UN804
NUCLEAR REACTOR THERMALHYDRAULICS DESIGN

Course Outline Jan – Mar 2026

INSTRUCTOR:
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Office hours: (registration by email required 2 days in advance)
Tuesday 19:00 – 21:00

COURSE DESCRIPTION:

This course covers the topic of thermal hydraulics design and operation of nuclear power reactors. It includes an overview of nuclear reactor systems, thermal hydraulic design requirements, limits, and margins, and thermal hydraulic phenomena related to reactor safety. The course covers the conservation equations and equation of state and applies them to describe single and two-phase flow and heat transfer in the reactor core and other reactor systems. The course describes and explains the energy conversion processes in the reactor core and other elements of the reactor heat transport systems. Also, the course provides information about the pressure drop and other thermal hydraulics parameters and phenomena in the reactor heat transport system. The course discusses the design, role, and functionality of various thermal hydraulics systems and components.

COURSE OUTCOMES:

The goal of this course is for the students to develop:

(a) Understand thermal hydraulics design of heat transport systems of most important operating power reactors and Small Modular Reactors;

(b) Understand, assess and categorize thermal hydraulic phenomena and processes that take place in a nuclear power plant and have important impact on reactor safety;

(c) Describe the effect thermal design limits on the nuclear power plant design characteristics and assess the level of reactor core thermal margins;

(d) Analyze complex thermal hydraulics systems with single and two-phase flows;

(e) Calculate pressure drop and heat generation and distribution inside the nuclear reactor during operation, post shutdown, and during various

accidents;

(f) Understand the role and function of various components of thermal hydraulics systems and assess their functionality and effectiveness;

(g) Understand key computer codes used for thermal hydraulic analysis,

TEXTBOOKS (essential)

- The Essential CANDU – UNENE, 2015. Chapter 6.
  CANDU textbook

TEXTBOOKS (for reference)

- Nuclear Systems: Thermal Hydraulic Fundamentals, Volume 1, Neil Todreas and Mujid Kazimi, CRC Press, 2021.
- Nuclear Systems: Thermal Hydraulic Fundamentals, Volume 2, Neil Todreas, Mujid Kazimi, and Mahmoud Massoud, CRC Press, 2022.
- Thermal Analysis of Pressurized Water Reactors, 3rd edition, L.S. Tong and J. Weisman, American Nuclear Society, 1996.
- Thermal Hydraulics of a Boiling Water Nuclear Reactor, R.T. Lahey and E.J. Moody, American Nuclear Society, 2nd edition, 1993.

TOPICS COVERED:

1. Introduction to thermalhydraulics
2. Thermal hydraulics design process
3. Thermal hydraulics of various power reactor types and designs, including SMRs
4. Design evolution of reactor thermal hydraulics systems
5. Thermal hydraulics design requirements
6. Thermodynamics and thermal hydraulics fundamentals
7. Heat transport system thermal hydraulics
8. Pressure losses in reactor thermal hydraulics components
9. Critical Heat Flux (CHF) and Post-Dryout heat transfer (PDO)
10. Thermal hydraulics experimental tests
11. Special topics: Critical Flow, Natural Circulation, Water Hammer
12. Thermal hydraulics computer tools

MARKING

Quizzes	6%
Assignment 1	12%
Assignment 2	12%
Midterm Exam	25%
Final Exam	45%

FINAL GRADES

Final grades will be assessed according to the McMaster/UNENE standard grading scheme.

COURSE LOGISTICS

Course runs in a hybrid mode, which means lectures are in person and online in parallel, and lectures are recorded. Course venue is at Durham College at Whitby as per schedule provided in this outline. Online attendance is provided by Zoom.

