LLNL-PRES-748204

Thermal Epithermal eXperiments (TEX) First Critical Experiments with Plutonium-Aluminum Zero Power Physics Reactor (ZPPR) Plates

Presented at the Nuclear Criticality Safety Program (NCSP) Technical Program Review
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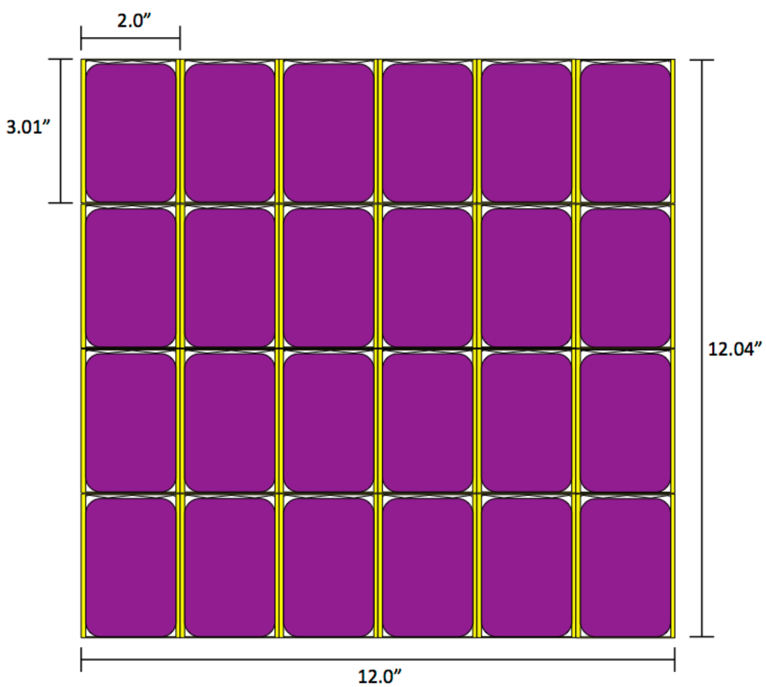
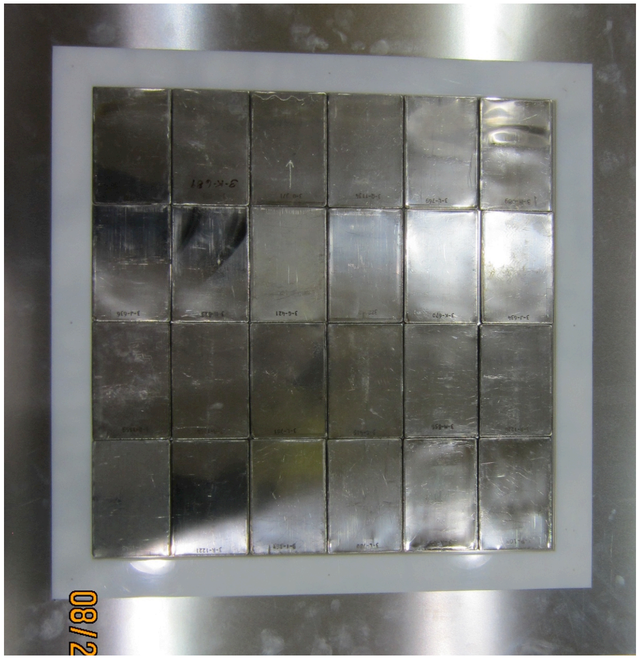
IER 184: Thermal/Epithermal eXperiments (TEX)

- TEX Goals
  - Using available NCSP fissile materials, create critical benchmarks to address the nuclear data and validation needs for criticality safety
  - July 2011 at Sandia National Laboratories, Albuquerque, NM
    - Representatives from US, UK, and France
    - Main take-aways
      - Intermediate spectrum experiments needed (only 2.1% of ICSBEP Benchmarks)
      - Test-bed assemblies that span multiple energy spectra are incredibly useful for nuclear data validation
      - Consensus prioritization of nuclear data needs (in order):
        - ^{239}Pu, ^{240}Pu, ^{238}U, ^{235}U, Temperature variations, Water density variations, Steel, Lead (reflection), Hafnium, Tantalum, Tungsten, Nickel, Molybdenum, Chromium, Manganese, Copper, Vanadium, Titanium, and Concrete (reflection, characterization, and water content)

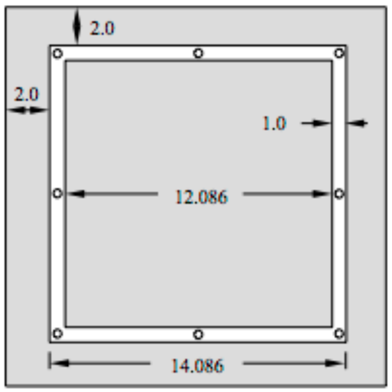
Plutonium TEX Experiments

- IER 184 is the Plutonium test bed experimental series, using excess plutonium/aluminum Zero Power Physics Reactor (ZPPR) plates
- Five baseline experiments, covering thermal, intermediate and fast fission energy regimes
- PANN plates arranged in approximately 12” x 12” layers (6 plates by 4 plates)

