Finite Element Modeling of the TREAT (as Built) Reactor and a Possible 20% Enriched Fuel TREAT

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TREAT Modeling

The Treat reactor was built in 1959 to test fuel for fast reactors

It operated through 1994

An attempt is being made to restart TREAT as part of the DOE Advanced Fuels Initiative

Originally using 93% enriched UO2, the restart may eventually require the use of < 20% enriched fuel.

This provides an interesting neutronics problem to address the differences.

As an aside, it seems interesting to point out that the original reactor was completed for a total cost of $1.46 M somewhat below the cost of the analyses that have been completed to address the restart.

TREAT Reactor

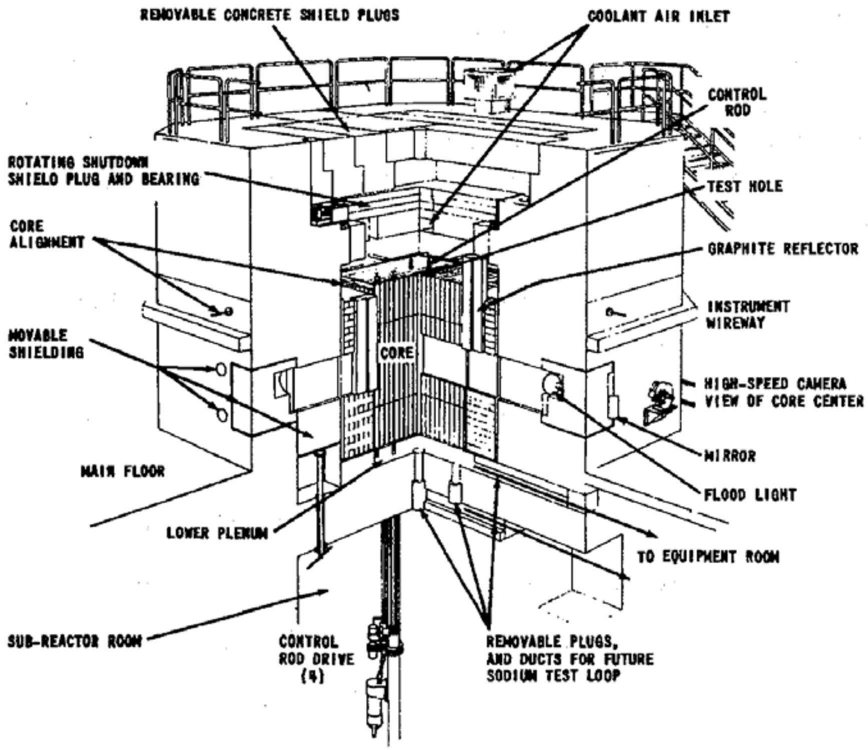


FIG. I
TREAT PERSPECTIVE

Plan View

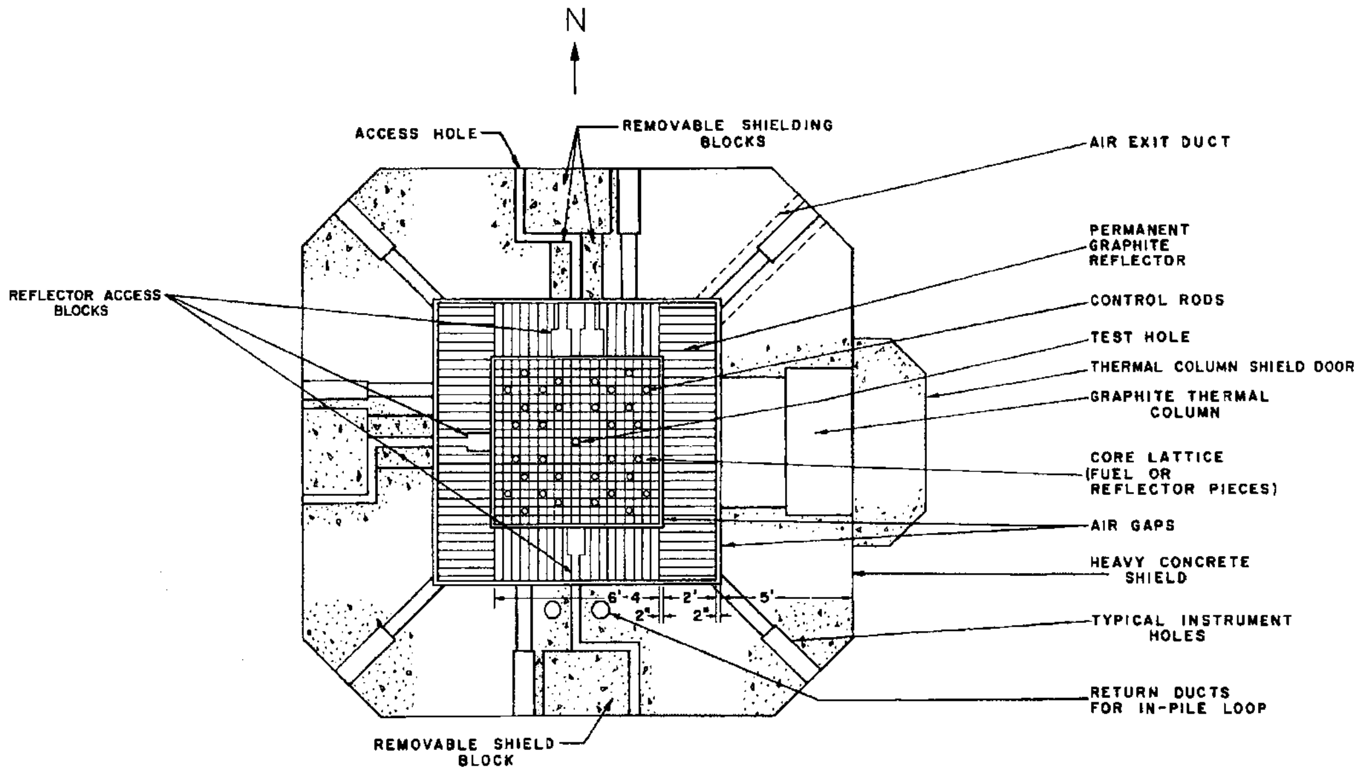


Fig. 2. Plan View of TREAT

Description

The core support plate contained a grid of 19x19 locations that could contain fuel elements, control elements, thermocouple elements, or reflector elements.

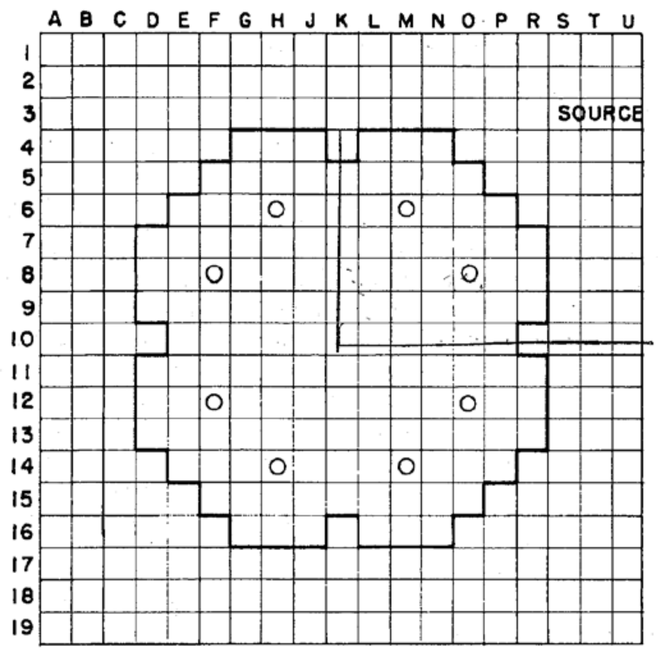
Each element was approximately 4 inches on a side and the fueled section was 4 feet long.

Some elements had a 2 foot high slot in the middle that allowed instruments to view the central test section during a test.

The fuel and reflector elements could be rearranged in a number of ways to obtain a critical configuration with the desired geometry.

