PROBLEM 1

PROBLEM 11.1 FROM BOOK

$\dot{V}_A = 2000$ cfm

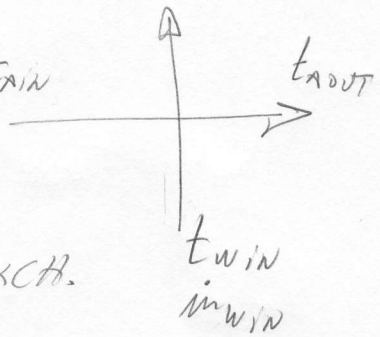
$t_{AIN} = 50°F$, $\varphi_{AIR} = 100\%$ SINGLE PAS CROSS FLOW HEA EXCH

$p_{ATM} = 14.7$ psia

$t_{AOUT} = 120°F$

$t_{WIN} = 180°F$

$\dot{m}_W = 30$ gpm



a) $t_{WOUT} = ?$ 100% EFFICIENT HEAT EXCH.

(*) $Q_{AIR} = Q_{WATER}$

$$\dot{m}_{AIR} = \rho_{AIR}\dot{V}_A = 0.075\frac{lb}{ft^3}\cdot 2000\frac{ft^3}{min}\cdot\frac{60\,min}{1\,hour} = 9{,}000\frac{lb}{h}$$

$$\dot{m}_{WATER} = \frac{\dot{V}_W}{v} = \frac{30\frac{gal}{min}\cdot\frac{60\,min}{h}\cdot 0.1337\frac{ft^3}{gal}}{0.01651\frac{ft^3}{lb}} = 14{,}576\frac{lb}{h}$$

$c_{P\,WATER} = 1$ Btu/lb F

$c_{P\,AIR} = c_{P\,DRY\,AIR} + W\cdot c_{P\,WATER\,VAPOR}$ (0.444 Btu/lb F)

$c_{P\,DRY\,AIR} \Rightarrow 0.240\frac{Btu}{lb°F}$

FROM PSYCHROM. CHART $W = 0.0076\frac{lb_w}{lb_{d.a.}}$

$c_{P\,AIR} = 0.2434$ Btu/lb

FROM (*) $\Rightarrow (\dot{m}c_p)_a(t_{AOUT} - t_{AIN}) = (\dot{m}c_p)_w\cdot(t_{WIN} - t_{WOUT})$

$\Delta t_{AIR} = 70°F$

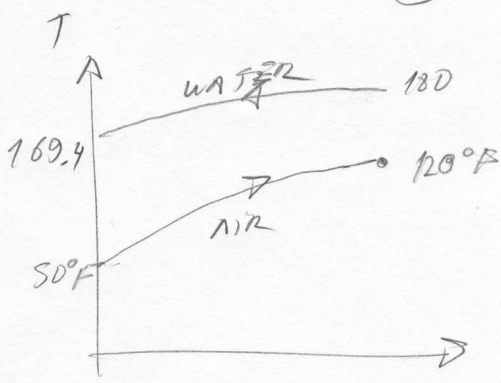
$(\dot{m}c_p)_a = 2{,}190.6\frac{Btu}{h°F}$

$(\dot{m}c_p)_w = 14{,}576\frac{Btu}{h°F}$

$$t_{WOUT} = t_{WIN} - \frac{(\dot{m}c_p)_a}{(\dot{m}c_p)_w}\cdot\Delta t_{AIR} = 180 - 0.1503\cdot 70 = \boxed{169.4°F}$$

b) CORRECTION FACTOR F

Fig 11.5 (PAGE 293)



$$P = \frac{t_{co} - t_{ci}}{t_{hi} - t_{ci}} = \frac{120-50}{180-50} = \frac{70}{130} = 0.54$$

$$R = \frac{t_{hi} - t_{hout}}{t_{cout} - t_{cin}} = \frac{10.6}{70} = 0.151$$

FROM FIGURE 11.5 $\Rightarrow F \approx 1$ SMALLER THAN 1 BUT CLOSE ASSUME $\boxed{F = 0.99}$

c) LMTD (Δt_m) = ?

$$\boxed{\Delta t_m = \frac{(t_{wout} - t_{Ain}) - (t_{win} - t_{Aout})}{\ln \frac{t_{wout} - t_{win}}{t_{win} - t_{Aout}}}} = \frac{119.4 - 60}{\ln \frac{119.4}{60}} = \frac{59.4}{0.99} = \boxed{86.3\ ^\circ F}$$

d) ε = ?

$$\boxed{\varepsilon = \frac{q}{q_{max}}} = \frac{(\dot{m}c_p)_{air}\,\Delta t_{AIR}}{(\dot{m}c_p)_{min}\,(t_{win} - t_{Ain})} = \frac{153{,}342\ \frac{Btu}{h}}{2190.6\ \frac{Btu}{hF}\ 130^\circ F} = \boxed{0.53}$$

$(\dot{m}c_p)_{min}$ ⇓ AIR

e) $$\boxed{C_R = \frac{(\dot{m}c_p)_{min}}{(\dot{m}c_p)_{max}} = \frac{2190.6}{14576} = 0.151}$$

f) NTU = ?

