rangle^2 (\Sigma k_w + \Sigma 4f$$

$\phi_v = 10\ L/s$

$\eta_{pomp} = 75\%$

$f = 0{,}1\ Re^{-1/4}$

$k_{w\,pijp\,in} = 1/2$

$k_{w\,pijp\,uit} = 1$

$k_{w\,L\,bocht} = 3/4$

$k_{w\,flens} = 2$

viscositeit $= \cancel{50}$ cP

$\rho = 0{,}7\ kg/L = 700\ kg/dm^3$

$$Re = \frac{\rho v D}{\eta} = \frac{700 \cdot v \cdot 5 \times 10^{-2}}{0.5 \times 10^{-3}} = 3{,}57 \times 10^5$$

$$f = 0{,}1\ Re^{-1/4} = 4.09 \cdot 10^{-3}$$

$$V = \frac{\phi_v}{A} = \frac{10 \cdot 10^{-3}}{\pi r^2} = 5{,}09\ m/s$$

$$A_{wr} = \tfrac{1}{2}\langle v \rangle^2 \left(\Sigma k_w + \Sigma 4f \tfrac{L}{D} \right) \phi_v \rho \qquad \Sigma k_w = 5$$

$$= \tfrac{1}{2} \cdot (5.09)^2 \left(5 + 4 \cdot 4{,}09 \cdot 10^{-3} \cdot \tfrac{2}{0{,}05} \right) = \underline{149{,}54} \quad 4f\tfrac{L}{D} =$$

$$\phi_A = 10 \cdot 10^{-3} \cdot 700 \cdot \left\{ \frac{p_1 - 1{,}65}{700} + 9{,}81(7) + 149{,}54 \right\} =$$

$p_2 = 1{,}65$ atm

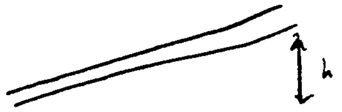
$p_1 = p_0 + \rho g h = 1\cancel{0} + 700 \cdot 9{,}81 \cdot 2 = 1{,}137 \times 10^5\ Pa$

$p_2 - p_1 = 5{,}127 \times 10^4\ Pa$

$\Rightarrow \phi_A = 2040\ W$

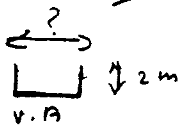
rendement 75% dus toevoeren $\frac{2040}{0{,}75} = 2720\ W$

42 a)



$L = 100$ km

$h = 100$ m



10 bochten met $k_w = 1$

$f = 4 \cdot 10^{-3}$

$\eta_w = 10^{-3}$ kg/m3

$\rho_w = 10^3$ kg/m³

$\Sigma k_w = 10$

B.V. $\quad 0 = -\phi_m \left\{ \frac{p_1 - p_2}{\rho} + g(h_2 - h_1) + \frac{1}{2}(v_2^2 - v_1^2) \right\} + \phi_A - A_w \phi_m$

$0 = -g(h_2 - h_1) - A_{wr}$

$A_{wr} = 4 f \, \frac{1}{2} v^2 \frac{L}{D_H} + \Sigma k_w \cdot \frac{1}{2} \langle v \rangle^2$

$D_H = \frac{4 \cdot opp}{nat\,omt} = \frac{4 \cdot 2 \cdot B}{4 + 2B} \Rightarrow \frac{1}{D_H} = \frac{B+4}{8B}$

$-9.81 \cdot 100 \quad -\left(4 \cdot 4 \cdot 10^{-3} \cdot \frac{1}{2} \, v^2 \, \frac{100 \cdot (B+4)}{8B} 10^3 + 10 \cdot \frac{1}{2} \cdot v^2 \right)$

$981 = 800 \langle v \rangle^2 \frac{W+4}{8W} + 5 \langle v \rangle^2 \quad \div$

$\phi_V = \langle v \rangle H W \qquad \phi_V = \frac{10.000 \text{ km}^2 \cdot 0,3}{s \text{ in an jaar}} = 95,1 \; ^{L}/_{s}$