TREAT Minimum Critical Core

LOADING DIAGRAM OF TREAT



1. No. of Regular Fuel Elements 133

2. No. of Fuel Elements with Control Rod Holes 8
Reactor Supercritical by ~60 ih

TREAT Model

All of the analysis performed here is based on the minimum critical core.

Given the symmetry in the vertical dimension a 2-dimensional code was chosen for the analysis.

FEMP2D is a finite element, p1, code that appears adequate for the analysis.

Cross sections were derived from the 238 group criticality library for ENDFVII.0 provided with SCALE 6.1.

The 238 group library was collapsed to 30 groups for most of the analysis– 20 fast and 10 thermal groups.

TREAT Model (2)

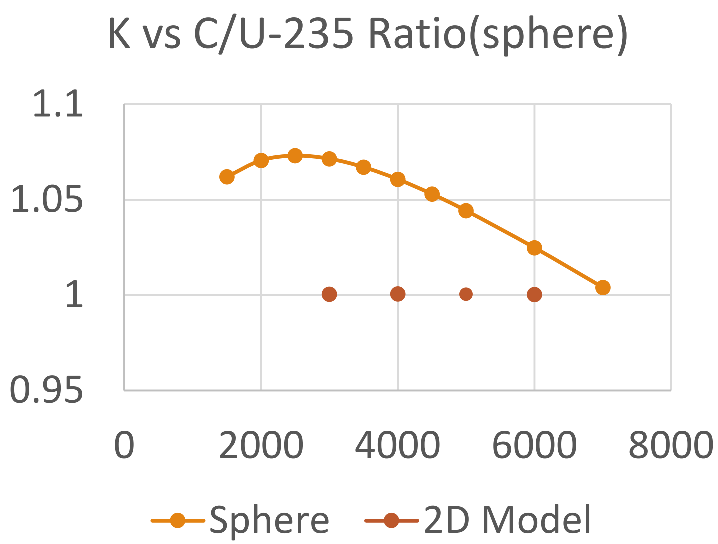
Two adjustments were made to the original design as a result of ‘as built’ measurements.

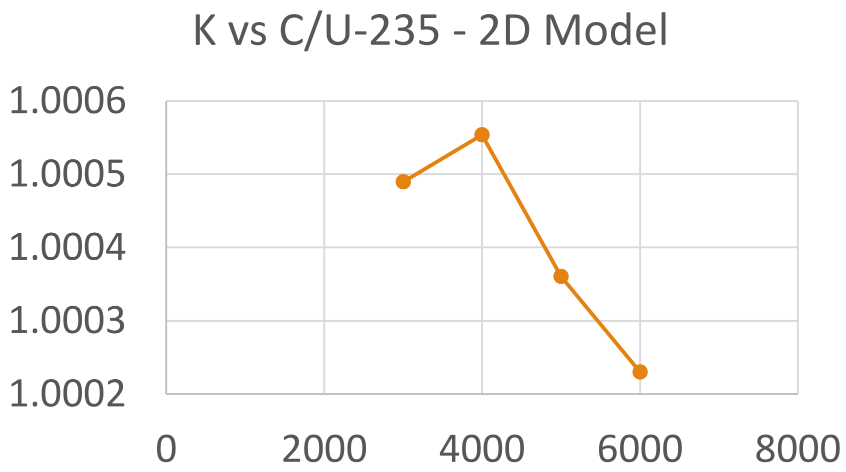
- The carbon in the core material was estimated to be only 59% graphite and 41% free carbon
- The boron concentration was greater than anticipated and measured to be approximately 7 ppm as opposed to 1 ppm.

The small core with control rods withdrawn had an excess reactivity of ~60 ih, or a Δk_{excess} of 0.00157

We estimated the transverse buckling to be based on the fuel height plus 2 fast diffusion lengths on both ends to give a dimension of 157.5 cm. This gave a Δk_{excess} of 0.00042. The exact Δk_{excess} in our model required an effective vertical dimension of 166. 5 cm

