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Enhancing TREATs Pulsing Capabilities Using TREAT Upgrade Fuel

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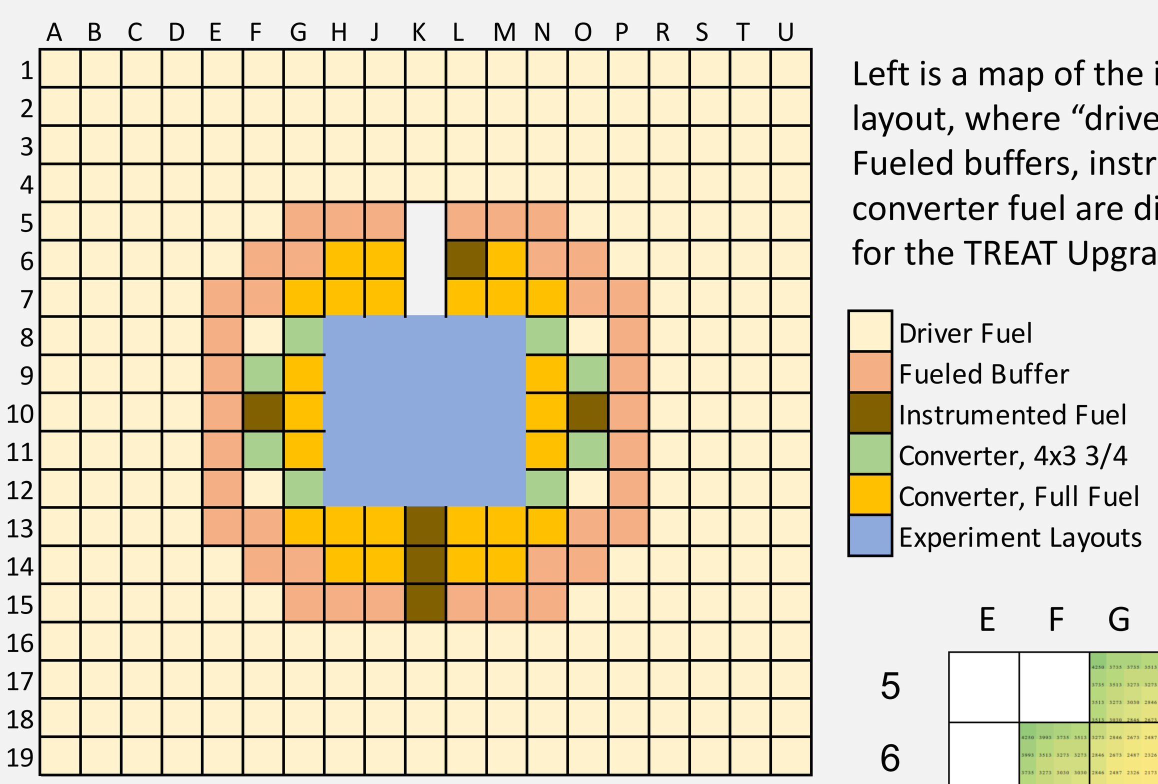
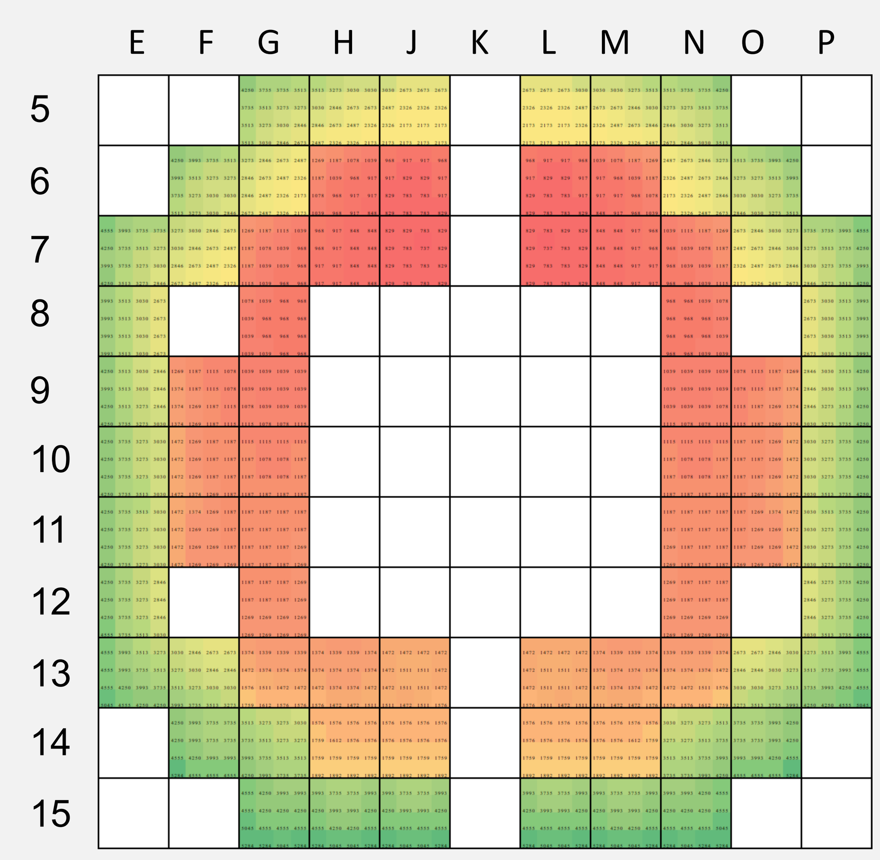
Abstract

