Reactor Power Detector Shadowing Effects and the Possibility of Violating Licensed Reactor Power Limits

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Previous Work

- Previous work at Oregon State [1] sought to determine cause of disagreement between measured and calculated reactivity worth of control rods at BOL in 2008.
- OSTR MCNP® model had low reactivity bias of \$0.07±0.04 at beginning of core life. However, measurements and calculations of some rods disagreed.
- Believed that neutronic shadowing effects were influencing the response of the fission chamber power detector by causing an under response in certain situations.

Previous Work

- Calculations are purely k_{eff} of system. Measurements are time of power rise at low powers using the fission chamber power detector.
- Found that neutronic shadowing of the fission chamber is negligible compared to actual control rod shadowing effects where rod worths are a function of the position of the others.
- Also found that flux tilts in skewed control rod configurations or heights can be a significant departure from normal flux distributions.

Thermal Flux Maps

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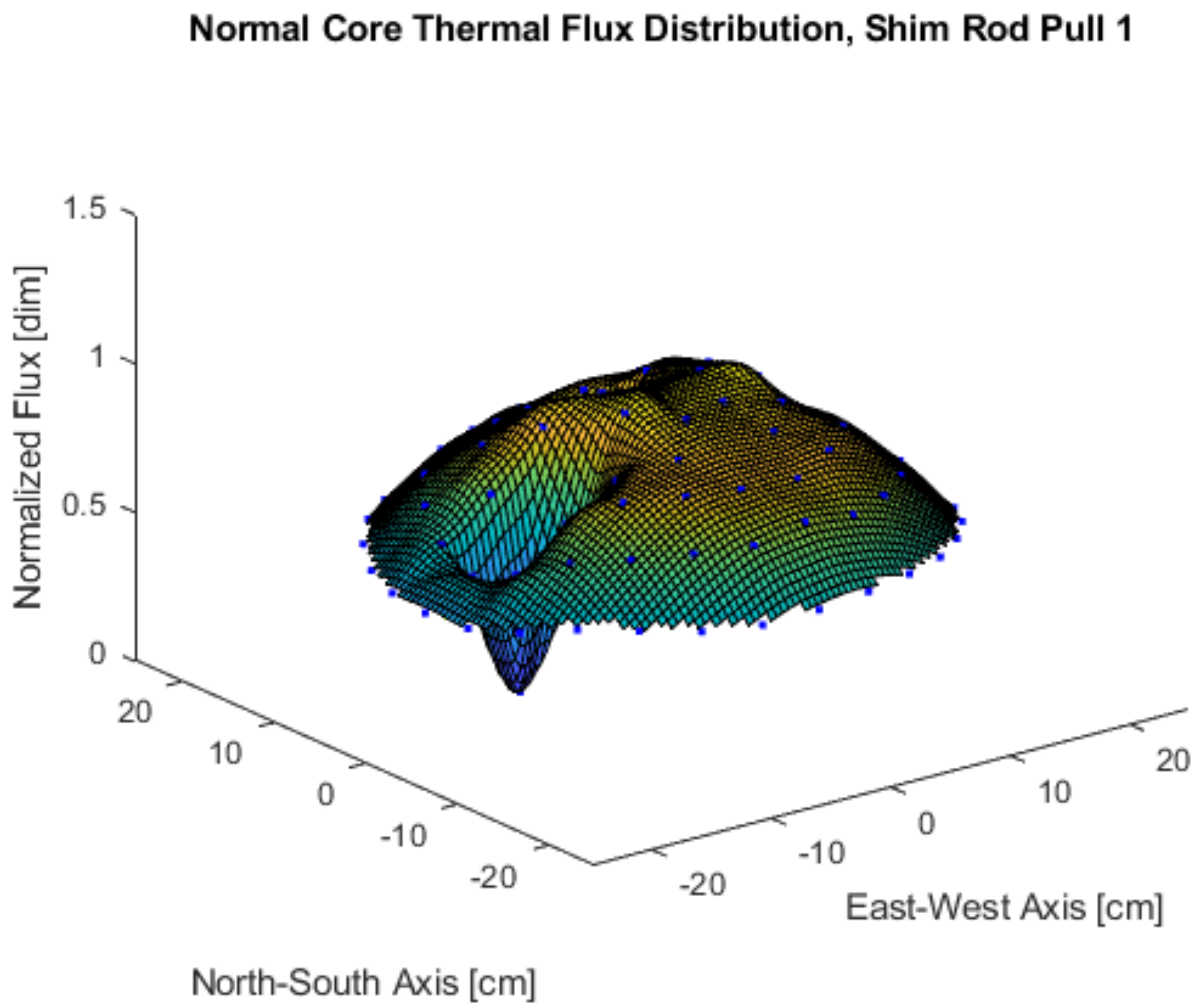

What if...