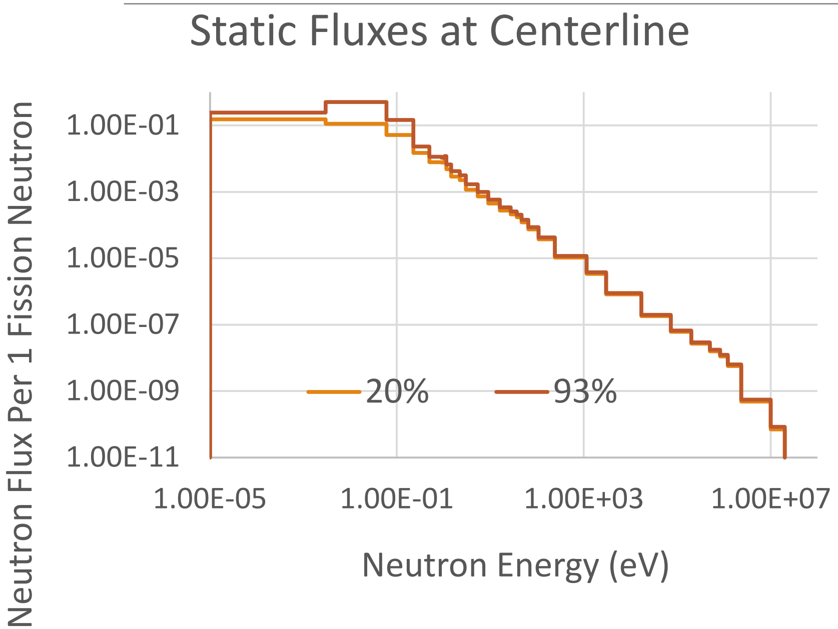
Estimating the C/U-235 Ratio for the Restart

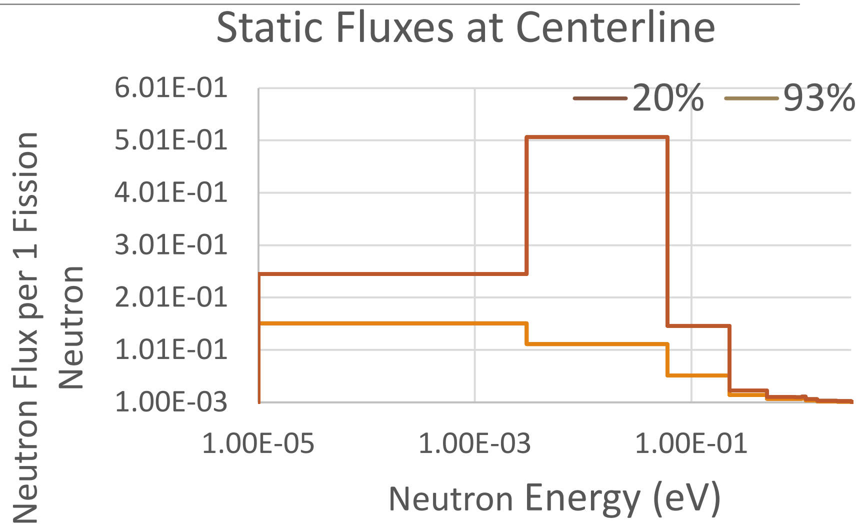




To estimate the required C/U-235 ratio for the restart core to have the same size as the original, we started with a spherical model with a graphite reflector with an exactly critical original core. The graph on the left gives the results for the equivalent sphere. It contains no control rod elements. The red dots at the bottom are the results of the 2D calculation and the expanded plot on the right indicates that the ratio for C/U-235 of about 4000 is optimum.