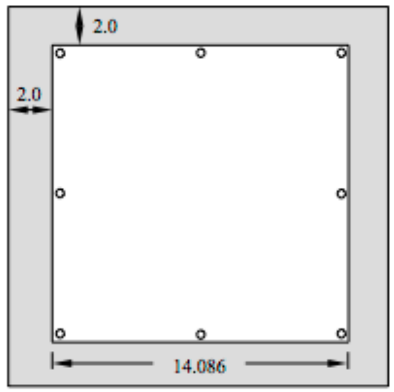




Trays Used to Facilitate Stacking Layers

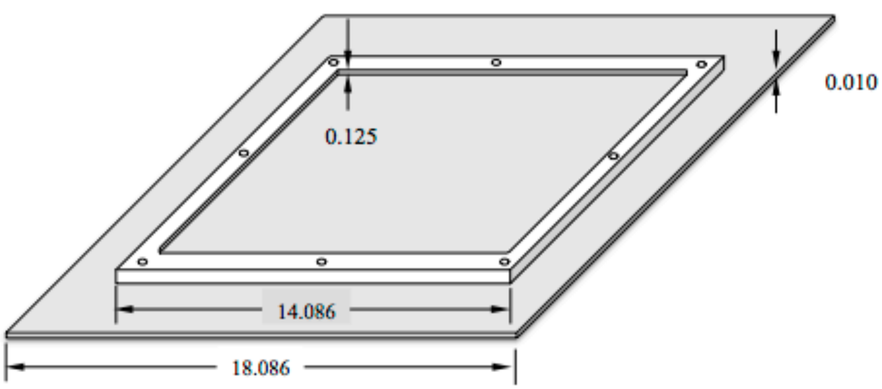


Top View of Tray

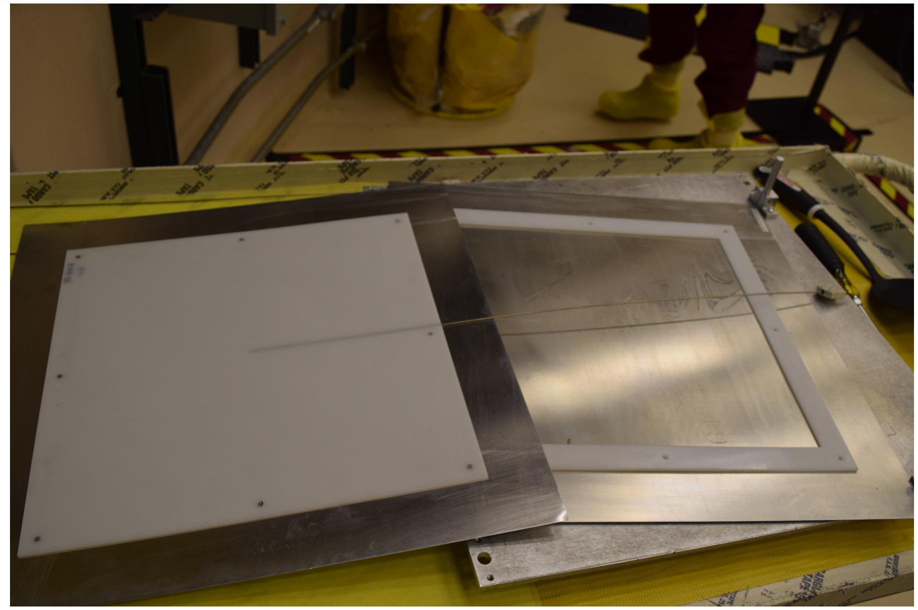


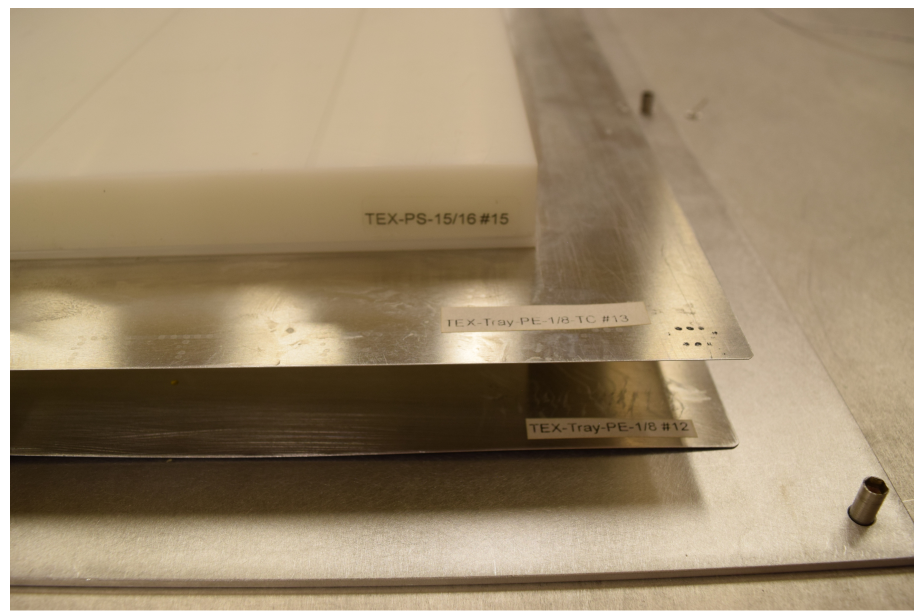
Bottom View of Tray

Side View of Tray

