# REGRESSION TESTING FOR BR2 RELAP5 MODELS

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## ABSTRACT

A RELAP5-3D model has been developed and updated for Belgium Reactor 2 (BR2) to support reactor conversion. The current model is based on the previous BR2 RELAP5/MOD 3.3 model [1,2,3]. Regression testing is applied to ensure consistency and to investigate differences in previous RELAP5 model versions. Python scripts are developed for the study and significantly increase the data processing efficiency.

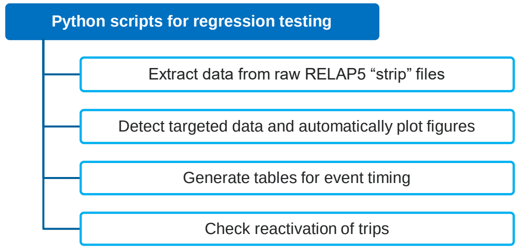
- Steady-state of BR2 with a representative core, historical transient tests, and in-pool LOCA scenarios are performed for regression testing.
- The results show that the updated RELAP5-3D model can capture the significant features of peak temperatures and flow rates and show similar trends to the previous RELAP5 models.
- The updated RELAP5-3D model and the newly developed regression testing capability completes the related BR2 2016 decennial review work and sets the stage to support further model development for reactor conversion.

## MOTIVATION

- The RELAP5/MOD 3.3 model was validated against historical 1963 transients' experimental data [1].
- Many updates to the BR2 model have been implemented into the RELAP5-3D model to accommodate the various accident scenarios.
- Two main objectives in the regression testing:
  - Verify consistency between current and previous RELAP5 models, and
  - investigate any discrepancies in simulation results due to model updates.

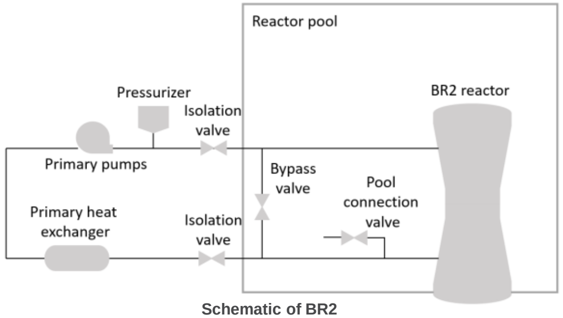
## METHODS

- Regression testing is performed through comparing the results of the current RELAP5-3D model with previous RELAP5 models.
- Python scripts are developed to enhance the efficiency of data processing.
- Python packages of pandas and matplotlib.pyplot are used.




## BR2 RELAP5 MODEL UPDATES

- 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



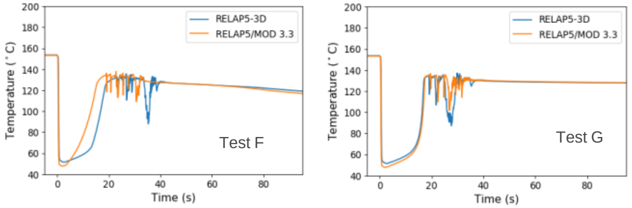

Schematic of BR2

## REGRESSION TESTING RESULTS (1) – HISTORICAL TRANSIENTS

- The regression testing is performed with a representative core in both current and previous RELAP5 models. The test conditions are based on the experimental tests in 1963 [4].
- Test A: Loss of flow at the maximum heat flux of 470 W/cm$^2$
- Test C: Untimely opening of bypass valve at the temporary heat flux limit of 600 W/cm$^2$
- Test F / G: Loss of pressure scenarios with / without bypass valve opening at the maximum heat flux of 470 W/cm$^2$
- For transients within 100 s, 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.

Test A

Test C




## REGRESSION TESTING RESULTS (2) – IN-POOL LOCA

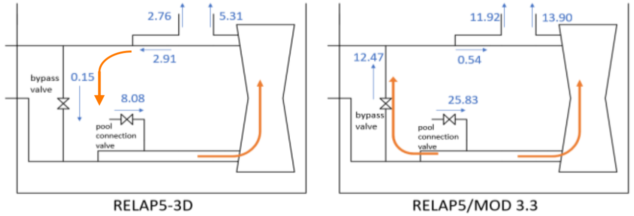
- In the BR2 updated RELAP5-3D model, the pool model can be switched to simulate a LOCA within and outside of the reactor pool [2].
- The pressure boundaries are updated to account for the average temperature and pressure in the reactor pool.

Reactor pool in the BR2 RELAP5-3D model

### Inlet and Outlet Pipe Breaks (In-pool LOCAs)

- Regression testing for six LOCA scenarios is performed with different pipe break locations within the reactor pool.
- 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 (listed in kg/s) are sensitive to small changes of pressure boundaries.

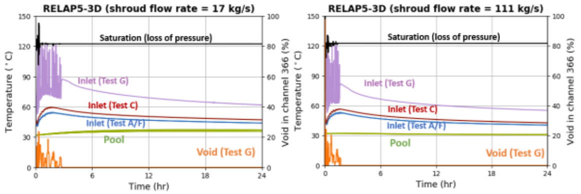



## REGRESSION TESTING RESULTS (3) – SHROUD COOLING FOR 24-HOUR TRANSIENT

- The historical test scenarios are simulated long term (24 hours) with both current and previous RELAP5 models with different shroud cooling flow rates.
- Coolant temperatures and void fractions of two RELAP5 models show very similar trends.

Comparison of two RELAP5 models

- The presence of at least a minimal shroud cooling rate can significantly reduce the nucleate boiling time in test G.




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 implementation of regression testing completes work related to the 2016 decennial review.
- 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

[1] J. Licht et al., RELAP5 Model Description and Validation for the BR2 Loss-of-Flow Experiments, ANL/GTRI/TM-14/10, Argonne National Laboratory, July 2015

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[3] J. Licht et al., Supplemental Thermal-Hydraulic Transient Analyses of BR2 in Support of Conversion to LEU Fuel, ANL-RTR-TM-16/3, Argonne National Laboratory, September 2016

[4] G. Stiennon et al., Experimental Study of Flow Inversion in the Belgium Reaction BR2, Proc. Third Int. Conf. Peaceful Use of Atomic Energy, Geneva, Switzerland, 1964