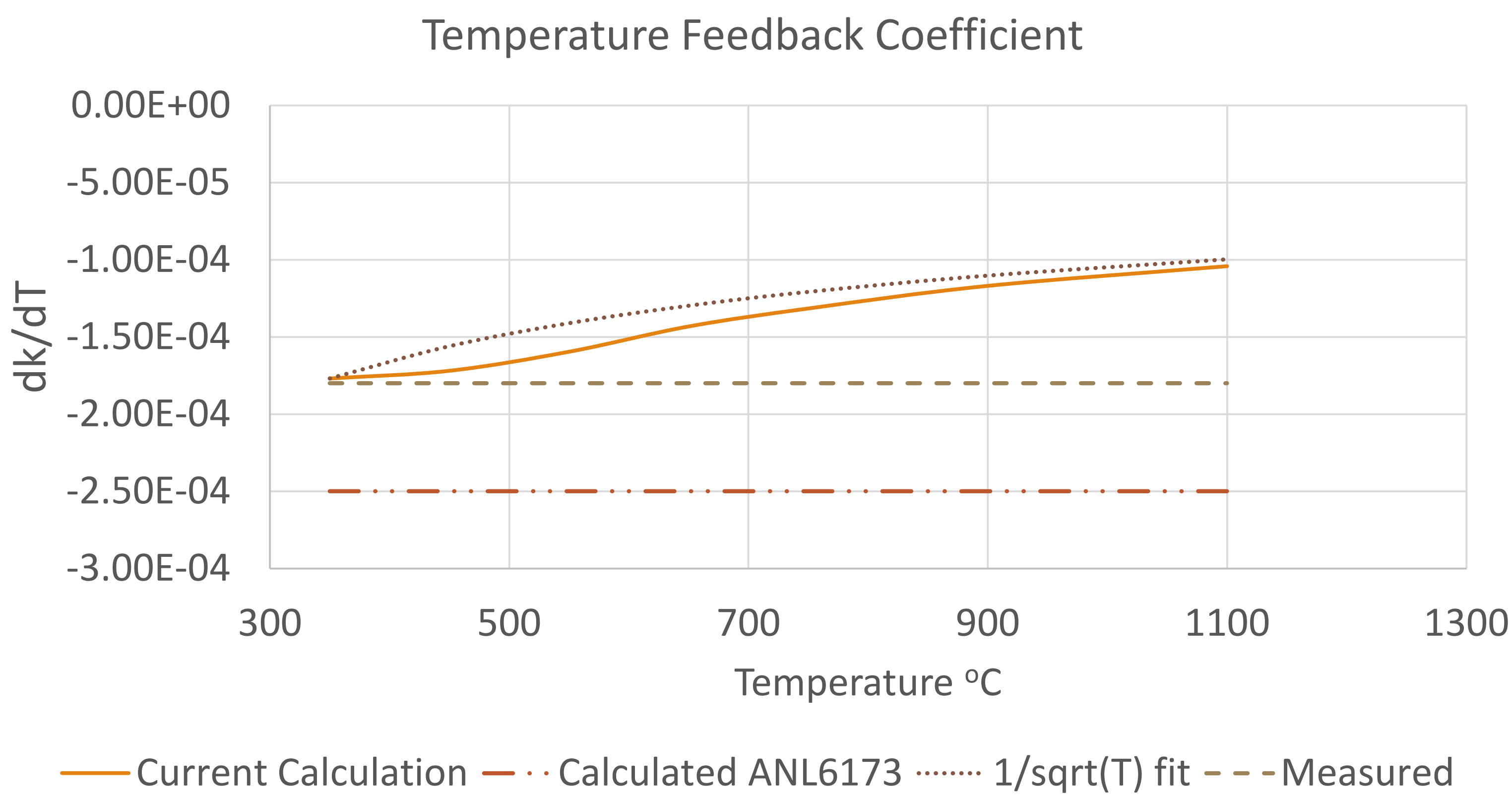
Centerline Flux in the Reactor



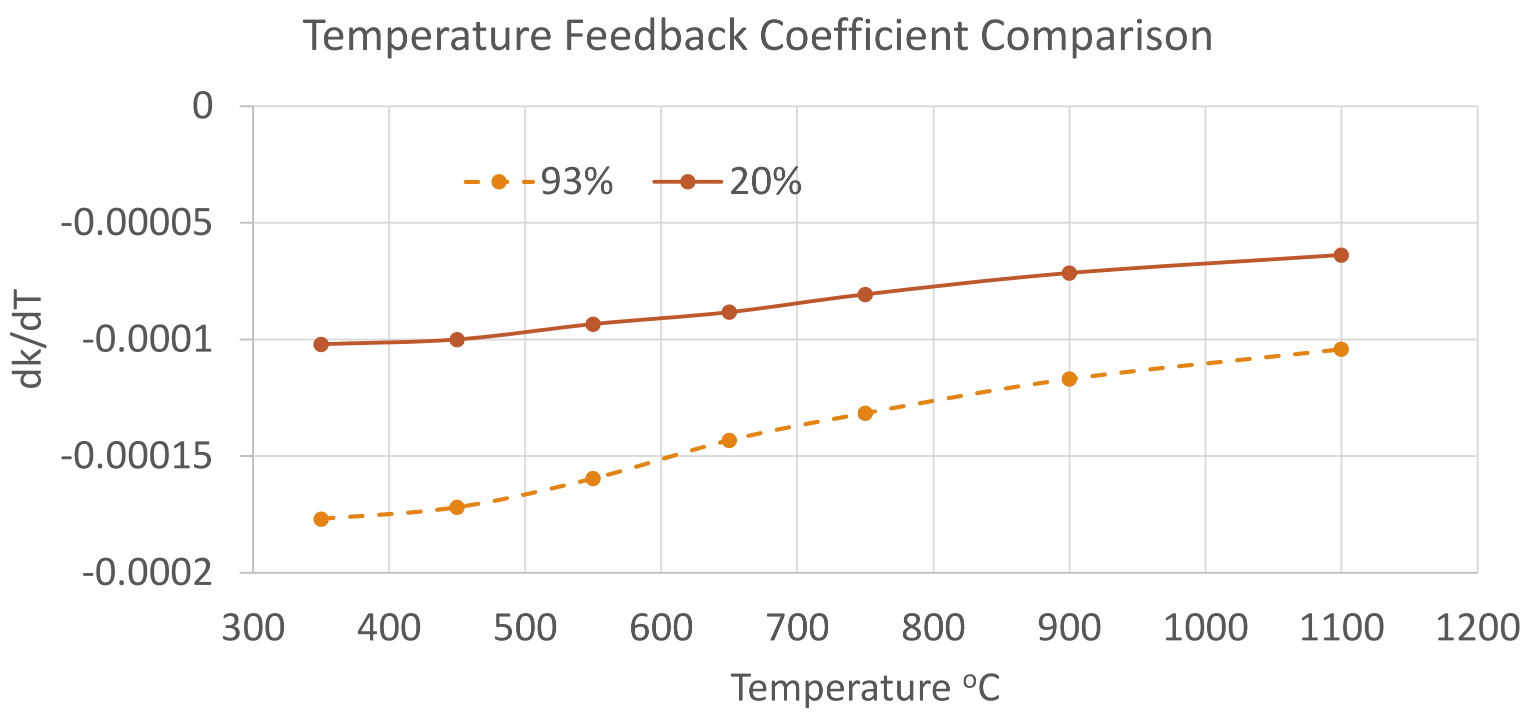


The figures above compare the fluxes on the centerline of the small core. There does not appear to be a big difference over the fast range. Neither spectrum shows a fission hump and both are primarily 1/E spectra. The major difference occurs in the thermal range where the group around 0.01 ev shows a flux per fission neutron for the 20% enriched core is about 1/5 that of the original 93% enriched core.