The Transient Reactor Test Facility (TREAT) at Idaho National Laboratory is an air-cooled, thermal, heterogeneous facility used to test reactor materials in simulated accident conditions by inducing fission heating with intense neutron pulses[1]. TREAT operated from 1959 until 1994 with the primary goal of testing fast reactor fuels[2] and was brought back online in 2017 to re-establish DOE's nuclear fuels transient testing capabilities[3]. Beginning in the late 1970s, Idaho National Laboratory worked in conjunction with other organizations to increase TREAT's capability for in-pile testing[1]. While these upgrades had not been implemented by the time the reactor was put into standby mode, new assemblies and graphite-urania fuel blocks with increased uranium concentrations had already been designed and fabricated. This project, as part of Idaho National Laboratory's Department of Reactor Physics, modeled the TREAT Upgrade (TU) fuel assemblies in MCNP and implemented them in an existing TREAT model. Calculations were performed using INL's high performance computer to find a critical combination of TU and standard fuel and this geometry's excess reactivity. Future work will include calculating a power coupling factor in the experiment, determining power peaking factors throughout the core, and assessing how much reactivity would be added by replacing the Inconel-625 cladding with silicon carbide.

Modeling TREAT Upgrade Fuel



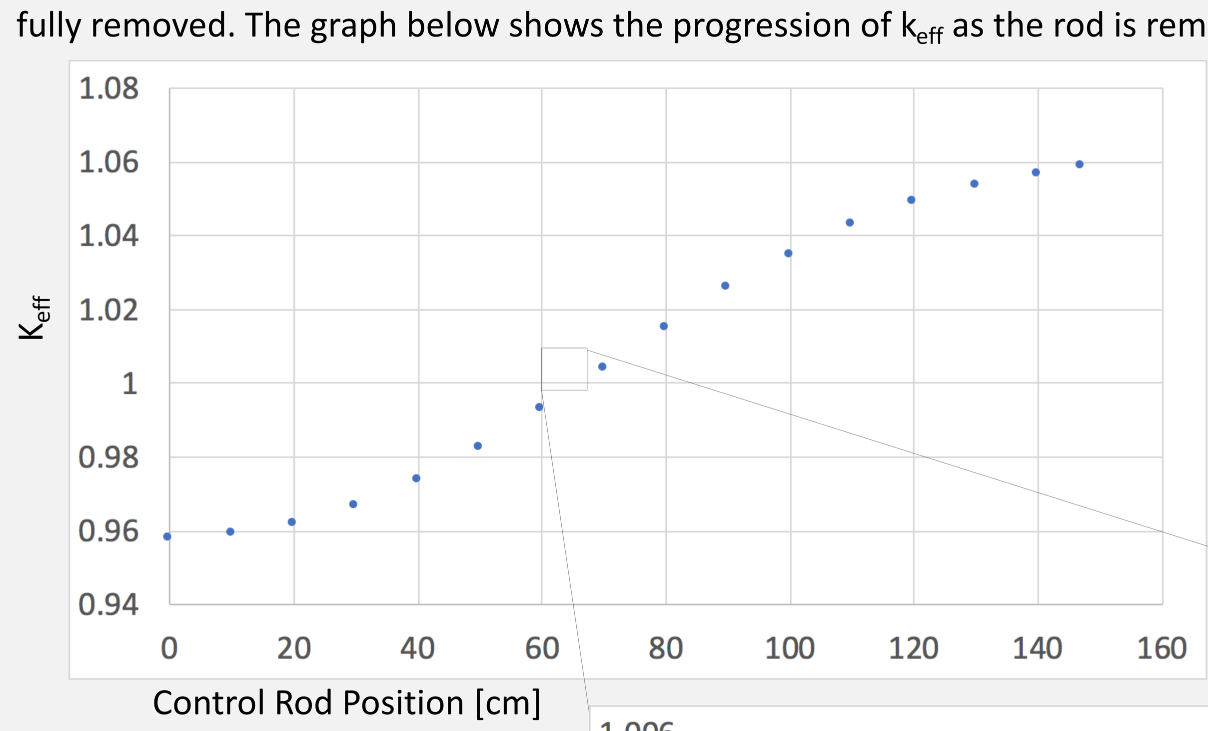
Left is a map of the intended Treat Upgrade core layout, where "driver fuel" is standard TREAT fuel. Fueled buffers, instrumented fuel, full and 4x3 ¾ converter fuel are different assembly types created for the TREAT Upgrade geometry.



