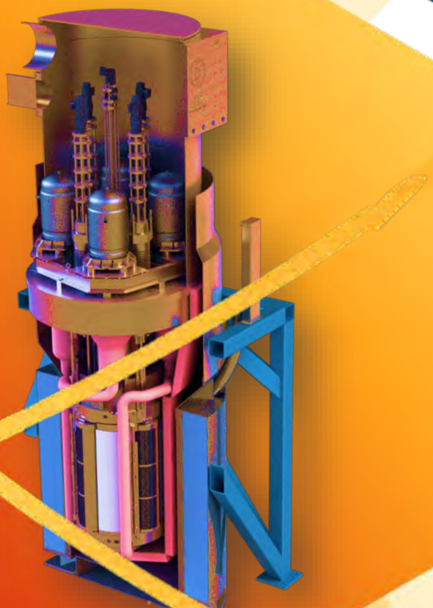
(Microreactor Applications Research, Validation & EvaLuation),



RELAP5-3D Modeling of MARVEL Dry Criticality Accident

May 18-20, 2026

Brandon Cox

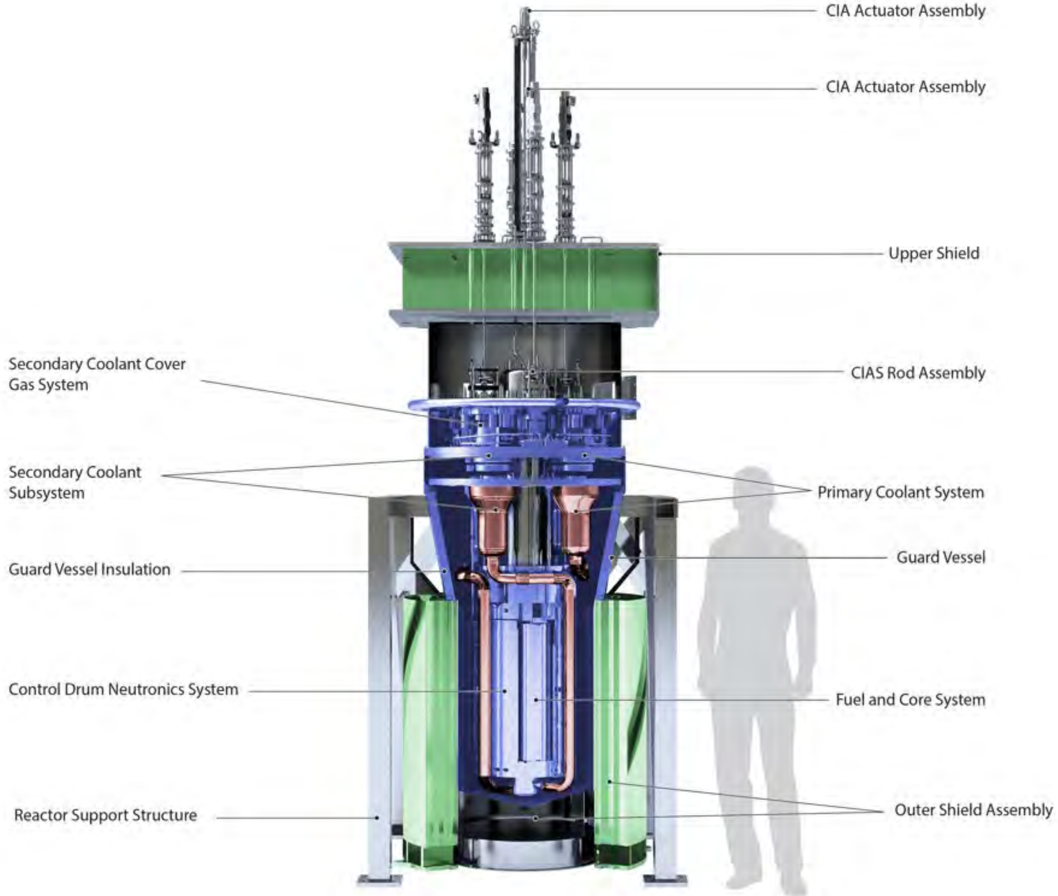
RELAP5-3D Developer and Analyst

Nuclear Reactor Technology Division, Idaho National Laboratory

INL/CON-26-92293

Marvel Dry Criticality

- Achieve criticality and operate reactor with air as coolant
  - No shielding
  - No guard vessel
  - Reactor accessible (not in pit)
- Ability to make repairs and adjustments if necessary
  - Extremely difficult to do so after NaK is installed and guard vessel is welded
- Validate the neutronics sooner