$95.1 = 2 \cdot \langle v \rangle \cdot W$

$\Rightarrow v = 47.55 / W \quad \simeq$

$\div + \simeq \quad \Rightarrow \quad v = 2,766$ m/s $\quad W = 17.19$ m

b) $\quad 0,3 \; m^3/m^2 \qquad$ zon schijnt 365 dag per jaar 1/2 dag

$\Rightarrow \frac{0,3}{365 \cdot 12 \cdot 3600} = 1,9 \times 10^{-8} \; m^3/s \cdot m^2 \quad$ verdampt

ΔH verdamp $= 22,6 \cdot 10^5$ J/kg

$E = 1.9 \cdot 10^{-5}$ kg/s $\cdot \; 22,6 \cdot 10^5$ J/kg $\Rightarrow 43$ J/s $= 43$ W

4.4. $\frac{dE}{dt} = \cancel{\phi_m} u_i - \cancel{\phi_m} u_{uit} - \phi_w + \phi_R$ $\qquad \phi_w = 4\pi R \; \lambda (T - T_o)$

$E_t = \rho c_p T V$

$$\frac{dE}{dt} = \rho c_p V \frac{dT}{dt} = -uA(T-T_o) + \phi_R$$

$$\rho V c_p \int \frac{dT}{\phi_R - uA(T-T_o)} = \int_0^t dt$$

$$\Rightarrow \quad t = \frac{-V_e c_p}{uA} \rho \ln \frac{\phi_R - uA(T-T_o)}{\phi_R} = \frac{2000}{9 \cdot 0.12} \ln \frac{1000 - 9 \cdot 90 \cdot 0{,}12}{1000}$$

$A = 0{,}47 \ m^2$ $\qquad c_p = 2000 \ J/kg\,°C$ $\qquad T_o = 20°C$

$u = 9 \ W/m^2°C$ $\qquad \phi_R = 1000 W$ $\qquad T = 110°C$

$\rho \cdot V_e = V_{bak} \cdot \rho = 27.3$

b. $1 - \frac{uA}{\phi_R}(T - T_o) = e^{-\frac{uAt}{V_e c_p}}$

$$-T = \frac{e^{\dots} - 1 - \frac{uA t_o}{\phi_R}}{\phi_R} \cdot uA \qquad t \to \infty$$

$t \to \infty \quad T = \frac{\phi_R}{ua} + T_o = 256\,°C$

c. $\frac{dE}{dt} = \phi_R$ $\qquad \rho V_e c_p \frac{dT}{dt} = \phi_R$

$\rho V_e c_p / \phi_R \, (T - T_o) = t$ $\qquad t = 4914 s = 1 h \, 22 m$

47 2 platen $d = 7{,}7$ mm

$T_{sm} = 160°C$

$T_0 = 20°C$

$T_{pers} = 220°C$

$a = 4.2 \times 10^{-7}\ m^2/s$

$$\frac{T - T_0}{T_1 - T_0} = \frac{160-20}{220-20} = \frac{140}{200} = 0{,}7$$

snijdt de at/b^2 kromme bij $0{,}6 = \frac{at}{b^2}$

$b = 7.7 \times 10^{-3}$ $\Rightarrow \frac{at}{b^2} = 0{,}6 = \frac{4{,}2 \times 10^{-7} \cdot t}{7.7 \times 10^{-3}}$ $\Rightarrow t = 847$ s

~~48 hal $V = 12.10^3\ m^3$~~

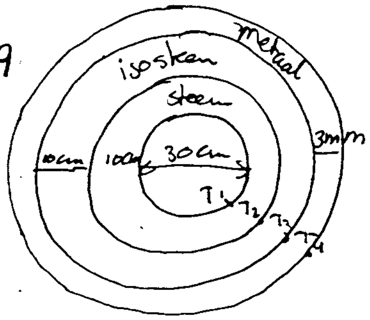
~~opp. raam 400 m^2 $u = 5\ W/m^2\,°C$~~

