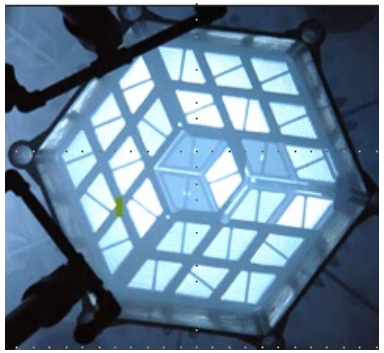
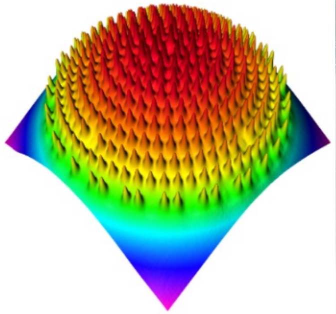
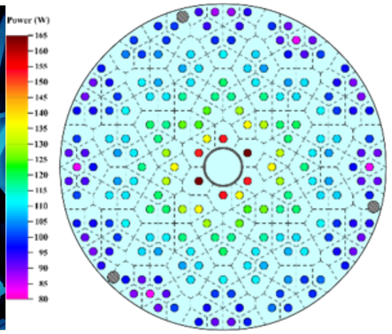
Regression Testing for BR2 RELAP5 Models

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Outline

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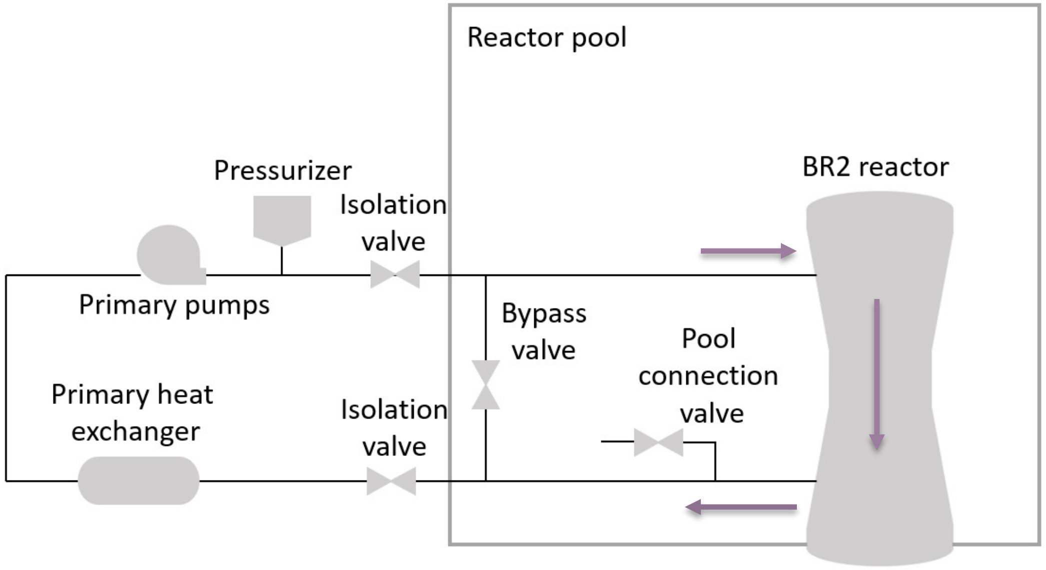
Introduction

- **Belgium Reactor 2 (BR2)** is a research reactor used for materials testing and radioisotopes production.
- A BR2 RELAP5 models have been developed to support reactor conversion.
  - From Highly-enriched uranium (HEU) to low-enriched uranium (LEU) fuel
- The BR2 RELAP5/MOD 3.3 model
  - Validated against historical 1963 transients' experimental data
- The BR2 RELAP5-3D model
  - Developed based on the RELAP5/MOD 3.3 model
  - Includes several model updates
- Regression testing
  - Compares the steady-state and transient results
  - Verifies consistency between current and previous RELAP5 models
  - Investigates any discrepancies in simulation results due to model updates



