CH EN 3453 – HEAT TRANSFER – FALL 2014

HOMEWORK #8

Due Friday, October 31 at 4:00 PM

Turn in to the CH EN 3453 basket at the main desk of the Chemical Engineering offices (MEB 3290)

Help session Wednesday, October 29 at 4:30 p.m. in MEB 2325

1. (12 pts) Define the following terms: (use symbols and equations if necessary)

(a) Thermal entrance region
(b) Hydrodynamic entrance region
(c) Fully developed flow
(d) Log mean temperature difference

Draw a simple diagram of each of the following types of concentric heat exchangers (Chap 11)

(e) Parallel flow
(f) Counterflow

2.* (8 pts) A thick-walled steel pipe (k = 60 W/m·K) carrying hot water is cooled externally by a cross-flow airstream at a velocity of 20 m/s and a temperature of 25°C. The inner and outer diameters of the pipe are D_i = 20 mm and D_o = 25 mm, respectively. At a certain location along the pipe, the mean temperature of the water is 80°C. Assuming the flow inside the tube is fully developed with a Reynolds number of 20,000, find the heat transfer rate to the airstream per unit length of pipe. (*This one requires a bit of chapter 3, chapter 7 and chapter 8. There are three resistances. Solve for the location in the pipe where the water is 80°C.*)

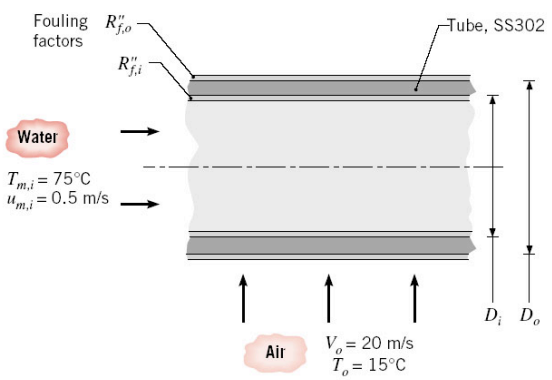
3.* (8 pts) A thin-walled, uninsulated 0.3-m-diameter duct is used to route chilled air at 0.05 kg/s through the attic of a large commercial building. The attic air is at 37°C, and natural circulation provides a convection coefficient of 2 W/m^2·K at the outer surface of the duct. If chilled air enters a 15-m-long duct at 7°C, what is its exit temperature and the rate of heat gain? Properties of the chilled air may be evaluated at an assumed average temperature of 300 K.

4.* (8 pts) Water flowing at 0.02 kg/s and $T_{m,i}$ 20°C enters an annular region formed by an inner tube of diameter D_i = 25 mm and an outer tube of diameter D_o = 100 mm. Saturated steam flows through the inner tube, maintaining its surface at a uniform temperature of $T_{s,i}$ = 100°C, while the outer surface of the outer tube is well insulated. If fully developed conditions may be assumed throughout the annulus, how long must the system be to provide an outlet water temperature of 75°C? What is the heat flux from the inner tube at the outlet?

More problems on the other side…

* Solutions for these problems are available on the course website: www.chen3453.com

5.* (8 pts) A type-302 stainless steel tube of inner and outer diameters Di = 22 mm and Do = 27 mm, respectively, is used in a cross-flow heat exchanger. The fouling factors R_f'' for the inner and outer surfaces are estimated to be 0.0004 and 0.0002 m^2·K/W, respectively.



(a) Determine the overall heat transfer coefficient based on the outside area of the tube, U_o. Compare the thermal resistances due to convection, tube wall conduction, and fouling.

(b) Instead of air flowing over the tube, consider a situation for which the cross-flow fluid is water at 15°C with a velocity of V_o = 1 m/s. Determine the overall heat transfer coefficient based on the outside area of the tube, U_o. Compare the thermal resistances due to convection, tube wall conduction and fouling.

6.* (8 pts) The condenser of a steam power plant contains N = 1000 brass tubes (k_t = 110 W/m·K), each of inner and outer diameters, D_i = 25 mm and D_o = 28 mm, respectively. Steam condensation on the outer surfaces of the tubes is characterized by a convection coefficient of h_o = 10,000 W/m^2·K.

(a) If cooling water from a large lake is pumped through the condenser tubes at 400 kg/s, what is the overall heat transfer coefficient Uo based on the outer surface are of a tube? Properties of the water may be approximated as $\mu = 9.60 \times 10^{-4}$ N·s/m^2, k = 0.60 W/m·K and Pr = 6.6.

(b) If, after extended operation, fouling provides a resistance of $R''_{f,i} = 10^{-4}$ m^2·K/W at the inner surface, what is the value of U_o?

(c) If water is extracted from the lake at 15°C and 10 kg/s of steam at 0.0622 bars are to be condensed, what is the corresponding temperature of the water leaving the condenser? The specific heat of water is 4180 J/kg·K.

7.* (8 pts) A two-fluid heat exchanger has inlet and outlet temperatures of 65 and 40°C for the hot fluid and 15 and 30°C for the cold fluid. Can you tell whether this exchanger is operating under counterflow or parallel-flow conditions? Determine the effectiveness of the heat exchanger.

8. (20 pts) Air at 2 atm pressure and 17°C flows in a long rectangular duct with dimensions 10 x 20 cm. The surface of the first 2.5 meters of the duct is maintained at 122°C, and the average exit air temperature from this section is 27°C. Determine the following:

(a) The air flow rate (kg/s)
(b) Total heat transfer (kW)

Hint: Remember that Re can be calculated in terms of mass flow. Also, you can assume turbulent flow.

9. (20 pts) A counterflow heat exchanger is used to heat water (c_p = 4.2 kJ/kg·K) from 20 to 75°C. The mass flow rate of water is 2.7 kg/s. The hot stream (c_p = 1.2 kJ/kg·K) enters the exchanger at 280°C and leaves at 120°C. The overall heat transfer coefficient is 160 W/m^2·K. Determine:

(a) The mass flow rate of the hot stream (kg/s)
(b) The heat exchanger surface area (kW)

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