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MENG 263 — ADAM SZOSTAK

FLUIDS & HEAT TRANSFER — C0301168

ASSIGNMENT III

WATER SIDE

OUTPUT : 90W

H_2O: AVERAGE TEMP • $T_{AVG} = 90°C$

INLET → OUTLET • $\Delta T = 12°C$

AMBIENT AIR TEMPERATURE • $T_{AIR} = 30°C$ (MAX)

DETERMINE INLET/OUTLET TEMP:

$T_{AVG} = \frac{T_{IN} + T_{OUT}}{2}$ — (1) $\Delta T = T_{IN} - T_{OUT}$

$T_{IN} = \Delta T + T_{OUT}$ — (2)   sub (2) into (1)

$T_{AVG} = \frac{\Delta T + T_{OUT} + T_{OUT}}{2}$

$T_{AVG} = \frac{\Delta T + 2T_{OUT}}{2}$

$2T_{AVG} - \Delta T = 2T_{OUT}$

$T_{OUT} = T_{AVG} - \frac{1}{2}\Delta T$

$T_{OUT} = 90°C - \frac{1}{2}(12°C)$

$T_{OUT} = 84°C$ — sub into (2)

↳ $T_{IN} = 12°C + 84°C$

$T_{IN} = 96°C$

∴ $T_{IN} = 96°C$ $T_{OUT} = 84°C$

Note: C_p of H_2O @ $T_{AVG} = 90°C$

↳ $C_p = 4208\ J/kg°C$

a.) MASS FLOWRATE ~

$\dot{Q} = \dot{m} C_p \Delta T$

$\dot{m} = \frac{\dot{Q}}{C_p \Delta T} = \frac{90\ W}{(4208\ \frac{J}{kg°C})(12°C)} = 0.001782349\ kg/s$

$\dot{m} = 178.232 \times 10^{-5}\ kg/s$

b.) CONVERT $\dot{m}$ TO m^3/s ~ $\left(\frac{178.232 \times 10^{-5}\ kg}{s}\right)\left(\frac{m^3}{1000\ kg}\right)$ ok

$\dot{Q} = 178.232 \times 10^{-8}\ m^3/s$

c.) TUBE SIZE ⇝ i) RECOMMENDED VELOCITY : $v = 2\ m/s$

ii) DETERMINE DIAMETER $\dot{Q} = vA$ $A = \pi r^2 \rightsquigarrow A = \pi\left(\frac{d}{2}\right)^2 \rightsquigarrow A = \frac{\pi}{4}d^2$

$\dot{Q} = v\frac{\pi}{4}d^2$

$d = \sqrt{\frac{4\dot{Q}}{\pi v}} = \sqrt{\frac{4(178.232 \times 10^{-8}\ m^3/s)}{\pi(2\ m/s)}}$ $\frac{m^3}{s} \cdot \frac{s}{m} \to m$ $d = 0.001065204\ m$

≥ HOLE DRILLED IN BACKPLATE CAN BE PRODUCED IN 1mm INCREMENTS ONLY ≤

$0.001065204\ m \times \frac{100\ cm}{m} \times \frac{10\ mm}{cm} \Rightarrow 1.065204\ mm$ CHOOSE $d = 1\ mm$ ✓

