Assignment II [2021]

ME 307: Heat Transfer Equipment Design

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1. Steam at a saturation temperature of 100°C is condensing in a bundle of 320 tubes within a 0.56 m wide duct. The tubes are arranged in a square, in-line pitch (p = 35.0 mm). The bundle is made of up to 20 rows of tubes with 3 cm OD and with 16 tubes in each row. The tube wall temperature in each row is kept constant at 93°C. The steam flows downward in the bundle, and at the 6th row of tubes, the local mass flow rate of vapour is 14.0 kg/s. Find the average heat transfer coefficient.

2. One counter-flow heat exchanger functions as a boiler. Water enters with mass flow rate of 0.01 kg/s and temperature 30°C. The water flows through the heat exchanger at constant pressure of 30 bar. The combustion gas used to heat the water enters at 400°C and flows at atmospheric pressure constant pressure with mass flow rate of 0.10 kg/s. The specific heat capacity of the combustion gas is approximately constant and equal to 1000 J/kg-K. Assuming the required pinch temperature $= 5 \pm 2$°C, estimate the steam generation rate and steam exit temperature. Recalculate the values for steam pressures of 1 bar and 10 bar.

3. Air at 20°C is to be preheated in a heat exchanger consisting of a staggered arrangement of 4-cm-OD tubes, 5 rows deep, with a longitudinal spacing of 6 cm and a transverse spacing of 8 cm. Steam is condensing inside the tubes, maintaining the tube wall temperature at 50°C. Determine (a) the average heat transfer coefficient for the tube bank and (b) the pressure drop through the tube bank. The methane flow velocity is 10 m/s upstream of the tube bank.

4. Air at atmospheric pressure and temperature $T_1 = 325$ K flows through a tube bundle in in-line tube arrangement. The tubes have and outside diameter, $D = 1.9$ cm and are maintained at a uniform temperature $T_s = 375$ K. It is given that: $S_L/D = S_T/D = 2.0$, $u_\infty = 8.0$ m/s. The bundle consists of 0.75 m long tubes, 15 tubes in the direction of flow and 20 tubes per row. Estimate:

   (a) average heat transfer coefficient,

   (b) exit temperature of air,

   (c) total heat transfer rate,

   (d) pressure drop across the tube bundle.

5. Oil is to be heated from 30°C using hot water at 100°C. Oil flow rate is 0.1 kg/s in, while water flow rate is 0.5 kg/s.The heat exchanger is made of 2 x 1 1/4 std. type M copper tubing that is 5.0 m long. Using appropriate fouling factors, rate the new and used DPHX, if

   (a) oil flows in the pipe,

   (b) water flows in the pipe.

6. 1.25 kg/s engine oil needs to be heated from 30°C to 50°C using hot water available at 100°C. Design suitable DPHX, and report the following information about the heat exchanger:

   (a) Tube dimensions

   (b) Mass flow rate of water

   (c) Outlet temperature of water

   (d) Pressure drop of each fluid in the heat exchanger

(e) Motor power required for the pumps assuming 60% pump efficiency.

7. Water is being heated in a STHX by condensing steam. The water is flowing in the tubes at a rate of 0.8 kg/s. The water enters the heat exchanger at 15°C and leaves at 58°C. The steam condenses on the shell side of the heat exchanger at a condensing pressure of 110 kPa. Determine the following:

   (a) Mass flow rate of the condensing steam (kg/s)
   (b) Heat transfer rate between the water and condensing steam (kW)
   (c) UA product of the heat exchanger (kW/K)

   Consider a situation where the cold water inlet temperature to the heat exchanger is adjusted to 20°C while its flow rate (0.8 kg/s) remains constant. For this scenario, determine the following:

   (a) Outlet temperature of the cold water (°C)
   (b) Heat transfer rate between the water and condensing steam (kW)

8. The evaporator of a refrigeration cycle is a shell and tube design being used to chill water. The water flows in the tubes while the refrigerant boils in the shell. The water enters the heat exchanger at a flow rate of 50 L/s. The average temperature of the water through the heat exchanger is 8°C. The shell of the heat exchanger has a diameter of 21.25 in. The tubes in the heat exchanger have a length of 4 m and are 3/4-in. 16 BWG tubes on a 1 in. square pitch. Determine the pressure drop (kPa) on the tube side of the heat exchanger for a 1-pass, 2-pass, and 4-pass tube design.

9. A STHX has a single shell and 4-tube passes. The shell diameter is 25 in. The shell contains 10 baffles with a spacing of 0.36 m. Water flows through the shell with a flow rate of 70 kg/s and an average temperature of 85°C. The tubes are $1\frac{1}{4}$-in. 13 BWG tubes on a $1\frac{9}{16}$-in. square pitch. Determine the following:

   (a) Shell-side convective heat transfer coefficient (W/m2 K)
   (b) Shell-side pressure drop (kPa)

10. Design a STHX that will heat water from 30°C to 60°C using engine oil available at 100°C. The flow rate of both fluids is the same, at 12 kg/s. Specify the following information about the heat exchanger:

    (a) Number of shell and tube passes
    (b) Diameter of the shell
    (c) Placement of the fluids (which fluid is in the shell? in the tubes?)
    (d) Type of tubes used in the shell (BWG specification)
    (e) Pitch of the tubes
    (f) Number of active tubes
    (g) Length of the tubes
    (h) Outlet temperatures of the engine oil
    (i) Pressure drop of each fluid in the heat exchanger