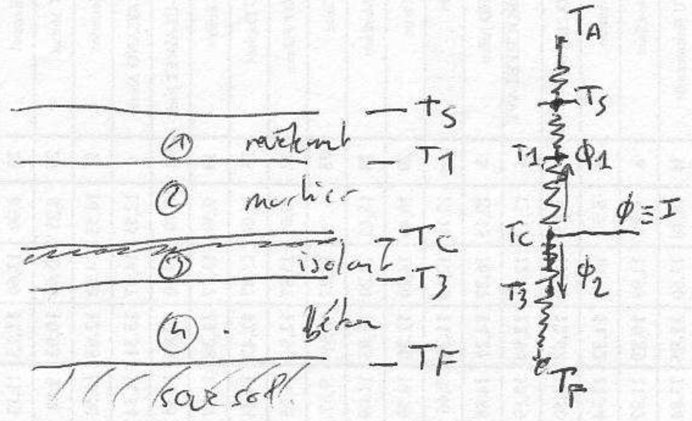
TT TD4.

A

1°) a)



$$\Phi_1 = \frac{T_C - T_A}{R_{T1}} \qquad \Phi_2 = \frac{T_C - T_F}{R_{T2}}$$

$$R_{T1} = \frac{1}{h_A S} + \frac{e_1}{\lambda_1 S} + \frac{e_2}{\lambda_2 S} \qquad R_{T2} = \frac{e_3}{\lambda_3 S} + \frac{e_4}{\lambda_4 S}$$

$$\Rightarrow \phi_1 = \frac{40-20}{\frac{1}{10 \times S} + \frac{1.10^{-2}}{2,5 \times S} + \frac{5.10^{-2}}{1,15 \times S}} = \underline{135,61 \ W/m^2}$$

$$\phi_2 = \frac{40-7}{\frac{2.10^{-2}}{0,02 S} + \frac{10.10^{-2}}{1,4}} = \underline{30,80 \ W/m^2}$$

donc $\phi = \phi_1 + \phi_2 = \underline{166,41 \ W m^{-2}}$.

b) $\Phi_1 = \dfrac{T_C - T_S}{\frac{e_1}{\lambda_1} + \frac{e_2}{\lambda_2}} \Rightarrow T_S = T_C - \phi_1 \left(\frac{e_1}{\lambda_1} + \frac{e_2}{\lambda_2} \right)$

$$= 40 - 135,61 \cdot \frac{1.10^{-2}}{2,5} + \frac{5.10^{-2}}{1,15}$$

$$\underline{T_S = 33,6 \ °C}$$

$\phi_1 = \dfrac{T_C - T_1}{\frac{e_2}{\lambda_2}} \Rightarrow T_1 = T_C - \phi_1 \dfrac{e_2}{\lambda_2}$

$$= 40 - 135,61 \times \frac{5.10^{-2}}{1,15}$$

$$\underline{T_1 = 34,1 \ °C}$$

$\phi_2 = \dfrac{T_C - T_3}{\frac{e_3}{\lambda_3}} \Rightarrow T_3 = T_C - \phi_2 \dfrac{e_3}{\lambda_3}$

$$= 40 - 30,80 \times \frac{2.10^{-2}}{0,02}$$

$$\underline{T_3 = 9,2 \ °C}$$

c) ϕ_2 est la puissance perdue.

$$\Rightarrow \frac{\phi_2}{\phi_T} = \frac{30,80}{166,41} = 18,5\%$$

d) $\frac{\phi_2}{\phi_T} = \frac{\phi_2}{\phi_1+\phi_2} < 10\% \Leftrightarrow 1\phi_2 < 0,1(\phi_1+\phi_2)$

$\Leftrightarrow \phi_2(1-0,1) < 0,1\,\phi_1$

on veut calculer e_3 $\Leftrightarrow \phi_2 < \frac{0,1}{0,9}\phi_1$

$\Rightarrow \phi_2$ à utiliser

donc $\frac{T_C-T_F}{\frac{e_3}{\lambda_3}+\frac{e_4}{\lambda_4}} < \frac{1}{9}\cdot\phi_1 = \alpha\phi_1$ $\quad \alpha = 1/9$.

$$\Leftrightarrow T_C-T_F < \alpha\phi_1\left(\frac{e_3}{\lambda_3}+\frac{e_4}{\lambda_4}\right)$$

