Water evaporation rates under infrared heating

Tahzinul Islam, Roger Kempers, Thomas Cooper
Department of Mechanical Engineering, York University, Toronto, Canada
kempers@yorku.ca, tcooper@yorku.ca

ABSTRACT

This study investigates the evaporation rates of water under infrared radiation. The objective is to characterize both heat and mass transfer within the system as well as phase change. Boiling in the conventional sense refers to the phenomenon where a hot surface is in contact with a liquid. For water, the saturation temperature is 100 °C at a pressure of 1 atmosphere. The formation of bubbles associated with nucleate boiling begin to form at the 'solid-liquid interface' with a few degrees of surface superheat. As the bubbles grow, they eventually depart the solid surface rise through the liquid pool. While pool boiling in this sense is reasonably well understood, an in-depth investigation of phase change at the 'liquid-liquid interface' under radiative heat flux has not been reported. In order to investigate the phase change at the liquid-liquid interface (infrared radiation penetrates a few microns below the top of the water surface), an experimental radiative evaporation test rig has been designed and constructed. This setup consists of a glass tube (100 mm diameter) sandwiched in between two 150 mm x 150 mm plastic plates. Inside the glass tube is a ~85 mm diameter aluminum heater block (emitter) at the top and a water pool approximately 12 mm deep at the bottom with a 6 mm gap in between the aluminum emitter and water surface. Infrared radiation from the emitter is transferred to the water surface due to the gap in between. Thus, conduction is mostly minimized, in order to isolate the study of radiative heating. The sensors within the setup include thermocouples, a mass balance, and a camera, which would probe for temperatures, evaporation rates and bubble profiles, respectively. Using a PID controller, the heater is set to 250 °C, emitting to the 100 °C water below (the electric flux in, $Q_{electric}$, is known). The results of interest include the temperature and mass transfer occurring within the radiative phase change test rig. The temperature distributions and mass curves are used to quantify two more flux values: $Q_{evaporation}$ and $Q_{radiation}$. The first of these is in the energy used to drive phase change of the top water surface to evaporate water. The second is in the radiation from emitter to the water surface. In addition to these results, pictures from the camera during the phase change help understand the heat and mass transfer mechanisms taking place at the interface.