Validation of a Simple RELAP5-3D Point Kinetics Model of the Full-Slotted MARCH Core in TREAT

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Outline

- Background
- Description of TREAT
- Description of the RELAP5-3D model
- Validation results
- Conclusions

Background

- The Transient Reactor Test (TREAT) facility has been restarted to test accident tolerant fuels for light water reactors that are designed to have better performance than traditional Zircaloy-clad UO_2 fuel during normal operation and accidents
- New experiments are being performed to test proposed fuel concepts and provide data for assessment of advanced multi-physics computer codes
- Calculations are required now to demonstrate that the experiments will meet program objectives and can be performed safely
  - The advanced multi-physics computer codes are not ready yet
  - The safety calculations for the experiments are presently being performed using input from RELAP5-3D
- RELAP5-3D point kinetics models of TREAT were developed and validated previously as described at the 2015 and 2018 IRUG meetings

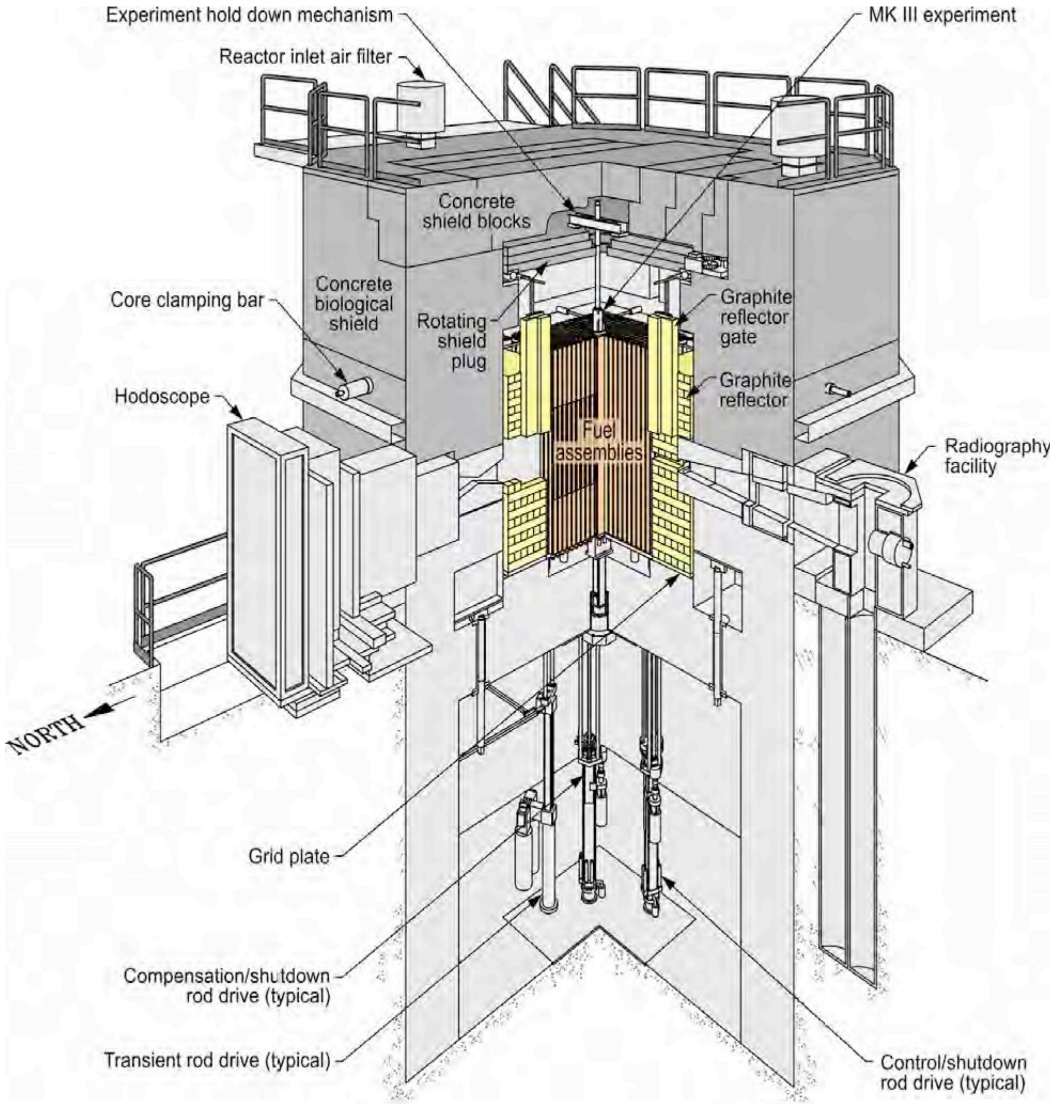
Background (cont'd)