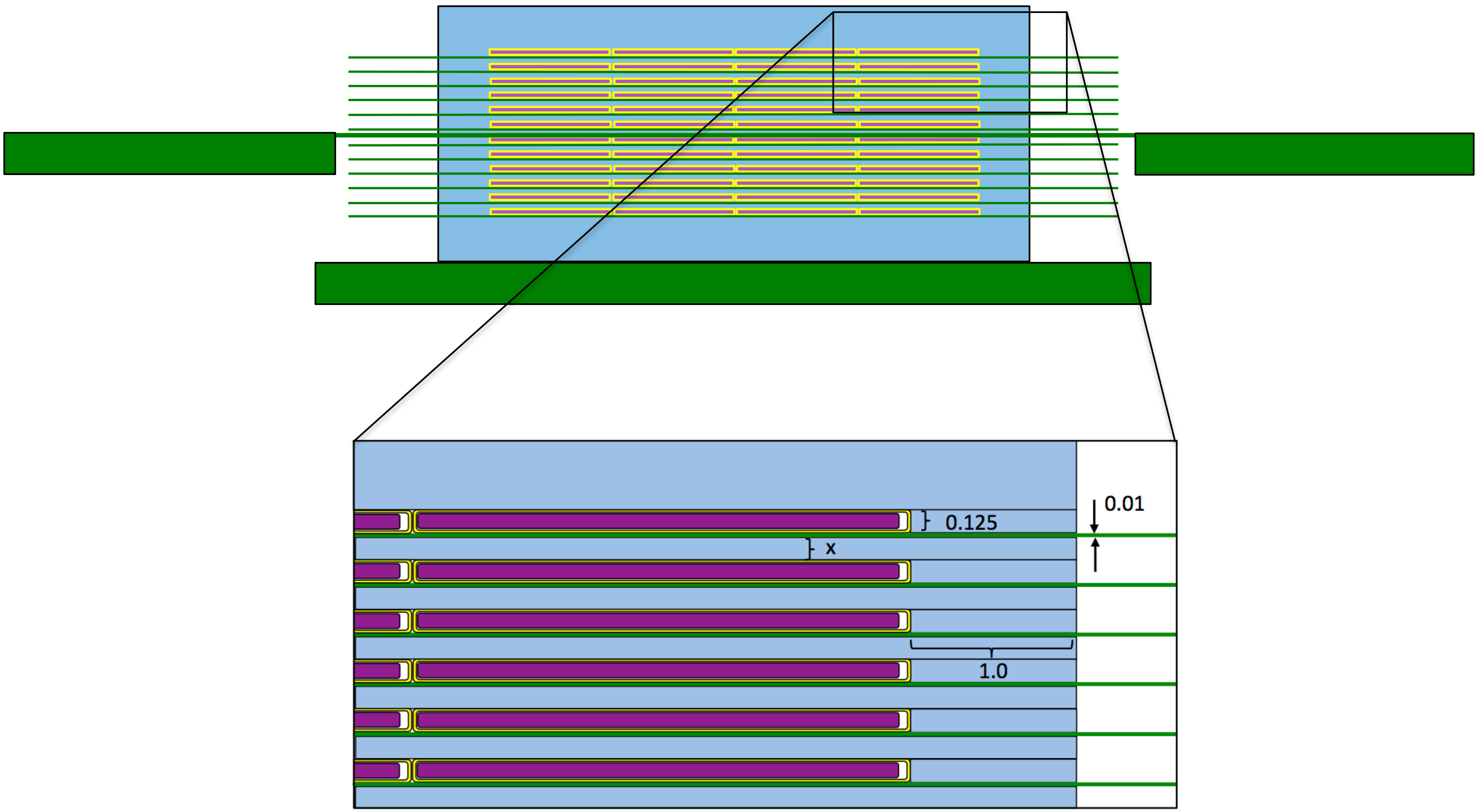


Perspective View of Top of Tray



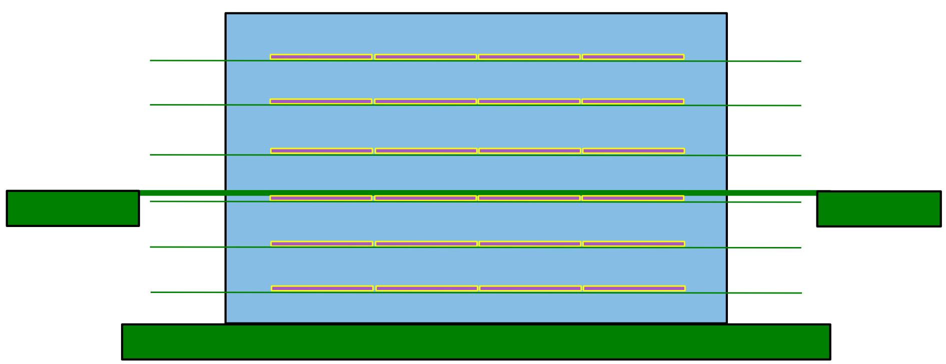


Plutonium Baseline Experiments

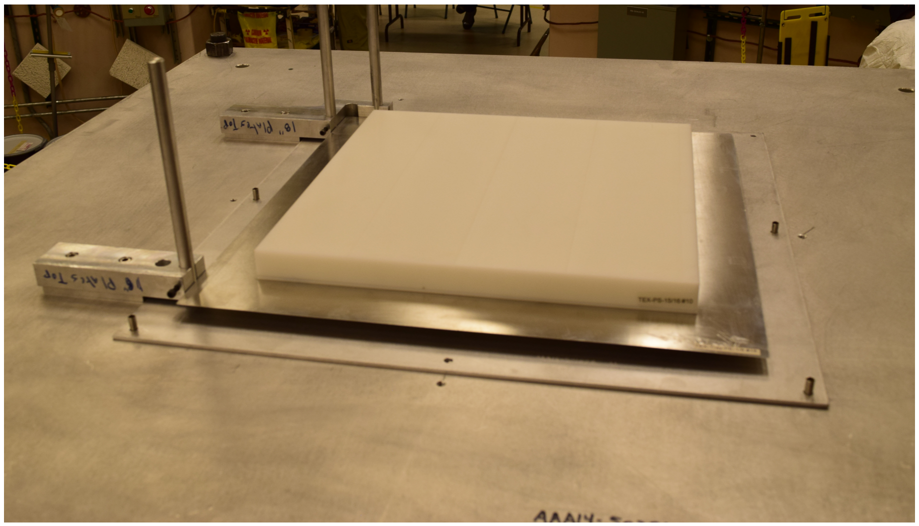


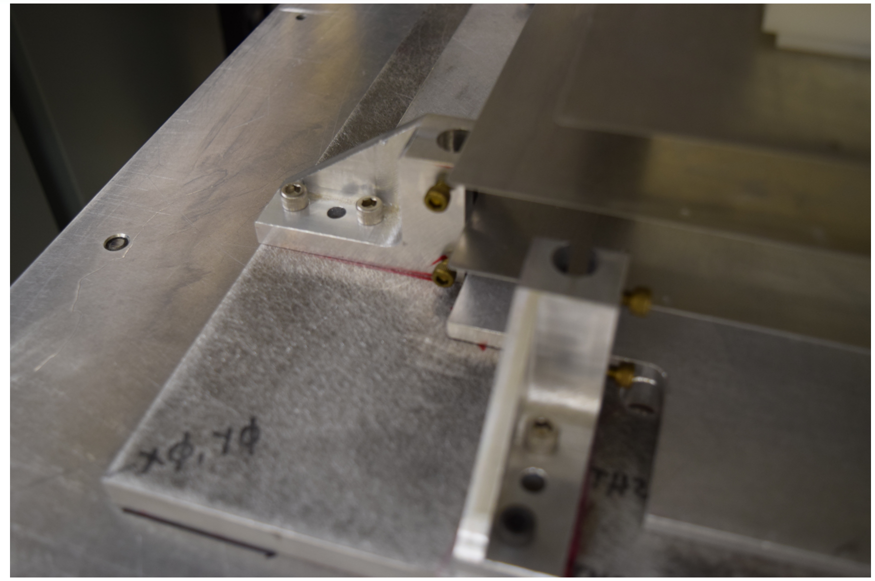
Completed Baseline Experiments

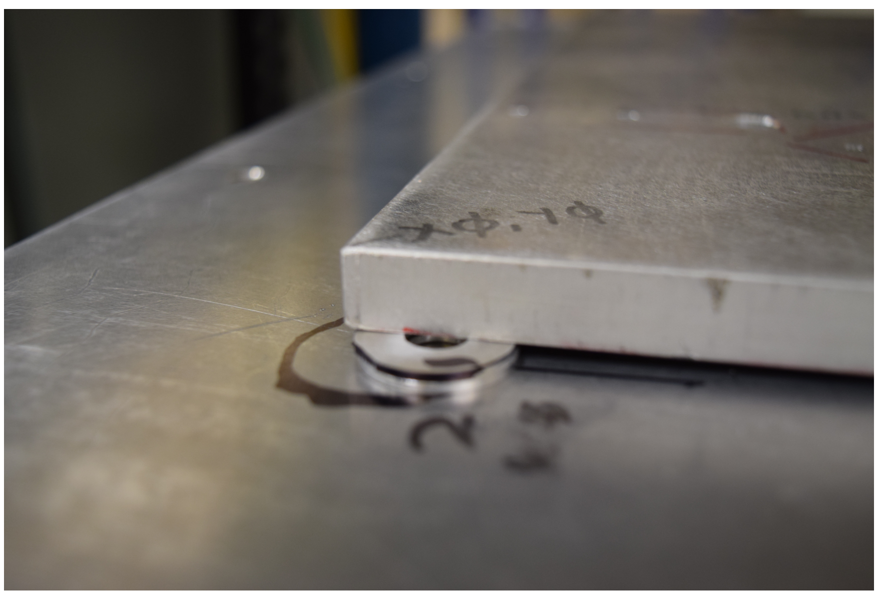
Experiment Number	Thickness of PE Plates (in)	Thermal Fission Fraction (<0.625 eV)	Intermediate Fission Fraction (0.625 eV-100 KeV)	Fast Fission Fraction (>100 KeV)
1	0 (no PE)	0.09	0.17	0.74
2	1/16	0.14	0.38	0.49
3	3/16	0.27	0.43	0.30
4	7/16	0.48	0.33	0.19
5	1	0.67	0.21	0.12