Schematic of BR2

BR2 RELAP5 Model Updates

- RELAP5 model updates include
  - Converted the input file from RELAP5/MOD 3.3 to RELAP5-3D
  - Updates/improvements to the control logic
  - Increased flexibility in shroud cooling settings to expand sensitivity studies
  - Improved consistency between the different reactor pool models

- Python scripts for regression testing
  - Enhance the efficiency of data processing
  - Python packages of pandas and matplotlib.pyplot

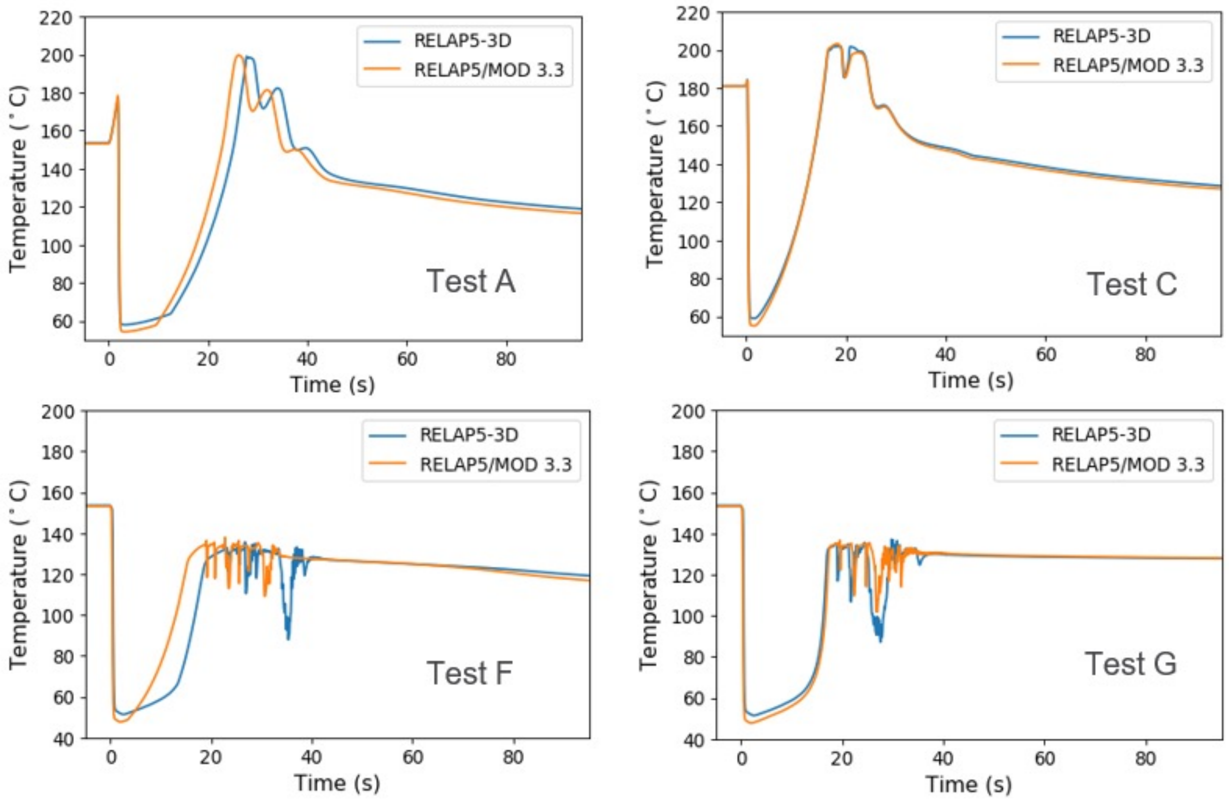
Python scripts for regression testing

- Extract data from raw RELAP5 “strip” files
- Detect targeted data and automatically plot figures
- Generate tables for event timing
- Check reactivation of trips

