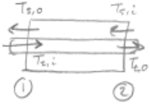
① 2-8 S+T Hxgr

Shell side: Water, 100,000 $\frac{lbm}{hr}$, $T_i = 180°F$, $T_o = 300°F$

Tube side: "Air", $T_i = 650°F$, $T_o = 350°F$

Hxgr: $A_o = 10{,}000\ ft^2$

a) $LMTD_{CF}$?, $LMTD_{CF} = \dfrac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$, If counter flow



$$LMTD_{CF} = \frac{(T_{t,i} - T_{s,o}) - (T_{t,o} - T_{s,i})}{\ln \frac{T_{t,i} - T_{s,o}}{T_{t,o} - T_{s,i}}} = \frac{(650-300) - (350-180)}{\ln \frac{350}{170}}$$

$\boxed{LMTD_{CF} = 249°F}$ (or °R → doesn't matter, since LMTD is a temperature difference)

b) $F_{2-8} = ?$

You can use any hxfr text. From Incropera + DeWitt, (or the spreadsheet link given on the wikidot page)

$$P = \frac{T_{t,o} - T_{t,i}}{T_{s,i} - T_{t,i}} = \frac{350-650}{180-650} = 0.64$$

$$R = \frac{T_{s,i} - T_{s,o}}{T_{t,o} - T_{t,i}} = \frac{180-300}{350-650} = 0.4$$

so $\boxed{F \approx 0.98}$

c) To find the ε, need the specific heats.

$c_{p,w} \approx 1.009 \frac{Btu}{lbm \cdot R}$, but don't know either $\dot{m}$ or c_p for air!

How to solve?

(1, cont.) c) $\dot{m}_a C_{pa} (T_{t,i} - T_{t,o}) = \dot{m}_W C_{pW} (T_{s,o} - T_{s,i})$

$(\dot{Q}_{shell} = \dot{Q}_{tube})$

$$C_a = C_W \frac{\Delta T_s}{\Delta T_t} = \underbrace{\left(100{,}000 \frac{lbm}{hr}\right)\left(1.009 \frac{Btu}{lbm \cdot R}\right)}_{= 100{,}900 \frac{Btu}{hr \cdot R} = C_W} \frac{120}{300}$$

$$C_a = 40{,}360 \frac{Btu}{hr \cdot R} = C_{min}$$

$$\varepsilon = \frac{\cancel{C_a}(\Delta T_t)}{\cancel{C_{min}}(T_{hi} - T_{ci})} = \frac{650 - 350}{650 - 180} = \boxed{0.638}$$

d) $\dot{Q} = U_o A_o (F\ LMTD_{CF})$, $\dot{Q} = C_a \Delta T_t = C_W \Delta T_s$

$$U_o = \frac{\dot{Q}}{A_o\ F\ LMTD} = \frac{\left(100{,}900 \frac{Btu}{hr \cdot R}\right)(120\ °R)}{(10{,}000\ ft^2)(0.98)(249\ °R)} = \boxed{4.96 \frac{Btu}{hr\ ft^2\ °R}}$$

2) A) Fluid Properties

Oil (tubes)

$\dot{m}_c = 110{,}000 \frac{lbm}{hr}$

$T_{c,i} = 100°F$

$\rho = 740 \frac{kg}{m^3} = 46.2 \frac{lbm}{ft^3}$

$c_p = 2.05 \frac{kJ}{kg \cdot K} = 0.4896 \frac{Btu}{lbm\ F}$

$k_f = 0.132 \frac{W}{mK} = 0.07627 \frac{Btu}{hr\ ft\ F}$

$\mu = 3.4\ cp = 8.225 \frac{lbm}{ft \cdot hr}$

$P_r = 4400$

Water @ 150°F

$\dot{m}_h = 66{,}000 \frac{lbm}{hr}$

$T_{hi} = 200°F$

$\rho = 61.2 \frac{lbm}{ft^3}$

$C_p = 0.9995\ Btu/lbm°F$

$k_f = 0.3732\ Btu/hr\,ft°F$

$\mu = 1.04\ lbm/ft \cdot hr$

$P_r = 2.786$

2. cont

B) Tube Properties

$N_t = 192$

$L = 12$ ft.