- The previous models simulated a half-slotted core that allowed viewing through the north hodoscope slot
- The simple RELAP5-3D model described at the 2015 IRUG meeting was modified to represent the core currently in TREAT
  - The core is now a full-slotted core that allows viewing through either the north or south hodoscope and contains the Minimal Activation Retrievable Capsule Holder (MARCH)
- The simple RELAP5-3D model described in the 2015 IRUG meeting was modified to represent the full-slotted MARCH core
- The simple model was validated using data from transients performed in the last year
- A description of the revised model and its validation are the subjects of this presentation

Description of TREAT

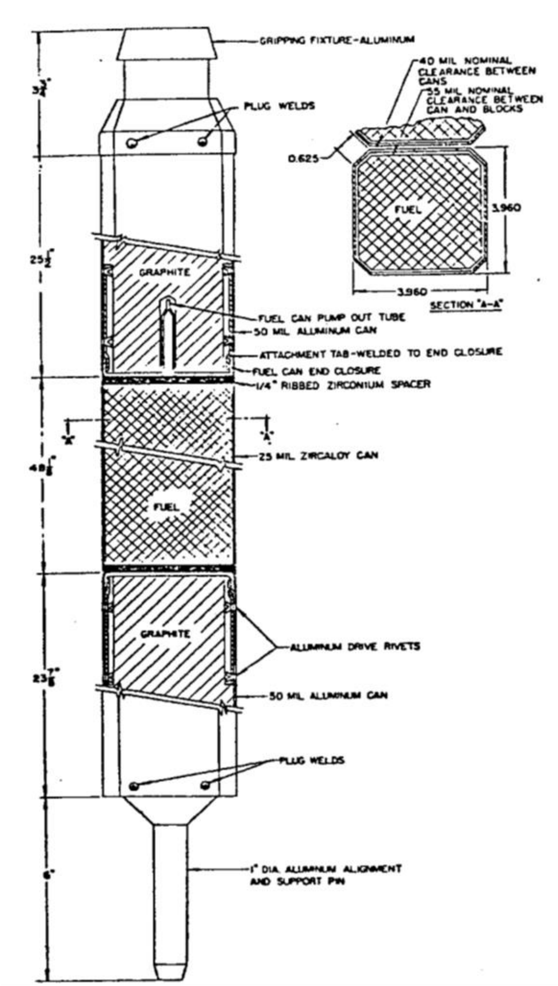
- TREAT is a dry reactor that went critical in 1959
- Operations were suspended in 1994
- The reactor was restarted in FY 2018
- Driver core is made up of urania dispersed in graphite blocks encapsulated by Zircaloy cans
- Square layout with 361 positions that are filled with fuel or dummy assemblies
- The size of the core varies from small to large (~ 150 to 340 fuel assemblies)
- Dummy assemblies are located around the periphery of the core and are filled with graphite for additional reflection
- Experiments are placed in the center of the core

Description of TREAT (cont'd)



- Core is set on a square gridplate
- Core is surrounded by graphite reflectors
- A small amount of cooling is provided by downflow of air
- The heat capacity of the graphite provides the primary heat sink during transients
- Reactivity control is provided by three banks of control rods
- The transient rods are used for high-speed transient control

Description of TREAT fuel assembly



- Each fuel assembly is a 4x4” “square” that contains fuel, a gas gap, and a Zircaloy can
- The gas gap was evacuated during manufacture
- Active core is 48” tall
- There is a small gap between fuel elements for air flow