$(\dot{m}c_p)_{min} = (\dot{m}c_p)_{AIR}$ AIR IS UNMIXED $(\dot{m}c_p)_m$ IS UNMIXED

WATER IS MIXED

$$\varepsilon = \frac{1}{C_R}\left\{1 - e^{-C_R(1 - e^{-NTU})}\right\} \Rightarrow \boxed{NTU = 0.81}$$

g) $A_o U_o$ = ?

$$NTU = \frac{A_o U_o}{(\dot{m}c_p)_{min}} \Rightarrow A_o U_o = NTU\,(\dot{m}c_p)_{min} = 0.81 \cdot 2191$$

$$\boxed{A_o U_o = 1730\ \frac{Btu}{h^\circ F}}$$

PROBLEM 2

PROBLEM 11.7 FROM BOOK

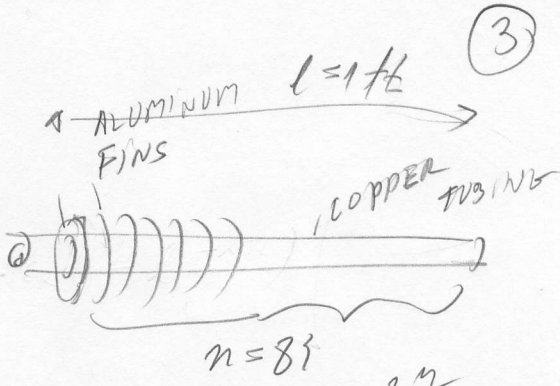
SIMILAR TO EXAMPLE 11.3.

$2y = 0.01$ in

$y = 0.005$ in

$D_2 \equiv D_F = 2$ in

$n/ft = 84$

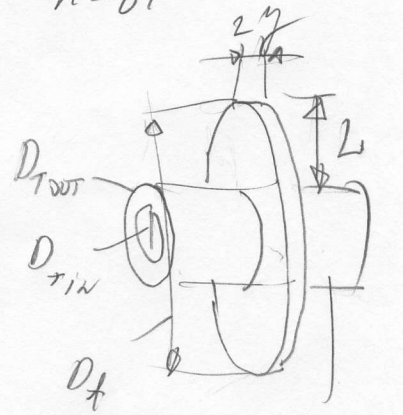


$D_{TUB_{OUT}} = 0.530$ in $\equiv D_1$

$D_{TUB_{IN}} = 0.480$ in $\equiv D_i$

$h_{OUT} = 9 \frac{Btu}{h\,ft^2\,°F}$

$h_{in} = 1000 \frac{Btu}{h\,ft^2\,°F}$



$K_{COPPER} = 223 \frac{Btu}{h\,ft\,°F}$

TO NEED ALL TERMS FOR: EQ. 11.39

$U_o = ?$

FIN EFFICIENCY: FROM FIG 11.11

$r_2/r_1 = D_F/D_{TOUT} = \frac{2''}{0.53''} = 3.77$

$L\sqrt{h_{OUT}/k\cdot y} = \left(\frac{2-0.53}{2}\right)''in \sqrt{9\ Btu/h\,ft^2\,°F / 120 \frac{Btu}{h\,ft\,°F} \cdot 0.005\ in \cdot \frac{12\ in}{ft}} =$

$L\sqrt{h/ky} = 0.822 \Rightarrow$

↑ CONDUCTIVITY FOR ALUMINUM $120 \frac{Btu}{h\,ft\,°F}$

$\Rightarrow \boxed{\phi = 0.68}$

FOR 1 ft long PIPE WITH FINS:

$A_{P,i} = \pi D_i l = 3.14 \cdot 0.48\ in\ (1\ ft) \cdot \left(\frac{ft}{12\ in}\right) = 0.126\ ft^2/ft$