The figure on the right represents the concentration gradient of TU fuel, with green at the lowest uranium concentration of 1:5300 and red at the highest of 1:500. Buffer assemblies have the lowest concentrations of the TU assemblies, indicated by the green and yellow outer ring in the right image, and converter assemblies have the highest, indicated by the red and orange inner ring.

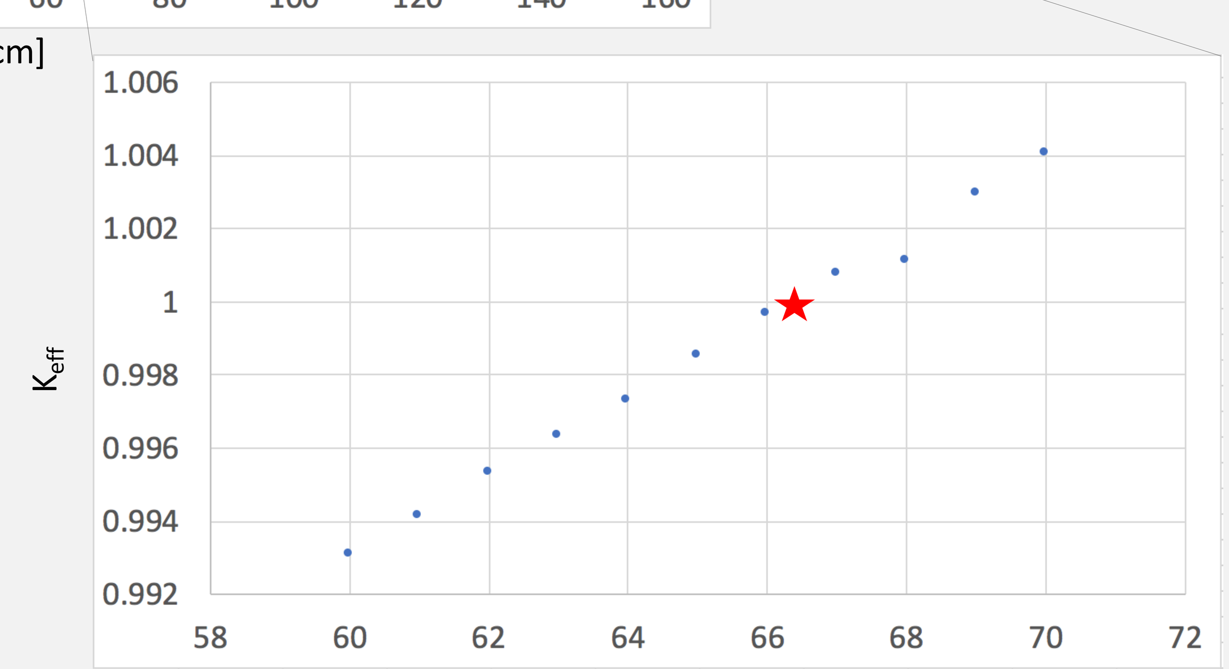
Control Rod Movement

Criticality is also controlled and maintained using control rods, which use boron carbide powder to absorb neutrons and can be inserted and removed into the reactor to control reactivity. Criticality with this arrangement was found to occur at a control rod insertion of approximately 66.3 cm, where 0 cm is fully inserted and 147.32 is fully removed. The graph below shows the progression of k_{eff} as the rod is removed.



K_{eff} was first calculated using MCNP by increasing the control rod position in increments of 10 cm until fully removed. One a window in which k_{eff} became 1, between 60 and 70 cm, the control rod position was increased in increments of 1, shown below.