Description of TREAT (cont'd)

- TREAT can perform two types of transients
  - Unshaped transients
    - The only reactivity addition is that required to initiate the experiment
    - The reactor power responds naturally due to thermal feedback
  - Shaped transients
    - The transient rods are moved during the test to obtain a desired power curve
    - The reactor power responds to the rod movement and the thermal feedback

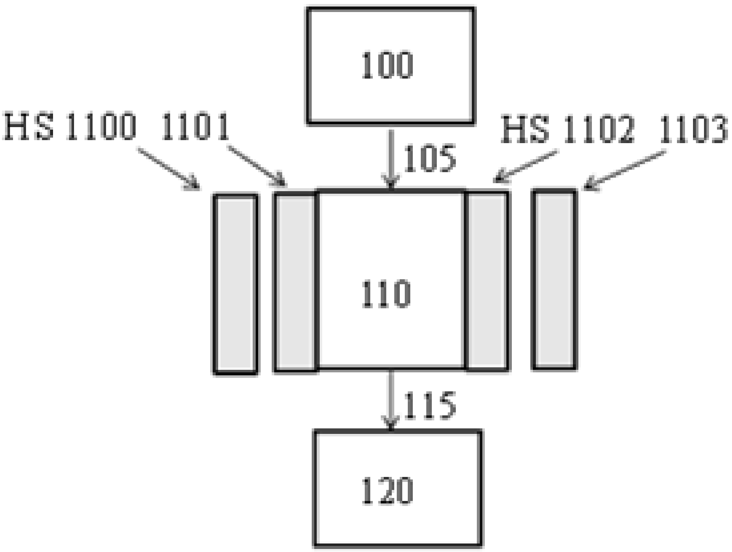
Description of the RELAP5-3D model of the full-slotted MARCH core

- The RELAP5-3D model was developed to calculate the reactor power during experiments
- The reactor power is needed to support other analyses required to demonstrate that the experiments will meet operational objectives and that they can be performed safely
- The model calculates the temperature of an average fuel assembly to supply thermal feedback to the point kinetics model
- The model also calculates the fuel temperature at the hot spot to determine the margins to thermal limits

Description of the RELAP5-3D MARCH model of the full-slotted core (cont'd)

- The full-slotted model is based on the simple half-slotted model described at the 2015 IRUG meeting
  - The number of fuel elements was reduced from 338 to 330 to accommodate viewing through the south hodoscope slot
  - The volumetric heat capacity of the fuel was revised based on a new fit produced by the TREAT program
  - The reactivity feedback due to changes in fuel temperature was revised based on new calculations
  - The worth of the transient rods was revised based on new measurements

Description of the RELAP5-3D model of the full-slotted core (cont'd)



- The model is very simple
- One heat structure represents all the fuel in the core
- Another heat structure represents all the Zircaloy cans
- Radiation between the two average heat structures is accounted for
- Conduction across the gap is neglected
- Two similar heat structures are used to represent the hottest fuel in the core
- A cylindrical heat structure is used to represent the square assemblies
- Distortions are accounted for by adjusting the heat transfer coefficient at the outer surface of the can and the thermal conductivity of the Zircaloy