$d = 0.001\ m$

iii) ACTUAL VELOCITY

$\dot{Q} = vA$

$v = \frac{\dot{Q}}{A}$

$v = \frac{\dot{Q}}{\frac{\pi}{4}d^2}$

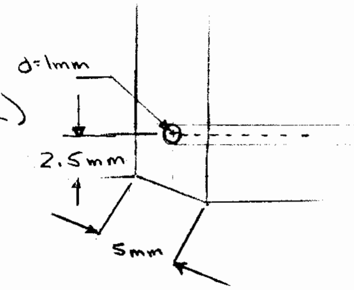
$v = \frac{4\dot{Q}}{\pi d^2}$

$v = \frac{4(178.232 \times 10^{-8}\ m^3/s)}{\pi(0.001\ m)^2}$

$v = 2.269320305\ m/s$

$V_{ACTUAL} = 2.269\ m/s$ ✓

d.) PLATE THICKNESS: choose $Th_B = 5\,mm \rightsquigarrow (0.005\,m)$ ✓



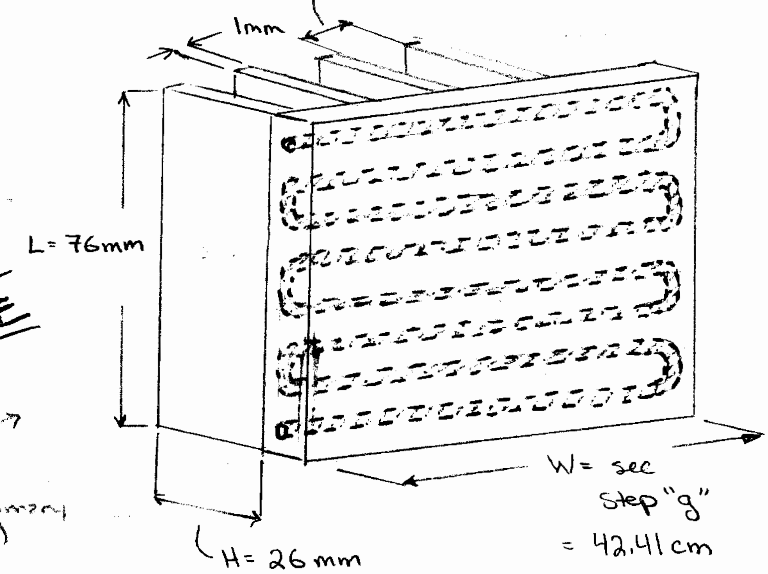
FIN SIDE

a.) Read section ✓

b.3 c.) ASSEMBLY LENGTH (L) & FIN HEIGHT (H)

$L = 76\,mm \rightsquigarrow (0.076\,m)$

$H = 26\,mm \rightsquigarrow (0.026\,m)$



d.) OPTIMUM FIN SPACING

FILM TEMP $T_f = \dfrac{T_\infty + T_s}{2} = \dfrac{30°C + 90°C}{2}$ $\quad T_f = 60°C + 273$

$T_f = 333\,K$

AIR AT FILM TEMP $(60°C \sim 333K)$

$Pr = 0.7207 \quad \nu = 1.896\times10^{-5} \quad K = 0.02808\ W/m°C \quad \beta = \frac{1}{T_f} = [333K]^{-1}$

$\beta = 0.003003003\ K^{-1}$ ✓

$$Ra = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2}Pr = \frac{(9.81\,m/s^2)(0.003003003\,K^{-1})(90°C-30°C)(0.076\,m)^3(0.7207)}{(1.896\times10^{-5})^2}$$ ✓

$Ra = 1.555\times10^{6}$ ✓

$$S_{OPT} = 2.714\frac{L}{Ra^{1/4}} = 2.714\frac{(0.076)}{(1.555\times10^{6})^{1/4}}$$

$S_{OPT} = 0.005841048\,m$

$S_{OPT} = 5.841\,mm$ ✓

CONVECTIVE HEAT TRANSFER COEFFICIENT

$$h = 1.31\frac{K}{S_{opt}} = 1.31\frac{(0.02808\,W/m°C)}{0.005841048\,m}$$

$h = 6.2976\ W/m^2°C$ ✓

e) SINGLE FIN BASE TEMP : $T_{AVG\,H_2O} = 90°C$

$A_{FIN} = 2w(L + \frac{1}{2}t)$

RESPECTIVELY $A_{FIN} = 2L(H + \frac{1}{2}t) = 2(0.076m)[0.026m + \frac{1}{2}(0.001m)]$

$A_{FIN} = 0.004028\,m^2$

$K_{ALUMINUM} = 207\,W/m°C$

$\xi = [L + \frac{1}{2}t]\sqrt{h/Kt}$ ✓

RESPECTIVELY $\xi = [H + \frac{1}{2}t]\sqrt{h/Kt} = [0.026m + \frac{1}{2}(0.001m)]\sqrt{6.29\,W/m^2°C / (207\,W/m°C)(0.001m)}$

$\xi = 0.1461$ ✓

$\therefore$ EFFICIENCY $\eta = 0.96$ ✓

$\dot{Q}_{FIN} = \eta h A(T_b - T_\infty)$

$= (0.96)(6.29\,W/m^2°C)(0.004028m^2)[90°C - 30°C] = 1.461133309W$ ✓

$\dot{Q}_{FIN} = 1.461W$

f.) NUMBER OF FINS REQUIRED $N_{FIN} = \frac{\dot{Q}_T}{\dot{Q}_{FIN}} = \frac{90W}{1.461W} = 61.602$ ✓

$N_{FIN} = 62$ ✓

g.) WIDTH OF HEAT SINK $n = \frac{W}{S+t}$

$W = n(s+t) = 62(0.005841m + 0.001m)$

$= 0.424142m$ ✓

$W = 42.41\,cm$

h.) ACTUAL TOTAL HEAT OUTPUT

AREA OF EXPOSED BASE $A_{EXP} = A_{BASE} - A_{FINBASE}$

$= [(0.4241m)(0.076m)] - 62[(0.076m)(0.001m)]$

$= 0.0275196\,m^2$

$\dot{Q}_{TOTAL} = h[A_{UNFIN} + N\{\eta A_{FIN}\}]\Delta T$ ✓

$= 6.2976\,\frac{W}{m^2°C}[0.0275196m^2 + 62\{(0.96)(0.004028m^2)\}](90°C - 30°C)$ ✓

$= 100.9881222\,W$ ✓

$\dot{Q}_{TOTAL} = 101\,W$ ✓

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