CEN 3311 HEAT TRANSFER

Example : Shell and Tube Heat Exchanger Design

$T_{ca} = 20 \, °C$

$T_{cb} = 60 \, °C$

$T_{ha} = 104.4 \, °C$

$T_{hb} = 104.4 \, °C$

$V_c = 2 \, m/s$

$\lambda = 2251000 \, J/kg$

$N = 100$

$\dot{m}_h = ?$

$L = ?$

$$\bar{T}_c = \frac{20 + 60}{2} = 40\ {}^oC$$

Properties of ethylene glycol at 40 °C are read from Table 4.

$\rho_c = 1101.43\ \text{kg}/m^3$

$\mu_c = 9.57 \times 10^{-3} kg/ms$
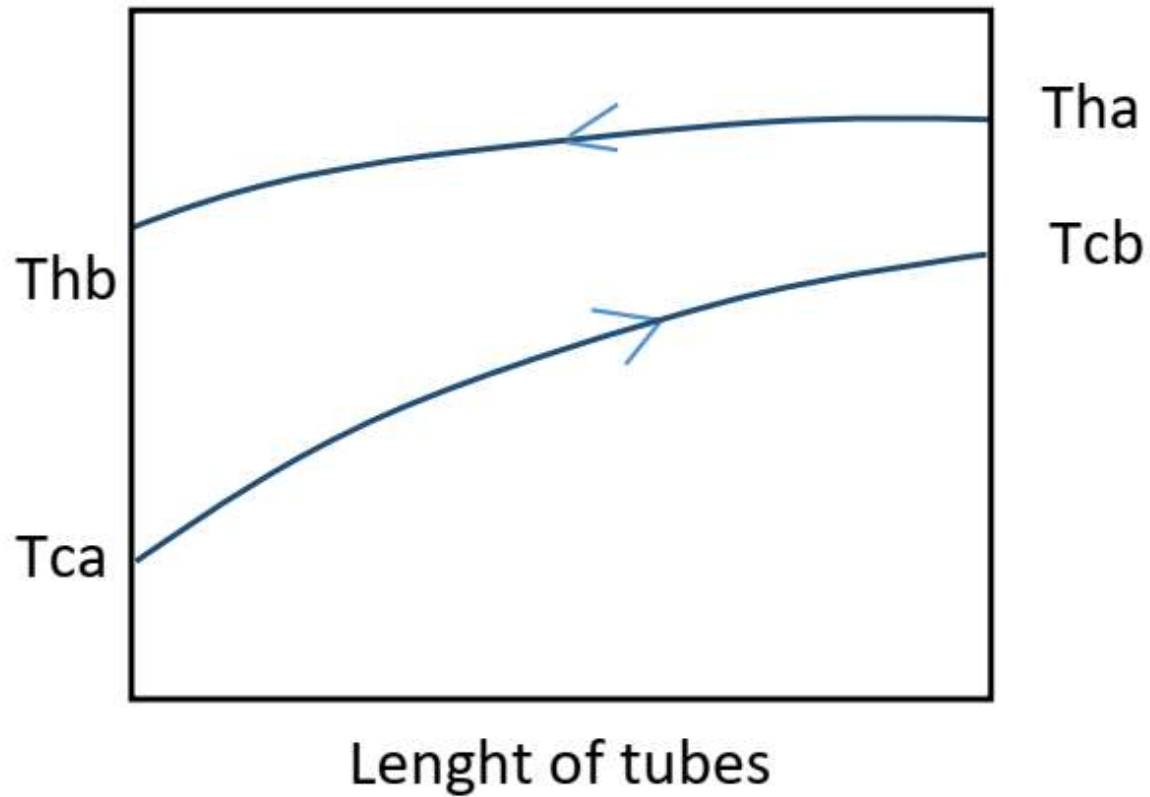
$\mu_w = 5.16 \times 10^{-3} kg/ms$

$C_{pc} = 2474\ \text{J/kg}\ {}^oC$

$k_c = 0.256 \text{W/m °C}$

$Pr_c = 93$

3/4-in BWG 16 pipe dimensions are read from Table 11.