Regression Testing Results (1) Historical Transients

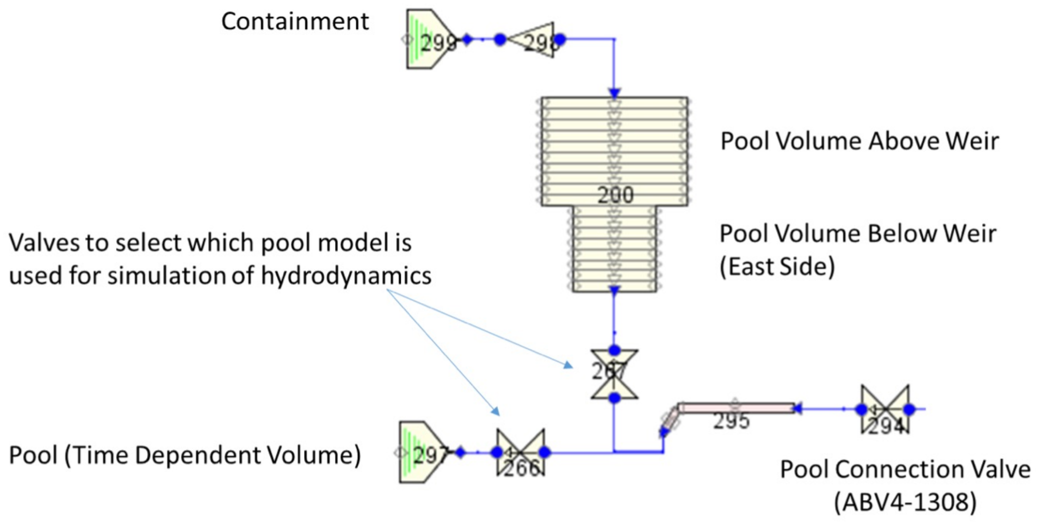
- The test conditions are based on the BR2 experimental tests in 1963.
- Four historical transient tests
  - Test A: Loss of flow at the maximum heat flux q''_{max} of 470 W/cm^2
  - Test C: Untimely opening of bypass valve at the q''_{max} of 600 W/cm^2
  - Test F: Loss of pressure scenarios with bypass valve opening at the q''_{max} of 470 W/cm^2
  - Test G: Loss of pressure scenarios without bypass valve opening at the q''_{max} of 470 W/cm^2
- The discrepancies of peak cladding temperatures of BR2 fuel are as expected and primarily caused by updates to the pump trip logic and related valve opening/closing times.

Peak cladding temperatures



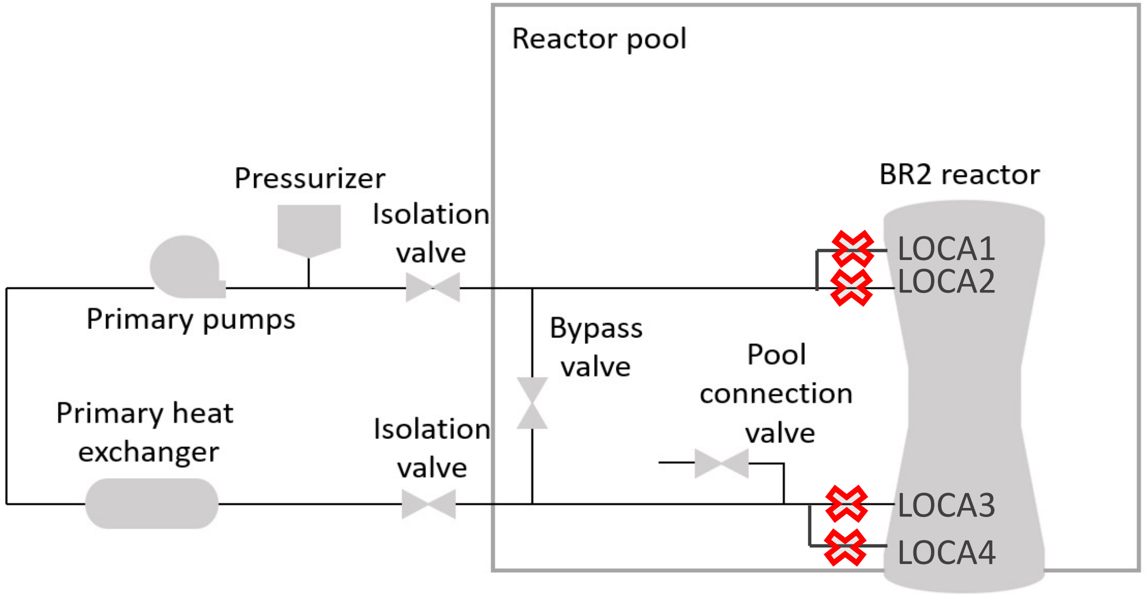
Regression Testing Results (2) In-pool LOCA

