Exercise 8.1

The surface of a horizontal $20mm$ diameter cylinder is maintained at an excess temperature of $5°C$ in saturated water at $1atm$. Estimate the heat flux using the appropriate free convection correlation and compare your result with the boiling curve of Figure 1. For nucleate boiling, estimate the maximum value of the heat transfer coefficient from the boiling curve.

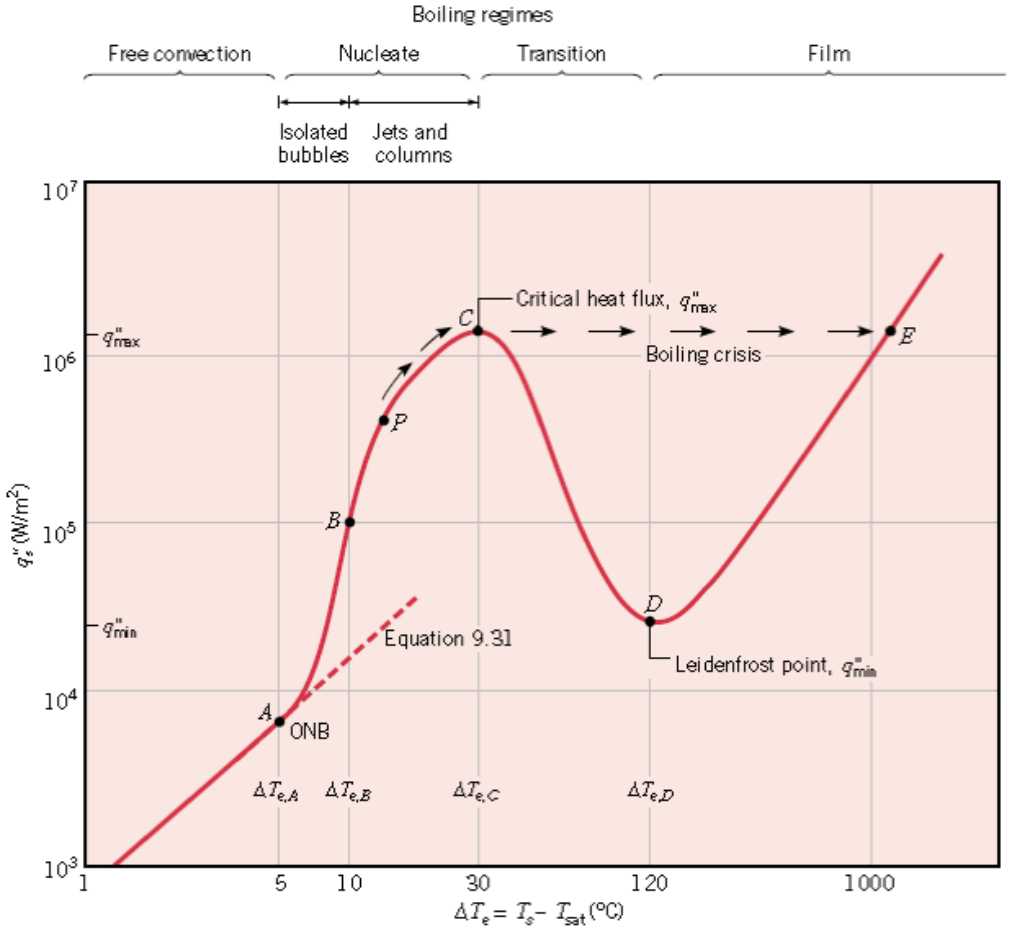
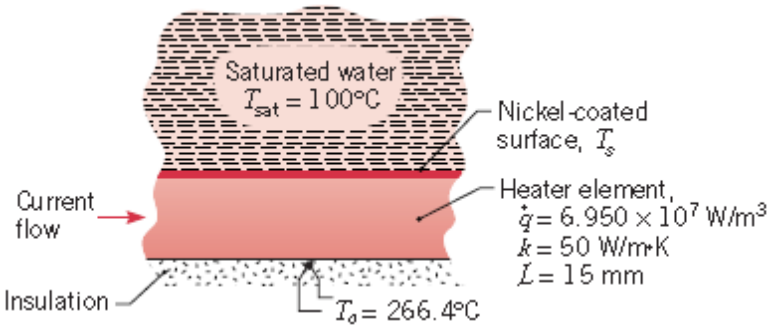


Figure 1: Typical boiling curve for water at $1atm$: surface heat flux q''_s as a function of excess temperature, $\Delta T_e \equiv T_s - T_{sat}$.

Exercise 8.2

A nickel-coated heater element with a thickness of $15mm$ and a thermal conductivity of $50W/mK$ 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 $6.95 \times 10^7 W/m^3$ and a temperature of $T_0 = 266.4°C$.



a) From the foregoing data, calculate the surface temperature T_s and the heat flux at the exposed surface. *Hint*: the heater has a uniform volumetric heat source. What is the temperature profile in the heater?

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

Exercise 8.3

A heater element of $5mm$ diameter is maintained at a surface temperature of $350°C$ when immersed horizontally in water under atmospheric pressure. The element sheath is stainless steel with a mechanically polished finish having an emissivity of 0.25.

a) Calculate the electrical power dissipation

b) If the heater were operated at the same power dissipation rate in the nucleate boiling regime, what temperature would the surface achieve? Calculate the rate of vapor production per unit length for this operating condition.

c) Sketch the boiling curve and represent the two operating conditions of parts (a) and (b). Compare the results of your analysis. If the heater element is operated in the power controlled mode explain how you would achieve these two operating conditions beginning with a cold element.

Exercise 8.4 FOR REVISION

A small steel bar, initially at a uniform, elevated temperature $T(0) = T_i$ is suddenly immersed in a large fluid bath maintained at T_{sat}. The initial temperature of the steel bar exceeds the Leidenfrost point corresponding to the temperature T_D of the boiling curve.

a) Sketch the variation of the average sphere temperature $T(t)$, with time during the quenching process. Indicate on this sketch the temperatures T_i, T_D and T_{sat} as well as the regimes of film, transition and nucleate boiling and the regime of single-phase convection. Identify the key features of the temperature history

b) At what time(s) in the cooling process do you expect the surface temperature of the steel bar to deviate most from its center temperature? Explain your answer.

c) The steel bar has $20mm$ in diameter, is $200mm$ long and has an emissivity of 0.9. It is indeed removed from a furnace at $455°C$ and suddenly submerged horizontally in a water bath under atmospheric pressure. What is the initial convection mechanism/mode? Estimate the initial heat transfer rate from the bar using the appropriate correlation.