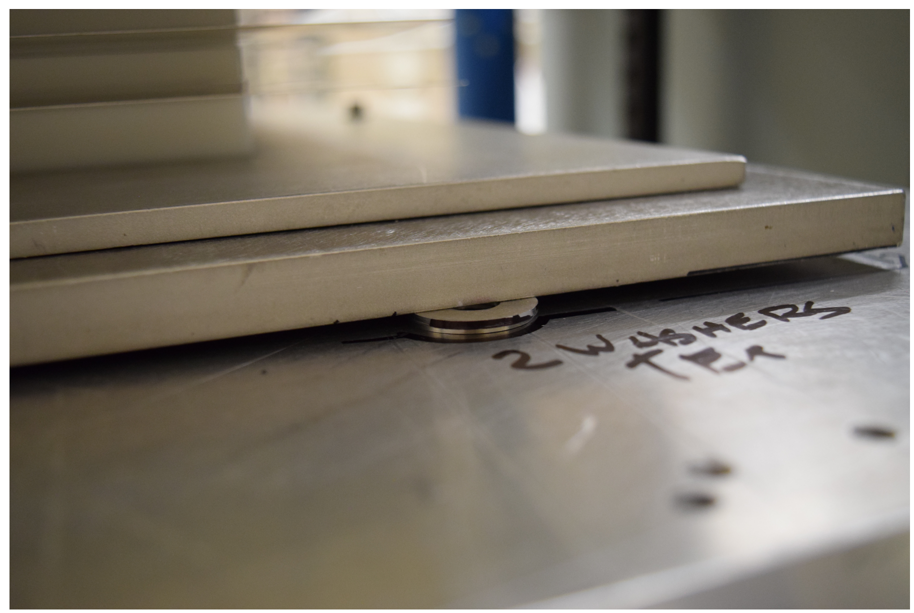


Alignment



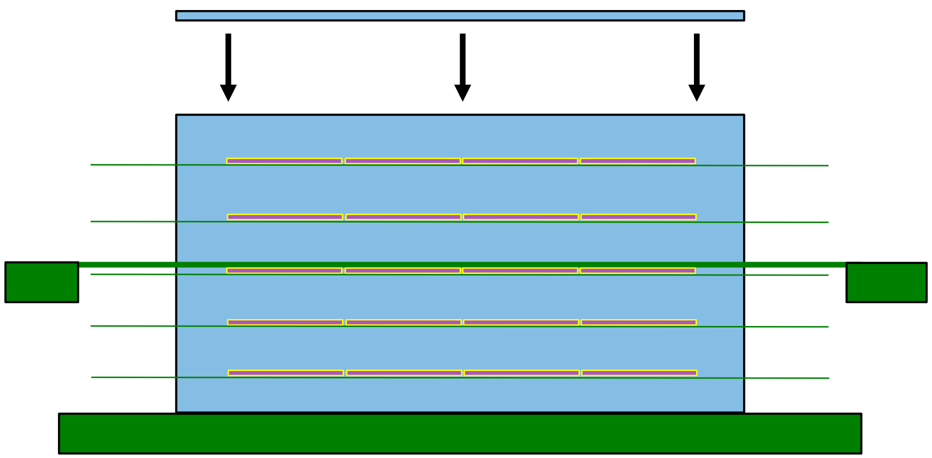


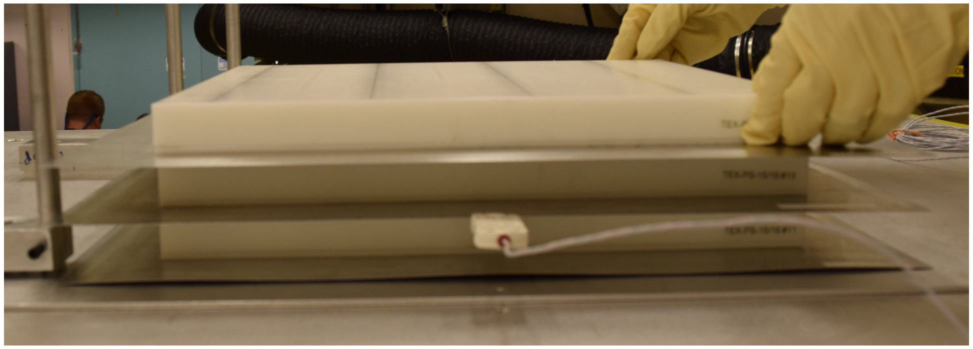




Experiment 5, 1" PE Moderator

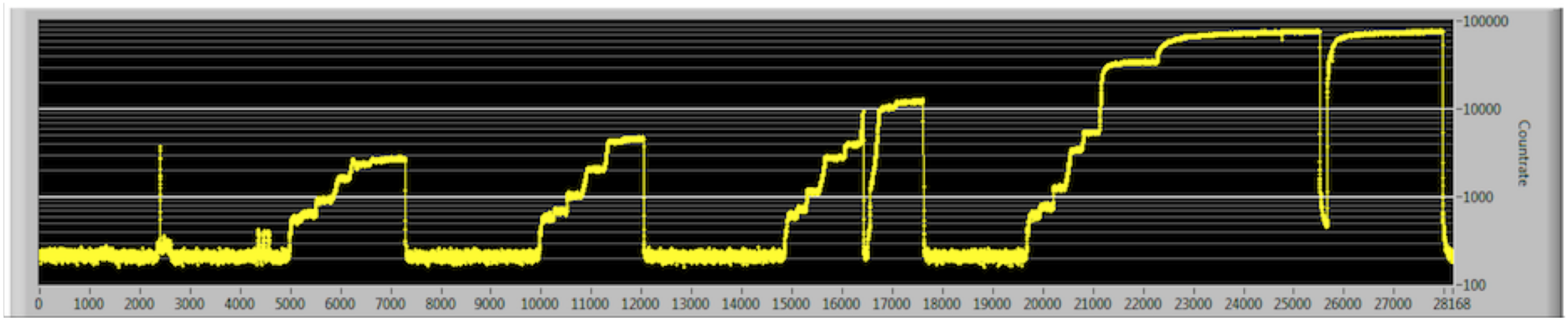
- CED-2 calculations predicted a critical configuration would fall between 5 full layers of Pu and 1 plate in the 6th layer
  - 5 layers was subcritical
  - With one plate in the sixth layer, criticality was achieved with a separation between the two assembly halves of 0.358"