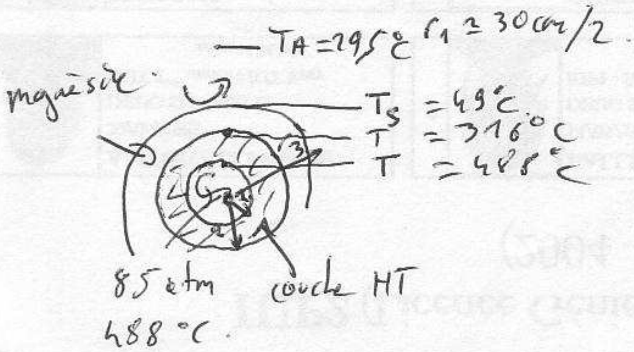
$$\Leftrightarrow \left(\frac{T_C-T_F}{\alpha\phi_1}-\frac{e_4}{\lambda_4}\right)\lambda_3 < e_3 \Rightarrow e_3 > \left[\frac{(40-7)\cdot \overset{1/\alpha}{9}}{135,61}-\frac{10\cdot10^{-2}}{1,40}\right]\cdot 0,02$$

$e_3 > 4,2$ cm. $\quad e \times 2 \simeq$ pertes/2.

e) $\Phi = \phi_1 \cdot S = 135,61 \times 12$

$\Phi = 1627,3$ W.

2) Vapeur et CPCU.



Soit V_1 le volume de la couche HT ϕ : diamètre conduite ($=30cm$).

Soit V_2 le — — magnésie

$V = \frac{\pi D^2}{4}$ $\Rightarrow$ $V_1 = \frac{\pi d_1^2 - \pi \phi^2}{4} \times L$ $\Rightarrow$ ~~V_2~~

$V_2 = \frac{\pi d_2^2 - \pi d_1^2}{4} \times L$

et $\frac{V_1}{V_1+V_2} = 0{,}15$ $(15\%) = A \Leftrightarrow V_1 = AV_1 + AV_2$

$\Leftrightarrow V_2 = \frac{(1-A)}{A} V_1$

donc $\frac{V_2}{V_1} = \frac{1-A}{A} = \frac{\pi d_2^2 - \pi d_1^2}{\pi d_1^2 - \pi \phi^2} \Leftrightarrow d_1^2(1+B) = d_2^2 - \phi^2 B$

$\Leftrightarrow d_1^2 = \frac{d_2^2}{1+B} - \phi^2 \frac{B}{1+B}$ $B = \frac{1-A}{A}$.

soit $\boxed{d_1^2 = \alpha d_2^2 + \beta}$

avec $\alpha = \frac{1}{1+B} = \frac{1}{1+\frac{1-A}{A}} = A = 0{,}15$ $\boxed{\alpha = 0{,}15}$

$\beta = \frac{B}{1+B}\phi^2 = \frac{1-A/A}{1+1-A/A}\phi^2 = \frac{1-A}{A} \cdot A \cdot \phi^2 (1-A)\phi^2 = (1-0{,}15) \cdot (3 \cdot 10^{-2})^2$

$\boxed{\beta = 76{,}5 \times 10^{-3}}$

b) résistance $R_1 = \frac{1}{h \cdot S} = \frac{1}{h \cdot \pi \phi \cdot L} = \frac{1}{3900 \times \frac{4180}{3600} \cdot \pi \cdot 30 \cdot 10^{-2} \cdot L} = 2{,}343 \cdot 10^{-4}$ $[°C/Wm.]$

HT : $R_2 = \frac{\ln \frac{d_1}{\phi}}{2\pi L \lambda} = \frac{\ln \frac{d_1}{0{,}3}}{2\pi \cdot 0{,}067 \times \frac{4180}{3600} L} = \frac{\ln \frac{d_1}{0{,}3}}{2\pi \cdot 0{,}067 \times 1{,}16} = \frac{\ln \frac{d_1}{0{,}3}}{2\pi \lambda}$

$R = \frac{\ln r_2/r_1}{2\pi L \cdot \lambda}$

magnésie $R_3 = \frac{\ln \frac{d_1}{d_2}}{2\pi \cdot 0{,}067 \times \frac{4180}{3600} \cdot L} = \frac{\ln d_1/d_2}{2\pi \times 0{,}067 \times 1{,}16} = \frac{\ln d_1/d_2}{2\pi \cdot 0{,}067 \times a}$

air extérieur $R_4 = \frac{1}{hS} = \frac{1}{7{,}8 \times a \cdot \pi d_2 \cdot L} = \frac{1}{7{,}8 a \pi d_2}$

$\varphi = \frac{498-316}{R_2} = \frac{316-49}{R_3} = \frac{49-29{,}5}{R_4}$.

D

dune $\dfrac{316-49}{R_3} = \dfrac{49-29,5}{R_4}$.