$D_i = 15.75 \times 10^{-3} m$

$D_o = 19.05 \times 10^{-3} m$

$$q = UAF_G\Delta\overline{T_L} = \dot{m}_c Cp_c(T_{cb} - T_{ca})$$

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$$\overline{\Delta T_L} = \frac{(T_{ha} - T_{cb}) - (T_{hb} - T_{ca})}{\ln\dfrac{(T_{ha} - T_{cb})}{(T_{hb} - T_{ca})}} = \frac{(104.4 - 60) - (104.4 - 20)}{\ln\dfrac{44.4}{84.4}} = 62.27\ ^oC$$

$\overline{\Delta T_L}$ must be corrected with F_G multiplication.

$$\eta = \frac{T_{cb} - T_{ca}}{T_{ha} - T_{ca}} = \frac{60 - 20}{104.4 - 20} = 0.47$$

$$z = \frac{T_{ha} - T_{hb}}{T_{cb} - T_{ca}} = \frac{104.4 - 104.4}{60 - 20} = 0$$

F_G is read from Figure 26 (a) as 1. $\overline{\Delta T_L}$ correction is found to be unnecessary.

$$\dot{m}_{1pipe} = \rho_c . V_c . S_i = 1101.43 \times 6 \times \frac{\pi}{4} \times (15.75 \times 10^{-3})^2 = 1.2875\ kg/s$$

$$\dot{m}_{total} = \dot{m}_c = \dot{m}_{1pipe} \times N = 1.2875 \times 100 = 128.75\ kg/s$$

$$\frac{1}{U_o} = \frac{1}{h_o} + \frac{D_o}{D_i h_i}$$

$$\text{Re} = \frac{D_i V_c \rho_c}{\mu_c} = \frac{15.75 \times 10^{-3} \times 6 \times 1101.43}{9.57 \times 10^{-3}} = 10876.2 > 10000 \; Turbulent\;flow$$

$$\text{Nu} = 0.023 \; \text{Re}^{0.8} \text{Pr}^{1/3} \left(\frac{\mu}{\mu_w}\right)^{0.14} = 0.023 \, (10876.2)^{0.8} (93)^{1/3} \left(\frac{9.57 \times 10^{-3}}{5.16 \times 10^{-3}}\right)^{0.14} = 192.59$$

$$h_i = \frac{Nu \times k_c}{D_i} = \frac{192.59 \times 0.256}{15.75 \times 10^{-3}} = 3130 W/m^2 \; {}^o C$$

$$T_f = \frac{T_h + T_w}{2} = \frac{104.4 + 60}{2} = 82.2 \; {}^o C$$

Properties of water at 82.2 °C

$$\rho_f = 970.2 \; kg/m^3$$

$$\mu_f = 3.47 \times 10^{-4} kg/ms$$

$$k_f = 0.673 \; W/m \; °C$$

$$h_o = 0.725 \left[\frac{\rho_f \, g \, (\rho_f - \rho_\vartheta) \, \lambda \, k_f^3}{N^{\frac{2}{3}} \, D_o \, \mu_f \, (T_h - T_w)} \right]^{\frac{1}{4}}$$

$$h_o = 0.725 \times \left[\frac{970.2^2 \times 9.81 \times 2251000 \times 0.673^3}{100^{2/3} \times 19.05 \times 10^{-3} \times 3.47 \times 10^{-4} \, (104.4 - 60)} \right]^{1/4} = 4079 \, W/m^2 \, {}^oC$$

$$\frac{1}{U_o} = \frac{1}{4079} + \frac{19.05}{15.75 \times 3130} \rightarrow U_o = 1583.3 \, W/m^2 \, {}^oC$$

$$q = \dot{m}_c Cp_c (T_{cb} - T_{ca}) = \dot{m}_h \lambda = 128.75 \times 2474 \times (60 - 20) = 12741100W \rightarrow \dot{m}_h = \mathbf{5.66 \, kg/s}$$

$$A = N \times \pi \times D_o \times L$$

$$q = UAF_G \overline{\Delta T_L} \rightarrow 12741100W = 1583.3 \times 100 \times \pi \times 19.05 \times 10^{-3} \times L \times 62.27 \rightarrow L = 21.6 \, m$$