$OD_t = 1'' = 0.083'$

$ID_t = 0.0833 - 2\left(\frac{\overset{BWG=13}{0.095}}{12}\right) = 0.0675$ ft.

$N_p = 4$

$k_w = 231 \frac{Btu}{hr \cdot ft \cdot {}^\circ R}$

C) Shell Properties

$ID_s = \frac{23.25}{12} = 1.938'$

$P_T = \frac{1.25}{12} = 0.1042'$

$N_b = 6$

$B = \frac{12}{7} = 1.714'$ (12' of tubes, divided into sections)

$C = P_T - OD_t = 0.02083'$

D) Flow Areas

$$A_t = \frac{N_t}{N_p} \frac{\pi ID_t^2}{4} = 0.1718 \text{ ft}^2$$

$$A_s = \frac{(ID_s)C(B)}{P_T} = 0.6643 \text{ ft}^2$$

E) Flow Velocities

$$V_t = \frac{\dot{m}_c}{\rho_c A_t} = 13863 \frac{ft}{hr} \quad ; \quad V_s = \frac{\dot{m}_h}{\rho_h A_s} = 1624 \frac{ft}{hr}$$

F) Shell Equiv. Diameter

$$D_e = \frac{4(P_T^2 - \pi OD_t^2/4)}{\pi OD_t} = 0.08245 \text{ ft.}$$

G) Re

$$Re_t = \frac{V_t \cdot ID_t \cdot \rho_c}{\mu_c} = 5256$$

$$Re_s = \frac{V_s \cdot De \cdot \rho_h}{\mu_h} = 7876$$

2, cont.

H) Nusselt # :

Tube

$$\xi = \frac{1}{(1.82 \log 5256 - 1.64)^2} = 0.03798$$

$$Nu_t = \frac{\frac{\xi}{8}(5256-1000)(4400)}{1+12.7\sqrt{\frac{\xi}{8}}\,(4400^{2/3}-1)}\left[1+\left(\frac{ID_t}{L}\right)^{2/3}\right] = 44.96$$

Shell

Same calcs, but De instead of ID_t

$$\xi = 0.03365$$

$$Nu_s = 46.2$$

I) Convection Coeff.

$$h_{inside} = \frac{(Nu_t)\,k_{f,c}}{ID_t} = 50.8 \frac{Btu}{hr\,ft^2\,°R}$$

$$h_{outside} = \frac{(Nu_s)\,k_{f,h}}{De} = 209.1 \frac{Btu}{hr\,ft^2\,°R}$$

J) Overall Hxfr Coeff

$$\frac{1}{U_o} = \frac{OD_t}{ID_t\,h_{in}} + \frac{OD_t}{2k_w}\ln\frac{OD_t}{ID_t} + \frac{1}{h_{out}} \rightarrow U_o = 34.33 \frac{Btu}{hr\,ft^2\,°R}$$

K) Outlet Temps and Heat Transfer

Using ε-NTU:

$$C_c = (\dot{m}c_p)_c = 53860 \frac{Btu}{hr\,°R} = C_{min}$$

$$C_h = (\dot{m}c_p)_h = 65965 \quad '' \quad = C_{max}$$

2, cont.

$$C_r = \frac{C_{min}}{C_{max}} = 0.8165$$

$$NTU = \frac{U_o A_o}{C_{min}} = \frac{U_o N_t (\pi OD_t L)}{C_{min}} = 0.3845$$

So $\varepsilon = 0.3364$

$$\boxed{\begin{aligned} \dot{Q} &= \varepsilon C_{min}(T_{hi} - T_{ci}) = 1.812 \times 10^6 \ \frac{\text{Btu}}{\text{hr}} \\ T_{co} &= \frac{\dot{Q}}{C_c} + T_{ci} = 133.6\ ^\circ F \\ T_{ho} &= T_{hi} - \frac{\dot{Q}}{C_h} = 172.5\ ^\circ F \end{aligned}}$$