Homework Assignment Number Eleven
Assigned: Wednesday, April 7, 1999
Due: Wednesday, April 14, 1999 BEFORE LECTURE STARTS.

Problem 1. Geankoplis 4.9-2, page 323

Solution:

$$q = UA\Delta T_{lm} = \dot{m}_{tube} C_p\left(\overline{T}_{tube}\right)\left(T_{tube,out} - T_{tube,in}\right)$$
$$q = UA\Delta T_{lm} = \dot{m}_{shell} C_p\left(\overline{T}_{shell}\right)\left(T_{shell,out} - T_{shell,in}\right)$$

Oil is cooled on the tube-side of the exchanger.

$$\dot{m}_{tube} C_p\left(\overline{T}_{tube}\right)\left(T_{tube,out} - T_{tube,in}\right) = 5.04 \cdot 2090 \cdot (344.3 - 366.5)$$
$$q = -233846 \text{ W}$$

Water is heated on the shell-side of the exchanger:

$$q = \dot{m}_{shell} C_p\left(\overline{T}_{shell}\right)\left(T_{shell,out} - T_{shell,in}\right)$$
$$q = 233846 \text{ W} = 2.02 \cdot 4184\left(T_{shell,out} - 283.2\right)$$
$$T_{shell,out} = 310.9$$

Since this is a 1-2 exchanger, calculate Y and Z to obtain F_T

$$Z = \frac{T_{hot,in} - T_{hot,out}}{T_{cold,out} - T_{cold,in}} = 0.801$$

$$Y = \frac{T_{cold,out} - T_{cold,in}}{T_{hot,in} - T_{cold,in}} = 0.333$$

For 1-2 shell and tube heat exchangers, compute the correction factor, F_T, for the log mean T difference from Figure 4.9-4(a) on page 270, Geankoplis.

$$F_T = 0.96$$

(Assume counter current flow.)

$$\Delta T_{lm} = \frac{\left(T_{shell,in} - T_{tube,out}\right) - \left(T_{shell,out} - T_{tube,in}\right)}{\ln\left(\frac{\left(T_{shell,in} - T_{tube,out}\right)}{\left(T_{shell,out} - T_{tube,in}\right)}\right)} = 58.3\text{K}$$

$$\Delta T_{lm} = F_T \Delta T_{lm} = 0.96 \cdot 58.3 = 56.0K$$

$$q = 233846 \text{ W} = UA\Delta T_{lm} = 340 \cdot A \cdot 56.0$$
$$A = 12.3m^2$$

Problem 2. Geankoplis 4.9-3, page 323

Solution:

$$q = UA\Delta T_{lm} = \dot{m}_{tube} C_p\left(\overline{T}_{tube}\right)\left(T_{tube,out} - T_{tube,in}\right)$$
$$q = UA\Delta T_{lm} = \dot{m}_{shell} C_p\left(\overline{T}_{shell}\right)\left(T_{shell,out} - T_{shell,in}\right)$$

Water is heated on the tube-side of the exchanger:

$$\dot{m}_{tube} C_p\left(\overline{T}_{tube}\right)\left(T_{tube,out} - T_{tube,in}\right) = 1.13 \cdot 4184 \cdot (358 - 318)$$
$$q = 189117 \text{ W}$$

Oil is cooled on the shell-side of the exchanger.

$$q = \dot{m}_{shell} C_p\left(\overline{T}_{shell}\right)\left(T_{shell,out} - T_{shell,in}\right)$$
$$q = 189117 \text{W} = \dot{m}_{shell} \cdot 1950(358 - 393)$$
$$\dot{m}_{shell} = 2.77 \frac{kg}{s}$$

Since this is a 1-2 exchanger, calculate Y and Z to obtain F_T

$$Z = \frac{T_{hot,in} - T_{hot,out}}{T_{cold,out} - T_{cold,in}} = 0.875$$

$$Y = \frac{T_{cold,out} - T_{cold,in}}{T_{hot,in} - T_{cold,in}} = 0.533$$

For 1-2 shell and tube heat exchangers, compute the correction factor, F_T, for the log mean T difference from Figure 4.9-4(a) on page 270, Geankoplis.

$$F_T = 0.83$$

(Assume counter current flow.)

$$\Delta T_{lm} = \frac{\left(T_{shell,in} - T_{tube,out}\right) - \left(T_{shell,out} - T_{tube,in}\right)}{\ln\left(\frac{\left(T_{shell,in} - T_{tube,out}\right)}{\left(T_{shell,out} - T_{tube,in}\right)}\right)} = 37.4K$$

$$\Delta T_{lm} = F_T \Delta T_{lm} = 0.83 \cdot 37.4 = 31.1K$$

$$q = 189117\,W = UA\Delta T_{lm} = 300 \cdot A \cdot 31.1$$
$$A = 20.3m^2$$

Problem 3.