$A_{P,m} = \frac{\pi(D_1 + D_i)\cdot l}{2} = \frac{3.14(0.53+0.48)}{2\cdot 12} = 0.132\ ft^2/ft$

$A_{P,o} = \pi D_1 [l - 84(2y)] = 3.14 \cdot 0.53\ in \left[12\ in - 84(2\cdot 0.005\ in)\right]\left(\frac{ft^2}{144\ in^2}\right) =$

$= 0.129\ ft^2/ft_{length}$

$A_F = \frac{\pi(D_2^2 - D_1^2)\cdot 2\cdot(84)}{4} = \frac{3.14(2^2 - 0.53^2)\ in^2 \cdot 2 \cdot 84}{4} \cdot \frac{ft^2}{144\ in^2} = 3.408\ ft^2/ft_{length}$

$A_o = A_{P,o} + A_F = 0.129 + 3.408 = 3.537 \ ft^2/ft_{length}$

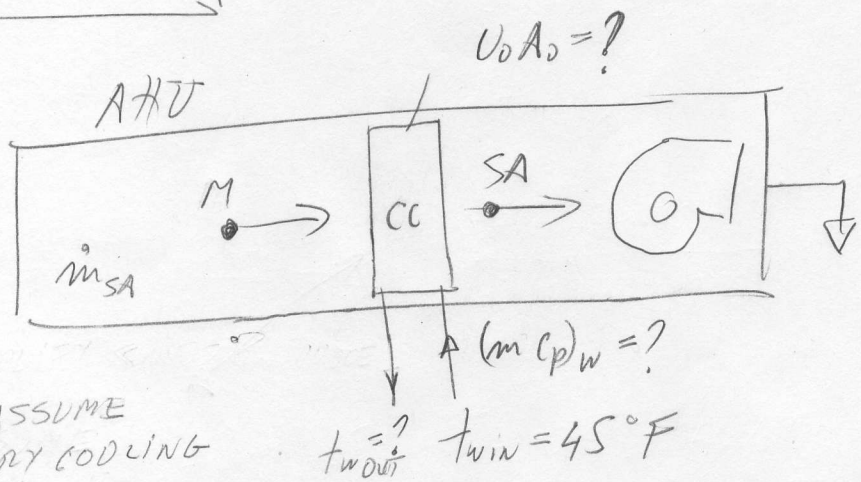
SUBSTITUTING K_P, K_f, A, L INTO 11.39:

$$U_o = \left[\frac{3.537}{0.126(1000)} + \frac{3.537(0.53-0.68)}{0.132(2)\cdot(12)\cdot 223} + \frac{1-0.68}{9\left(\frac{0.129}{3.408} - 0.68\right)} + \frac{1}{9} \right]^{-1}$$

$$U_o = \left[0.028 + 2.5\cdot 10^{-4} + 0.05 + 0.111 \right]^{-1}$$

$$\boxed{U_o = 5.28 \ \frac{Btu}{h\ ft^2 \cdot F}}$$

PROBLEM 3

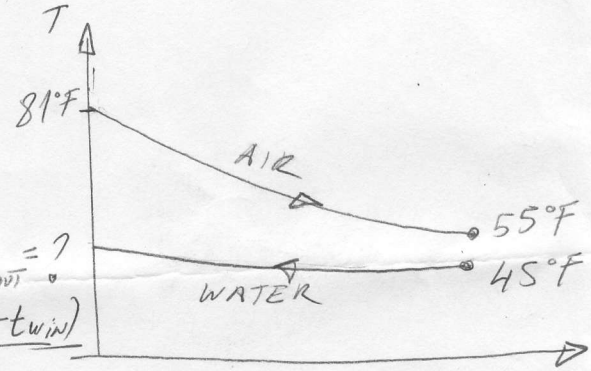


$Q_{CC} = 195600$ Btu/h
$t_{SA} = 55°F$
$t_M = 81°F$

ASSUME DRY COOLING

$$Q_{CC} = \dot{m}(h_{SA} - h_M) = (mc_p)_{AIR}(t_{SA} - t_M) \Rightarrow (mc_p)_{AIR} = \frac{Q_{CC}}{\Delta t_{AIR}}$$

$$(mc_p)_{AIR} = \frac{195600 \frac{Btu}{h}}{26°F} = 7523 \frac{Btu}{h°F}$$



TO SOLVE THE PROBLEM WE NEED 3 SETS OF EQUATIONS:

I $$Q_{CC} = U_0A_0 \cdot \Delta t_m \cdot F \qquad \Delta t_m = \frac{(t_{AIN} - t_{WO}) - (t_{AOUT} - t_{WIN})}{\ln \frac{t_{AIN} - t_{WO}}{t_{AOUT} - t_{WIN}}}$$

F = CORRECTION FACTOR

II $$\varepsilon = \frac{Q_{CC}}{(mc_p)_{min}(t_{AIR_{IN}} - t_{WATER_{IN}})}$$

III $$\varepsilon = \frac{1}{C_R}\left[1 - e^{[-C_R(1 - e^{-NTU})]}\right] \qquad NTU = \frac{U_0A_0}{(mc_p)_{min}} \qquad C_R = \frac{(mc_p)_{max}}{(mc_p)_{min}}$$

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3 EQUATIONS WITH 3 UNKNOWNS: ε, t_{WOUT}, $(mc_p)_{WATER}$

$\Rightarrow$ CLOSE SYSTEM OF EQUATIONS!

SOLUTIONS BY ITERATIVE PROCEDURE:

GUESS: $t_{WOUT} = 55°F$

CALCULATE $$(mc_p)_{WAT} = \frac{Q_{CC}}{\Delta t_W} = \frac{195600}{10} = 19560 \frac{Btu}{h°F}$$

$\Rightarrow (mc_p)_{min} = (mc_p)_{AIR}$, $C_R = 0.385$

FIRST ITERATION

FROM EQUATION I

$$\Delta t_m = \frac{26-10}{\ln 2,6} = 16.7\,^\circ F, \quad P = \frac{10}{36} = 0,28, \quad R = \frac{26}{10} = 2,6 \Rightarrow \text{FIG 11.5} \Rightarrow F = 0,92$$

$$U_o A_o = \frac{Q_{cc}}{\Delta t_m \cdot F} = \frac{195600}{16.7 \cdot 0,92} = 12731 \frac{Btu}{h\,^\circ F} \Rightarrow \text{RESULT FOR GUESS VAL.}$$

CORRECT TEMP $t_{w,in}$:

FOR EQ II $\quad \varepsilon = \frac{81-55}{81-45} = 0,72$

USE EQUATION III TO FIND NEW $C_R = \frac{(mc_p)_{AIR}}{(mc_p)_{WAT}}$

$$NTU = \frac{U_o A_o}{(mc_p)_{AIR}} = \frac{12731}{7523} = 1,69$$

$$\varepsilon = \frac{1}{C_R}\left[1 - e^{[-C_R(1-e^{-NTU})]}\right] \Rightarrow \text{CALCULATE NEW } C_R \quad \text{FOR } \varepsilon = 0,72 \text{ \& } NTU = 1,69$$

$$C_R = \ldots = 0,31 \Rightarrow (mc_p)_{WAT} = \frac{7523}{0,31} = 24268 \frac{Btu}{h\,^\circ F}$$

CALCULATE NEW $t_{w\,OUT} \Rightarrow t_{w\,OUT} = t_{w\,IN} + \frac{Q_{cc}}{(mc_p)_w} = 53\,^\circ F$

SECOND ITERATION:

$$\Delta t_m = \frac{28-10}{\ln 2,8} = 17,5\,^\circ F, \quad P = \frac{8}{36} = 0,27, \quad R = \frac{26}{8} = 3,7 \Rightarrow F = 0,95$$

$$U_o A_o = \frac{195600}{17.5 \cdot 0,95} = 11765 \frac{Btu}{h\,^\circ F}, \quad \varepsilon = \frac{81-55}{81-55} = 0,72, \; NTU = 1,56$$

$$C_R = 0,24, \quad (mc_p)_{WAT} = \frac{7523}{0,24} = 31346 \frac{Btu}{h\,^\circ F}, \quad t_{w\,OUT} = 51.3\,^\circ F$$

THIRD ITERATION:

$$\Delta t_m = \frac{29.7-10}{\ln 2,97} = 18,1\,^\circ F, \quad P = \frac{6.3}{36} = 0,17, \quad R = \frac{26}{6.3} = 4 \Rightarrow F = 0,95$$

$$U_o A_o = \frac{195600}{18.1 \cdot 0,95} = 11375 \frac{Btu}{h\,^\circ F}, \quad \varepsilon = \frac{81-55}{81-55} = 0,72, \; NTU = 1,52$$

$$C_R = 0,22, \quad (mc_p)_{WAT} = \frac{7523}{0,22} = 34195 \frac{Btu}{h\,^\circ F}, \quad \boxed{t_{w\,OUT} = 50.8\,^\circ F}$$