Engineering Faculty Document
No.: 113-23
April 17, 2023

TO: The Engineering Faculty

FROM: The Faculty of the School of Nuclear Engineering

RE: New graduate course – NUCL 65100 Dynamics of Nuclear Thermal-hydraulic Systems

The Faculty of the School of Nuclear Engineering has approved the following new graduate course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM (IF ALREADY OFFERED WITH TEMPORARY NUMBER)**:**
NUCL 69700R – Selected Topics in Nuclear Engineering II, Dynamics of Nuclear Thermal-Hydraulic Systems

Spring Semester

3 total credits

Prerequisites: NUCL 551 and NUCL 552; Permission of instructor

Year offered	Enrollment
Spring 2013	11
Spring 2014	2
Spring 2015	9
Spring 2019	6
Spring 2020	6
Spring 2022	7

TO:
NUCL 65100, Dynamics of Nuclear Thermal-hydraulic Systems

Spring Semester

3 total credits

Prerequisites: NUCL 551 and NUCL 552; Permission of instructor

This course discusses and analyzes various two-phase flow instabilities important for nuclear reactor systems. For the interfacial stabilities, Kelvin-Helmholtz and Rayleigh-Taylor instabilities as well as flooding and flow reversal instabilities are addressed. For the static instabilities, flow excursion instability that can reach the critical heat flux condition is analyzed relative to fast reactor and high flux research reactors. For the dynamic instabilities the density wave instabilities are discussed in detail. The characteristic equation is obtained and how to determine the stability of the system is discussed. Both the encirclement theory and the D-Partition stability boundary theory are explained. In addition, each student's research is studied through presentations, questions and discussions.

RATIONALE:

This is an advanced graduate course that covers important topic in nuclear reactor thermal-hydraulics analysis. It builds on existing 500 level courses in thermal-hydraulics currently offered in the School and complement student training and research programs in the thermal-hydraulics area. The course was offered as a temporary course, NUCL 697R, six times in the past. It was well received by graduate students from Nuclear Engineering and Mechanical Engineering. There are no such equivalent courses in the Purdue Grad programs and very few institutes in US offer this course.

Head/Director of the School of Nuclear Engineering

Link to Curriculog entry: https://purdue.curriculog.com/proposal:21080/form

NUCL 65100 Dynamics of Nuclear Thermal-hydraulic Systems

1. **Credit Hours:** 3
   Meeting time: Mon, 2:30 -5:00 pm or TBA

2. **Instructors:** Mamoru Ishii, 765-494-4587, ishii@purdue.edu
   Office hours: Tue & Thu, 2:00 – 3:00 pm
   AERO 10B, 1375 Aviation Dr., W. Lafayette, IN

3. **Textbook(s):**
   - *Thermo-Fluid Dynamics of Two-phase flow* by M. Ishii & T. Hibiki

   References:
   - *Study on Flow Instabilities in Two-phase Mixtures (ANL-76-23)* by M. Ishii
   - *Thermally Induced Flow Instabilities in Two-phase Mixtures in Thermal Equilibrium (Ph.D. Thesis)* by M. Ishii
   - *Two-fluid Model Stability, Simulation and Chaos* by M. L. De Bertodano, W. Fullmer, A. Clausse & V. Ransom

4. **Course Description:**
   This course discusses and analyzes various two-phase flow instabilities important for nuclear reactor systems. For the interfacial stabilities, Kelvin-Helmholtz and Rayleigh-Taylor instabilities as well as flooding and flow reversal instabilities are addressed. For the static instabilities, flow excursion instability that can reach the critical heat flux condition is analyzed relative to fast reactor and high flux research reactors. For the dynamic instabilities the density wave instabilities are discussed in detail. The characteristic equation is obtained and how to determine the stability of the system is discussed. Both the encirclement theory and the D-Partition stability boundary theory are explained. In addition, each student's research is studied through presentations, questions and discussions.

5. **Prerequisites:** NUCL 551 and NUCL 552; Permission of instructor

6. **Learning Objectives:**
   - Understand the Physics and Analytical Method to Solve Interfacial Instabilities in Two-phase Flow, Static Instabilities, Flow Excursion and Flow Reversal Dynamic Instability caused by Kinematic Waves
   - Their implications in
     - Interfacial Structures in Coolant in Nuclear Reactors
     - Sodium Cooled Fast Reactor Safety
     - High Flux Research Reactor and Isotope Production Reactors
     - Boiling Water Reactor Designs
     - Natural Circulation Passively Safe Reactors
   - Learn about Small Perturbation Method, Characteristic Equation, Response Function, Encirclement Theory, D-Partition Method and Stability Map
   - Learn how to present research progress and analyze and discuss it

7. Assignments:

- Assignments are mostly given to let student obtain the same analytical results given in the class by themselves
- Assignments are due in one week
- There are midterm and final examinations
- Students must submit all homework. The late homework will not get any points

8. Course Schedule*:

Weeks	Topics
1	• Various Flow Two-Phase Flow Instabilities • Instabilities in Various Nuclear Reactors
2 - 3	• Interfacial Instabilities • Kelvin-Helmholtz Instability • Rayleigh-Taylor Instability
4 - 6	• Static Flow Excursion Instabilities ▪ Loop Type Sodium Cooled Fast Reactors ▪ Isotopic Production Reactors ▪ High Flux Research Reactors • Analytical Solution for Flow Excursion Instabilities • Determination of Reactor Safety and Recovery from Flow Excursion
7 - 10	• Density Wave Instability • Transient Drift Flux Model • Small Perturbation Method • Transfer Function and Characteristic Equation • Encirclement Theory • D-Partition Method • Non-dimensional Characteristic Equation • Scaling Parameters of Dynamics of Two-phase Flow System • Stability Map • Key Parameters for Stability
11 - 12	• Flashing Induced Flow Instability • Boiling Water Start-up Transient and Instability
13 - 16	• Research Presentations, Questions and Discussions

* Schedule and assignments subject to change. Any changes will be posted on Brightspace.

9. Grading:

Midterm Exam	30%
Final Exam	30%
Presentation, Questions, Discussions & Homework	40%

Scale: A >= 80%, B >= 60%, C >= 50%, F < 50%

10. Attendance Policy:

Students are expected to attend all classes unless prior permission for absence from the Instructor.

11. Past Records as NUCL 697R:

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Spring 2013	11
Spring 2014	2
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Spring 2019	6
Spring 2020	6
Spring 2022	7