$\Rightarrow \dfrac{(316-49)\,2\pi\,0{,}067\,\ell}{\ln d_1/d_2} = (49-29{,}5)\,7{,}8\,\ell\pi\,d_2$

$\ln d_1/d_2 = \dfrac{(316-49)\cdot 2\times 0{,}067}{(49-29{,}5)\cdot 7{,}8}\cdot\dfrac{1}{d_2} = \dfrac{X}{d_2}$

$\underline{\underline{X = 0{,}2352}}$.

c) $d_1^2 = \alpha d_2^2 + \beta$ $\Rightarrow \dfrac{d_1^2}{d_2^2} = \alpha + \dfrac{\beta}{d_2^2}$ $\Rightarrow \alpha + \dfrac{\beta}{d_2^2} = e^{2X/d_2}$

$\ln\dfrac{d_1}{d_2} = \dfrac{X}{d_2}$ $\Rightarrow \dfrac{d_1}{d_2} = e^{X/d_2}$

$\Rightarrow \boxed{\alpha + \dfrac{\beta}{d_2^2} - e^{2X/d_2} = 0.}$

$d_2 = 0{,}536 \Rightarrow d_1 = \sqrt{\alpha d_2^2 + \beta}$

$= \sqrt{0{,}15\times 0{,}536^2 + 76{,}5\,10^{-3}}$

$\boxed{d_1 = 0{,}346\ m}$

dune ~~$R_1 \Rightarrow R_2 = \dfrac{\ln \frac{d_1}{\phi}}{2\pi\lambda}$~~ $\Rightarrow \varphi = \dfrac{488-316}{R_2} = \dfrac{49-29{,}5}{R_4}$ (cf. b)

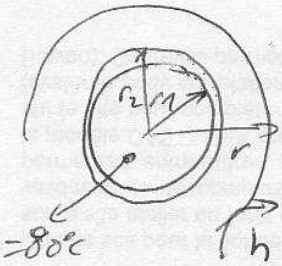
$\Rightarrow \dfrac{(488-316)\,2\pi\lambda}{\ln d_1/\phi} = (49-29{,}5)\cdot 7{,}8\,a\,\pi\,d_2$

$\Rightarrow \lambda = \dfrac{(49-29{,}5)\cdot 7{,}8\cdot a\,d_2\cdot\ln\frac{0{,}346}{0{,}3}}{(488-316)\times 2}$

$\underline{\underline{\lambda = 39{,}26\ mW/mK}}$

3°) (E

a)



$T_1 = 80°C$

$$R_{tube\,cu} = \frac{\ln \frac{r_2}{r_1}}{2\pi\lambda_1 L} = \frac{\ln\frac{7}{6}}{2\pi \cdot 380 \cdot L} = 6{,}45\times10^{-5}\ W^{-1}\cdot K$$

$$R_{isolat} = \frac{\ln r/r_2}{2\pi\lambda_2 L} = \frac{\ln\frac{15}{7}}{2\pi\, 0{,}10\, L} = 1{,}213\ W^{-1} K$$

$T_A = 20°C$

$$R_{conv} = \frac{1}{h 2\pi r L} = \frac{1}{10\cdot 2\pi\cdot 15\cdot10^{-3}} = 1{,}061\ W^{-1}K$$

$\Rightarrow R_{tube\,cu} \ll R_{isolat}$ et $R_{conv} \Rightarrow$ on peut négliger $R_{tube\,cu}$.

b) $$R_T(r) = \frac{\ln r/r_2}{2\pi\lambda_2 L} + \frac{1}{2\pi h r L}$$

c) non isolée : $R_{tube\,cu} \ll R_{conv} \Rightarrow \phi_{1\,perdu} = \dfrac{T_1-T_A}{\frac{1}{2\pi h r_2 L}} = \dfrac{80-20}{\frac{1}{2\pi\cdot10\cdot7\cdot10^{-3}}}$

$$\phi_{1\,perdu} = 26{,}40\ W\cdot m^{-1}$$

isolée : $$\phi_{2\,perdu} = \frac{T_1-T_A}{\frac{\ln r/r_2}{2\pi\lambda_2 L}+\frac{1}{h2\pi r L}} = \frac{80-20}{\frac{\ln\frac{8\cdot10^{-3}}{7\cdot10^{-3}}}{0{,}10}+\frac{1}{10\cdot 8\cdot10^{-3}}}(2\pi L) = 27{,}25\ W\cdot m^{-1}$$