- Results raised the question: Can the OSTR be operated such that total core power exceeds the licensed steady-state power limit of 1.1 MW_{th}, despite the reactor power measuring channels reading 1.0 MW_{th}?

- Could be possible due to localized power peaking in regions furthest from the detectors.

Power Detector Placement

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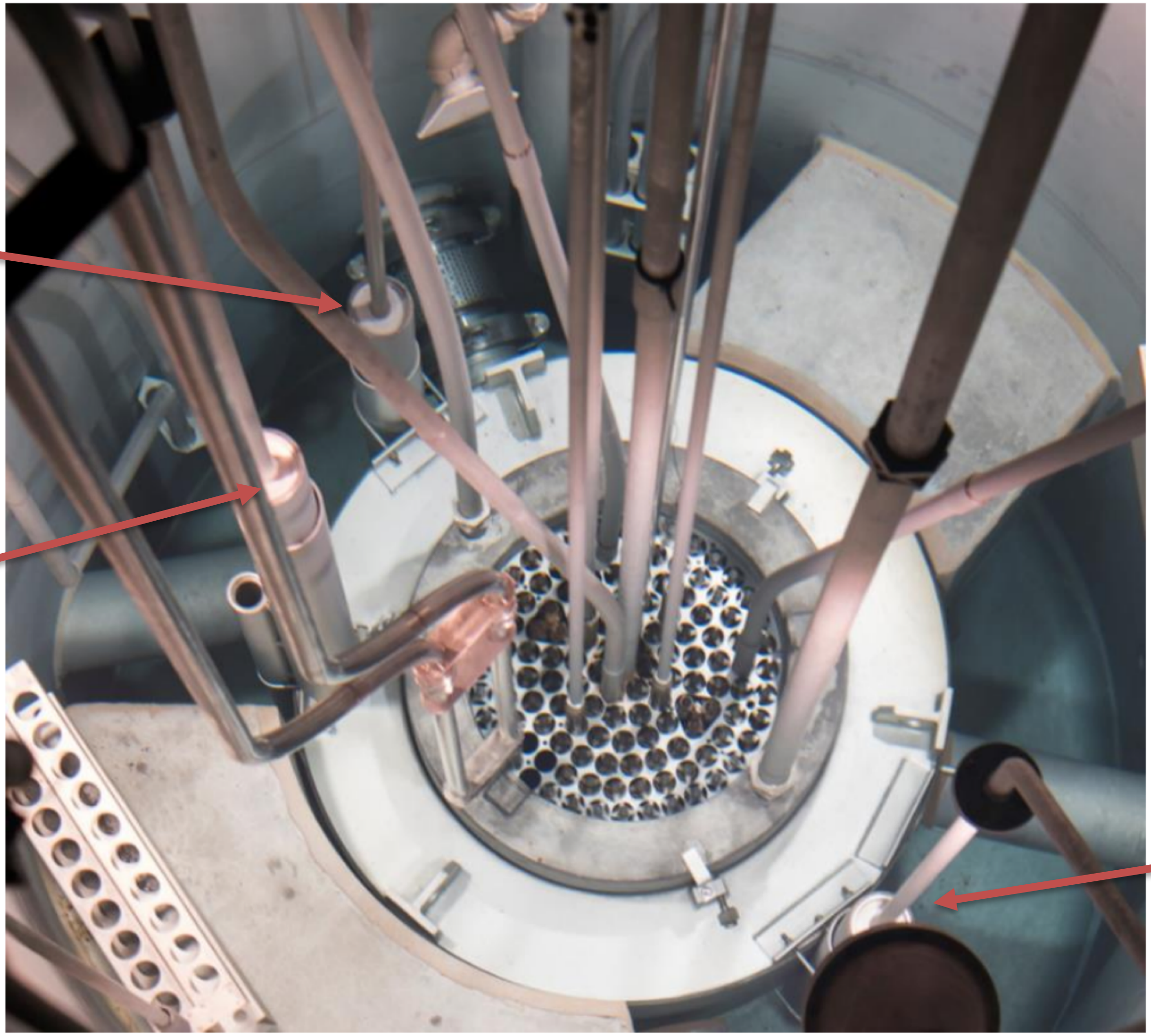
Safety Power (UIC)

Percent Power (UIC)



Fission Chamber

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OSTR Power Detectors

- Calibrated using a calorimetric method at 1.0 MW_{th} with rods banked at ~69% withdrawn.