MRP Microreactor Program

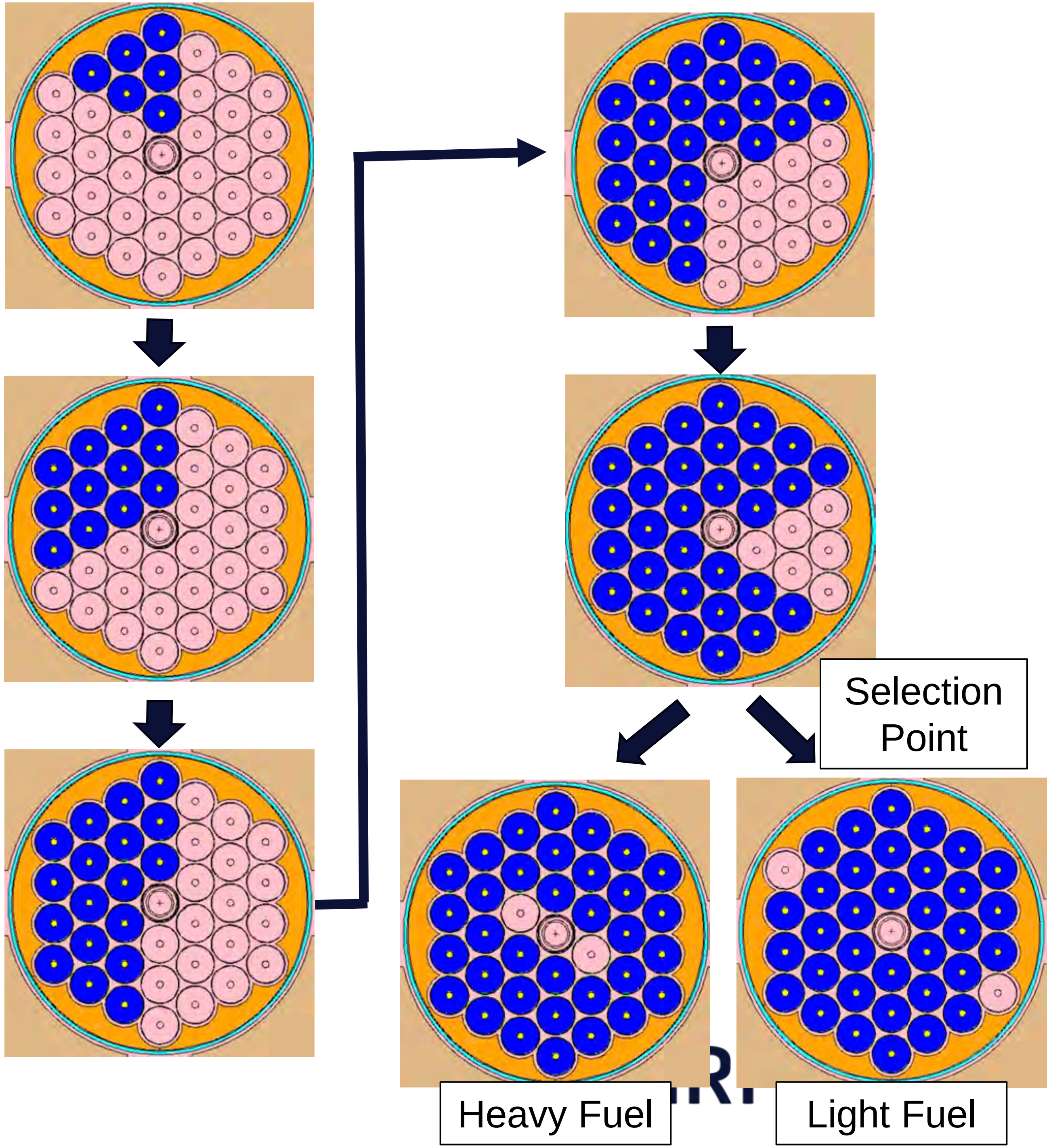
Low Power Physics Testing

- Provide de-risking of key characteristics of MARVEL design
  - Testing and validation of instruments and measuring devices
- Validation of reactor physics models for excess reactivity and shutdown margin
  - Confirm approach to criticality performance
    - 1/m measurements at various fuel loadings
  - Neutron source
  - Control drum worth
- Create a neutronic benchmark for industry, researchers, academia