$\phi_2 > \phi_1$!!! alors qu'il y a eu isolant

$\Rightarrow$ la résistance thermique ajoutée par l'isolant ne compense pas le supplément de perte par convection entre la surface de l'isolant et le milieu extérieur dû à l'↗ de la surface d'échange !

d)

on cherche pour $r = r_m$ le flux perdu max :

LF

$$\phi_2 = \frac{(T_1 - T_A)\,2\pi L}{\frac{\ln r/r_2}{\lambda_2} + \frac{1}{r.h}}$$

ϕ_2 max $\Rightarrow$ $\frac{\ln r/r_2}{\lambda_2} + \frac{1}{rh}$ minimum $\Rightarrow f(r) = \frac{1}{\lambda_2}\ln\frac{r}{r_2} + \frac{1}{r.h}$

minimum $\left| \begin{array}{l} \frac{df}{dr} = 0 \\ \frac{d^2f}{dr^2} > 0. \end{array}\right.$

$$\left.\frac{df(r)}{dr}\right|_{r_m} = \frac{1}{\lambda_2}\frac{1}{r} - \frac{1}{r^2 h} = \frac{1}{r}\left[\frac{1}{\lambda_2} - \frac{1}{rh}\right]$$

$$\left.\frac{df(r)}{dr}\right|_{r_m} = 0 \Leftrightarrow r_m = \frac{\lambda_2}{h} = \frac{0{,}10}{10} = \underline{0{,}01\ m.}$$

$$\cancel{\frac{d^2f(r)}{dr^2} = -\frac{1}{r^2}\left[\frac{1}{\lambda_2} - \frac{1}{rh}\right] + \frac{1}{r}\left(\frac{1}{r^2h}\right) = \frac{1}{r^2}\left[\frac{1}{rh} - \frac{1}{\lambda_2} + \frac{1}{rh}\right] = -\frac{1}{r^2\lambda_2}} < 0$$

$$\frac{d^2f(r)}{dr^2} = -\frac{1}{\lambda_2 r^2} + \frac{3}{r^3 h} = \frac{1}{r^2}\left(\frac{3}{rh} - \frac{1}{\lambda_2}\right)$$

$$\left.\frac{d^2f(r)}{dr^2}\right|_{r=r_m} = \cancel{\frac{1}{r^2}\left(\frac{3}{h} - h\right)} = \frac{1}{r^2}\left(\frac{3}{\lambda_2} - \frac{1}{\lambda_2}\right) = \frac{1}{r^2}\left(\frac{2}{\lambda_2}\right) > 0$$

$\Rightarrow$ donc c'est bien un minimum

d'où $\phi_{max} = \dfrac{(T_1 - T_A)\,2\pi L}{\frac{\ln\frac{\lambda_2}{hr_2}}{\lambda_2} + \frac{1}{\lambda_2}} = 27{,}79\ W.m^{-1}$

e) si $r = 15.10^{-3} > r_m$.

$$\phi_{2\,perdu} = \frac{T_1 - T_A}{\frac{\ln r/r_2}{2\pi\lambda_2} + \frac{1}{2\pi r.h}} = \frac{80 - 20}{\frac{\ln 15/7}{2\pi \cdot 0{,}1} + \frac{1}{2\pi 10 . 15.10^{-3}}} = \underline{26{,}38\ W/m}$$

non isolée $\phi_1 = 26{,}40\ W.m^{-1}$

isolée (15 mm isolant) $\phi_2 = 26{,}38\ W m^{-1} \simeq \phi_1 \Rightarrow$ ça ne sert à rien d'isoler des conduites de faible diamètre !

6

4) a). $R_t = \text{Force} = m\vec{\gamma} \Rightarrow R_t \equiv [L\,M\,T^{-2}]$

$\rho = \frac{m}{V} \Rightarrow \rho \equiv [L^{-3} M]$

$V = \text{distance}/\text{temps} \Rightarrow V \equiv [L\cdot T^{-1}]$

$L = \text{longueur} \Rightarrow L \equiv [L]$

$\nu = \text{viscosité cinématique } \frac{\mu}{\rho} \Rightarrow \nu \equiv [L^2 T^{-1}]$

$g = \text{accélération} \Rightarrow g \equiv [L\,T^{-2}]$

$\sigma = \text{tension superficielle} = \text{force} \Rightarrow \sigma \equiv M T^{-2}$

b).

	R_t	ρ	V	L	ν	g	σ
L	1	-3	1	1	2	1	0
M	1	1	0	0	0	0	1
T	-2	0	-1	0	-1	-2	-2

3 vecteurs indépendants (L, M, T = 3 grandeurs) $\Rightarrow$ 3 variables de base + $(7-3) = 4$ groupes π_i

V, L : $[g] \equiv \left[\frac{V^2}{L}\right] \Rightarrow$ non !