~~luchtverversing 3 m^3/s~~

~~a) Φ_A pomp als $\Delta T = 59°C$ te handhaven.~~

~~49~~

49



$\lambda_{steen} = 1{,}0\ W/m°C$

$\lambda_{isosteen} = 0{,}1 W/m°C$

$\lambda_{metaal} = 20 W/m°C$

$\phi_{A} = 1000W$

stationaire toestand: alles wat toegevoerd wordt wordt afgegeven.

a. $\phi_w'' = -\lambda \dfrac{dT}{dx}$

$\phi_w^{\bullet} = -\lambda \dfrac{dT}{dr} 4\pi r^2 = 1000$

$$-\int_{T_1}^{T_2} dT = \frac{\phi_w^{\bullet}}{4\pi\lambda_s}\int_{R_1}^{R_2}\frac{dr}{r^2}$$

$$T_1 - T_2 = \frac{\phi_w^{\bullet}}{4\pi\lambda_s}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

analoog
$$T_2 - T_3 = \frac{\phi_w^{\bullet}}{4\pi\lambda_i}\left(\frac{1}{R_2} - \frac{1}{R_3}\right)$$
$$T_3 - T_4 = \frac{\phi_w^{\bullet}}{4\pi\lambda_m}\left(\frac{1}{R_3} - \frac{1}{R_4}\right)$$

$$\Rightarrow T_1 - T_4 = \frac{\phi_w^{\bullet}}{4\pi}\left\{\frac{1}{\lambda_s}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) + \frac{1}{\lambda_i}\left(\frac{1}{R_2} - \frac{1}{R_3}\right) + \frac{1}{\lambda_m}\left(\frac{1}{R_3} - \frac{1}{R_4}\right)\right\}$$

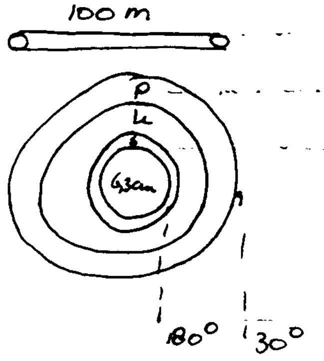
$= 4{,}645 \cdot 2\ °C =$ diameter ingevuld

b. $2 \cdot 464{,}5 + 30 = \cancel{994}\ 959°C$

$T_1 - T_4 = 928°C$ $\quad$ T_1 = T binnenwand

$T_1 = 929 + 30 = 959°C$ $\quad$ T_4 = T buitenwand $= 30°C$

53.



$R_1 = 3{,}15$ cm
$R_2 = 7{,}3/2$ cm $= 3{,}65$ cm
$R_3 = 5{,}65$ cm
$R_4 = 6{,}15$ cm
$\lambda_s = 45$ W/m °C
$\lambda_k = 0{,}06$ W/m °C
$\lambda_p = 0{,}5$ W/m °C

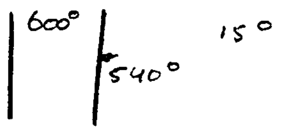
$$\Phi_w'' = -\lambda \frac{dT}{dr}$$
$$\Phi_w = -\lambda \frac{dT}{dr} \cdot 2\pi r \cdot L$$
$$-\int_{T_1}^{T_2} dT = \int_{R_1}^{R_2} dr \cdot \frac{1}{r} \cdot \cancel{\frac{2\pi L}{\Phi_w}} \frac{\Phi_w}{2\pi L \lambda}$$

$$T_1 - T_2 = \frac{\Phi_w}{2\pi L \lambda_s} \ln \frac{R_2}{R_1}$$
$$T_2 - T_3 = \frac{\Phi_w}{2\pi L \lambda_k} \ln \frac{R_3}{R_2}$$
$$T_3 - T_4 = \frac{\Phi_w}{2\pi L \lambda_p} \ln \frac{R_4}{R_3} \quad +$$