MRP Microreactor Program

Fuel Loading

- Marvel reactor fully loaded – 36 fuel rods
  - 6 fuel assemblies with 6 rods
- Initial criticality will occur with 5 fuel assemblies (Pac-man core)
- Core configuration with fully loaded (34 rods) will depend on as built fuel
  - Heavy vs light
- Run the reactor at 100 W for one shift
- RELAP5-3D modeled accident scenarios with 5 and 6 fuel assemblies

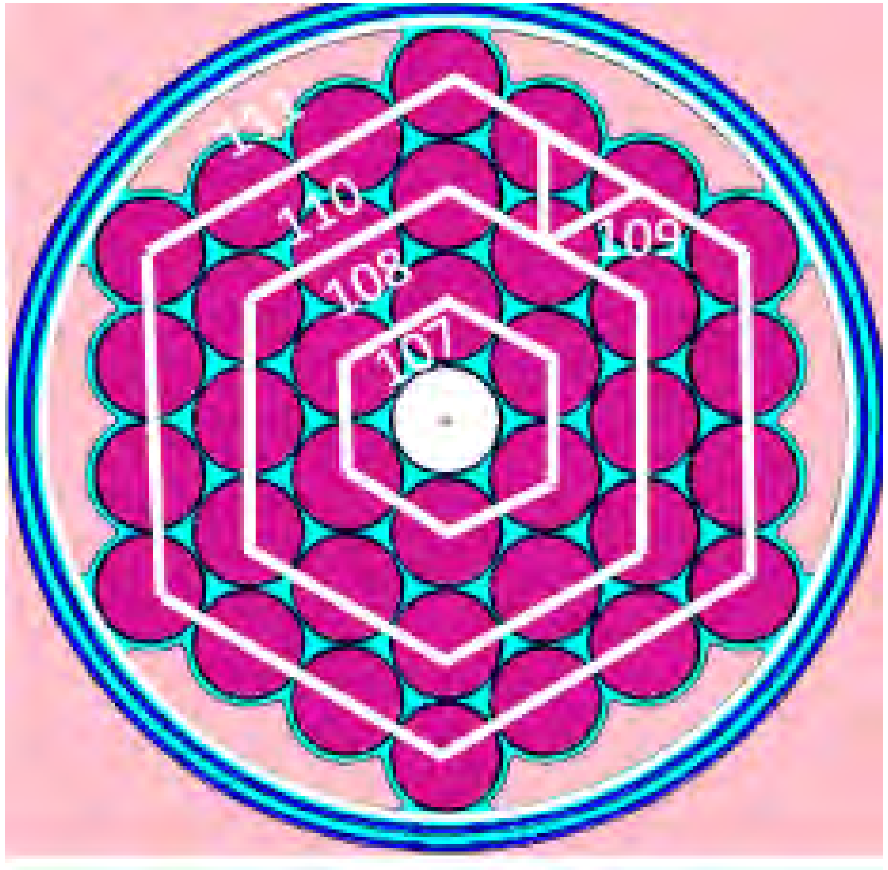


Unprotected Transient Over Power (UTOP)

