References:

- W.L. McCabe, J.C. Smith, P. Harriott., *Unit Operations of Chemical Engineering*, McGraw Hill, N.Y., (7th Ed.) 2005
- J.P. Holman, Heat Transfer, McGraw-Hill, N.Y., 1989.
- F.P. Incropera, D.P. de Witt, Fundamentals of Heat and Mass Transfer, John Wiley & Sons, N.Y., (3th Ed.) 1990.
- C.J. Geankoplis, Transport Processes and Unit Operations, Prentice-Hill Inc., N.J., (3th Ed.) 1993
- Y. Cengel , Introduction to Thermodynamics and Heat Transfer , , McGraw Hill, 2nd Edition 2008

13 : Heat transfer equipment; types, analysis

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.

$\rho_c = 1101.43\ kg/m^3$

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

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

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

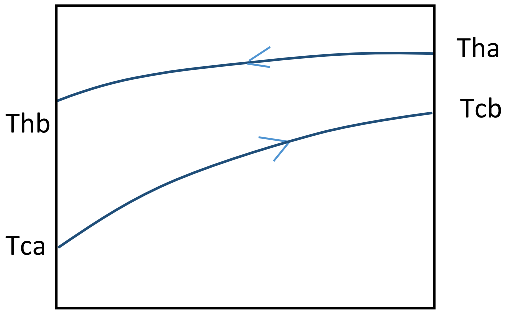
$k_c = 0.256 W/m\ °C$

$Pr_c = 93$

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

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

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



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

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

$\Delta\overline{T_L}$ 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. $\Delta\overline{T_L}$ correction is found to be unnecessary.

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

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

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

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

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

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

$$T_f = \frac{T_h + T_w}{2} = \frac{104.4 + 60}{2} = 82.2\,^oC$$

Properties of water at 82.2 °C

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

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

$$k_f = 0.673\ W/m\ °C$$

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

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

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

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

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

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