Refinements of a TREAT Model for Transient Analysis

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Overview of Talk

1. Describe the Transient Reactor Test Facility
2. Describe the need for time-dependent modeling.
3. Overview of T-ReX.
4. KENOVI model of TREAT
5. Updates to model
6. Future work

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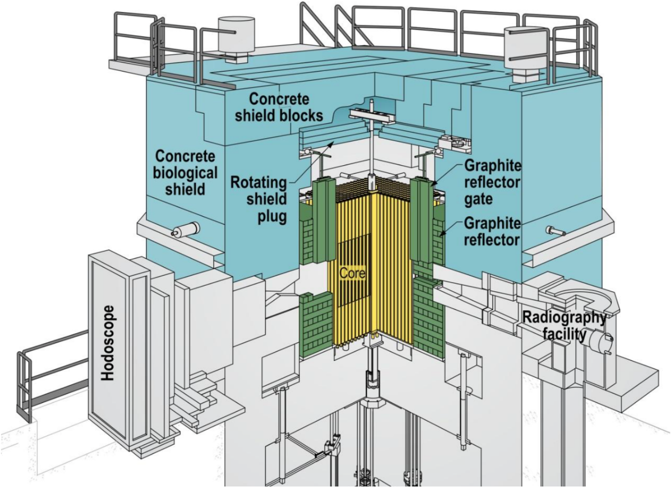
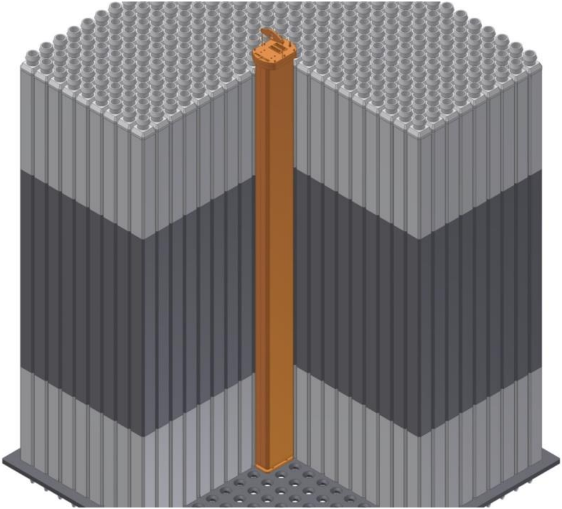
Transient Reactor Test Facility (TREAT) Overview

- Transient Reactor Test Facility (TREAT).
- Designed to evaluate fuel performance.
- Rapid energy deposition.
- No resultant core damage.
- Short, high energy neutron pulses.
- Highly enriched uranium (93.1%)
- UO_2 fuel particles in graphite matrix
- Dispersed in graphite matrix 1:10000 $^{235}U/C$

Transient Reactor Test Facility (TREAT) Overview



Full Core Representation of TREAT



Motivation

- Overall goal of modeling and simulation efforts is to minimize experimental calibration time.
- If calibrations are minimized then experiments will be conducted more quickly.
- Allow for better optimization of test vehicles before irradiation in TREAT.
- Help verify new multi-physics codes.

How to Model TREAT

- Why typical analysis methods fail?
  - Deterministic codes face the challenge of creating meshes.
  - Diffusion based approaches have difficulty modeling streaming and high leakage.
- Motivates the use of Monte Carlo methods with time-dependent capabilities.
  - Models are very close to actual configuration.
  - Models are easier to generate.
  - Streaming and leakage are properly accounted for.

Feedback

- Feedback is an essential component to transient simulations.
- Core is 100 ppm HEU → little resonance absorption in 238U.
- As core heats, a shift in the thermal spectrum takes the core back to a new critical state
  - → Eventually rods are driven in to completely shut down the reactor.
- Temperature distribution throughout the core determines the feedback.

T-ReX Approach

- Solve the time-dependent transport equation with the explicit representation of delayed neutrons.
- Incorporate models that match the geometry exactly.
- Obtain the flux with a method that is able to resolve streaming issues.
- $\rightarrow$ We use a time-dependent Monte Carlo solver.
  - Now called the Transient-Reactor eXperiment simulator (T-ReX)

Improved Quasi-Static (IQS) Method

- Neutron flux (ϕ) is factored into two components:
  - **Amplitude function** $A(t)$
    - Highly dependent on time
    - Accounts for rapid reactivity/power changes
  - **Shape function** $\Phi(r, E, \Omega, t)$
    - Accounts for spatial variation of neutrons over time.