- The detectors are physically moved until response on measuring channel instruments matches calorimetric calculation.

- Detectors are calibrated to a flux distribution that exists at banked control rod heights at 1.0 MW_{th}.

Flux Distribution

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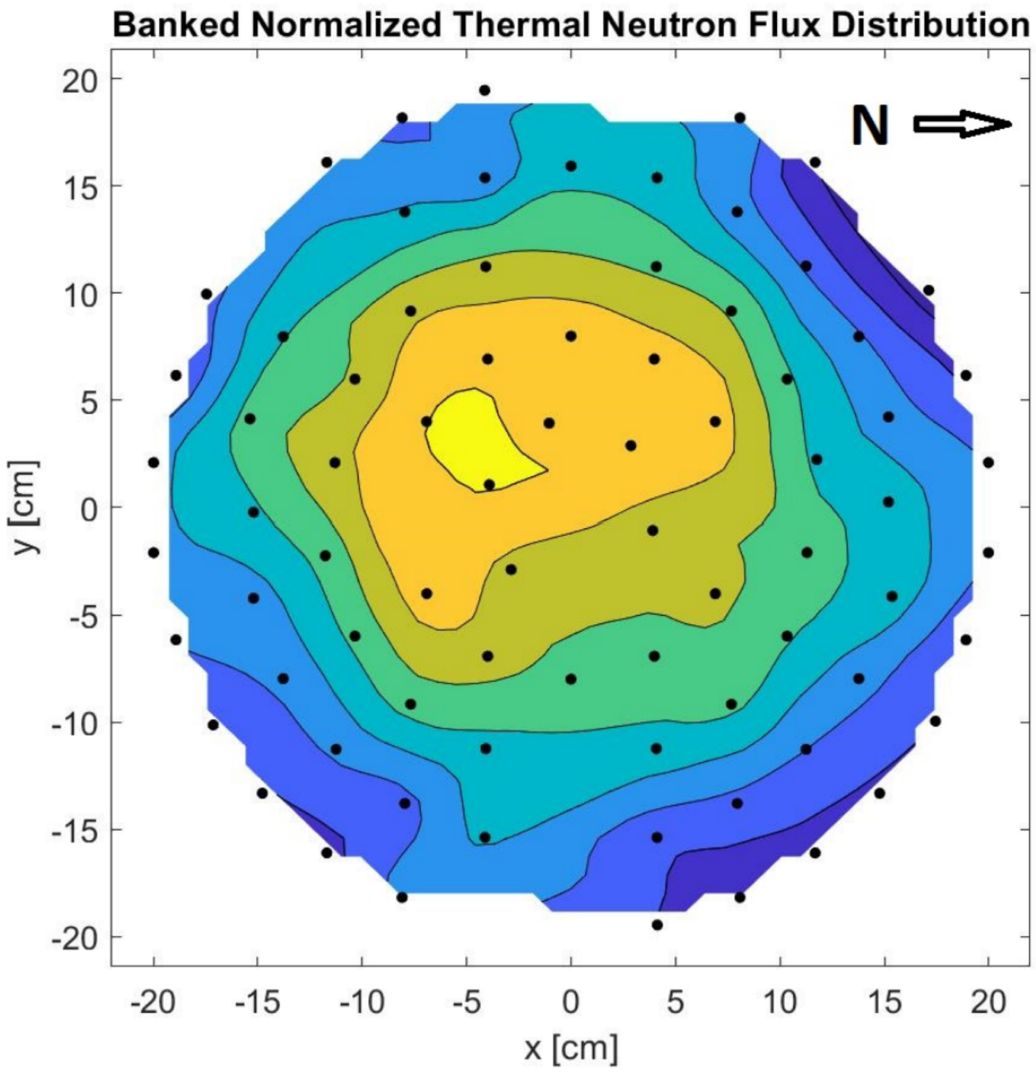

