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Measurement and Simulation of Decay Heat in the ISIS TS1 Target

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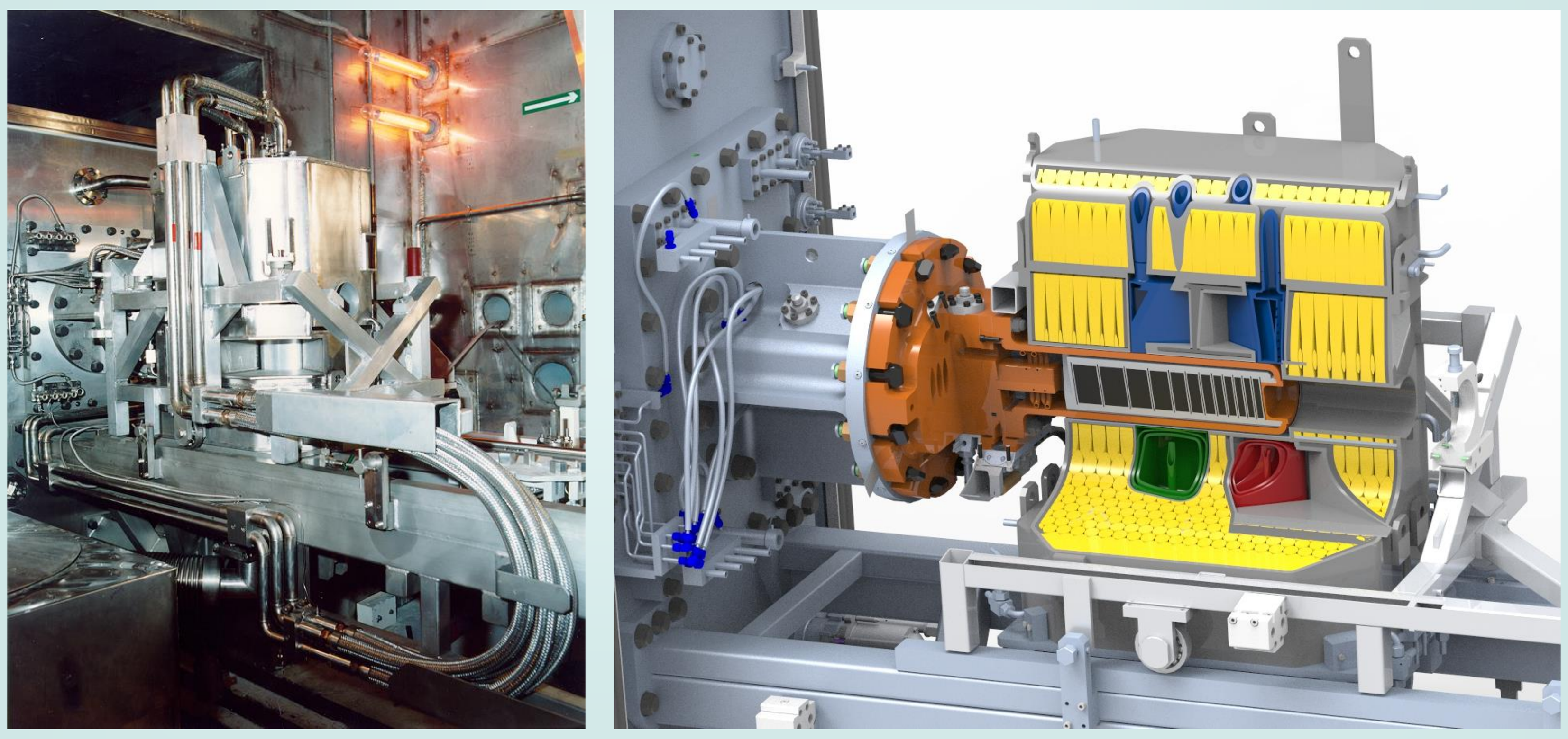
1. Background

Managing decay heat is an important safety concern for spallation facilities, but calculating the magnitude of decay heat relies on complex computer simulations which are difficult to validate. Of particular concern is the temperature rise due to decay heat in a loss-of-coolant accident (LOCA) scenario. Presented here is a method for simulating decay heat induced temperature rises which was compared with measurements made on an ISIS TS1 target. The results were conservative but reasonably accurate, and suggest that MCNPX/CINDER90 may be over-estimating decay heat in the ISIS target.