- Reactivity insertion of $1.33
  - Reactivity worth of full rotation of 1 control drum
  - More reactivity than excess reactivity with 5 fuel assemblies
  - Nearly instantaneous
- Initial conditions at 20 ºC
- Natural circulation of air
- No secondary cooling
- Imposed Safety Limits:
  - Peak fuel temperature: 900ºC
    - Ensures structural integrity of U-ZrH
  - Peak clad temperature: 764ºC
    - Set to prevent boiling of NaK

Bounding Peaking Power Scenarios

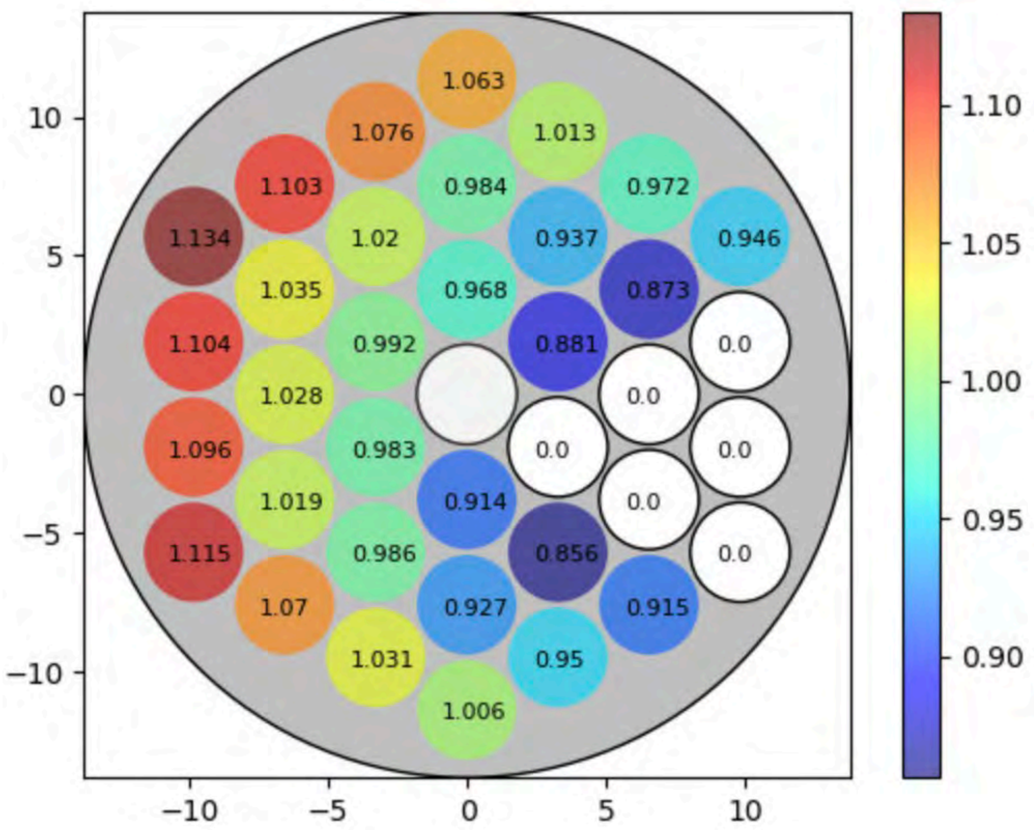
- Core split into 5 channels (see image)
  - 4 radial channels plus hot channel
- Hot channel contains max channel power factor (CPF)
  - Channel power factor = weighted sum of radial peaking factors of fuel in contact with channel
    - E.g., $\frac{1}{6}\sum peaking\ factors$
- Using MCNP, sweep of control drums position to determine max CPF (not max peaking factor) for each core configuration
- Due to asymmetry, 5 assembly core contains bounding CPF of all configuration.