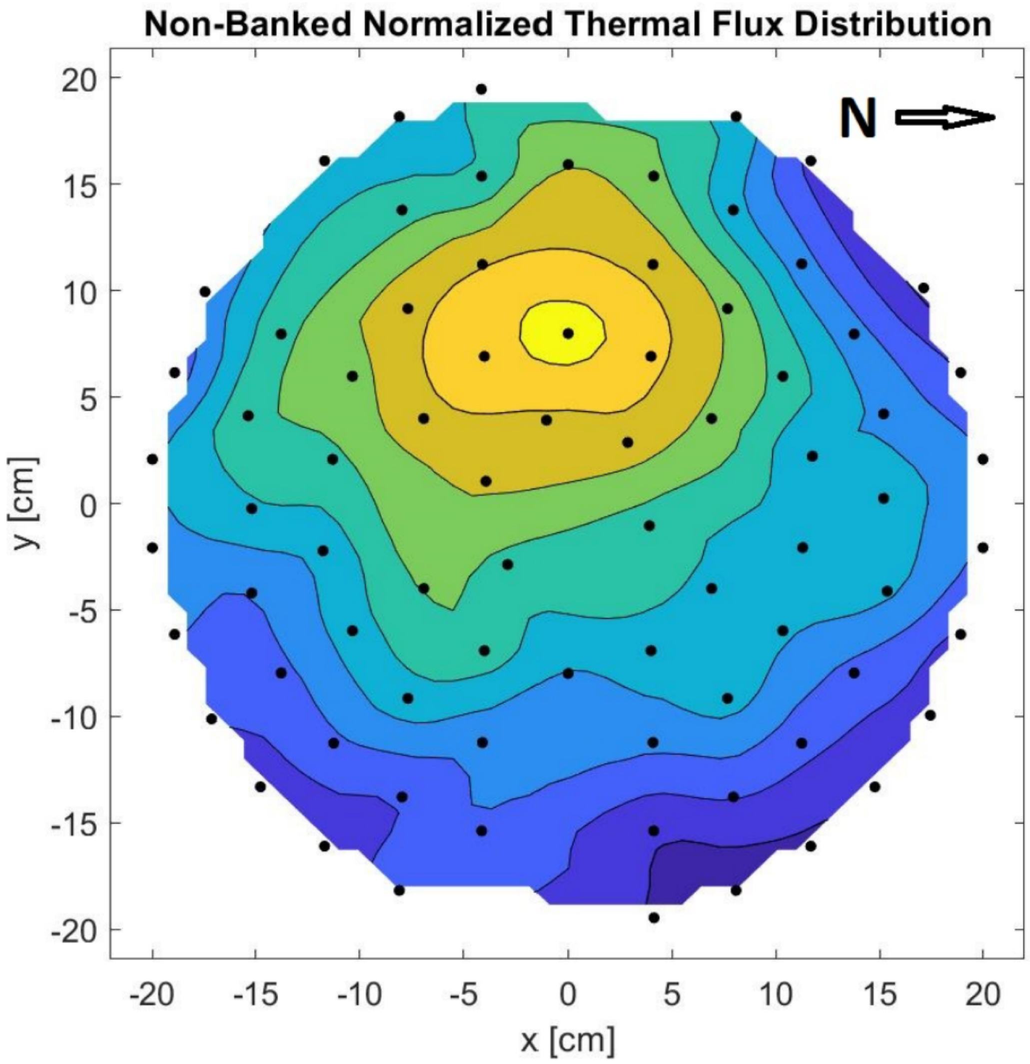

CLICIT Core Configuration