2. Measurements

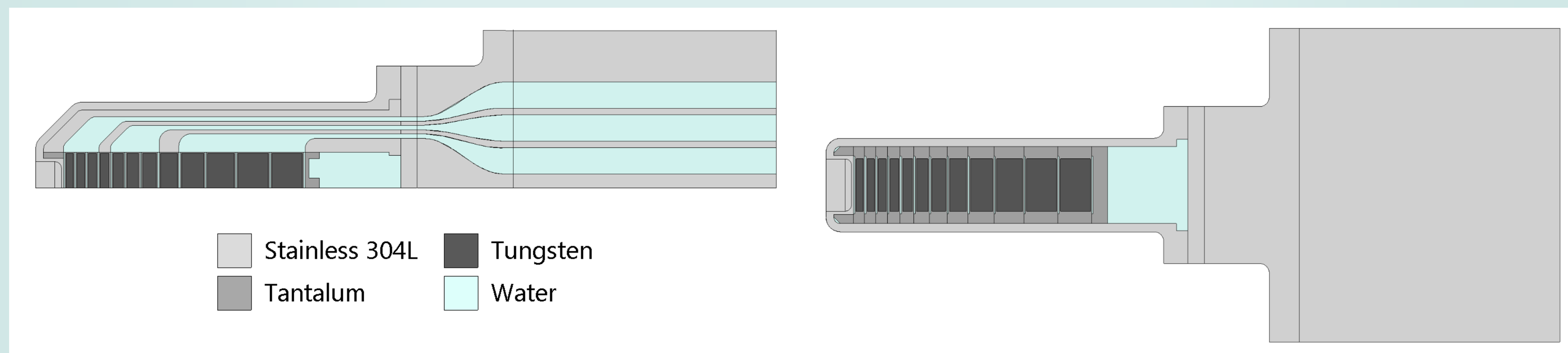
- Turn off proton beam and pumps, then measure the temperature rise in all twelve target plates as functions of time
- Essentially reproduces the first half hour of a cooling failure in a controlled way
- Repeated at cooling times 1 minute, 1 hour, 3 hours, 1 day, 3 days, 7 days and 14 days
- Results recently published in two papers by D. Findlay et al. [1] [2]



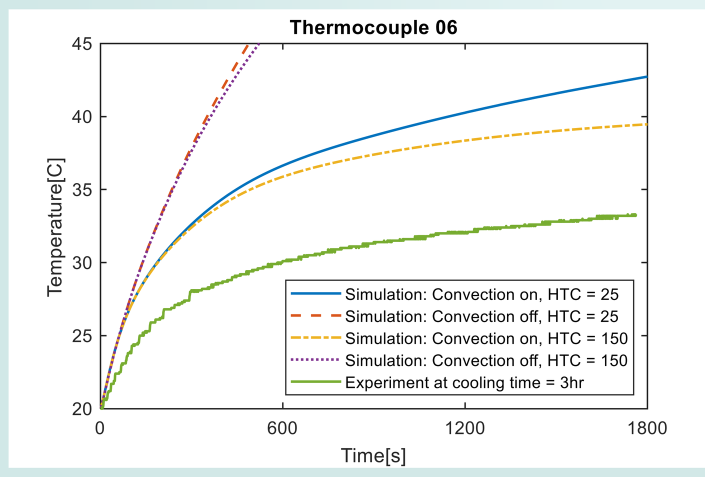
Current TS1 Target, Reflector and Moderator (TRAM) assembly. Left: Photograph of TRAM in the remote handling cell (although measurements were made with the TRAM in the void vessel). Right: CAD section through TRAM, courtesy of Dan Coates.

3. Simulations

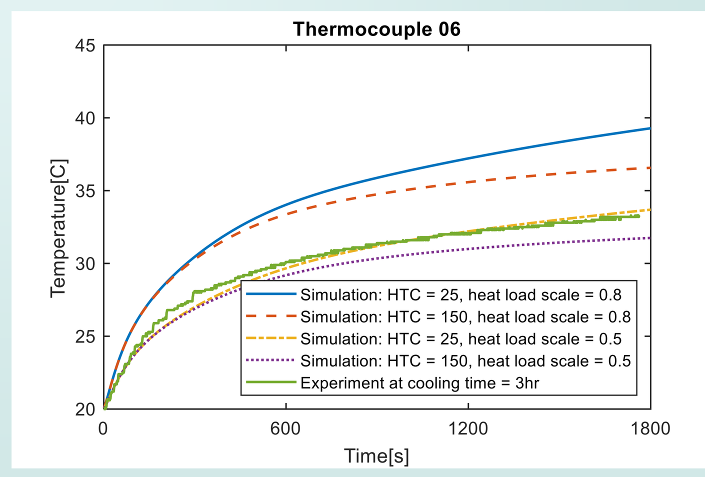
- Thermal-fluid model in ANSYS CFX, decay heat values from MCNPX/CINDER90.
- Free convection in cooling water must be included to match measured data
- Heat transfer to surroundings simplified to a constant heat transfer coefficient (HTC)
- Heat load assumed uniform over each plate and each material



Sections through the simulation geometry, viewed from top down with half symmetry (left) and side on (right).