- In the BR2 updated RELAP5-3D model, the pool model can be switched to simulate a LOCA within and outside of the reactor pool.
- The pressure boundaries are updated to account for the average temperature and pressure in the reactor pool.



Reactor pool in the BR2 RELAP5-3D model

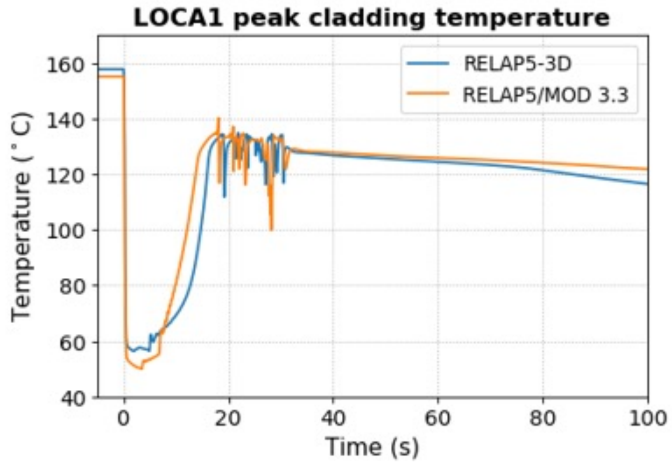
- Regression testing for six LOCA scenarios
- Inlet pipe breaks: LOCA 1, LOCA 2 and LOCA 1+2
- Outlet pipe breaks: LOCA 3, LOCA 4 and LOCA 3+4