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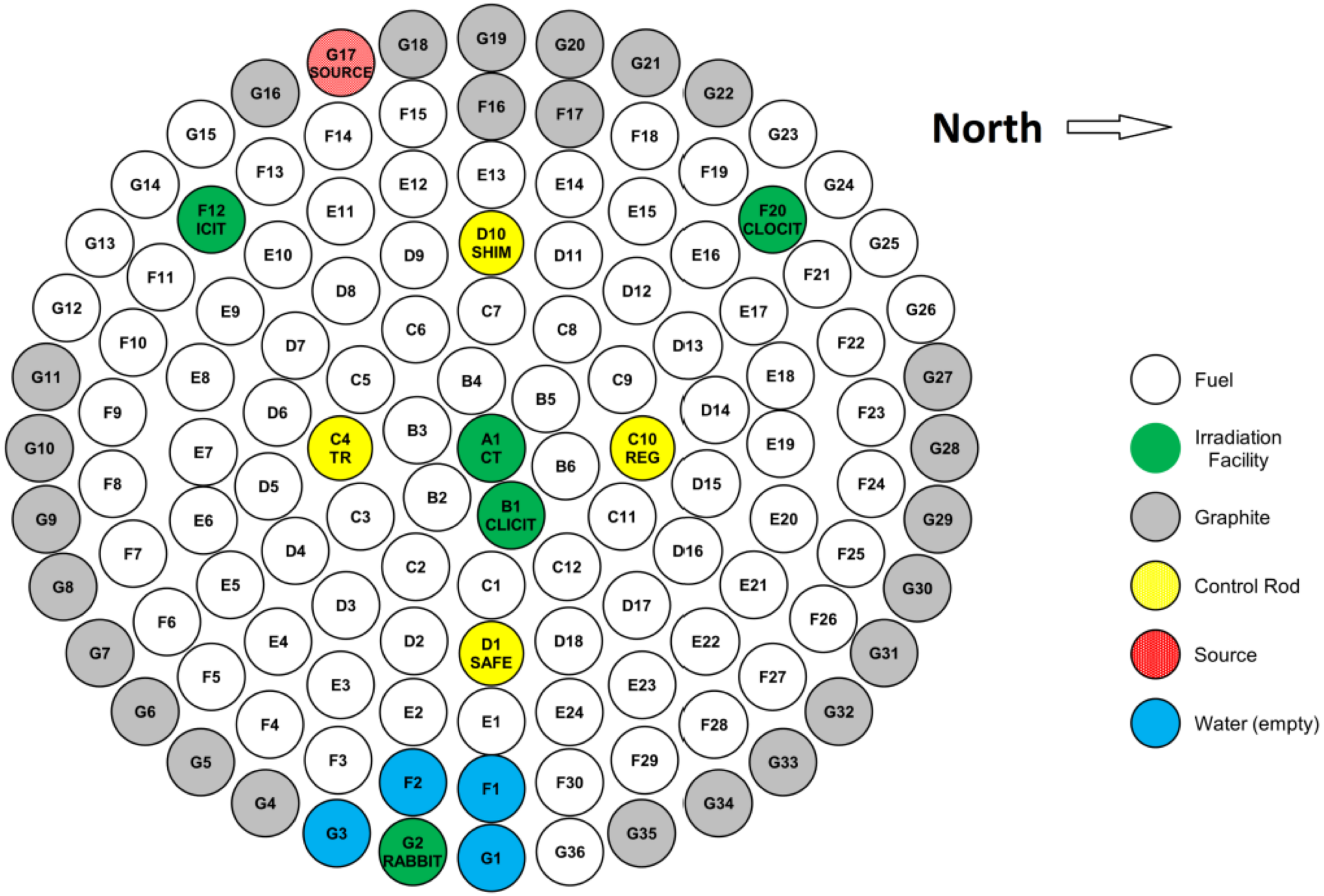
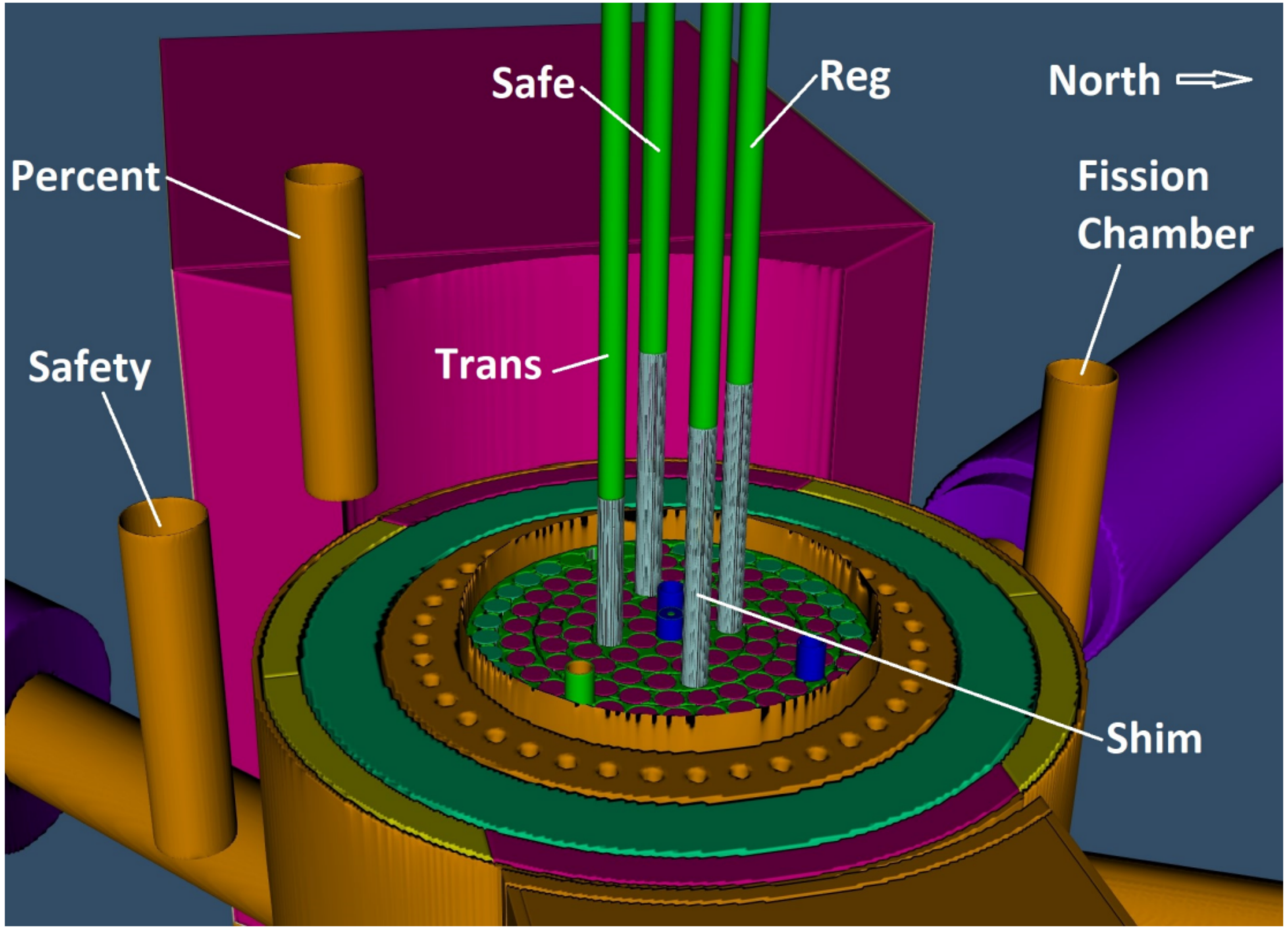