- To obtain a benchmark configuration with full closure, additional reactivity was added to the 5 layer configuration by adding thicker upper reflector sheets





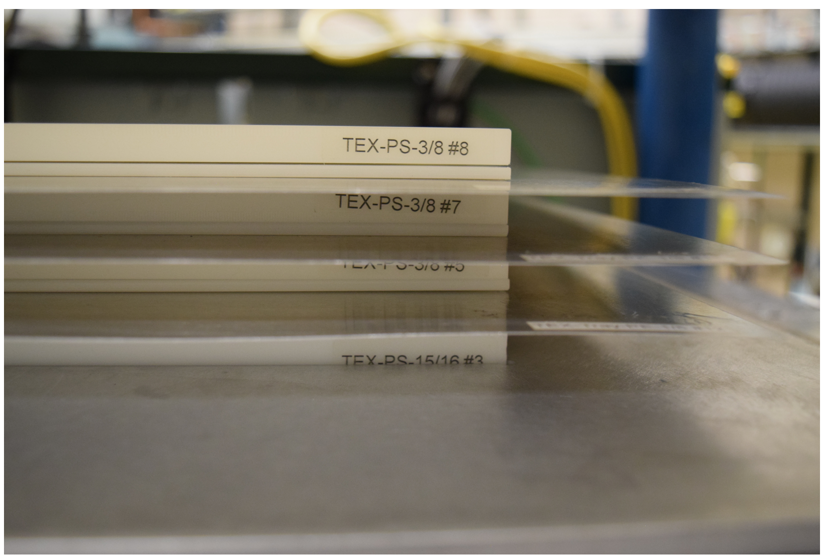
Experiment 5 Benchmark Configuration

- Two additional 1/8” reflector sheets added to the 1” upper reflector, for a total upper reflector thickness of 1.25”
- Configuration was kept together for 45 minutes, then ram was run out and reinserted, keeping the configuration together for 45 minutes
  - Count rate increased steadily and linearly
  - Estimated excess reactivity of 0¢