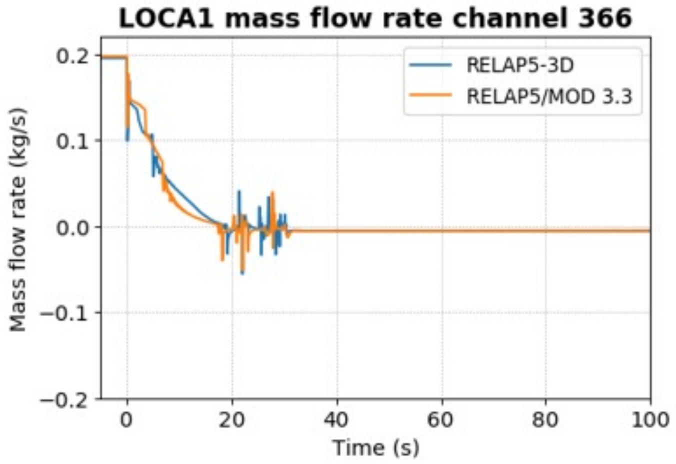


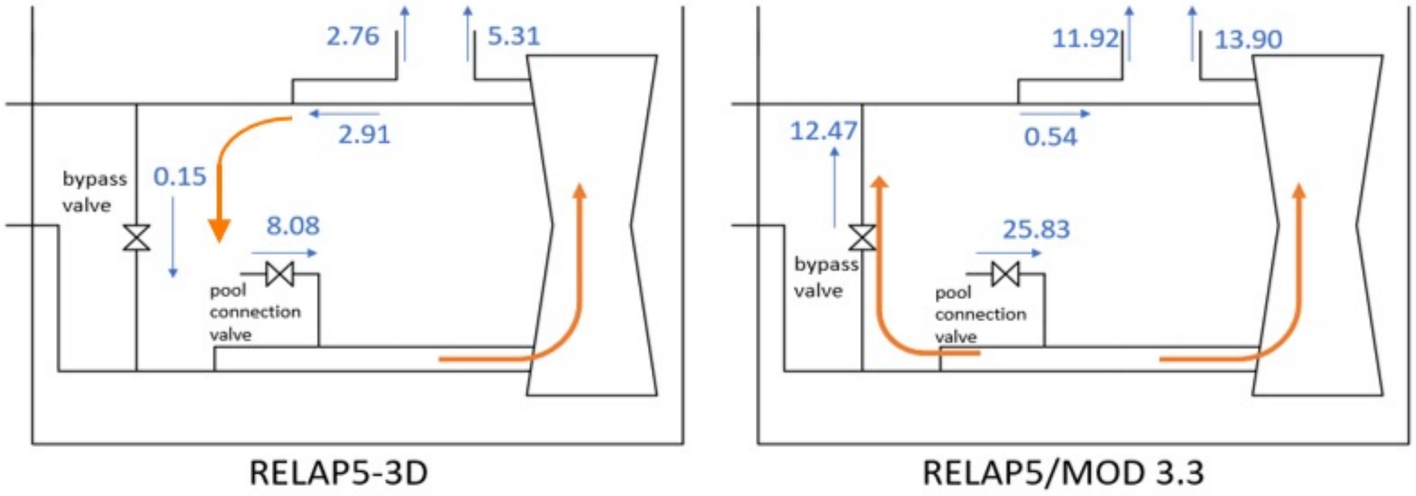
In-pool LOCA locations

Regression Testing Results (2) In-pool LOCA

- Due to trip updates in valves and primary pumps, the differences in peak cladding temperatures and flow rates are as expected.
- Overall, both RELAP5 models demonstrate similar transient results within the first 100 s.
- With pool model updates, the comparison shows that natural circulation flow directions and magnitudes are sensitive to small changes of pressure boundaries.