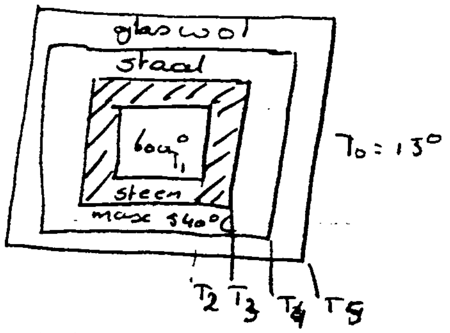
$$T_1 - T_4 = \frac{\Phi_w}{2\pi L} \left\{ \frac{1}{\lambda_s} \ln \frac{R_2}{R_1} + \frac{1}{\lambda_k} \ln \frac{R_3}{R_2} + \frac{1}{\lambda_p} \ln \frac{R_4}{R_3} \right\}$$
$$150° = \dots$$
$$\Phi_w = 150° \cdot 2\pi L \cdot \{ \qquad \}^{-1} = 12642 \text{ W}$$
$$= 12{,}6 \text{ kW}$$

b. $\text{verlies} = \frac{12{,}6}{2913} = 4{,}34 \cdot 10^{-3}$ kg/s

c. $T_3 = \frac{\Phi_w}{2\pi\lambda_p} \ln \frac{R_4}{R_3} + T_4 = 33{,}4$ °C

56 

neem aan warmteverlies is overal gelijk.



$\Phi_w'' = 440\ W/m^2$

$\Phi_w'' = \alpha \cdot \Delta T$
$\Phi_w'' = -\lambda \frac{dT}{dx}$ } kijken wat gegeven is en dan kiezen wat je gebruikt

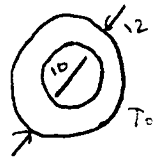
$\Phi_w'' = \alpha_i (T_1 - T_2) \rightarrow T_1 - T_2 = \frac{1}{\alpha_i} \Phi_w''$
$\Phi_w'' = -\lambda \frac{dT}{dx} = -\lambda \frac{(T_3 - T_2)}{d_{steenlaag}}$ ga uit van vlakke plaat benadering
$\Rightarrow T_3 - T_2 = \frac{d_s}{\lambda_s} \Phi_w''$

$T_1 - T_3 = \Phi_w'' \left\{ \frac{1}{\alpha_i} + \frac{d_s}{\lambda_s} \right\}$ weet T_1 en T_3 enz
$\Rightarrow d_s = 58\ nm$

$T_3 - T_4 = \frac{d_{st}}{\lambda_{st}} \Phi_w''$
$T_4 - T_5 = \frac{d_g}{\lambda_g} \Phi_w''$
$T_5 - T_0 = \frac{1}{\alpha_4} \Phi_w''$

$T_1 - T_0 = \left\{ \frac{1}{\alpha_1} + \frac{d_s}{\lambda_s} + \frac{d_{st}}{\lambda_{st}} + \frac{d_g}{\lambda_g} + \frac{1}{\alpha_4} \right\} \Phi_w''$

$\Rightarrow d_g = 50\ mm$

64 

V_{water} 6 cm/sec
$L_{pijp} = 20$ meter
$T_0 = 20°C$
$\alpha_u = 80$ kcal/m² °C uur
$\eta_w = 10^{-3}$ kg/m sec
λ_w warmtegeleidings coeff 0,54 kcal/m°C uur
$\rho = 1000$ kg/m³
$c_p = 1$ kcal/kg °C
$\lambda_B = 43$ kcal/m°C uur

$T_{begin\ pijp}$ 100°C

$Nu = 0{,}023\, R_e^{\,0{,}8} P_r^{\,0{,}033}$

$Nu = \frac{\alpha_i D_i}{\lambda_w}$ $\quad R_e = \frac{\rho v D_i}{\eta}$ $\quad P_r = \frac{\eta c_p}{\lambda} = \frac{\nu}{a} = \frac{\eta/\rho}{\lambda/\rho c_p}$

