plate and the range $15 < q_s'' < 235\ \text{kW/m}^2$, $C = 5.56$ and $n = 3$. Units of ΔT_e are kelvins. Compare predictions from this expression with the Rohsenow correlation ($C_{s,f} = 0.013$, $n = 1$) for pressures of 2 and 5 bars with $\Delta T_e = 10°\text{C}$.

10.9 In Example 10.1 we considered conditions for which vigorous boiling occurs in a pan of water, and we determined the electric power (heat rate) required to maintain a prescribed temperature for the bottom of the pan. However, the electric power is, in fact, the control (independent) variable, from which the temperature of the pan follows.

(a) For nucleate boiling in the copper pan of Example 10.1, compute and plot the temperature of the pan as a function of the heat rate for $1 \le q \le 100$ kW.

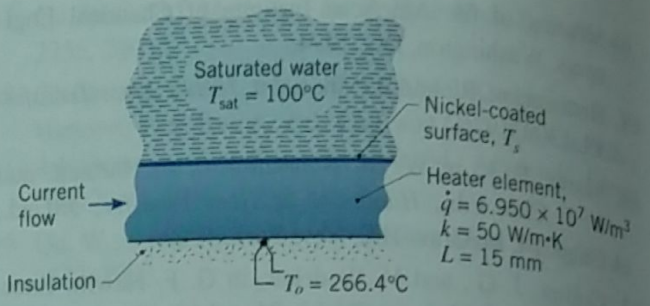
(b) If the water is initially at room temperature, it must, of course, be heated for a period of time before it will boil. Consider conditions shortly after heating is initiated and the water is at 20°C. Estimate the temperature of the pan bottom for a heat rate of 8 kW.

10.10 Calculate the critical heat flux on a large horizontal surface for the following fluids at 1 atm: mercury, ethanol, and refrigerant R-134a. Compare these results to the critical heat flux for water at 1 atm.

10.11 Water at atmospheric pressure boils on the surface of a large horizontal copper tube. The heat flux is 90% of the critical value. The tube surface is initially scored; however, over time the effects of scoring diminish and the boiling eventually exhibits behavior similar to that associated with a polished surface. Determine the tube surface temperature immediately after installation and after prolonged service.

10.12 The bottom of a copper pan, 150 mm in diameter, is maintained at 115°C by the heating element of an electric range. Estimate the power required to boil the water in this pan. Determine the evaporation rate. What is the ratio of the surface heat flux to the critical heat flux? What pan temperature is required to achieve the critical heat flux?

10.13 A nickel-coated heater element with a thickness of 15 mm and a thermal conductivity of 50 W/m·K is exposed to saturated water at atmospheric pressure. A thermocouple is attached to the back surface, which is well insulated. Measurements at a particular operating condition yield an electrical power dissipation in the heater element of $6.950 \times 10^7\ \text{W/m}^3$ and a temperature of $T_o = 266.4°\text{C}$.



(a) From the foregoing data, calculate the surface temperature, T_s, and the heat flux at the exposed surface.

(b) Using the surface heat flux determined in part (a), estimate the surface temperature by applying an appropriate boiling correlation.

10.14 Advances in very large scale integration (VLSI) of electronic devices on a chip are often restricted by the ability to cool the chip. For mainframe computers, an array of several hundred chips, each of area 25 mm², may be mounted on a ceramic substrate. A method of cooling the array is by immersion in a low boiling point fluid such as refrigerant R-134a. At 1 atm and 247 K, properties of the saturated liquid are $\mu = 1.46 \times 10^{-4}\ \text{N·s/m}^2$, $c_p = 1551\ \text{J/kg·K}$, and $Pr = 3.2$. Assume values of $C_{s,f} = 0.004$ and $n = 1.7$.

(a) Estimate the power dissipated by a single chip if it is operating at 50% of the critical heat flux. What is the corresponding value of the chip temperature?

(b) Compute and plot the chip temperature as a function of surface heat flux for $0.25 \le q_s''/q_{max}'' \le 0.90$.

10.15 Saturated ethylene glycol at 1 atm is heated by a horizontal chromium-plated surface which has a diameter of 200 mm and is maintained at 480 K. Estimate the heating power requirement and the rate of evaporation. What fraction is the power requirement of the maximum power associated with the critical heat flux? At 470 K, properties of the saturated liquid are $\mu = 0.38 \times 10^{-3}$ N·s/m², $c_p = 3280$ J/kg·K, and $Pr = 8.7$. The saturated vapor density is $\rho = 1.66\ \text{kg/m}^3$. Assume nucleate boiling constants of $C_{s,f} = 0.01$ and $n = 1.0$.

10.16 Copper tubes 25 mm in diameter and 0.75 m long are used to boil saturated water at 1 atm.

(a) If the tubes are operated at 75% of the critical heat flux, how many tubes are needed to provide a vapor production rate of 750 kg/h? What is the corresponding tube surface temperature?

(b) Compute and plot the tube surface temperature as a function of heat flux for $0.25 \le q_s''/q_{max}'' < 0.90$. On the same graph, plot the corresponding number of tubes needed to provide the prescribed vapor production rate.