MRP Microreactor Program

Initial Criticality (5 assemblies) Configuration

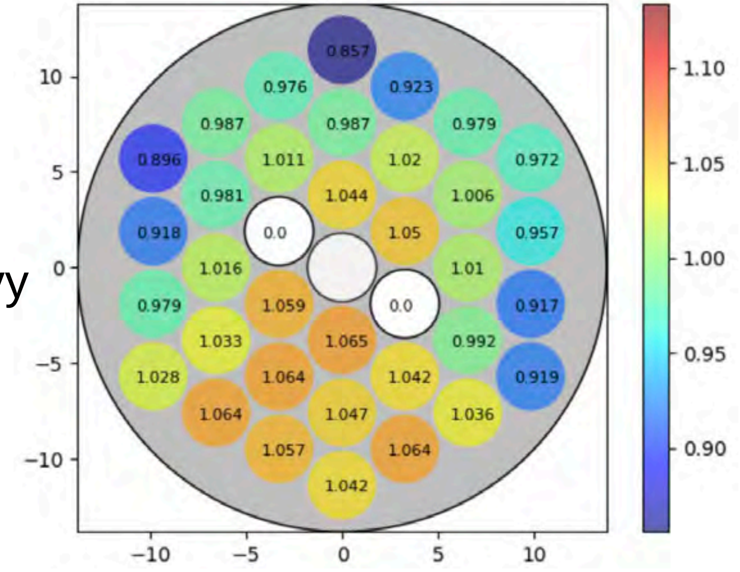
- Hot channel max CPF = 0.546
- Asymmetry leads to highest local peaking factors
- Flow area of 6th fuel assembly excluded from model for conservatism
  - Will be used for testing sensors



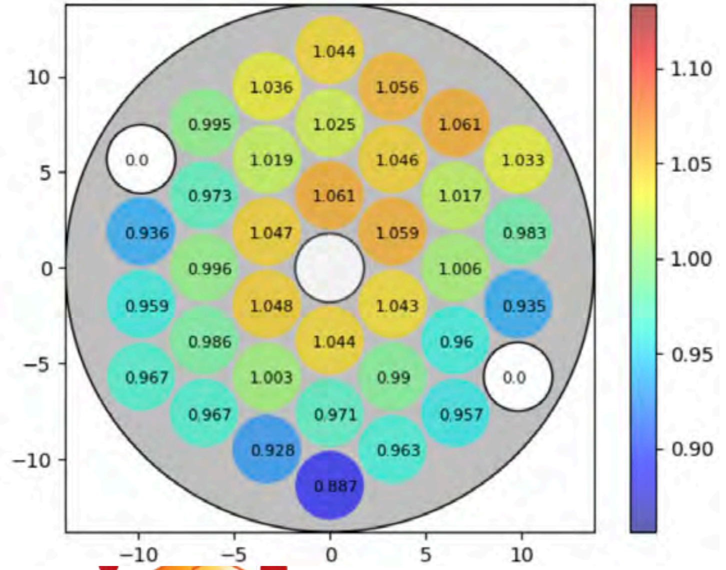
Full Loading Options

- Heavy fuel configuration removes inner rods with more reactivity
- Light fuel configuration removed outer rods with less reactivity
- Max CPFs:
  - Heavy – 0.531
  - Light - 0.528