K_{eff} was found to equal one at 66.3 cm.



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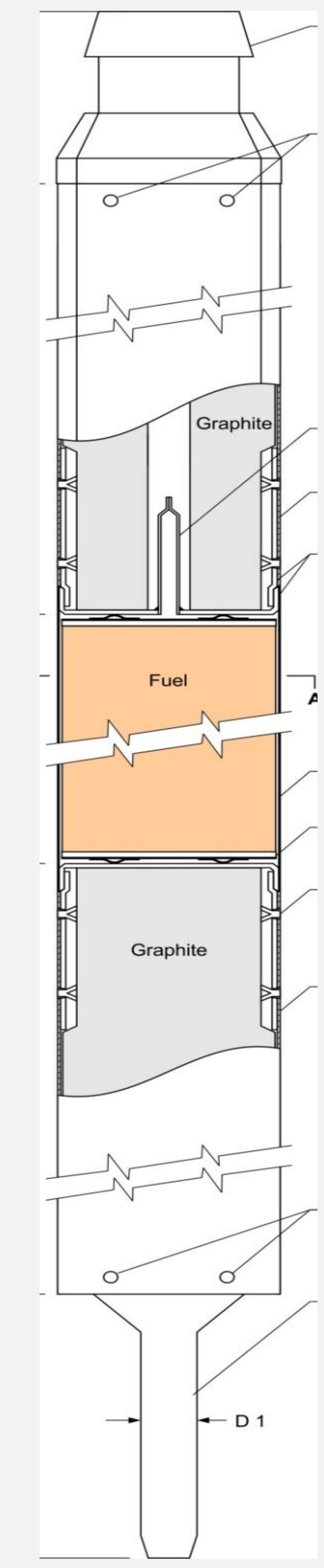
Standard Fuel vs. TREAT Upgrade Fuel

The main differences between the Standard Fuel (SF) and TREAT Upgrade (TU) fuel from a modeling and neutronics perspective are as follows:

- Changes in construction materials
- Increase fuel length by 1' and resulting decrease in reflector length
- Continuous outer cladding
- Increase in uranium concentration in fuel and introduction of azimuthal C/U ratio variation