$R_e = \frac{6 \cdot 1000 \cdot 10^{-2} \cdot 10 \cdot 10^{-2}}{10^{-3}} = 6 \times 10^{+3}$

$P_r = \frac{10^{-3} \cdot 1 \times 10^3}{0{,}54 \times 10^3} * 3600$
tijd uur en sec

$$\alpha_i = 0{,}023\, Re^{0{,}8}\, Pr^{0{,}33} \cdot \lambda_w / D_i = 244{,}6 \ \frac{kcal}{m^2\,°C\,uur}$$

b $\phi_w'' = const$ => vlakkeplaat benadering

$$T_1 - T_2 = \frac{1}{\alpha_i}\,\phi_w''$$
$$T_2 - T_3 = \frac{d}{\lambda}\,\phi_w''$$
$$T_3 - T_4 = 1/\alpha_u\,\phi_w''$$

$$\phi_w'' = (T_1 - T_4)/\left\{\frac{1}{\alpha_1} + \frac{d}{\lambda_{st}} + \frac{1}{\alpha_u}\right\} = U\,\Delta T$$

$$U = 58{,}6\ kcal/m^2\,°C\,uur$$

$\frac{1}{\alpha_u}$ = grootste warmte weerstand

c.

neem klein elementje van buis

$$\phi_m c_p (T_x - T_{x+\Delta x}) - U\,(\langle T\rangle - T_0)\,\pi \langle D\rangle\,\Delta x = 0$$
$$\phi_m c_p (-dT) - U\,(T - T_0)\,\pi \langle D\rangle\,dx = 0$$
$$\int_{T_{in}}^{T_{uit}} \frac{dT}{T-T_0} = -U\pi\langle D\rangle \frac{1}{\phi_m c_p}\int_0^L dx$$
$$\ln\frac{T_{uit}-T_0}{T_{in}-T_0} = \underbrace{-U\pi\langle D\rangle \frac{1}{c_p\phi_m} L}_{\text{allemaal bekend}} \Rightarrow T_{uit} = 83\,°C$$

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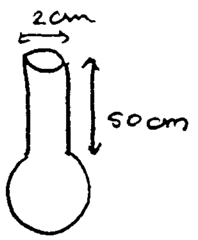

verdampingssnelheid = 16,5 μgr /s

$T_0 = 15°C$

$p = 1$ atm

a als nu hals ϕ 4cm is en lengte 100cm wat is dan de verdampingssnelheid.

$\phi'' = -D \frac{dc}{dx}$ $\phi_0 = -D \frac{dc}{dx} \cdot A$

A wordt 4x zo groot
l zit in dx.
$\Big\}$ $\phi_1 = \frac{4}{2} \cdot \phi_0$ dus 2 x zo grote diffusiesnelheid

b. $\phi = -D \frac{dc}{dx} \; 1/4 \pi d^2 = \frac{\phi_m}{M} = \frac{16,5 \times 10^{-6}}{74} = 2,2 \times 10^{-7}$ mol/s $M = 74$ gr./mol

$\frac{dc}{dx}$ mag je schrijven als $c_{begin} - c_{eind}$ / lengte   omdat geen v.d. andere componenten afh. is van x of t
neem concentratie boven in stof 0

$c_1 = \frac{P_v}{RT} = \frac{4,85 \cdot 10^4}{8,314 \cdot 288} = 20,3$ mol/m³

$D = \frac{4 \phi l}{\pi d^2 c_1} = 1,75 \cdot 10^{-5}$ m/s

88 aanname : 1) verdamping = stationair
2) op ∞ is concentratie 0
3) ~~...~~ straal veranderd niet