Heavy



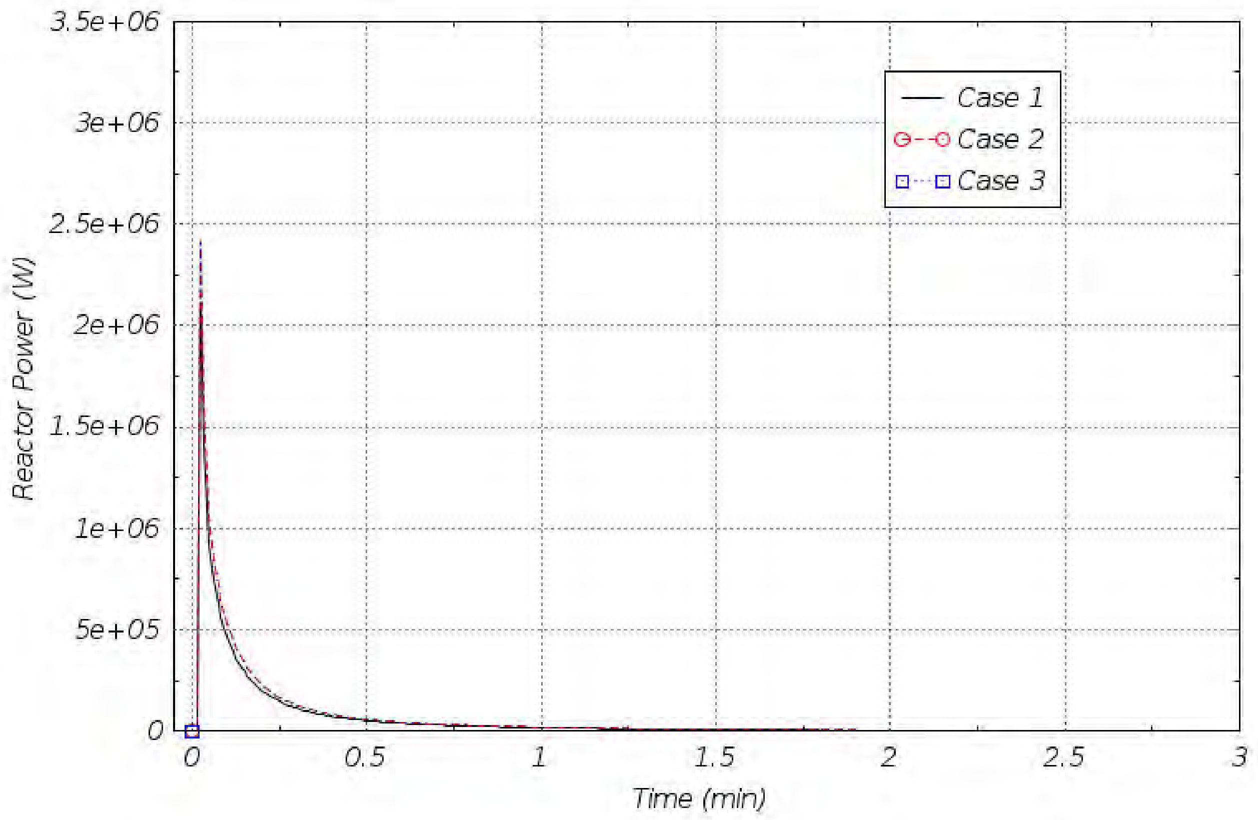
Light



Results – Peak Power

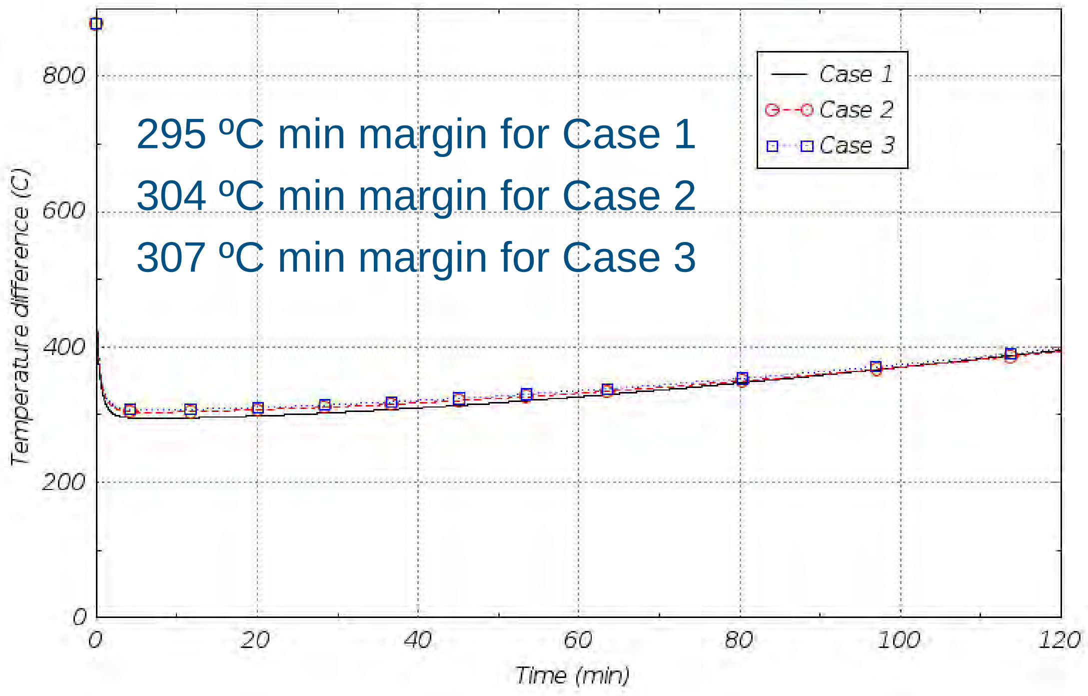
- Case 1 – 5 fuel assembly configuration
- Case 2 – Heavy fuel Configuration
- Case 3 – Light fuel configuration