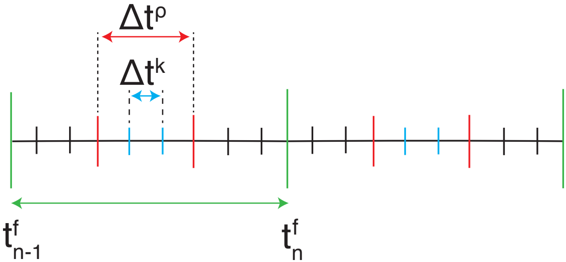
Flux Factorization

$$\phi(r, E, \Omega, t) = A(t)\Phi(r, E, \Omega, t) \rightarrow \text{Transport Equation}$$

Result: coupled functions solved on different time scales

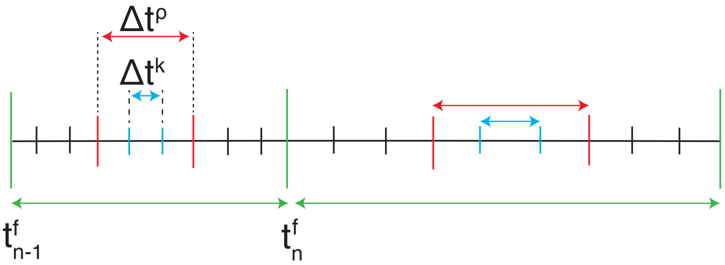
Typical IQS Time Scale

- Flux shape found at t_n^f times (largest)
- Reactivity parameters found on Δt^ρ intervals
- Amplitude found on Δt^k intervals (smallest)
- Below is the proto-typical time scale in IQS.



Time Scale in T-ReX

- Better representation of the time scale in T-ReX.



- The flux shape update interval may vary and in turn change the intervals at which the point kinetics equations and reactivity parameters are evaluated.

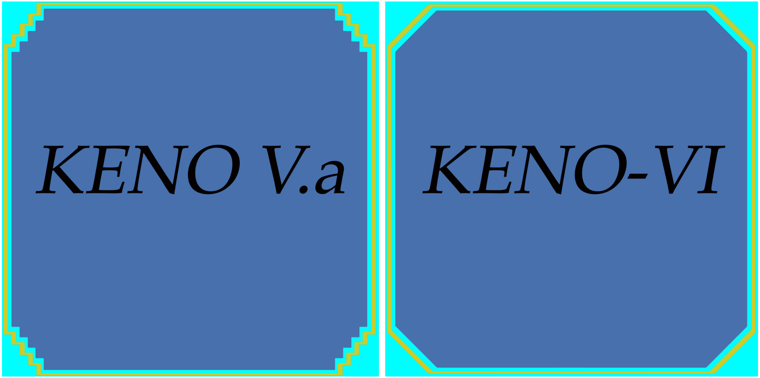
M8 Calibration (M8CAL) Experiments

- M8CAL experiments performed prior to placing TREAT on standby.
- Series of calibrations designed to understand core before evaluating fuel.
- Has the most complete data set.
- Includes experiments done post facility upgrade in late 1980s.
- *Note*, these experiments were only to optimize the core, not to evaluate fuel.