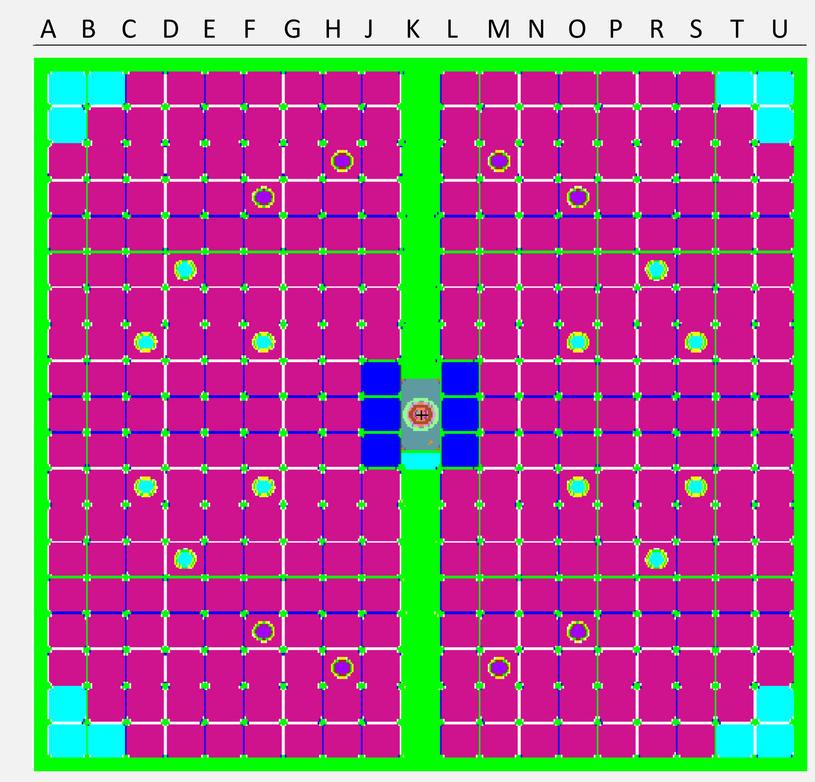
SF vs. TU Materials and Dimensions

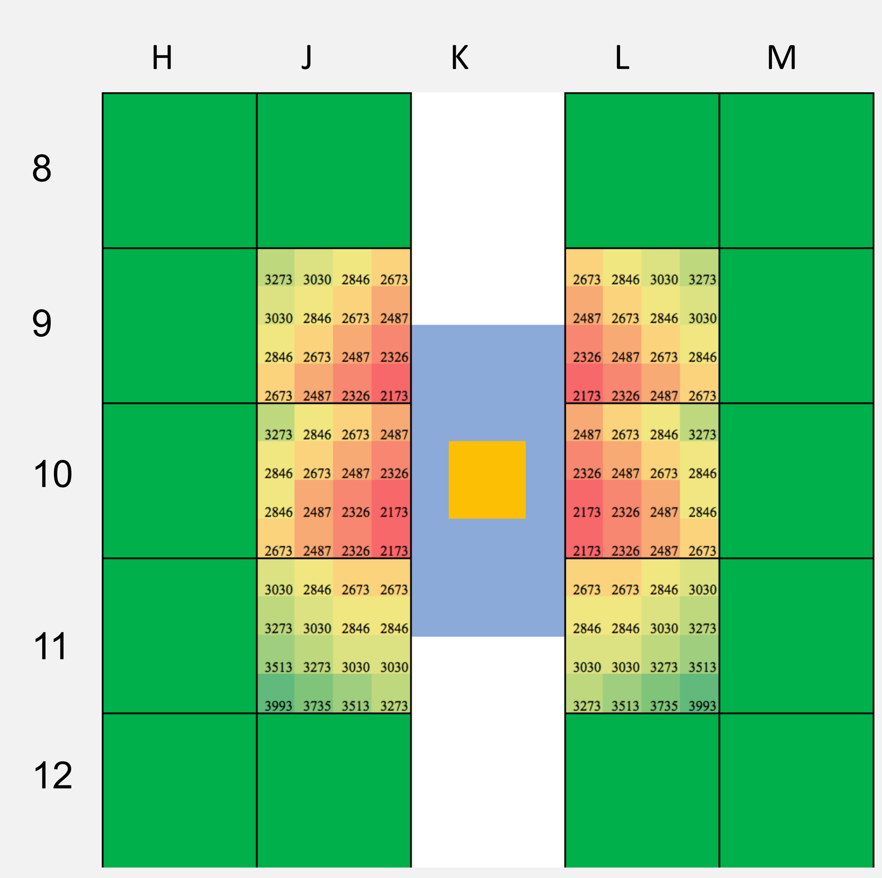
Component	SF Material	TU Material	SF Length, in	TU Length, in
Top Fitting	Al-1100	Inconel-600	3.75	4.25
Top Reflector	CP-2 Graphite	CP-2 Graphite	25.5	18.6
Fuel	Graphite-Urania Fuel, C/U ~10,000	Graphite-Urania Fuel, C/U between ~5300 and 500	48.125	60
Bottom Reflector	CP-2 Graphite	CP-2 Graphite	23.875	17.25
Bottom Fitting	-	Inconel-600	-	1.5
Alignment and Support Pin	Al-1100	Inconel-600	6	5.65



Achieving Criticality

Various combinations of TU and standard fuel were used to find a critical geometry. Standard fuel has a C/U ratio of 10,000, so the buffer TU fuel with the lowest uranium concentrations were used first. Criticality was found to occur using assemblies F7, O7, G6, N6, F13, and O13 from the intended TU arrangement, placed at the six fuel locations closest to the experiment as shown right.





The concentrations of the TU fuel included in the arrangement above are show at the left. The solid green blocks are the standard fuel, with the experiment in blue and yellow.

Future Work

- Calculate a power coupling factor
  - Ratio of energy in test fuel to energy dumped into core
  - Goal value between 0.7 and 1.2, to confirm that too much or too little energy isn't being put into the fuel relative to the entire core
- Calculate power peaking factors
  - Ratio of assembly's energy deposition to core average energy deposition
  - Used to confirm that no one assembly in the core is undergoing much higher thermal stress than the rest of the core and to determine which assembly is the limiting assembly
- Assess added reactivity from switching Inconel-625 cladding to silicon carbide
  - The nickel in Inconel causes it to absorb many more neutrons than silicon carbide, so switching to silicon carbide would boost excess reactivity in the core.

References

1. M. T. Kalman, M. A. Caruso, D. A. Prelewicz, G. B. Peeler,H. J. E. Jr., M. K. Prabjakara, and B. P. Singh, "Interim design report for the treat upgrade full fuel assembly," Tech. Rep. (NUS Corporation, 1981).
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