- Transient peak power maximums:
  - 2.12 MW for Case 1
  - 2.42 MW for Case 2 and 3

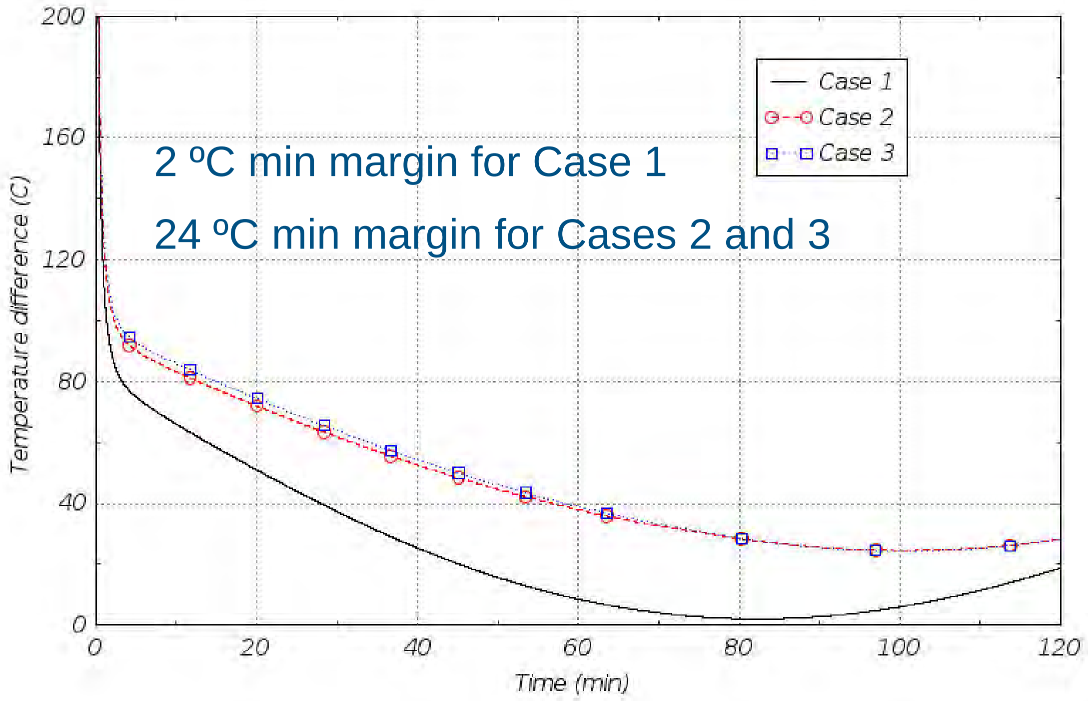


Results – Peak Temperature Margins

Fuel Temperature Margin



Clad Temperature Margin



- Limits are respected
- Lots of conservatism built in

MRP Microreactor Program

Conclusions

- The UTOP at CZP-DRY transient evolution shows that all the acceptance criteria are respected in all three scenarios
- The initial criticality configuration with 5 fuel assemblies has a maximum channel power factor of 0.546 and is the bounding case

- Questions?

MRP Microreactor Program