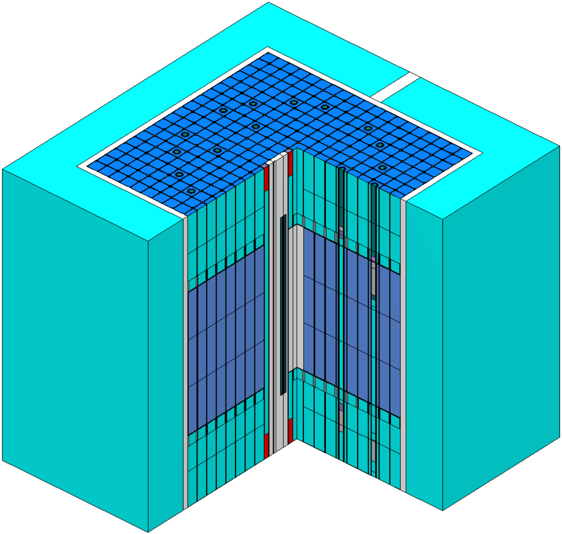
Recent Improvements

- T-ReX now supports calculations of the flux shape in parallel with KENO-VI from SCALE 6.2.1.
  - Previously, only the simplistic KENO V.a was available.
- M8CAL 2855, 2856 and 2857 temperature-limited transients were modeled
- KENO-Va model had insufficiently large regions

Recent Improvements

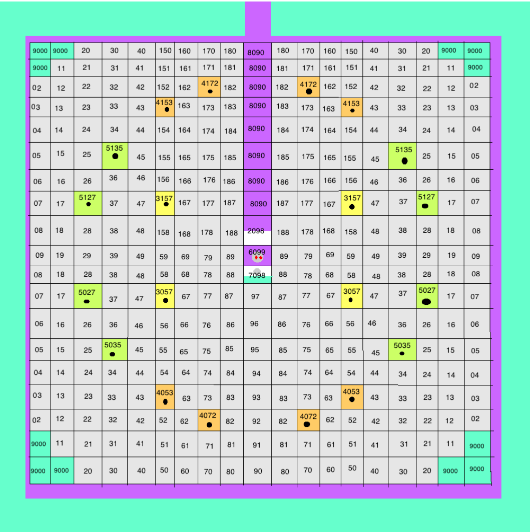


KENO-VI TREAT Model



Representation of M8CAL

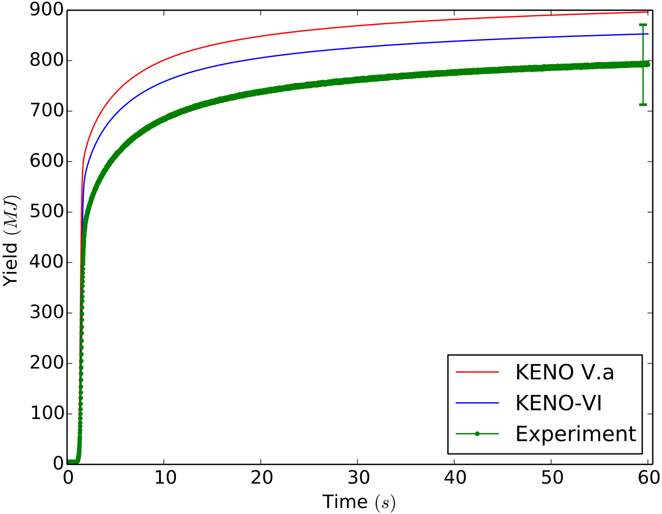
- TREAT
- Motivation
- T-ReX
- **Model**
- Updates
- Conclusion
- Future



Geometric Modeling Challenges

- T-ReX requires pre-transient and forward geometric inputs to be identical
  - Geometry-based transients require "tricking" the program with overlapping regions
- KENO-VI does not naturally use octagons
- KENO-VI does not allow 2nd-order grouping of regions ("or")

Comparison to Experiment (2855)



Recent Updates

- Several aspects of geometry were updated to reflect best current understanding of reactor.
- Several material definitions were updated- graphitization caused k-eff to increase, and zircaloy caused k-eff to decrease.
- Rod insertions were modified.

Rod Insertions

- Rod insertion values had been taken from earlier models, which had been altered to get correct k-eff.
- When corrected to best estimated insertion, pretransient was slightly supercritical and reactivity insertion was 5.5-7.0% too high.
- Rods were modified to agree with experimental values of k-eff and reactivity insertion by adjusting rods by 1-5 cm.

Conclusion

- Modeling TREAT and simulating TREAT experiments is challenging.
- Our full-core simulations with T-ReX are generally in good agreement with the experiments.

Future Work

- Use updated TREAT model for energy studies
- Look at ‘shaped transients’ from M8CAL.
- Use heat transfer in reactivity feedback

Questions?

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U.S. Department of Energy

GAMeS LAB