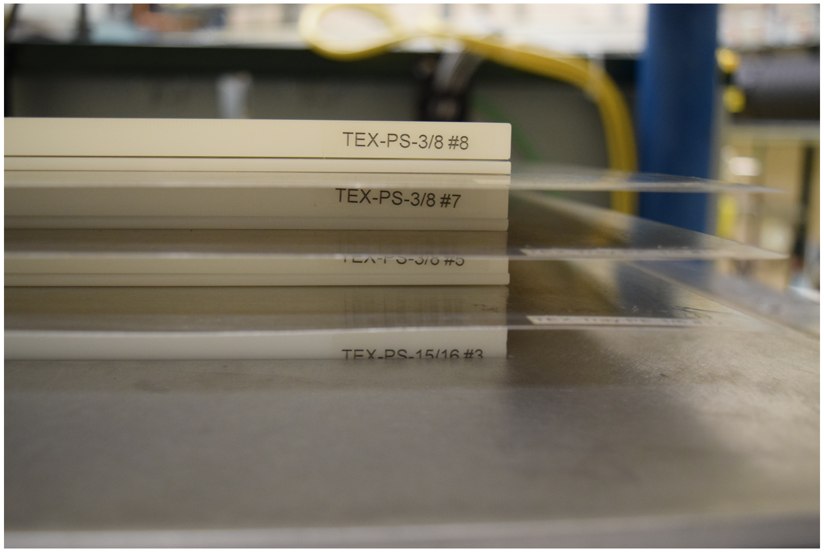
Experiment 4, 7/16" PE Moderator

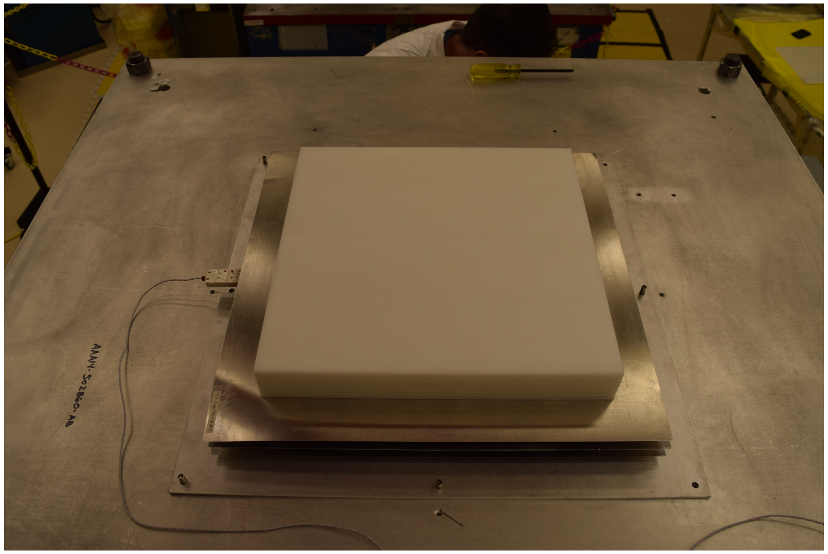
- Two benchmark critical configurations were completed for Experiment 4
- Partial Layer Configuration
  - CED-2 calculations predicted 2 plates in the eighth, top layer would be just critical
  - Critical configuration achieved with 4 plates in eighth layer
    - Estimated excess reactivity of 41.53¢



Experiment 4, 7/16” PE Moderator

- Two benchmark critical configurations were completed for Experiment 4
- Additional Reflector Height
  - Seven full layers of Pu plates with an upper reflector height of 1.6875”
    - Estimated excess reactivity of 26.17¢





