Chapter 7: Boiling & Condensation

Repeated Questions:

1. Pool Boiling Regimes:

- **Q.** Explain different regimes of Pool Boiling (Pool Boiling Curve). **(SUMMER 2023, 7 Marks; WINTER 2024, 7 Marks; WINTER 2025, 3 Marks OR; SUMMER 2026, 3 Marks OR)**

Answer:

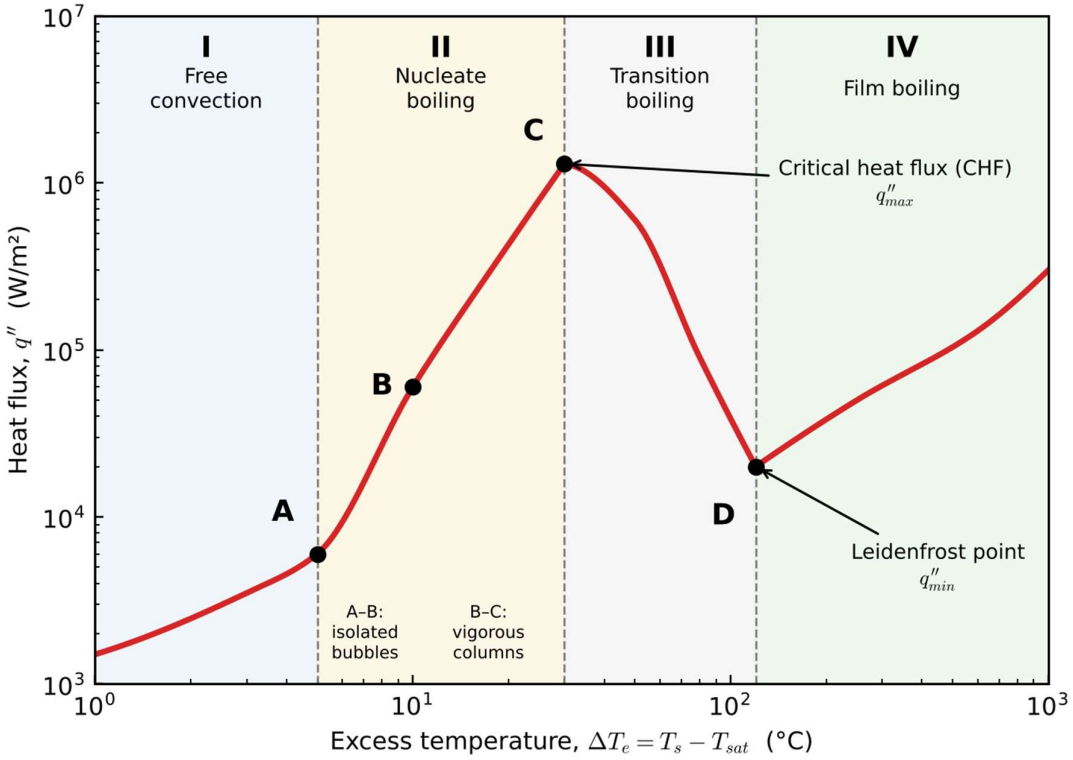


Fig. 16: Pool boiling curve for water showing regimes I–IV, CHF (point C) and Leidenfrost point (point D)

Regimes:

- **Free convection boiling ($\Delta T_e < 5°C$):** Liquid near the surface is superheated; heat transfer by natural convection. No bubbles form.
- **Nucleate boiling ($5°C < \Delta T_e < 30°C$):** Bubbles form at nucleation sites. Two sub-regions: isolated bubbles (higher h) and vigorous bubble columns. Highest heat transfer coefficient occurs here.
- **Transition boiling ($30°C < \Delta T_e < 120°C$):** Unstable regime; bubbles coalesce into vapor patches. Heat flux decreases as ΔT_e increases. Critical heat flux (CHF) occurs at the end of nucleate boiling.
- **Film boiling ($\Delta T_e > 120°C$):** A continuous vapor film covers the surface. Heat transfer by conduction/convection through vapor and radiation. Heat flux increases again but with low h.

