<u>Boiling and Condensation</u>

Practice problems

1. A 1.4-mm diameter horizontal platinum wire is held in a pool of saturated water at 100ºC and 1.013 bar. The wire is electrically heated so that boiling occurs. Calculate the heat flux supplied when (a) Tw – Tsat = 1ºC and (b) Tw – Tsat = 15ºC

   [Ans: (a) 1.12 kW/m^2; (b)476.9 kW/m^2]

2. An aluminum cylinder, 2-cm in diameter and 15-cm long, is heated to a temperature of 500ºC and immersed horizontally in a liquid nitrogen bath at -196ºC. Liquid nitrogen has a saturation temperature of -196ºC at around atmospheric pressure. Neglecting heat transfer from the end faces, calculate the initial heat transfer rate. Take emissivity of the Al surface to be 0.4. *[Ans: 655 W]*

3. A metal-clad heating element of 6-mm diameter and emissivity of 1 is horizontally immersed in a bath of water at normal atmospheric pressure (1.103 bar). The surface temperature of the metal is 255ºC under steady state boiling conditions. Calculate the power dissipation per unit length of the heater. *[Ans: 1.39 kW/m]*

4. A cylindrical heating element with a diameter of 1-cm and length of 30-cm is immersed in a pool of saturated water at atmospheric pressure. The cylindrical surface is plated with Ni. Calculate the heat flux and total heat transfer from the cylinder to the water pool when the surface temperature T_w is 108ºC. Also calculate the critical heat flux. Assume Rohsenow's constant C_{sf} for Ni-water to be 0.006

   [Ans: q''=7x10^5 W/m^2; q=6.6 kW; CHF=1.26x10^6 W/m^2]

5. The surface temperature of the heating element in Problem 4 is raised to T_w=300ºC. Calculate the average heat transfer coefficient, heat flux a total heat transfer rate from the heater to the pool. Assume emissivity of heater surface to be 0.8

   [Ans: h=220 W/m^2-K; q''=4.4x10^4 W/m^2; q=414 W]

6. Water boils in a pressurized cylindrical vessel with inner diameter of 20-cm at a pressure of 4.76 x 10^5 Pa. The bottom surface of the pressure vessel is made of polished copper and its temperature is maintained at 160ºC. Assume nucleate boiling and calculate the total heat

transfer rate from the bottom surface to the boiling water. C_{sf} for polished Cu-water is 0.013. Later verify the correctness of the nucleate boiling assumption.

[Ans: xx]

7. Heat transfer coefficients for boiling are usually large compared to those for single phase convection. Estimate the flow velocity of water that would be required to produce a value of h in forced convection during flow through a long, smooth tube of 6-mm diameter compared to pool boiling of water on a Nickel coated surface at atmospheric pressure with superheat of 8ºC. *[Ans: 31.5 m/s]*

8. The outer surface of a vertical tube having a length of 1-m and outer diameter of 80-mm is exposed to saturated steam at atmospheric pressure and is maintained at 50ºC by flow of coolant inside the tube. Calculate the rate of heat transfer to the coolant and the rate of steam condensation at the surface. *[Ans: 66.4 kW, 0.0276 kg/s]*

9. Saturated Freon-12 at 50ºC condenses on a 3-cm diameter horizontal tube, the outer surface of which is kept at 40ºC. Find the average condensation heat transfer coefficient.

   [Ans: 1244 W/m^2-K]

10. A vertical plate 2.5 m high is maintained at uniform temperature of 54ºC is exposed to saturated steam at atmospheric pressure. Estimate the condensation rate and heat transfer rate per unit width of the plate. How would these values change if the height of the plate is reduced to half? Assume film condensation.

    [Ans: 649 kW/m, 0.27 kg/s/m; 299 kW/m, 0.125 kg/s/m]

11. Saturated steam at 1.43 bar and 110ºC condenses on a vertical tube, 1.9-cm OD and 20-cm long. The tube surface is maintained at a temperature of 109ºC. Calculate the average heat transfer coefficient and the local heat transfer coefficient at the bottom edge of the plate. *[Ans: 17,637 W/m^2-K, 13,227 W/m^2-K]*

12. Saturated R-22 vapor at 262 K condenses as a film on a horizontal tube (22 mm OD) whose outer wall is at a temperature of 258 K. Calculate the average heat transfer coefficient and the film Reynolds number at the bottom of the tube.

    [Ans: 2622.3 W/m^2-K, Re_δ = 54]