$[\nu] \equiv [V\cdot L] \Rightarrow$ non ! $\Rightarrow$ reste donc ρ, σ

$\underline{\rho, V, L}$: $\pi_1, \pi_2, \pi_3, \pi_4$.

π_1 : $\alpha_i = R_t \Rightarrow \pi_1 = \rho^a V^b L^c . R_t^d$

$$\left.\begin{array}{l} -3a + b + c + d = 0. \\ a + d = 0. \\ -b - 2d = 0. \end{array}\right\} \text{hyp} : d = 1 \to b = -2 \to a = -1 \to c = -2$$

$$\Rightarrow \pi_1 = \frac{1}{\rho}\cdot\frac{1}{V^2}\cdot\frac{1}{L^2}\cdot R_t.$$

π_2 : $\alpha_i = \nu \Rightarrow \pi_2 = \rho^a V^b L^c \nu^d$

$$\left.\begin{array}{l} -3a + b + c + 2d = 0 \\ a = 0. \\ -b - d = 0. \end{array}\right| \text{hyp} : d = 1 \Rightarrow b = -1 \Rightarrow a = 0 \Rightarrow c = -1$$

$$\pi_2 = \frac{1}{V}\cdot\frac{1}{L}\cdot\nu = \frac{1}{Re} \rightsquigarrow \pi'_2 = Re \quad (\text{hyp} : d = -1).$$

π_3 : $\alpha_i = g \Rightarrow \pi_3 = \rho^a V^b L^c g^d$

$$\left.\begin{array}{l} -3a + b + c + d = 0 \\ a = 0. \\ -b - 2d = 0 \end{array}\right| \text{hyp} : d = 1 \Rightarrow b = -2 \Rightarrow a = 0 \Rightarrow c = 1$$

$$\pi_3 = \frac{1}{V^2}\cdot L\cdot g \to \pi'_3 = Fr \quad (\text{hyp} : d = -\tfrac{1}{2})$$

$\pi_4 : x_i = \sigma \Rightarrow \pi_4 = \rho^a V^b L^c \sigma^d$.

$$\left.\begin{array}{l} -3a+b+c=0 \\ a+d=0 \\ -b-2d=0 \end{array}\right\} \text{hyp} : d=1 \Rightarrow b=-2 \Rightarrow a=-1 \Rightarrow c=-1$$

$$\pi_4 = \frac{1}{\rho}\frac{1}{V^2}\cdot\frac{1}{L}\cdot\sigma \Rightarrow \pi'_4 = Wb \ (\text{hyp } d=-1)$$

donc $F(R, \rho, V, \ell, \nu, g, \sigma) = \rho^a V^b \ell^c \cdot G(\pi_1, \pi_2, \pi_3, \pi_4) = \emptyset$

$$\Leftrightarrow G(\pi_1, \pi_2, \pi_3, \pi_4) = 0 \text{ ou } H(\pi_1, \pi'_2, \pi_3, \pi'_4) = 0$$

$$\Leftrightarrow \pi_1 = I(\pi'_2, \pi'_3, \pi'_4) = I(Re, Fr, Wb).$$

$$\Leftrightarrow \frac{R_t}{\rho V^2 L^2} = I(Re, Fr, Wb).$$

ou $R_t = \rho V^2 L^2 \, I(Re, Fr, Wb) \Rightarrow$ trouver $I(Re, Fr)$ ou $Re = \mathcal{F}(Fr)$.

les forces de tensions superficielles $\ll$ aux forces d'inertie suffisamment loin de la carène $Re \gg Wb$.

$$\Rightarrow R_t = \rho V^2 L^2 \, I(Re, Fr).$$

coefficient de résistance $C_T = \dfrac{R_T}{\frac{1}{2}\rho S V^2} = f(Re, Fr)$ $\quad S = L^2 \Rightarrow$ surface mouillée de la carène.

Rque: $Fr = \dfrac{V}{\sqrt{gL}}$ $\begin{array}{l}\leftarrow \text{inertie} \\ \leftarrow \text{gravité}\end{array}$ $\Big\} \Rightarrow$ détermine le champ de vagues

$Re = \dfrac{V.L}{\nu}$ $\begin{array}{l}\leftarrow \text{inertie} \\ \leftarrow \text{viscosité}\end{array}$ $\Big\} \Rightarrow$ rapport inertie/viscosité $\Rightarrow$ couche limite de frottement!