Key points:

- **Critical heat flux (CHF):** Maximum safe heat flux; exceeding it causes burnout.
- **Leidenfrost point:** Minimum heat flux in film boiling.

- **Q.** Differentiate between nucleate and film boiling. **(WINTER 2025, 3 Marks OR)**

Answer:

Basis	Nucleate boiling	Film boiling
Vapor formation	Discrete bubbles at nucleation sites	Continuous vapor film
Heat transfer coefficient	High	Low
Surface contact	Liquid contacts surface	Surface covered by vapor
Regime	Before CHF	After Leidenfrost point

- **Q.** Draw the Boiling curve for water showing various regimes. **(SUMMER 2026, 3 Marks OR)**

Answer:

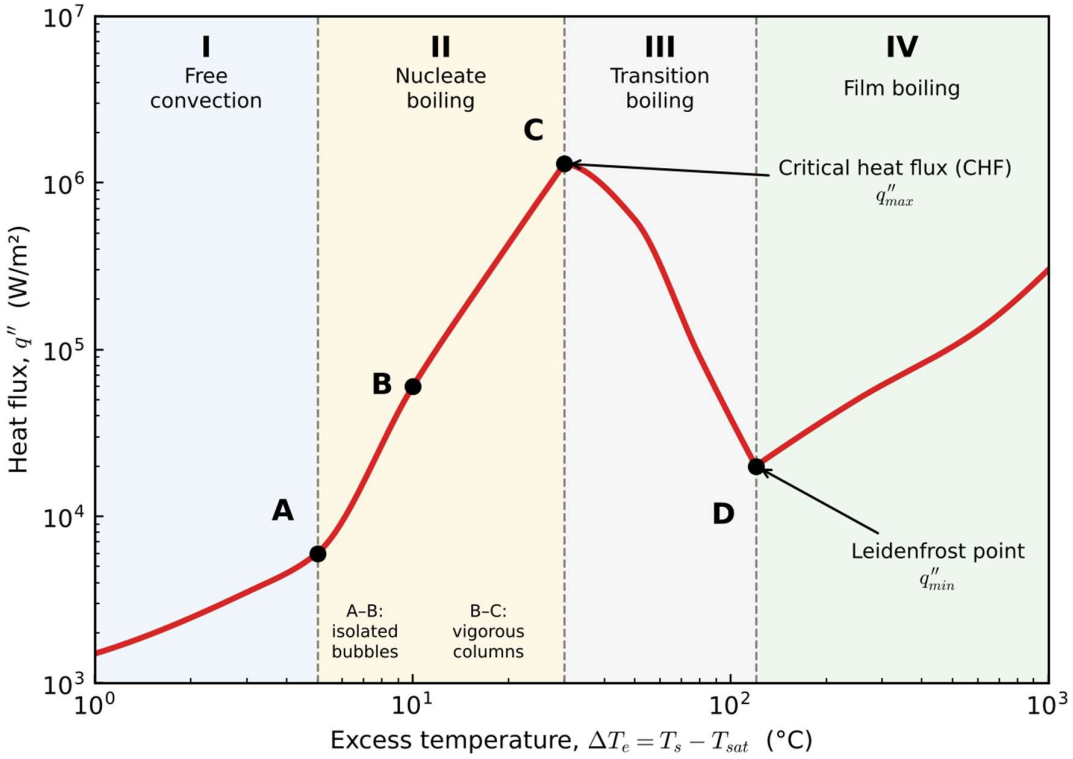


Fig. 17: Pool boiling curve for water showing regimes I–IV, CHF (point C) and Leidenfrost point (point D)

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2. Filmwise & Dropwise Condensation:

- **Q.** Differentiate between Filmwise and Dropwise Condensation. **(SUMMER 2023, 4 Marks; WINTER 2023, 4 Marks; SUMMER 2024, 7 Marks OR; WINTER 2025, 4 Marks; SUMMER 2026, 3 Marks)**

Answer:

Basis	Filmwise condensation	Dropwise condensation
Condensate form	Continuous liquid film on surface	Discrete droplets
Heat transfer coefficient	Lower	Much higher (5–10 times)
Surface condition	Wets the surface	Non-wetting surface (promoters)
Practical use	Common in industrial condensers	Difficult to maintain; used in some special cases

- **Which has higher heat transfer?** Dropwise condensation has significantly higher heat transfer coefficient because droplets do not insulate the surface, whereas filmwise condensation creates a liquid film that adds conduction resistance.