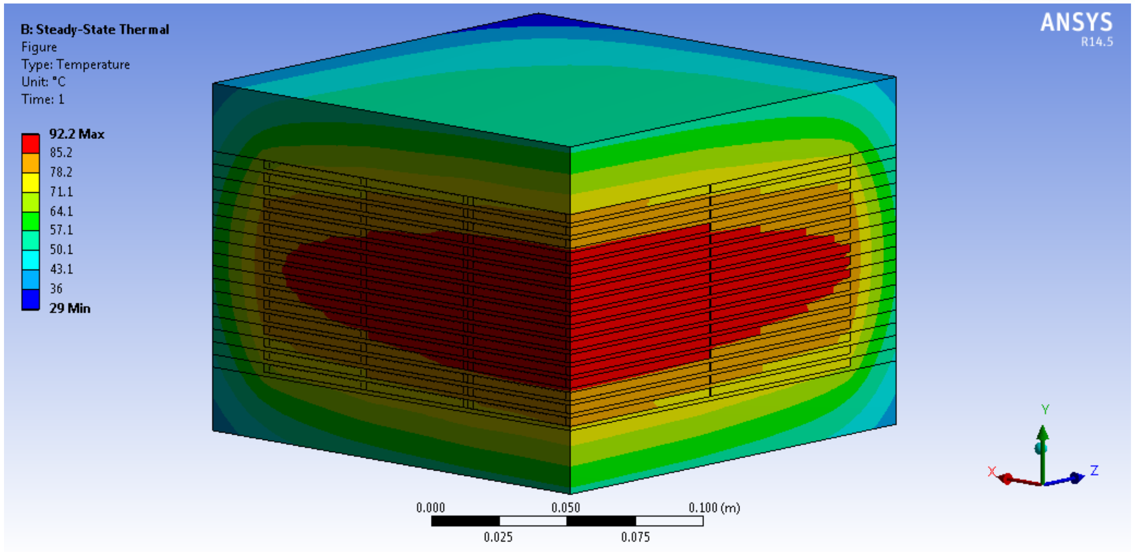
Heat Load Calculations

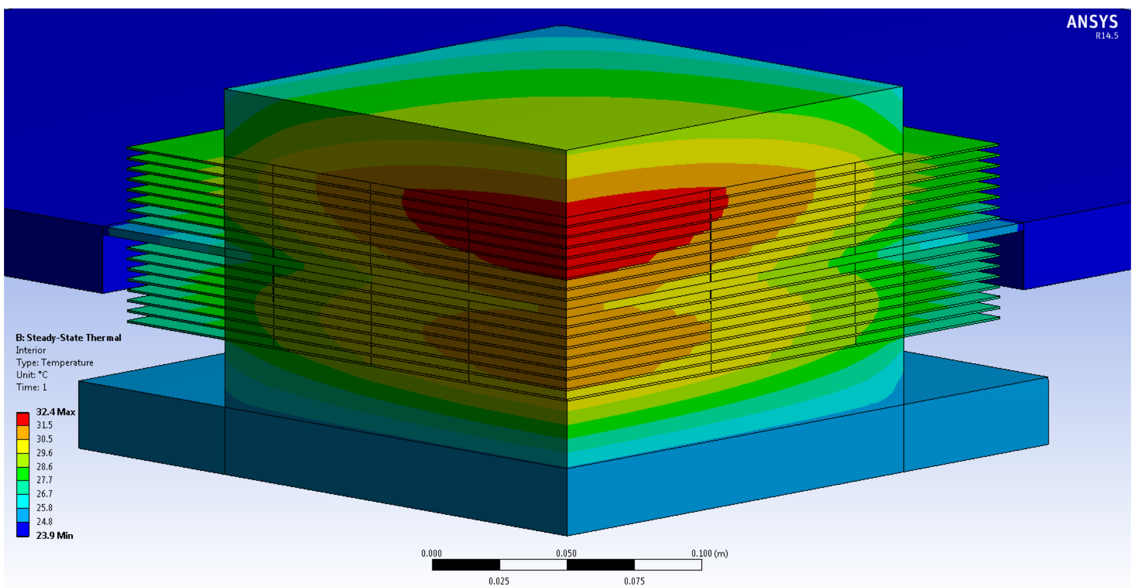
- Tens of kg quantities of Plutonium plates required for TEX configurations produce lots of heat

Isotope	Mass per ZPPR Plate (g)	Specific Power (mW/g)[14]	Heat Source (mW)
^{239}Pu	98.87	1.9288	190.700456
^{240}Pu	4.697	7.0824	33.2660328
^{241}Pu	0.0032	3.412	0.0109184
^{242}Pu	0.0049	0.1159	0.00056791
^{241}Am	0.4021	114.2	45.91982
Total	**103.9772**		**269.8977951**

- Heat load calculations were completed to ensure temperatures would not impact the polyethylene moderators (maximum long-term service life temperature of 80 °C)

Heat Load Calculations



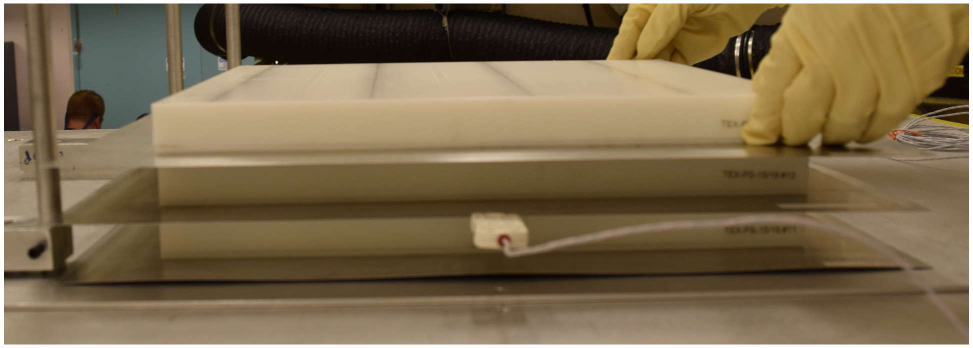


- ANSYS 14.5.0 Finite Element Analysis Software used to model TEX configurations with PE moderation
  - With 0.01" aluminum heat dispersal plates ("fins")
  - Without 0.01" aluminum heat dispersal plates

Predicted Temperatures Agreed with Measurements

	Ambient (C)	Peak Temperature (C)	Temperature Over Ambient (C)
Experiment 4 Measured	21.5 ± 1.0	34.1 ± 1.0	12.6 ± 2.0
Experiment 4 Predicted	22.0	32.7	10.7
Experiment 5 Measured	21.6 ± 1.0	32.4 ± 1.0	10.8 ± 2.0
Experiment 5 Predicted	22.0	31.8	9.8

- Overall, ANSYS models predicted very well the peak measured temperatures
- Aluminum heat dispersal plates (fins) worked!



Current Work (FY2018) for IER-184

- Complete 8 additional configurations
  - 3 additional baselines
  - 5 configurations including tantalum
- Sample a Pu/Al ZPPR plate to determine impurity content and confirm historical isotopic and chemical composition
  - Major cost of characterization (200K-300K) being covered by another program
- Analyze data and work on ICSBEP benchmark

Thanks to LANL and NCSP!