University of Al-Mustansiriyah
College of Engineering
Department of Mechanical Engineering

Phase Change and Applications II

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Lecture (1):

Boiling Basic Concepts

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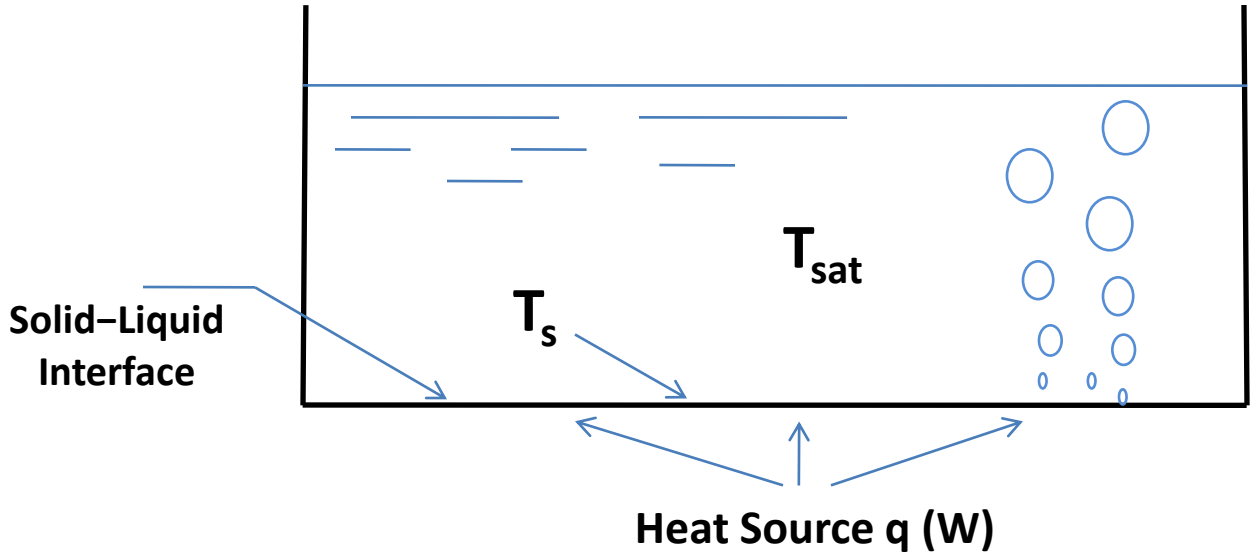
Boiling

Boiling occurs at the solid–liquid interface when surface temperature T_s exceeds saturation temperature T_{sat} at the corresponding liquid pressure. The term ($T_s - T_{sat}$) is called **Excess Temperature** (ΔT_e)



Types of Boiling

According to liquid movement

Pool Boiling

(Liquid is stationary or quiescent)

Fluid near the interface moves due to free convection and bubble growth and detachment

Forced Convection Boiling

(Liquid moves due to external means)

Free convection and bubble dynamics also contribute in the process

According to liquid temperature

Subcooled Boiling

(Liquid temperature is below T_{sat})

Bubbles generated at the interface may condense again in the liquid

Saturated Boiling

(Liquid temperature equals T_{sat})

Bubbles grow further and reach the liquid surface and escape

Bubbles formation and growth depends on:–

- Excess temperature ΔT_e
- Nature of the surface (smooth or rough)
- Thermophysical properties of the fluid

(surface tension, viscosity.. etc)

Important Definitions

Power (q) :− The total amount of heat delivered to the surface per unit time (W).

Heat flux (q''):− Amount of heat per unit time per unit area delivered to the surface (W/m^2).

Power per unit length (q') :− This term is used with heating wires or long slim heaters to mean the power delivered per unit time per unit length of the wire (W/m)

Heat quantity (Q) :− The total amount of heat delivered in a specified period of time (J). So, $Q = q \times \text{time}$

Latent heat of vaporization (h_{fg}) :− The quantity of heat required to vaporize one kg of a liquid (kJ/kg)

Boiling rate ($\dot{m}$) :− The mass of vapor generated per unit time during the boiling process (kg/s). So, $q = \dot{m} \times h_{fg}$

Heat Transfer Coefficient (h)

Boiling is a heat transfer process. In heat transfer processes, the effects of fluid properties and type of surfaces are grouped into single parameter called (**heat transfer coefficient**) with the symbol (h) and units ($W/m^2\ ^oC$).

So, the relation between heat, temperatures and area can be written as follows, and it is called **Newton's Law of Cooling**:−

$$q = h_b\ A\ (\ T_s - T_{sat}\ ) = h_b\ A\ \Delta T_e \qquad (1)$$

Where:−

h_b = boiling heat transfer coefficient ($W/m^2\ ^oC$)

A = Boiling heat transfer area (m^2)

Pool Boiling Curve of Water at 1 atm