*MSc thesis proposal for:*

# CFD study of flow in T-junctions and branch pipes

## Background

NRG PALLAS is actively involved in several research projects in the nuclear field. A significant effort is dedicated to the investigation and development of cutting-edge methodologies that can be beneficial for the nuclear engineering community. One of the key research themes within this scope is the long-term operation (LTO) of nuclear power plants. As many plants worldwide approach or exceed their original design lifetimes, ensuring the structural integrity of critical components becomes increasingly important. Extending operational lifetimes safely requires a deep understanding of degradation mechanisms, particularly those that are difficult to detect or predict, such as thermal fatigue in stagnant or low-flow piping systems.

Thermal fatigue phenomena in normally stagnant branch lines connected to the primary loop of pressurized water reactors have been identified as a significant contributor to several pipe cracking events in the past decade. These so-called "dead legs" are susceptible to complex flow and temperature fluctuations driven by turbulent mixing and thermal stratification, which can induce high-cycle thermal stresses on pipe walls. However, the prediction and inspection of at-risk piping are still based largely on semi-empirical models developed from low-resolution data. Detailed simulation of these phenomena remains challenging due to the complex interaction of flow regimes and the long computational times required for high-fidelity modeling. Consequently, there is a pressing need for improved experimental data and validated computational models to capture the mechanisms leading to crack initiation and propagation in these systems.

Within this research project, the focus is on performing medium-resolution simulations, based on the Unsteady Reynolds-averaged Navier–Stokes (URANS) or hybrid approach, to investigate the flow and thermal behavior in dead-ended branch lines. Various turbulence models, geometric configurations, and flow conditions are to be tested to assess their impact on thermal stratification, re-laminarization, and vortex-driven mixing. The obtained results are to be compared with available reference data to properly assess the performance of the various approaches. This work aims to deepen the understanding of the physical phenomena governing flow in dead legs, enhance the predictive accuracy of CFD models, and ultimately improve the reliability and safety of aging nuclear power plants.

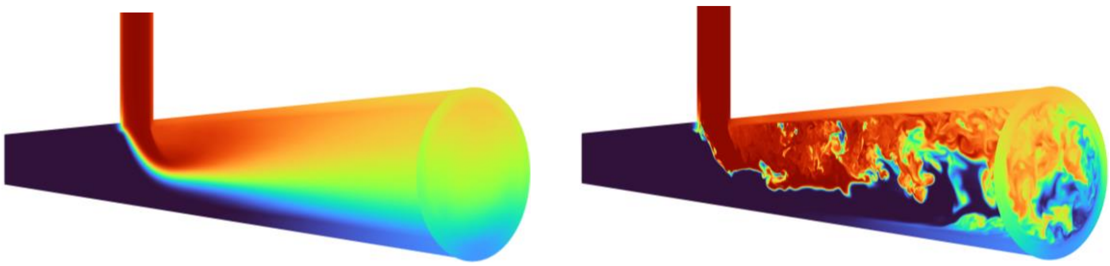

**Fig:** Simulation of thermal mixing in a T-junction using [left] low-resolution, and [right] high-resolution modelling approaches.

## Research Proposal

The proposed research aims to improve the understanding of flow and thermal fatigue phenomena in dead-ended branch lines of nuclear power plants through advanced numerical simulations. The work will start with a focused literature study to identify key knowledge gaps and select a relevant experimental reference case. Based on this, appropriate turbulence models, geometric configurations, and boundary conditions will be chosen to perform medium-resolution simulations. The numerical results will be compared against experimental data to evaluate model accuracy and capture dominant flow and temperature fluctuation mechanisms. Depending on the student's progress, design and verification of a novel high-resolution simulation case is also foreseen. Ultimately, the study will enhance predictive modeling capabilities and support more reliable assessments of thermal fatigue risks in aging nuclear systems.

**Objectives/Results**

- Literature review on flow in T-junctions and branch pipes, in order to get familiar with the topic.
- Selection of a suitable test case among available reference cases
- Gain understanding of important physical phenomena
- Test various turbulence models and modeling approaches, and (inter-)compare with reference data.
- If time permits, design and verification of a novel high-resolution simulation case
- Report on the performance of the selected models, thereby making recommendations on the use of these models.

**Your profile**

- MSc. student in applied science, with specialization in computational fluid mechanics
- Good knowledge of turbulence modelling and numerical methods
- Required computer experience: Linux, Windows, programming (Python and preferably C++) and Git
- Fluency in written and spoken English
- Excellent analytical and problem solving skills
- An interest in scientific research and publication
- Creativity, independence, dedication, and good communication and social skills

**Our offer**

- A challenging thesis project to be executed within a successful team with an informal atmosphere and an excellent reputation
- Strong support from enthusiastic members of the CFD team
- Monthly allowance/stipend
- Housing and transportation compensation for the period of stay

**Contact details for more information**

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