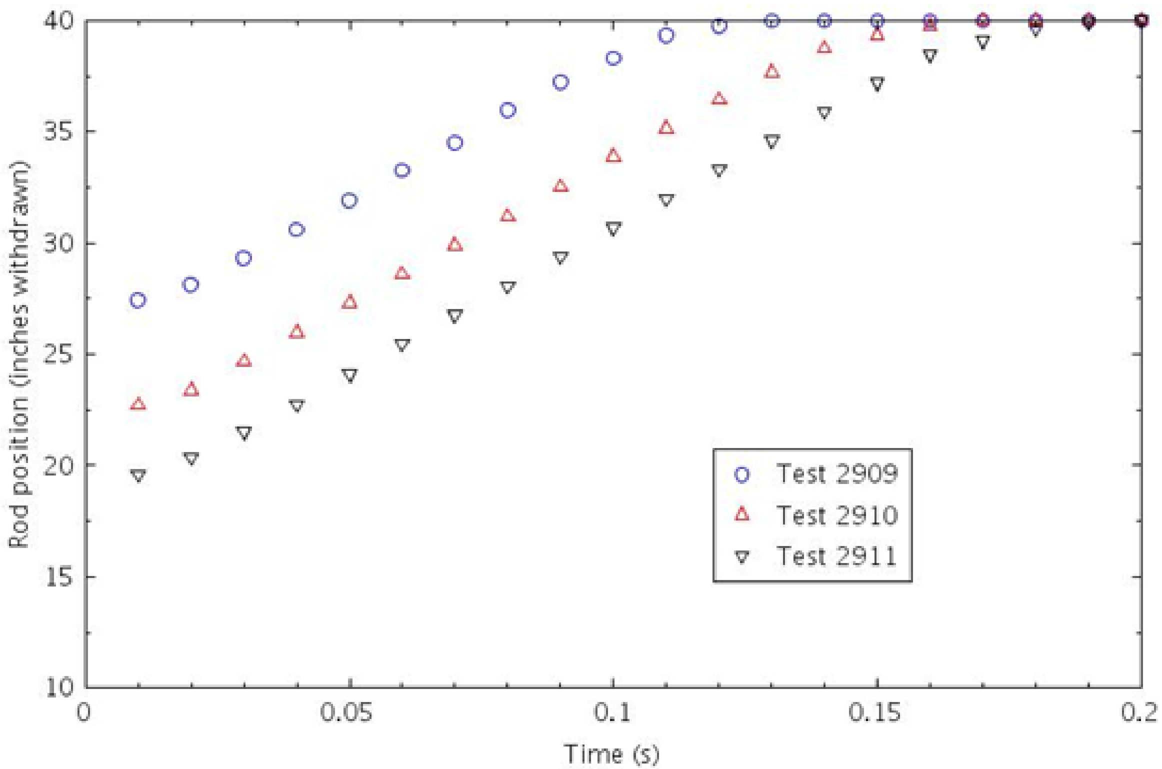
The RELAP5-3D model was validated using data from three new transients

- All three transients were unshaped and were initiated by near step insertions of reactivity
  - Transient 2909 (0.0171 dk/k or 2.38$)
  - Transient 2910 (0.0294 dk/k or 4.10$)
  - Transient 2911 (0.0388 dk/k or 5.41$)
- The measured power from the log channel of the control computer was judged to be the most reliable based on previous experience and was used in this validation
  - The energy deposition in the core is the integral of the measured power

The RELAP5-3D model was validated using data from three new transients (cont'd)

