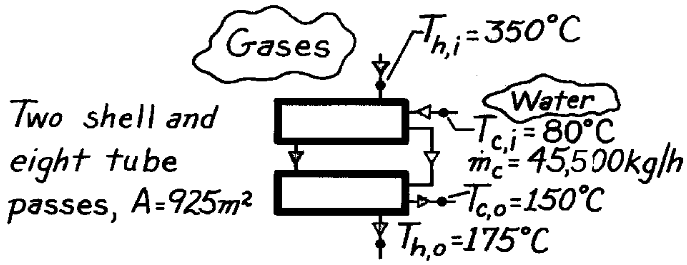
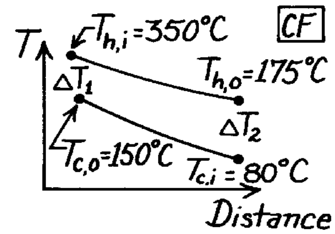
PROBLEM 11.10

KNOWN: Heat exchanger with two shell passes and eight tube passes having an area $925 m^2$; 45,500 kg/h water is heated from 80°C to 150°C; hot exhaust gases enter at 350°C and exit at 175°C.

FIND: Overall heat transfer coefficient.

SCHEMATIC:





ASSUMPTIONS: (1) Negligible losses to surroundings, (2) Constant properties, (3) Exhaust gas properties are approximated as those of atmospheric air.

PROPERTIES: *Table A-6*, Water $\left(\overline{T}_c = (80 + 150)°C/2 = 388K\right)$: $c_c = c_{p,f} = 4236$ J/kg·K.

ANALYSIS: Since this is a shell-and-tube heat exchanger, we will use the ε - NTU method, for which

$$C_c = \dot{m}_c c_c = \frac{45{,}500 \text{ kg/h}}{3600 \text{ s/h}} \times 4236 \text{ J/kg}\cdot\text{K} = 5.35 \times 10^4 \text{ W/K}$$

$$q = C_c(T_{c,o} - T_{c,i}) = 5.35 \times 10^4 \text{ W/K } (150 - 80)°C = 3.75 \times 10^6 \text{ W}$$

Then we can find C_h from an energy balance on the hot stream,

$$C_h = q/(T_{h,i} - T_{h,o}) = 3.75 \times 10^6 \text{ W}/(350 - 175)°C = 2.14 \times 10^4 \text{ W/K}$$

Thus

$$C_r = C_{min}/C_{max} = 0.40$$

$$\varepsilon = q/C_{min}(T_{h,i} - T_{c,i}) = 3.75 \times 10^6 \text{ W}/2.14 \times 10^4 \text{ W/K } (350 - 80)°C = 0.648$$

From Eqs. 11.31b and c, with n = 2,

$$F = \left(\frac{\varepsilon C_r - 1}{\varepsilon - 1}\right)^{1/n} = 1.45, \quad \varepsilon_1 = \frac{F - 1}{F - C_r} = 0.429$$

From Eqs. 11.30c and 11.30b,

$$E = \frac{2/\varepsilon_1 - (1 + C_r)}{(1 + C_r^2)^{1/2}} = 3.0$$

$$(NTU)_1 = -(1 + C_r^2)^{-1/2} \ln\left[\frac{E - 1}{E + 1}\right] = 0.637$$

and from Eq. 11.31d,

$$NTU = n(NTU)_1 = 1.27$$

Therefore,

$$U = NTU \times C_{min}/A = 1.27 \times 2.14 \times 10^4 \text{ W/K}/(925 \text{ m}^2) = 29.5 \text{ W/m}^2\cdot\text{K} \qquad <$$

COMMENTS: Compare the above result with representative values for air-water exchangers, as given in Table 11.2.