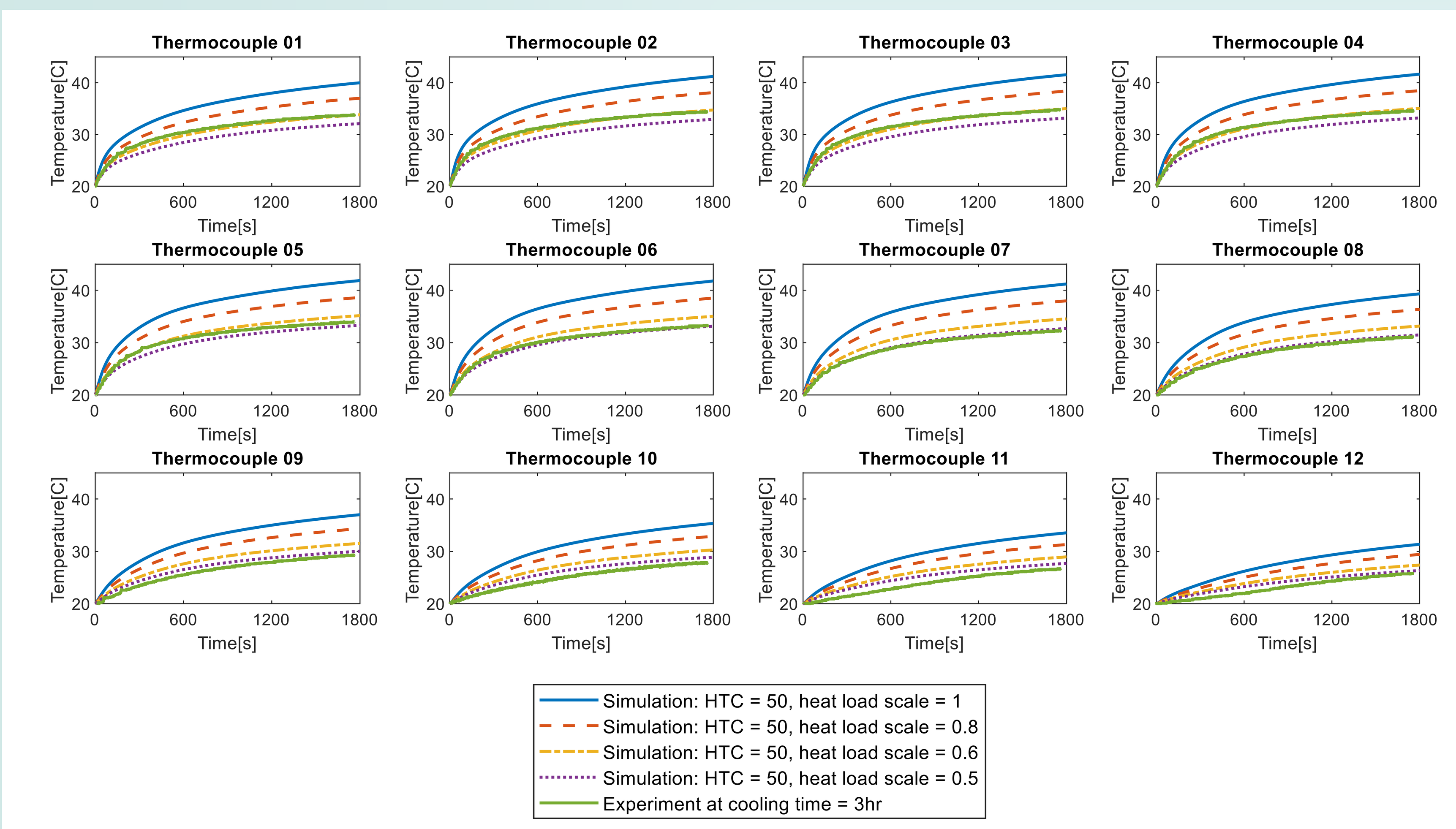
Simulations with and without convection at the minimum and maximum estimated heat transfer coefficient.