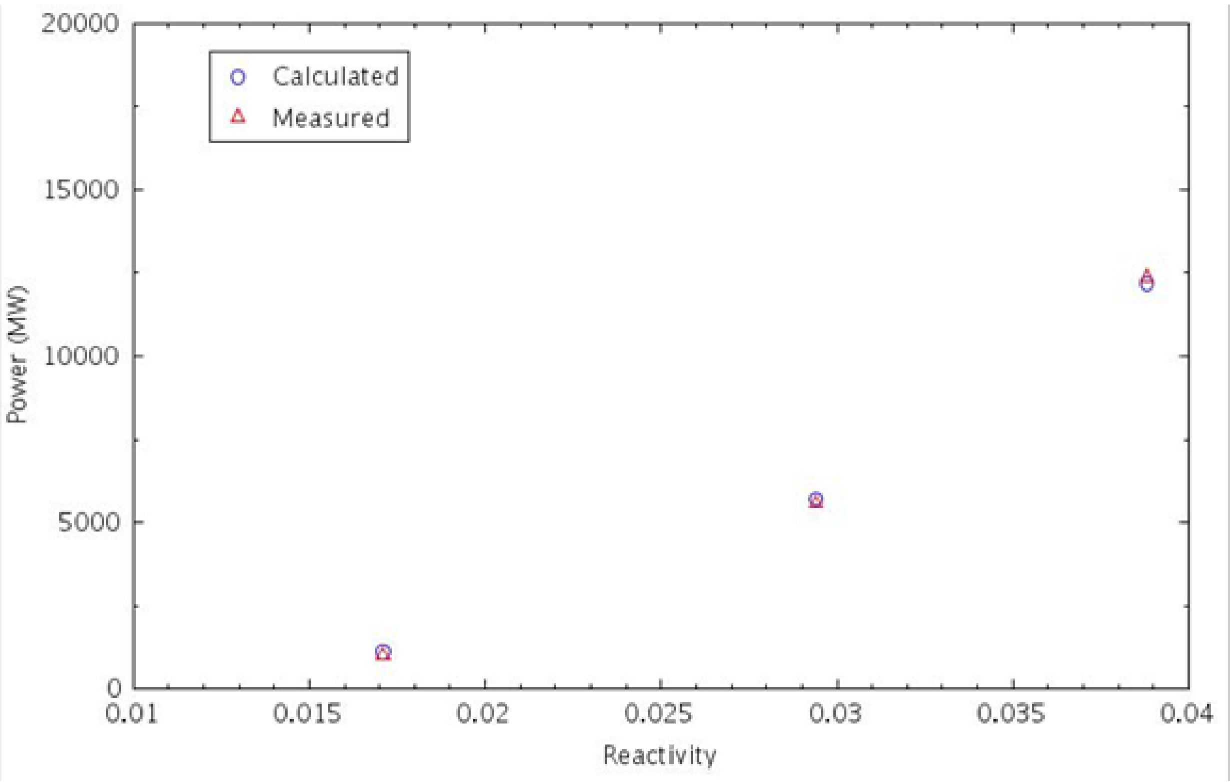
- Preliminary calculations of the validation transients with the MARCH feedback table resulted in slightly non-conservative values of energy deposition and maximum fuel temperature
  - The average ratio of the calculated to measured energy deposition was 0.976
  - The calculated maximum fuel temperatures were 6.3°C lower, on average, than the measured values
- The calculated reactivity feedback was reduced by 2% so that the results of the validation calculations would be slightly conservative

The near step insertions were modeled based on the movement of the transient rods



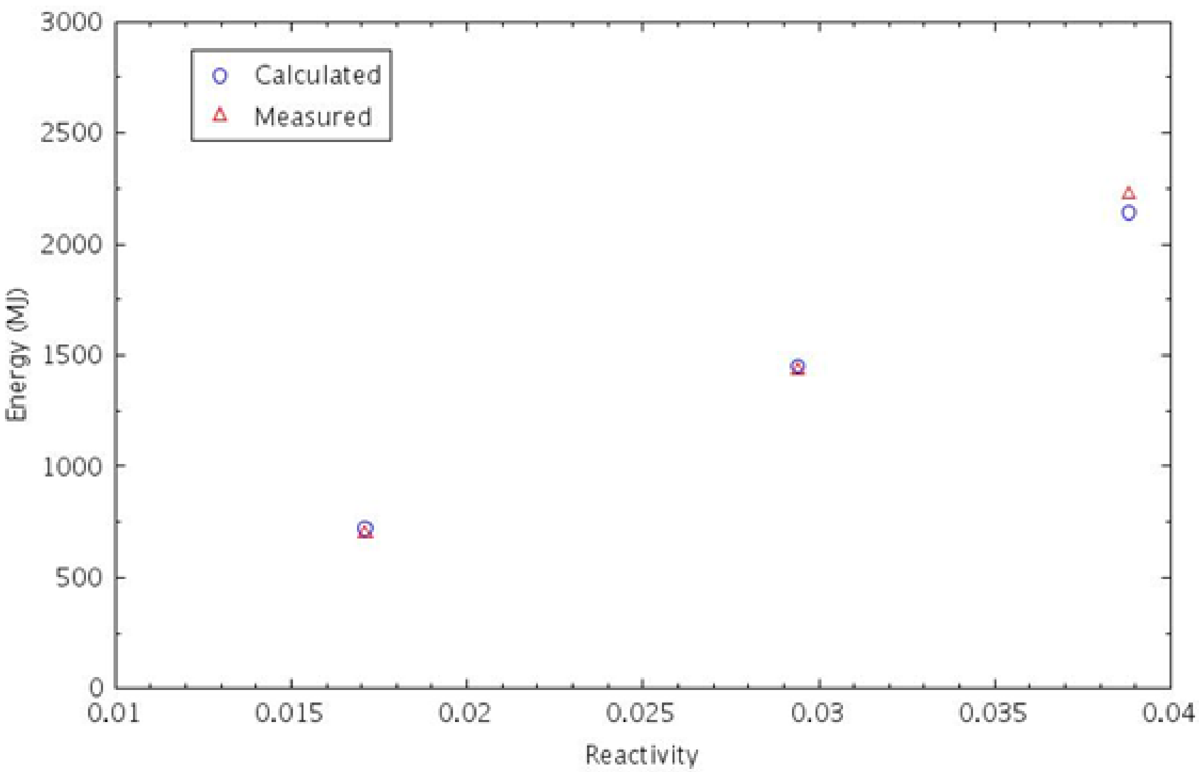
- The input position was based on the average of the measured positions of the four transient rods
- The transient rods accelerate and decelerate quickly and reach a maximum velocity of about 140 inches/s