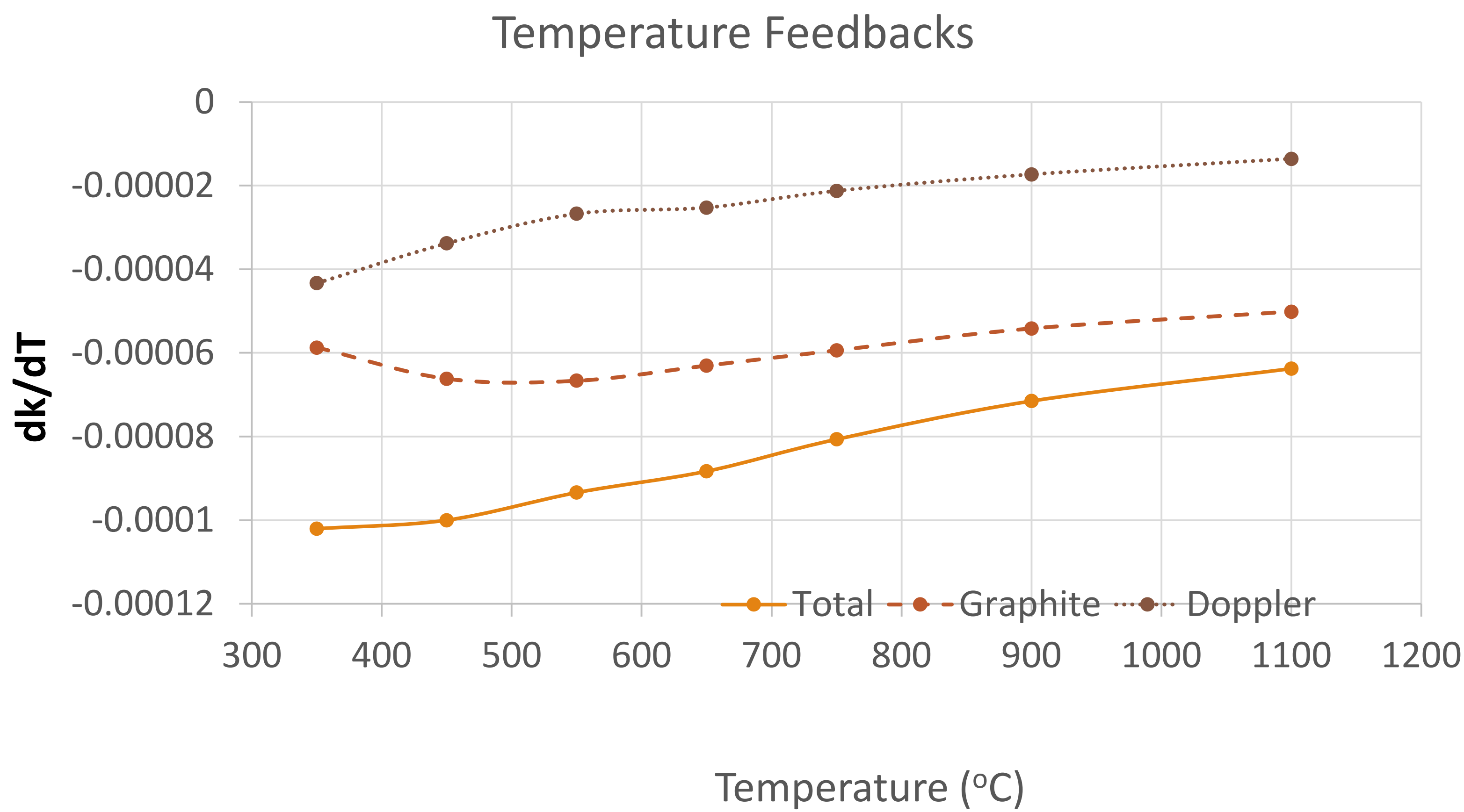
As Built Temperature Feedback Coefficient