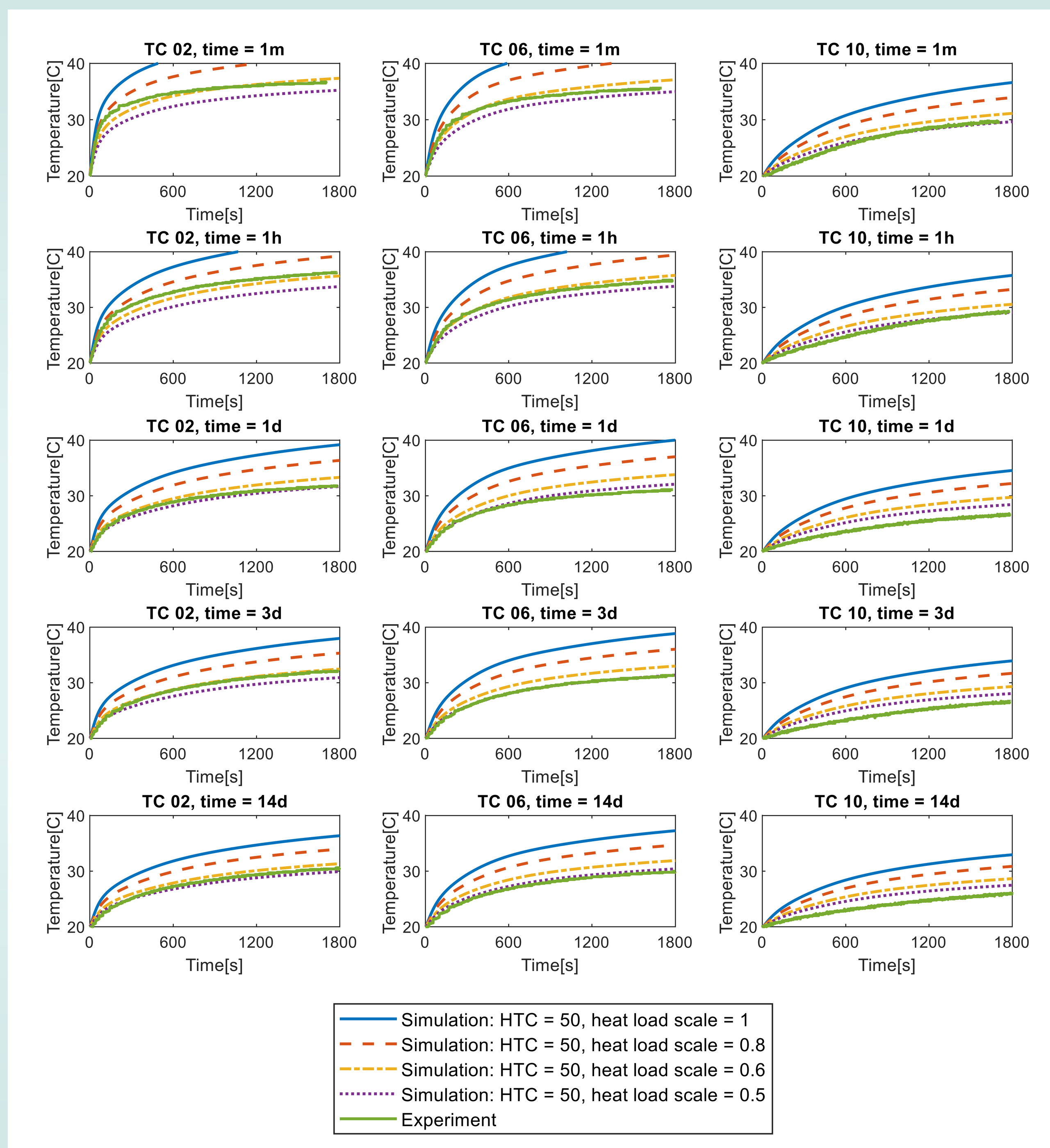
Simulations with varying HTC values and heat load scale factors. Convection is on in all cases.

4. Results

- Convection effects become apparent after about 100s, and HTC effects become increasingly significant after about 300s.
- Scaling down the heat load produces a much better fit to data. Required scale factor is around 0.7 for upstream plates and 0.4 for downstream plates
- A heat transfer coefficient of 50W/(m^2.K) gives reasonably good results for all plates and cooling times. Equivalent to conduction through ≈3mm of static helium.



Comparison of simulated and measured temperature rise in all plates at cooling time = 3 hours.



Results for plates 2, 6 and 10 at cooling times between 1 minute and 14 days.

5. Conclusions

The measured temperature rises were compared to simulations using a conjugate thermal-fluid model of the target in ANSYS CFX and decay heat values from the Monte Carlo code MCNPX. Simulations using this model produced a conservative but reasonably accurate estimate of temperature rise due to decay heat, as compared with the measured data. This is an important first step in establishing a reliable, experimentally validated approach for simulating temperatures in loss-of-coolant accident scenarios on this and other current and proposed spallation targets.

References

[1] D.J.S. Findlay et al., “Measurement and calculation of decay heat in ISIS spallation neutron target,” Nucl. Instr. Meth. A, vol. 908, pp. 91-96, 2018.

[2] G.M. Allen et al., “Decay heat in ISIS spallation neutron target as function of cooling time,” Nucl. Instr. Meth. A, vol. 933, pp. 8-11, 2019.

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