Mechanical Engineering Dept. Department

Syllabus

ME 448: Engineering of Nuclear Reactors (3-0-3)

Course Catalog Description:

Basic principles of reactor physics, thermodynamics, fluid flow and heat transfer. Engineering design of nuclear power plants. Light-water reactor technology. Thermal limits in nuclear fuels. Thermal-hydraulic behaviour of the coolant. Nuclear safety and dynamic response of nuclear power plants.

Course Pre-requisites:

- ME 204: Thermodynamics II

Course Co-requisites:

- ME 315: Heat Transfer

Course Objectives:

1. Introduce students to the engineering design and safety of nuclear fission power plants.
2. b. Enable students to use basic principles of reactor physics, thermodynamics, fluid flow, heat transfer and structural mechanics in the engineering of the nuclear power plant.

Course Learning Outcomes:

CLO1. Describe the design and operating conditions of Light Water Reactors, including the design features and materials of the fuel pins and fuel assemblies, core internals, RPV and primary systems components, as well as BOP components

CLO2. Explain the physical bases of the thermo-mechanical limits for the fuel, cladding and reactor coolant

CLO3. Describe the principles of nuclear safety, in particular the principle defense-in-depth, the critical safety functions, the design-basis and beyond-design-basis accidents, the features of the engineered safety systems, including the functions and designs of the reactor containment

CLO4. Calculate primary membrane stresses in pressure components of simple geometry such as cylindrical and spherical shells

CLO5. Apply mass, momentum and energy conservation equations to predict the velocity, pressure and temperature fields within the reactor core, in the presence of single- or two-phase flows

CLO6. Apply fundamental concepts/tools of probabilistic risk assessment, and calculate failure probabilities using fault and event trees.

Learning Resources:

- N. E. Todreas, M. S. Kazimi, Nuclear Systems, Vol. 1, Taylor and Francis, 2012
- • Gavrilas, M., P. Hejzlar, N. E. Todreas, and Y. Shatilla, Safety Features of Operating Light Water Reactors of Western Design, 2nd Ed., Center for Advanced Nuclear Energy Systems (CANES), MIT, 2000 • Collier, J. G., and J. R. Thome. Convective Boiling and Condensation. 3rd ed. New York, NY: Oxford University Press, 1996.
- • https://www.iaea.org/
- • Y. A. Çengel, R. H. Turner, J. M. Cimbala, Thermal-Fluid Sciences, 3rd edition, McGraw-Hill, 2008. (thermodynamics, single-phase fluid dynamics and heat transfer) • Whalley, P. B., Boiling, Condensation and Gas-Liquid Flow, Oxford Science Publications, 1987. (boiling and two-phase flow) • R. A. Knief, Nuclear Engineering, 2nd Edition, 2008 (originally published by Taylor and Francis, currently printed by the American Nuclear Society)

Lecture Assessment Plan:

Assessment Task	Week Due	Weight
term project and case study	14	10.0%
final exam	15	35.0%
Major exam	8	20.0%
quizes	biweekly	15.0%
homework	weekly	20.0%

Lecture Weekly Schedule:

Week#	Topics
1	Course intro and nuclear power overview
2	Basic reactor physics concepts
	Thermal parameters in reactor analysis (linear power, power density, etc.), decay heat and their relationship to core design
3	Thermal parameters in reactor analysis (linear power, power density, etc.), decay heat and their relationship to core design (Continue)
	Review of conservation equations
4	Review of conservation equations (Continue)
	Description of the PWR (core, primary system, BOP)
5	Description of the BWR (core, reactor coolant system, BOP)
6	Other reactor designs (heavy water, liquid metal, gas, molten salt)
7	Thermal Analysis of Fuel Elements (introduction to fuels and heat conduction equation + temperature distributions + core max temperature)
8	Single-phase Coolant Heat Transfer (correlations + heat exchangers)
9	Pure Substance Model and Intro to Two-phase Coolant Flow
	Two-phase Coolant Flow and Heat Transfer (pressure drop + pool and flow boiling + boiling crises)

Week#	Topics
10	Two-phase Coolant Flow and Heat Transfer (pressure drop + pool and flow boiling + boiling crises) (Continue)
11	Two-phase Coolant Flow and Heat Transfer (pressure drop + pool and flow boiling + boiling crises) (Continue)
	Power Cycles (Rankine and Brayton)
12	Power Cycles (Rankine and Brayton) (Continue)
	Structural Mechanics (elasticity fundamentals + thin-shell theory + stress limits)
13	Nuclear Safety (defence-in-depth + design-basis and severe accidents + engineered safety systems + containment + emergency response)
	Elements of PRA
14	Elements of PRA (Continue)
	Dynamic behaviour of PWR / BWR using IAEA simulators
15	Review of Ideal Gas and incompressible Fluid Models + Single-phase Coolant Flow (pressure drop and natural circulation)