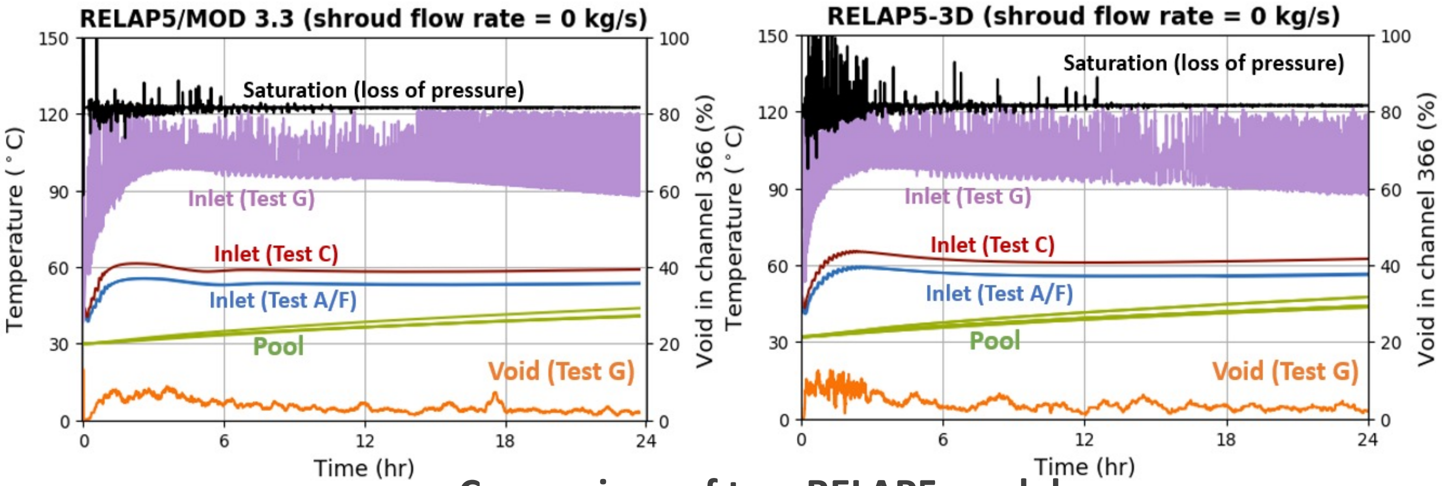




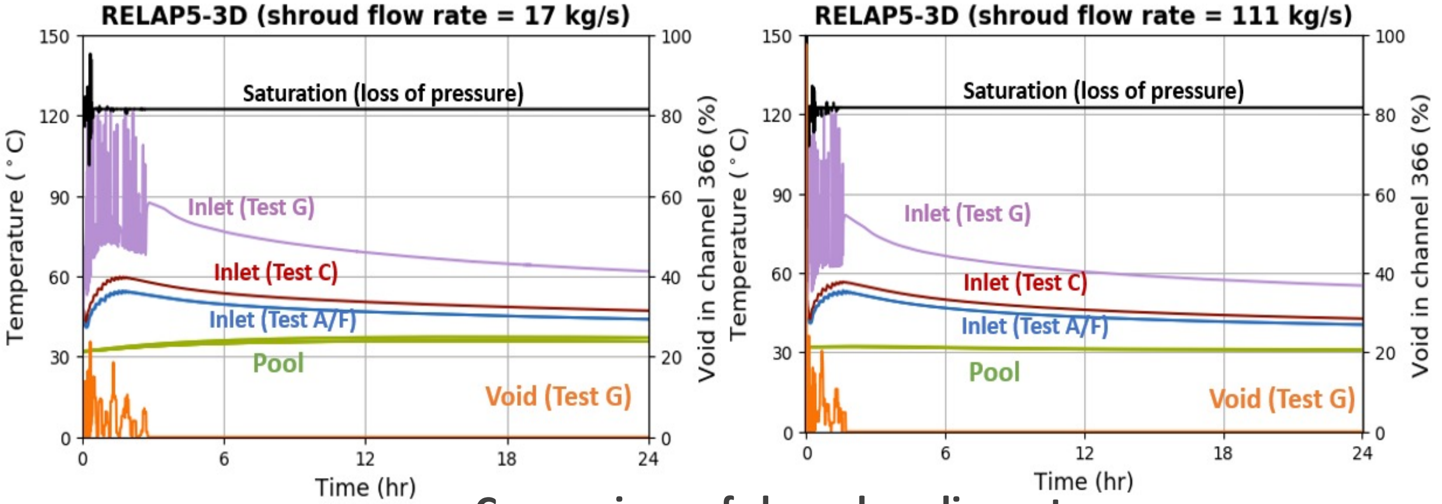
Comparison of natural circulation flow (in kg/s) of LOCA1 at 24 hours

Regression Testing Results (3) - Shroud Cooling for 24-hour Transient

- The shroud cooling is an external cooling system to the reactor vessel wall.
- For long-term transient (24 hours), coolant temperatures and void fractions of two RELAP5 models show very similar trends.
- The presence of at least a minimal shroud cooling rate can significantly reduce the nucleate boiling time in Test G.



Comparison of two RELAP5 models



Comparison of shroud cooling rates

Conclusions and Future Work

- The regression testing compares result differences from model updates and verifies that the current RELAP5-3D model can reproduce important features and show similar results to the previous RELAP5/MOD 3.3 model.
- The python scripts for regression testing improve efficiency in data processing and will be applied to further conversion analyses.
- The current RELAP5-3D model benefits analyses to support BR2 conversion and show capability to adapt to further model updates and additional regulatory requirements.

References

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