$\mathbb{D} = 0{,}5 \cdot 10^{-5}\ m^2/s$
$d = 5 \cdot 10^{-2}\ m$
dampspanning $= 10^{-3}$ atm
$\rho_{bol} = 1500\ kg/m^3$
mol. gew. $= 200 \cdot M$
temp $= 20°C$

? gewichtsafname na 1 uur

$\cancel{\phi_m = \mathbb{D} \frac{d\rho}{dx} \cdot 4\pi r^2 = -\mathbb{D} \frac{d\rho}{dx} \cdot \pi d^2}$

$\phi_m = -\mathbb{D} \frac{dc}{dx} \cdot \pi d^2 = \frac{\phi_m}{M} =$

$= -\mathbb{D}\ \pi d^2 \cdot M \cdot (c_1 - c_2)/l$

$c_2 = 0$

$c_1 = \frac{P_v}{RT} = \frac{10^{-3} \cdot 10^5}{8{,}314 \cdot 293} =$

$\phi = \mathbb{D}\ \pi d^2\ M\ \frac{c_1}{l}$

na 1 uur is $\phi \cdot 3600$ kg verdampt

totale massa na 1 uur $= \frac{4}{3}\pi r^3 \cdot 1500 - \phi\, 3600 =$

$\phi = -\mathbb{D} \frac{dc}{dr} 4\pi r^2$

$\phi \int \frac{dr}{r^2} = -4\pi \mathbb{D} \int_{c_0}^{c_\infty = 0} dc \qquad = -\phi \frac{1}{r}\Big|_{r_0}^{\infty} = -4\pi\mathbb{D}\,[c]_{c_0}^{0}$

$\frac{\phi}{r_0} = 4\pi\mathbb{D}\, c_0 \Rightarrow \phi = 4\pi\mathbb{D}\, r_0\, c_0$

$c_0 = \frac{p}{RT}$ p = dampspanning

$\Rightarrow \phi = 6{,}5 \times 10^{-8}\ mol/s$

aanname R blijft gelijk $\Rightarrow$ afname gewicht $= \phi \cdot t \cdot M = 4{,}7\ 10^{-5}$ kg

massa bol $= \rho\ \frac{4}{3}\pi r^3 = 9{,}8 \times 10^{-3}$ kg is $\approx$ 100 x gewichtsafname

dus aanname r is constant is goed

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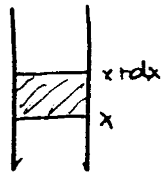

$R_A = -k c_A$

$\phi''_{m A,x} = -\mathbb{D}\frac{dc_A}{dx} = -\phi''_{m B,x} = \mathbb{D}\frac{dc_B}{dx}$

$-\mathbb{D}\frac{dc_A}{dx} = \mathbb{D}\frac{dc_B}{dx}$

$\phi = -\mathbb{D}\frac{dc}{dx} A$ proces verloopt stationair

$0 = \underbrace{(-\mathbb{D}\frac{dc}{dx}\cancel{A})_x}_{\text{instroom A}} - \underbrace{(-\mathbb{D}\frac{dc}{dx}\cancel{A})_{x+dx}}_{\text{uitstroom A in gebied}} - \underbrace{k c_A \cancel{A}\Delta x}_{\text{wat wegreageert}}$

$\Delta x \to 0$ $\quad \mathbb{D}\left(-d\left(\frac{dc}{dx}\right)\right) - k c_A \cdot dx = 0$

$+\mathbb{D}\left(\frac{d^2c}{dx^2}\right) - k c_A$

neem $c = c_0 e^{\lambda x}$ $\quad \lambda^2 e^{\lambda x} - \frac{k}{\mathbb{D}} e^{\lambda x} = 0$

$\lambda^2 - k/\mathbb{D} = 0$

$\lambda = \pm\sqrt{\frac{k}{\mathbb{D}}}$

$\Rightarrow \quad c = c_0 e^{-\sqrt{k/\mathbb{D}}\cdot x}$