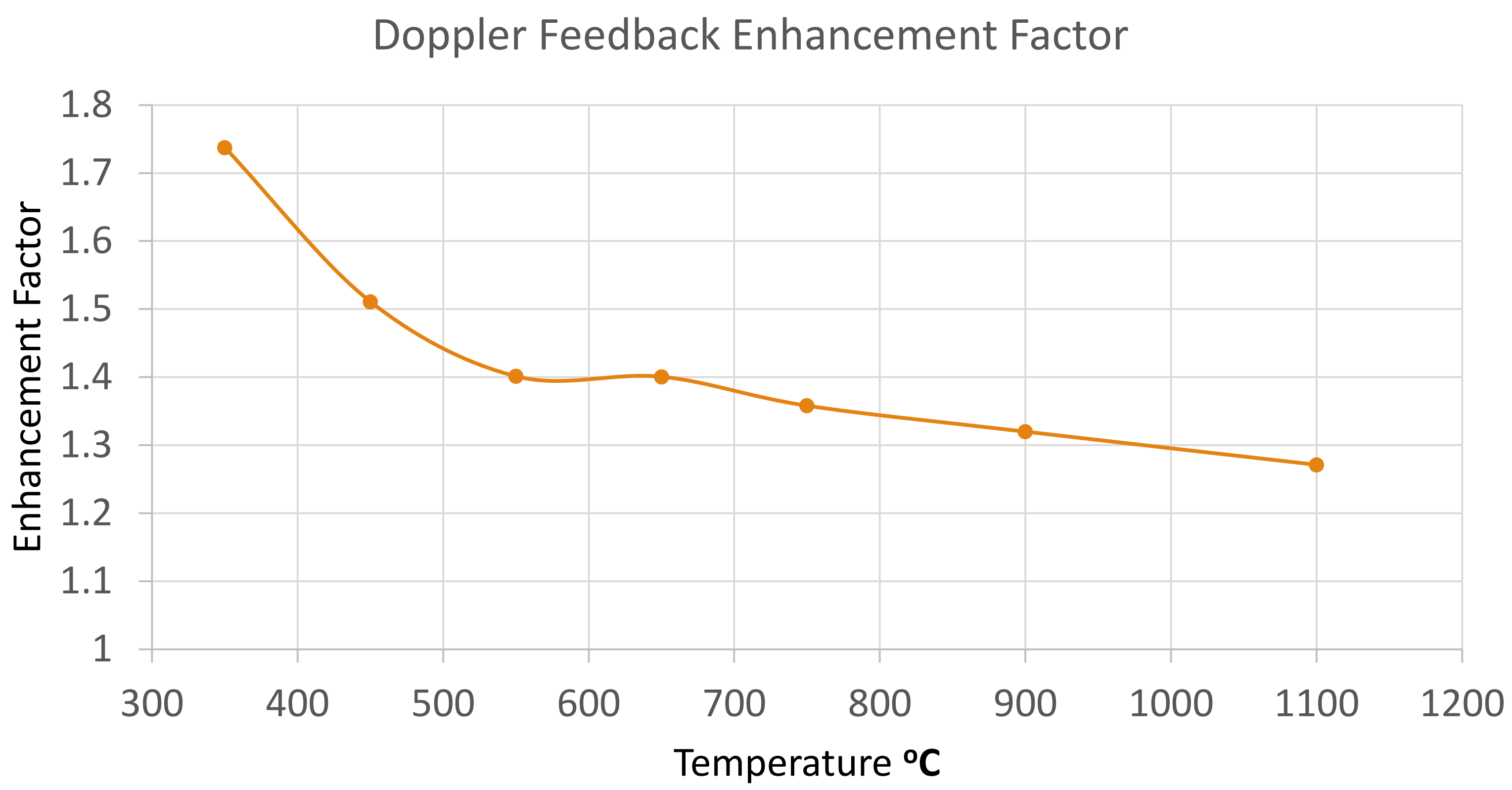
Temperature Feedback Comparison



TREAT Restart Feedbacks



U-238 Doppler Enhancement



Transient Models

Calculated TREAT As Built Lifetime 246 μsec

Calculated TREAT Restart Lifetime 185μsec

α=(k-1)/l,   l=(k-1)/α

Reported Lifetime 700 to 1000 μsec

Major discrepancy - still investigating

Modeled 4 transients described in ANL-6173

Feedback coefficient reduced from 1.8E-4 to 1.3E-4 based on peak core temperature rather than an isothermal core

Matched reactivity insertion, reduced lifetime by 25%, reduced temperature feed back by 45%, and increased core mass by 56.2 kg.

Transient Model Results

			Peak Power (MW)		
Δk	$\rho(\$)$	Tau	Measured	PK Mod	Restart(PK)
0.0095	1.319	0.31	54	62.8	140.3
0.0115	1.597	0.19	140	134	319
0.0155	2.153	0.105	380	399	1007.3
0.019	2.639	0.075	860	781	2025.1
			Temperature Rise (K)		
Δk	$\rho(\$)$	Tau	Measured	PK Mod	Restart(PK)
0.0095	1.319	0.31	119	91.7	159
0.0115	1.597	0.19	145	110	191
0.0155	2.153	0.105	176	145	254
0.019	2.639	0.075	237	176	310

Conclusions

A TREAT RESTART core is possible that will fit in the original footprint with 20% enriched fuel and a C/U-235 ratio of ~4000.

The thermal flux on centerline will be significantly lower if no adjustments are made.

The temperature feedback coefficient will be reduced by approximately 45%.

Nominal transients will reach larger peak powers and greater core temperature rises.