Redo parts (b) and (c) from Problem 3, Homework 10, using the Matlab code given at http://clausius.engr.utk.edu/che240/text/codes.html

(b) Use your code to solve the following problem:

We will be using cold water to cool hot water in a 1-1 shell and tube heat exchanger. The hot water is inside the tubes. The cold water is in the shell. The flow is counter-current.

The cold water enters the shell at $T_{shell,in} = 250K$. The hot water enters the tubes at $T_{tube,in} = 400K$. The flow-rate of the hot stream is $\dot{m}_{tube} = 0.10 \frac{kg}{s}$ and the flow-rate of the cold stream is $\dot{m}_{shell} = 0.20 \frac{kg}{s}$.

The heat exchanger is made of stainless steel tubes of outside diameter 1 inch ,BWG 10. The length of the tubes and the length of the shell are $L = 4.0m$; the number of tubes, $N_{tube} = 24$; the diameter of the shell, $D_{shell} = 0.15m$. Use fouling factors for city water.

Determine the six quantities specified in part (a)

(c) Repeat Part (b) with cocurrent flow.

Solution:

(a) I used the code, hxchnger_v2.m available on the course website.

(b) I iterated until both outlet temperatures were constant within 0.00001 Kelvin.

```
» hxchger_v2
initial guess:  Ttubeout = 370.000000 Tshellout = 281.500000
at j =    1, i =   25:  Ttubeout = 298.569505 Tshellout = 340.750000
at j =    2, i =   25:  Ttubeout = 311.014789 Tshellout = 311.125000
…
at j =   23, i =   24:  Ttubeout = 301.612188 Tshellout = 298.940543
at j =   24, i =   24:  Ttubeout = 301.612182 Tshellout = 298.940536
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```
Tube-side Temp (K)  inlet:  400.000000, outlet 301.612182, avg 350.806088
Shell-side Temp (K)  inlet:  250.000000, outlet 298.940536, avg 274.470271
Wall Temp (K):  Tube-side = 300.771756, Shell-side = 295.300084, avg = 298.035920
Heat Transfer coefficients  shell film, heat film, overall (W/m^2/K):
hshell = 259.205906 htube = 147.361123 Uo = 73.371215
Uo = 73.371215 Ui = 100.195101
Heat Transferred (W): q = 41360.433298 q_tube = 41360.434493 q_shell = 41360.427860
Enthalpy Changes (W): tube = -41374.088821 shell = 41360.436210
```

(c) For cocurrent flow, I had to change the variable flow from 1 to 0.
Then I reran the code:

```
» hxchger_v2
initial guess:  Ttubeout = 370.000000 Tshellout = 281.500000
at j =    1, i =   25:  Ttubeout = 306.997020 Tshellout = 340.750000
at j =    2, i =   25:  Ttubeout = 343.078103 Tshellout = 311.125000
…
at j =   23, i =   25:  Ttubeout = 312.982627 Tshellout = 293.403824
at j =   24, i =   25:  Ttubeout = 312.982632 Tshellout = 293.403831
Tube-side Temp (K)  inlet:  400.000000, outlet 312.982632, avg 356.491319
Shell-side Temp (K)  inlet:  250.000000, outlet 293.403831, avg 271.701912
Wall Temp (K):  Tube-side = 314.655192, Shell-side = 291.497858, avg = 303.076525
Heat Transfer coefficients  shell film, heat film, overall (W/m^2/K):
hshell = 242.314115 htube = 156.575664 Uo = 74.890121
Uo = 74.890121 Ui = 102.269306
Heat Transferred (W): q = 36745.975914 q_tube = 36745.977922 q_shell = 36745.982630
Enthalpy Changes (W): tube = -36667.588518 shell = 36745.966614
```

Comparing with (b), we see that 11.2% less heat is transferred in the cocurrent case.