The calculated maximum power is in reasonable agreement with the measurements as a function of reactivity



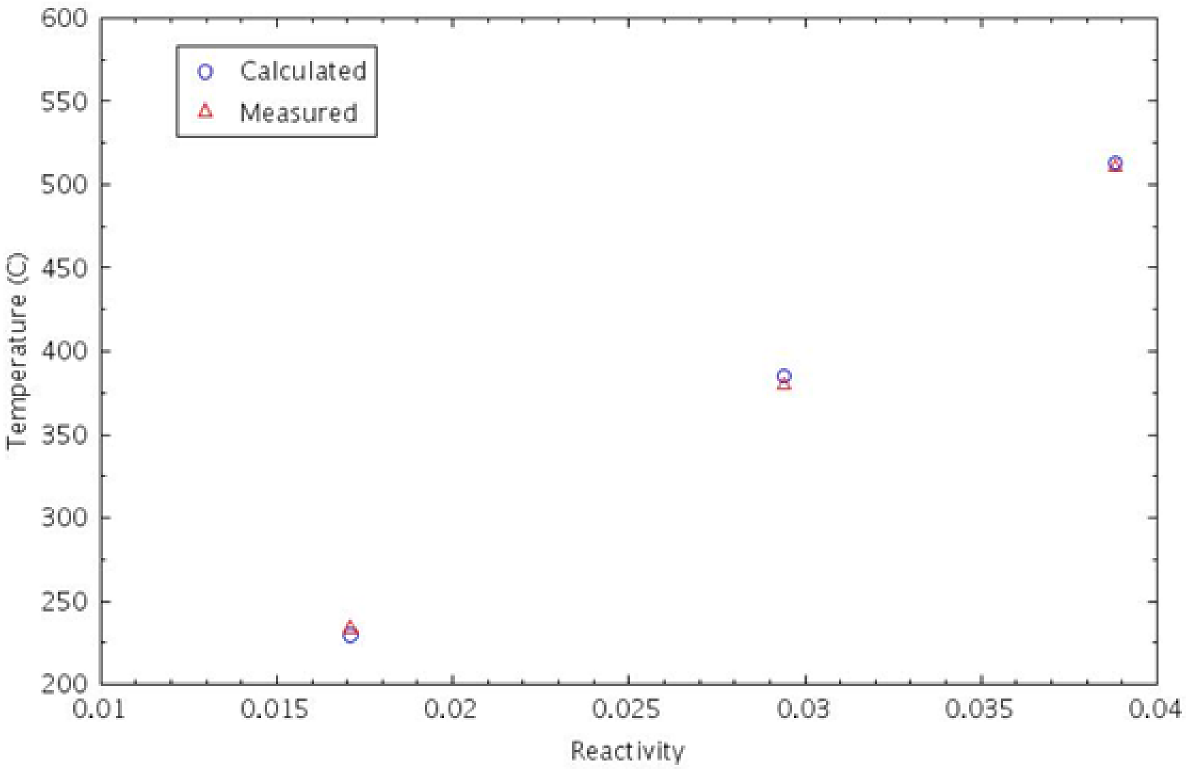
- The calculated maximum reactor powers were within the scatter of the measurements or were conservative for each transient

