TEE-903 Phase Change Thermal Processes

Course Objectives

1. The objectives of the course are as under:
   a. To describe the present state-of-the-art knowledge about boiling and condensation heat transfer.
   b. The students will learn boiling and condensation models and investigate the heat transfer in conventional, mini and micro channels
   c. To discuss the instrumentation, working principles, and capabilities of quantifying boiling and condensation phenomenon in thermal systems
   d. To provide the students with the advanced academic background necessary to contribute effectively to technically demanding projects in the field of boiling and condensation.

Course Contents

2. Contents with suggested contact hours

No.	Topics	Contact Hours
a.	**Boiling and Condensation** • Vapor Liquid Equilibrium Properties • Representation of Solid-Liquid-Vapor Phase Interactions • Regimes of boiling • Two-Phase Flow • Condensation	2
b.	**Pool Boiling** • Pool Boiling Curve • Heterogeneous Bubble Nucleation and Ebullition • Nucleate Boiling Correlations • Hydrodynamic of Pool Boiling • Film Boiling • Minimum Film Boiling • Transition Boiling	5

	• Enhancement Techniques in Pool Boiling	
c.	**Flow Boiling** • Forced-Flow Boiling Regimes • Flow Boiling Curves • Flow Patterns and Temperature Variation in Subcooled Boiling • Onset of Nucleate Boiling • Onset of Significant Void • Hydrodynamics of Subcooled Flow Boiling • Pressure Drop in Subcooled Flow Boiling • Partial Flow Boiling • Fully Developed Subcooled Flow Boiling • Characteristics of Saturated Flow Boiling • Saturated Flow Boiling Heat Transfer Correlations • Flow-Regime-Dependent Correlations for Saturated • Boiling in Horizontal Channels • Two-Phase Flow Instability	6
d.	**Critical Heat Flux and Post-CHF Heat Transfer in Flow Boiling** • Critical Heat Flux Mechanisms • Microscopic Analysis of CHF Mechanisms • Experiments and Parametric Trends • Correlations for Upward Flow in Vertical Channels • Correlations for Subcooled Upward Flow of Water in Vertical Channels • Mechanistic Models for DNB • Mechanistic Models for Dry out • CHF in Inclined and Horizontal Channels • Post-Critical Heat Flux Heat Transfer	5

e.	**Boiling Heat Transfer in Small Passages** • Minichannel- and Microchannel • Boiling Two-Phase Flow Patterns and Flow Instability • Flow Regimes in Minichannels • Flow Regimes in Arrays of Parallel Channels • Onset of Nucleate Boiling and Onset of Significant Void • ONB and OSV in Channels • Boiling Heat Transfer • Critical Heat Flux in Small Channels	8
f.	**Condensation** • Basic Processes in Condensation • Thermal Resistances in Condensation • Laminar Condensation on Isothermal, Vertical, and Inclined Flat Surfaces • Empirical Correlations for Wavy-Laminar and Turbulent Film • Condensation on Vertical Flat Surfaces Interfacial Shear • Laminar Film Condensation on Horizontal Tubes • Condensation in the Presence of a Noncondensable Fog Formation	5
g.	**Internal-Flow Condensation and Condensation on Liquid Jets and Droplets** • Two-Phase Flow Regimes • Condensation Heat Transfer Correlations for a Pure Saturated Vapor • Effect of Noncondensables on Condensation Heat Transfer • Direct-Contact Condensation	4

	• Mechanistic Models for Condensing Annular Flow	
h.	**Flow Condensation in Small Channels** • Flow Condensation in Small Channels • Condensation Flow Regimes and Pressure Drop in Small Channels • Flow Regimes in Minichannels • Flow Regimes in Microchannels • Pressure Drop in Condensing Two-Phase Flows • Flow Condensation Heat Transfer in Small Channels	4
i.	**Instrumentation in Boiling and Condensation** • Local Void Fraction Measurements • Line Void Fraction Measurements • Area Void Fraction Measurements • Mass Flow Rate Measurements • Volumetric Interfacial Area Measurements • Liquid Crystal Thermography in Boiling • High Speed Camera • Thermal Imaging Camera • Measurements of Other Quantities of Interest	4
j.	**Special Topics and Applications**	2
		45

Course Outcomes

3. Upon successful completion of this course, the student will gain the knowledge about the theory and existing works that are address to a specific problem. Acquiring the ability to solve the scientific problems in the field of boiling and condensation technology and develop energy efficient systems.

4. **Recommended Reading (including Textbooks and Reference books).**

No.	Title	Author(s)	Books
a.	Two-Phase Flow, Boiling and Condensation	S. Mostafa Ghiaasiaan	Text
b.	Boiling Heat Transfer and Two-Phase Flow	L. S. Tong, Y. S. Tang	Text
c.	Handbook of Phase Change: Boiling and Condensation	Satish G. Kandlikar	Text
d.	Convective Boiling and Condensation	John G. Collier and John R. Thome	Ref
e.	Heat Transfer in Condensation and Boiling	Karl Stephan	Ref
f.	Multiphase Flow Dynamics: Nuclear Thermal Hydraulics	Nikolay Ivanov Kolev	Ref
g.	Nuclear System I: Thermal Hydraulic Fundamentals	N.E. Todreas, and M.S. Kazimi	Ref
h.	Nuclear Heat Transport	M. M. El-Waqil	Ref
i.	Liquid-Vapor Phase-Change Phenomena	Van P. Carey	Ref
j.	Heat Transfer and Fluid Flow in Minichannels and Microchannels	Satish G. Kandlikar, Srinivas Garimella, Dongqing Li, Ste ´phane Colin and Michael R. King	Ref