Methods

- Use OSTR MCNP Model to compare detector “response” in the banked 1.0 MWth and skewed 1.06 MW_{th} configurations with different multiplier cards.
- Thermal flux tally on detector can volume. Thermal flux proportional to detector response.
- If detector tally is similar (within either’s relative error) in both situations it would suggest it is possible the detector cannot distinguish between a total core power of 1.0 MW_{th} and 1.06 MW_{th} for the different core flux distributions.

OSTR Model



Methods

- For banked configuration, all rods withdrawn to ~69%, 1.0 MWth multiplier card used.

- For skewed configurations, the shim rod is fully withdrawn and other three incrementally withdrawn until a keff of approximately 1.0 is achieved. 1.06 MW_{th} multiplier card used.

- Assumptions: fuel temp same in both situations (600 K), power defect between 1.0 and 1.06 MW_{th} negligible.

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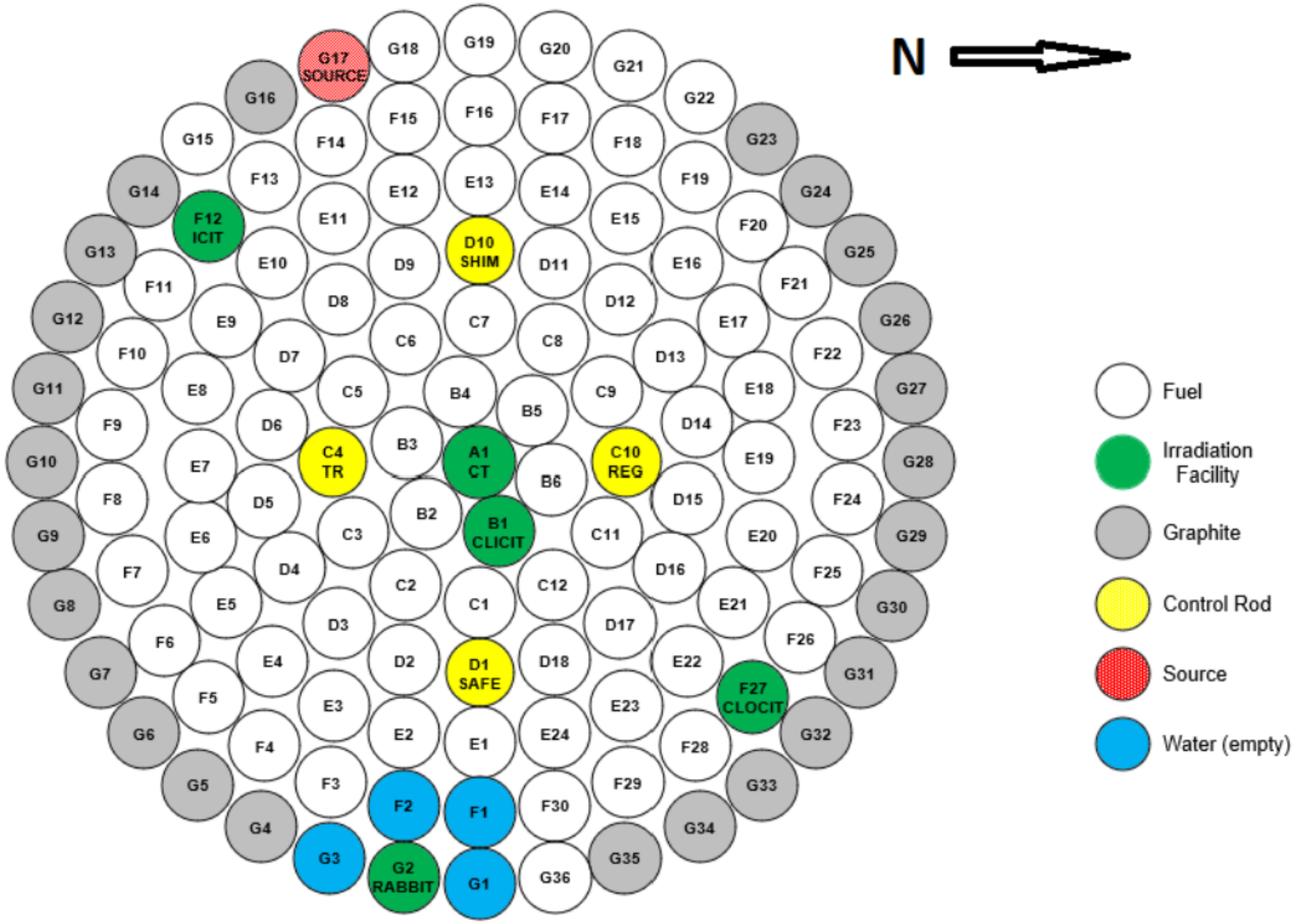
Alternative Core Concept

- "Are there core configurations that are worse than others for this phenomenon?"
- An alternative core configuration was proposed in hopes of maximizing the peaking effect in the NW region of the core.
- Moved the cadmium-lined irradiation tube from F20 to F24 and replaced graphite elements in the western region with fuel from the North and South.