Students can attend lectures in person or online. However, UNENE encourages students to attend as may lectures in person as possible to take advantage of meeting professors and colleagues from various nuclear industry organizations and for networking. There are two days that students need to attend in person: Day V in the schedule below, for in person attendance of the midterm exam and Day IX for in person attendance of the final exam. Students who cannot attend in person these two days need to get an approval from the professor at the first day of the course to do these exams by invigilation at another university that is closer to their residence location.

Lecture material, assignments and quizzes are given to students using CANVAS. Students are provided with access to CANVAS and are expected to be familiar with using CANVAS before the course begins.

Regardless of how students attend lectures (in person or online), students are required to have functioning laptops, audio and video equipment. If attending online, students are required to make appropriate arrangements to have online video on during attendance. During lecture attendance, students are required to be logged into Zoom and CANVAS in parallel.

SCHEDULE

I. Jan 10, Saturday

1. Course introduction
- 1.1. Student introduction
- 1.2. Scope and schedule
- 1.3. Course objectives, outcomes, assignments, exam

2. Thermal hydraulics design process
- 2.1. Thermal hydraulics introduction
- 2.2. Generic design process outline
- 2.3. Design verification and validation

3. Thermal hydraulics design requirements
- 3.1. Heat transfer considerations
- 3.2. Uranium fuel forms and fuel sheath (cladding) materials
- 3.3. Reactor coolants and neutron moderators

Quizzes and discussion

II. Jan 11, Sunday

4. Thermal hydraulics of various power reactor types and designs
- 4.1. Reactor generations
- 4.2. CANDU design
- 4.3. Pressurized Water Reactors (PWRs) design
- 4.4. Boiling Water Reactors (BWRs) design

5. Thermal hydraulics of Small Modular Reactors (SMRs)
- 5.1. SMRs types
- 5.2. BWRX-300 design

Quizzes and discussion

III. Jan 31, Saturday

6. Design evolution of reactor thermal hydraulics systems

6.1. Reactor Heat Transport System
6.2. Reactor Core, Fuel and Fue Channel
6.3. History of CANDU Design

7. Thermal hydraulics fundamentals
7.1. Reactor cooling function fundamentals
7.2. Two-phase flow methodology
7.3. Boiling flow

8. Nuclear Power Plant Thermodynamics fundamentals
8.1. First law of thermodynamics
8.2. Second law of thermodynamics
8.3. Rankine cycle and Nuclear Power Plant Rankine cycle

Quizzes and discussion

IV. Feb 1, Sunday

9. Heat transport system thermal hydraulics
9.1. Primary Side Flow and Heat Transfer
9.2. Secondary Side Flow and Heat Transfer
9.3. Steam generator without and with preheater

10. Fuel-coolant heat transfer
10.1. General heat conduction equation and thermal energy equation
10.2. Heat transfer in radial and axial direction

11. Pressure losses in reactor thermal hydraulics components
11.1. Conservation equations
11.2. Single-phase pressure gradient
11.3. Two-phase pressure gradient
11.4. Pressure distribution in CANDU primary heat transport system

Quizzes and discussion

V. Feb 21, Saturday

12. Critical Heat Flux (CHF)
12.1. CHF importance in thermal margins evaluation
12.2. CHF terminology and mechanisms
12.3. Prediction methods
12.4. Reactor thermal margins

Midterm Exam – 11:00 – 12:30

Quizzes and discussion

VI. Feb 22, Sunday

13. Post dryout heat transfer (PDO)
13.1. Transition boiling
13.2. Film boiling
13.3. Drypatch spreading
13.4. Experimental techniques and results

14. Thermal hydraulics experimental tests
14.1. Integral experiments
14.2. Header experiments
14.3. Other experiments

Quizzes and discussion

VII. Mar 7, Saturday

15. Critical Flow

16. **Natural Circulation**
17. **Water hammer**

Quizzes and discussion

VIII. Mar 8, Sunday

18. **Thermal hydraulics computer tools and methodologies**

Preparation for final exam

IX. Mar 28, Saturday

FINAL EXAM – 11:00 – 14:00