The calculated energy deposition is in reasonable agreement with the measurements as a function of reactivity



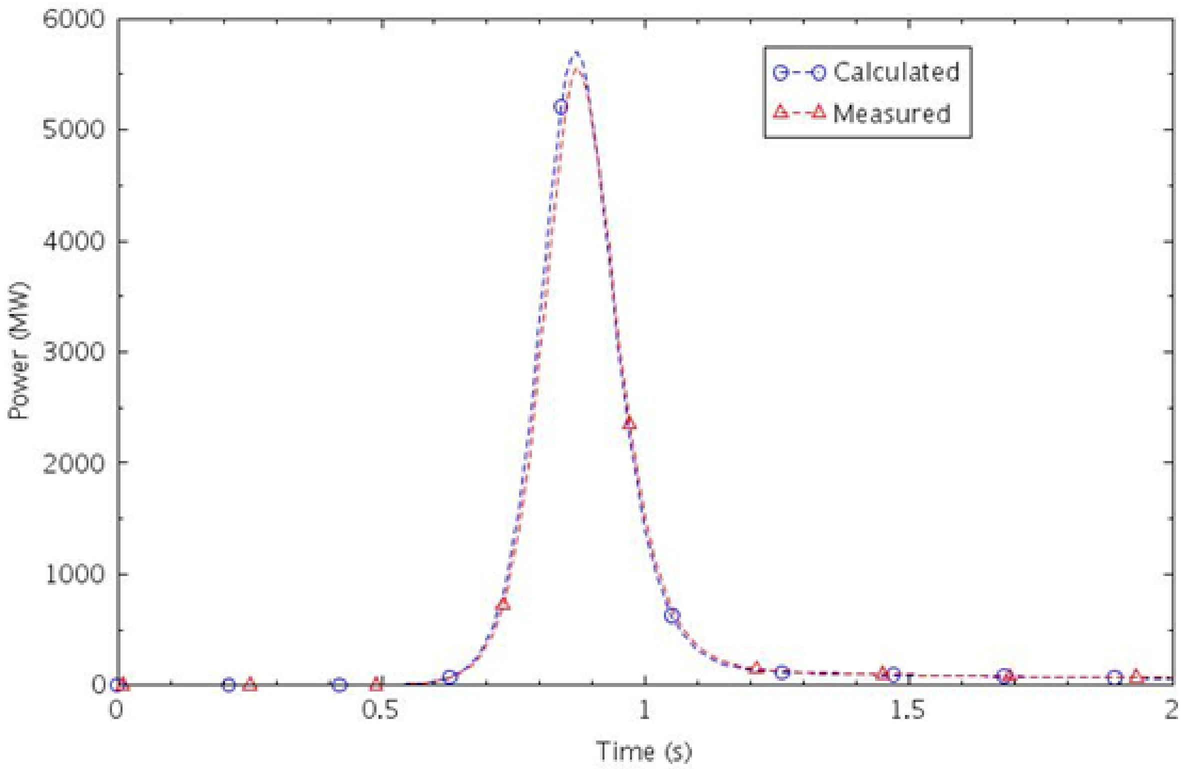
- The calculated energy deposition was conservative or within the scatter in the measurements for each transient
- The average ratio of the calculated to measured energy deposition was 1.002

The calculated maximum fuel temperature is in reasonable agreement with the measurements as a function of reactivity