Alternative Core Configuration



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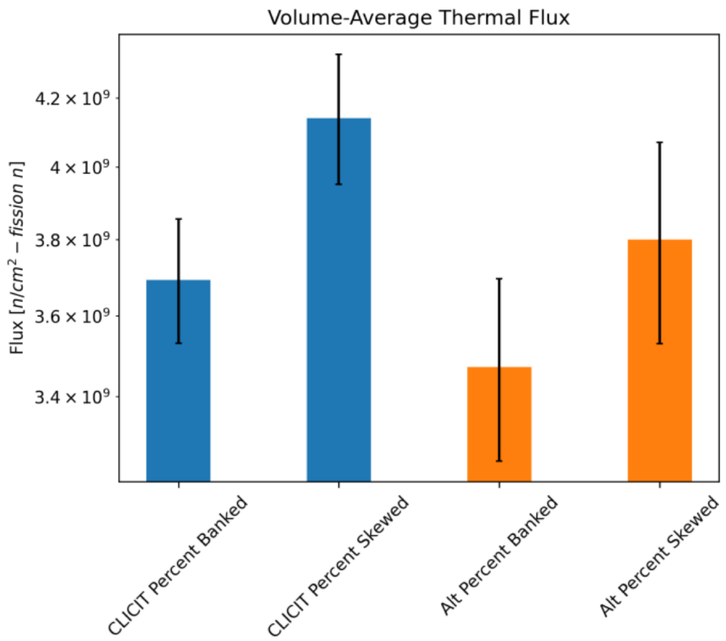
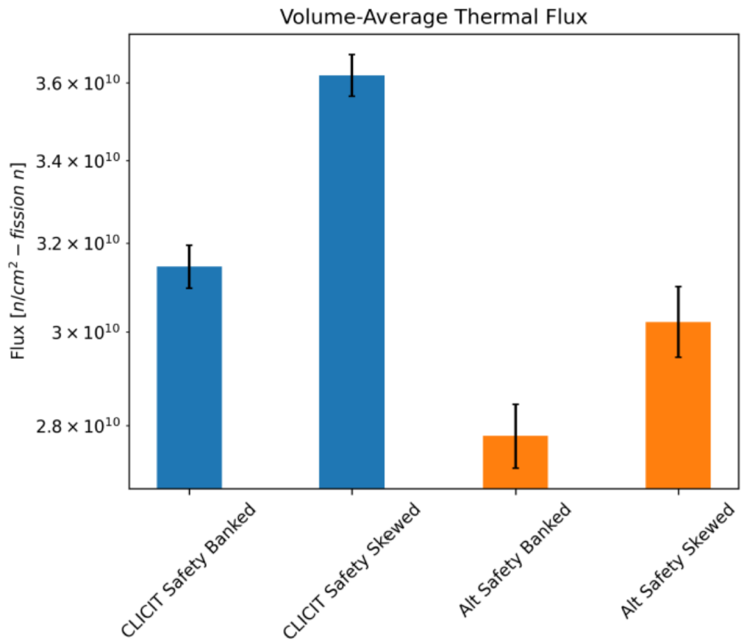
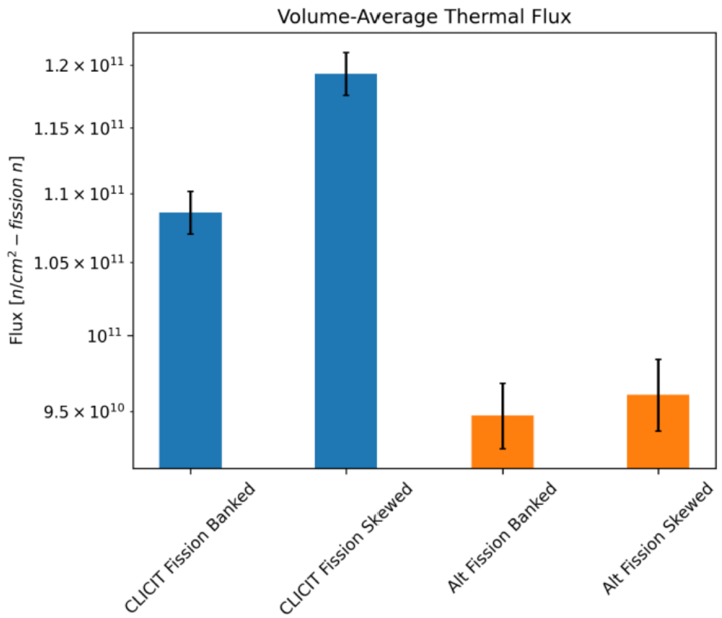
Results







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Conclusions

- The alternate core results suggest it may be possible to unknowingly violate a license limit by operating the OSTR in an extremely tilted manner, close to the SCRAM set-points, in certain core configurations.
- However, a power detector calibration would take place with any core configuration change.
- While these results are interesting, they are perhaps irrelevant in practical terms because calibrations are performed following configuration changes.

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Conclusions

- However, results demonstrate why it is important to perform calibrations with any core configuration change.
- Results show the importance of the fact that, in the calorimetric method for calibrating power detectors, the calibration process is calibrating power detectors to a neutron flux distribution that existed during that process.
- Illustrates why operating in banked control configurations consistently is good operating practice.

Conclusions

- Perhaps the most importantly, Results suggest that the current OSTR CLICIT core is resilient to violating its steady-state license limit 1.0 MW_{th} if operated in this manner.
- This may be due to diverse detector placement around the core.
- Of interest for future study is the effect these tilted operating configurations have on assemblies where all reactor power detectors are located on one side of the core.

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Questions?