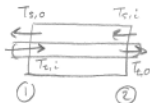


① 2-8 S+T Hxgr

Shell side: Water,  $100,000 \frac{\text{lbm}}{\text{hr}}$ ,  $T_i = 180^\circ\text{F}$ ,  $T_o = 300^\circ\text{F}$ Tube side: "Air",  $T_i = 650^\circ\text{F}$ ,  $T_o = 350^\circ\text{F}$ Hxgr:  $A_o = 10,000 \text{ ft}^2$ a)  $LMTD_{cf}$ ? ,  $LMTD_{cf} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$ , If counter flow

LMTD

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

$LMTD_{cf} = 249^\circ\text{F}$  (or  $^\circ\text{R} \rightarrow$  doesn't matter, since LMTD is a temperature difference)

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

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

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

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

so  $F \approx 0.98$

c) To find the  $\epsilon$ , need the specific heats.

$C_{p,w} \approx 1.009 \frac{\text{Btu}}{\text{lbm} \cdot ^\circ\text{R}}$ , but don't know either  $\dot{m}$  or  $C_p$  for air!

How to solve?

$$(1, \text{cont.}) \dot{m}_a C_{p,a} (T_{e,i} - T_{e,o}) = \dot{m}_w C_{p,w} (T_{s,o} - T_{s,i})$$

$$(\dot{Q}_{\text{shell}} = \dot{Q}_{\text{tube}}) \quad \approx 100,900 \frac{\text{Btu}}{\text{hr} \cdot \text{R}} = C_w$$

$$C_a = C_w \frac{\Delta T_s}{\Delta T_c} = (100,900 \frac{\text{lbm}}{\text{hr}}) (1.009 \frac{\text{Btu}}{\text{lbm} \cdot \text{R}}) \frac{120}{300}$$

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

$$E = \frac{C_a (\Delta T_c)}{C_{\text{min}} (T_{h,i} - T_{c,i})} = \frac{650 - 350}{650 - 180} = \boxed{0.638}$$

$$d) \dot{Q} = U_o A_o (F \text{ LMTD}_{cF}), \quad \dot{Q} = C_a \Delta T_c = C_w \Delta T_s$$

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

② (A) Fluid Properties

Oil (tubes)

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

$$T_{c,i} = 100^\circ \text{F}$$

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

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

$$k_f = 0.132 \frac{\text{W}}{\text{m} \cdot \text{K}} = 0.07627 \frac{\text{Btu}}{\text{hr ft} \cdot \text{F}}$$

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

$$Pr = 4400$$

Water @ 150°F

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

$$T_{h,i} = 200^\circ \text{F}$$

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

$$c_p = 0.9995 \text{ Btu/lbm} \cdot \text{F}$$

$$k_f = 0.3732 \text{ Btu/hr ft} \cdot \text{F}$$

$$\mu = 1.04 \text{ lbm/ft} \cdot \text{hr}$$

$$Pr = 2.786$$

2. cont

## (B) Tube Properties

$$N_t = 192$$

$$L = 12 \text{ ft.}$$

$$OD_t = 1" = 0.083'$$

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

$3WG = 13$   
 $\downarrow$   
 $0.095$

$$N_p = 4$$

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

## (C) Shell Properties

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

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

$$N_b = 6$$

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

$$C = P_T \cdot OD_t = 0.02083'$$

## (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

$$V_t = \frac{\dot{m}_c}{\rho_c A_t} = 13863 \frac{\text{ft}}{\text{hr}}$$

$$V_s = \frac{\dot{m}_h}{\rho_h A_s} = 1624 \frac{\text{ft}}{\text{hr}}$$

## (F) Shell Equiv. Diameter

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

## (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 # :

$$\frac{\text{Tube}}{F} = \frac{1}{(1.82 \log_{10} 5256 - 1.64)^2} = 0.03798$$

$$Nu_{\epsilon} = \frac{\frac{F}{8} (5256 - 1000)(4400)}{1 + 12.7 \sqrt{\frac{F}{8}} (4400^{2/3} - 1)} \left[ 1 + \left( \frac{ID_e}{L} \right)^{2/3} \right] = 44.96$$

ShellSame calc, but  $D_e$  instead of  $ID_e$ 

$$F = 0.03365$$

$$Nu_s = 46.2$$

(I) Convection Coeff.

$$h_{\text{inside}} = \frac{(Nu_{\epsilon}) k_{f,c}}{ID_e} = 50.8 \frac{\text{Btu}}{\text{hr ft}^2 \text{ } ^\circ\text{R}}$$

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

(J) Overall Hxfr Coeff.

$$\frac{1}{U_o} = \frac{OD_e}{ID_e h_{in}} + \frac{OD_e}{2kw} \ln \frac{OD_e}{ID_e} + \frac{1}{h_{out}} \rightarrow U_o = 34.33 \frac{\text{Btu}}{\text{hr ft}^2 \text{ } ^\circ\text{R}}$$

(K) Outlet Temps and Heat Transfer

Using E-NTU:

$$C_c = (\dot{m}c_p)_c = 53860 \frac{\text{Btu}}{\text{hr } ^\circ\text{R}} = C_{\text{min}}$$

$$C_h = (\dot{m}c_p)_h = 65965 \text{ " } = C_{\text{max}}$$

2, cont.

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

$$NTU = \frac{U_o A_o}{C_{min}} = \frac{U_o N_e (\pi O D_E L)}{C_{min}} = 0.3845$$

So  $\epsilon = 0.3364$

$$\dot{Q} = \epsilon C_{min} (T_{hi} - T_{ci}) = 1.812 \times 10^6 \frac{\text{Btu}}{\text{hr}}$$

$$T_{co} = \frac{\dot{Q}}{C_c} + T_{ci} = 133.6^\circ \text{F}$$

$$T_{ho} = T_{hi} - \frac{\dot{Q}}{C_h} = 172.5^\circ \text{F}$$