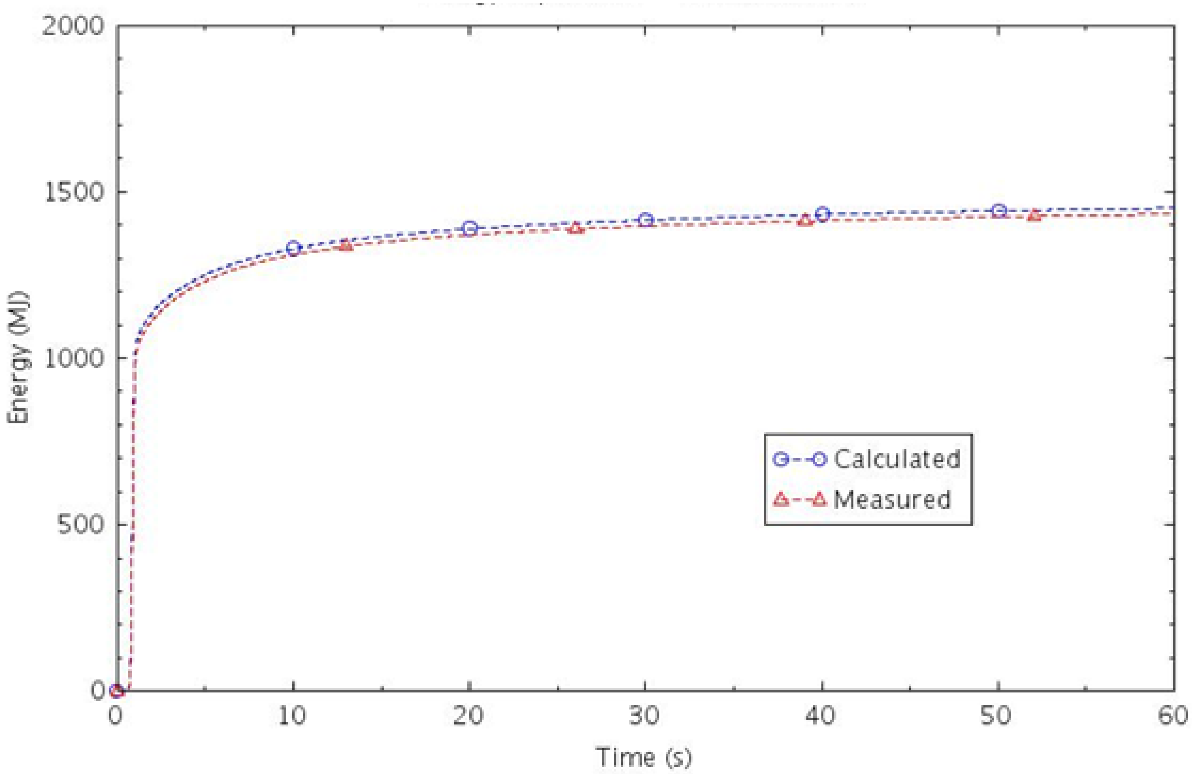
- The calculated maximum fuel temperatures were, on average, 1.3°C higher than the measured values
- The deviations between the calculated and measured temperatures were probably close to the uncertainty in the measurements

The calculated powers are in reasonable agreement with the measurements as a function of time



- These results are for Transient 2010

The calculated energy depositions are in reasonable agreement with the measurements as a function of time



- These results are for Test 2910

Conclusions

- The simple RELAP5-3D model of TREAT was modified to represent the full-slotted MARCH core
- Modifications were made to represent the worth of the transient rods and reactivity feedback for the MARCH core
  - The reactivity feedback was multiplied by 0.98 to provide slightly conservative results
- The modified model was validated using data from Transients 2909, 2910, and 2911, which were unshaped transients initiated with near step insertions of reactivity of about 1.7%, 2.9%, and 3.9%, respectively

Conclusions (cont'd)

- The RELAP5-3D calculations were in reasonable agreement with the measured results
  - The calculated maximum reactor powers were within the scatter of the measurements or were conservative
  - The average ratio of the calculated to measured energy deposition was 1.002
  - The calculated maximum fuel temperatures were, on average, 1.3°C higher than the measured values
- The results of the RELAP5-3D calculations are currently being used as input for the thermal and structural evaluations of new TREAT experiments