- **Q.** Explain condensation process. What are the two modes of condensation. **(WINTER 2025, 4 Marks)**

Answer:

- **Condensation process:** When a vapor contacts a surface at temperature below its saturation temperature, it releases latent heat and changes to liquid. The mode depends on how the liquid wets the surface.

Two modes:

1. Filmwise condensation: Condensate forms a continuous film on the surface. The film thickness grows along the flow direction, adding thermal resistance.
2. Dropwise condensation: Condensate forms discrete droplets that grow and roll off, exposing fresh surface to vapor. Higher heat transfer rates.

- **Key point:** Dropwise condensation is preferred for high heat transfer but is difficult to sustain; filmwise is common in practice.

- **Q.** Differentiate Filmwise and Dropwise condensation. Which type has higher heat transfer film condensation and why? **(SUMMER 2026, 3 Marks)**

Answer:

Basis	Filmwise condensation	Dropwise condensation
Condensate	Continuous film	Discrete droplets
Heat transfer	Lower	Higher
Surface	Wetted	Non-wetted
Sustainability	Stable	Requires promoters; not stable

- **Note:** Dropwise condensation has higher heat transfer because no insulating film forms. Filmwise condensation is the mode where a film forms, and its heat transfer is lower due to film resistance.

Other Important Questions:

1. Boiling:

- **Q.** Explain the physical mechanism of boiling. **(WINTER 2023, 3 Marks)**

Answer:

- **Nucleation:** Vapor bubbles form at cavities and scratches on the heated surface where trapped vapor exists.
- **Bubble growth:** Heat from the surface vaporizes liquid at the bubble interface; bubble grows due to evaporation and pressure difference.
- **Bubble detachment:** Buoyancy overcomes surface tension; bubble leaves the surface.
- **Convection enhancement:** Bubble motion agitates the liquid, increasing heat transfer.
- **Regime transition:** As ΔT_e increases, bubble population increases; eventually bubbles coalesce, leading to transition and film boiling.

- **Q.** Applications of boiling heat transfer. **(WINTER 2023, 3 Marks OR)**

Answer:

- Steam generation in boilers and power plants.
- Evaporators in refrigeration and air-conditioning.
- Cooling of nuclear reactor cores.
- Cooling of electronic components (immersion cooling).
- Distillation and chemical process evaporators.
- Desalination plants.

- **Q.** Differentiate between subcooled and saturated boiling. **(WINTER 2025, 3 Marks)**

Answer:

Basis	Subcooled boiling	Saturated boiling
Bulk liquid temperature	Below T_{sat}	At T_{sat}
Bubble behavior	Bubbles collapse in subcooled liquid	Bubbles rise through saturated liquid
Location	Near heated surface only	Throughout the liquid
Heat transfer	Local boiling at surface	Bulk boiling with vapor generation

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2. Condensation:

- **Q.** Explain why condenser tubes are horizontal. **(WINTER 2025, 4 Marks OR)**

Answer:

- **Higher heat transfer coefficient:** Horizontal tubes allow condensate to drain more easily, reducing film thickness and increasing h.
- **Thinner condensate film:** Gravity helps condensate fall away, minimizing insulating film resistance.
- **Better drainage:** Horizontal arrangement prevents accumulation of condensate along the tube length.
- **Improved performance:** For filmwise condensation, horizontal tubes give higher average heat transfer coefficient than vertical tubes of the same length.

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