IER 479: An Update on the Low Temperature TEX Experiment

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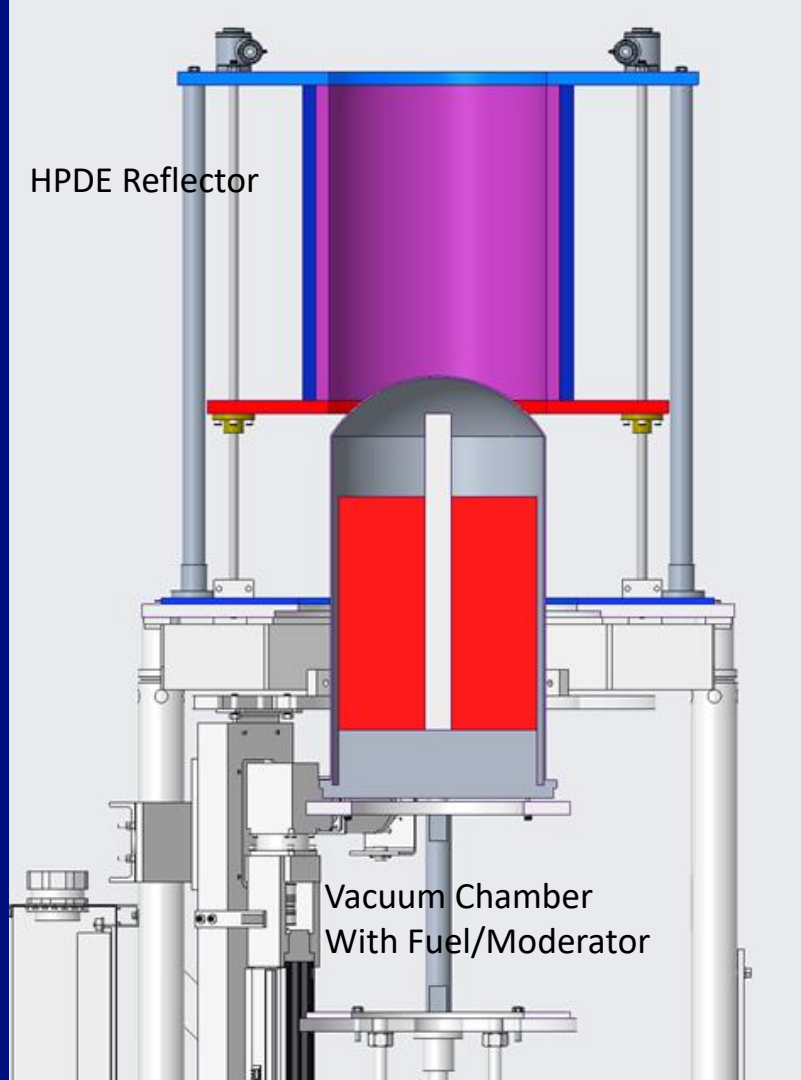
Overview

- Background
- Current Status
- Design
  - Vacuum chamber standoff
  - 1/M Approach to Critical Design
    - Handstack inside vacuum chamber
    - Reflector
    - Reflector Support
    - Subcritical on withdrawal of one SSM
    - Temperature Approach to Critical
  - Loss of Vacuum Accident
- Future Work

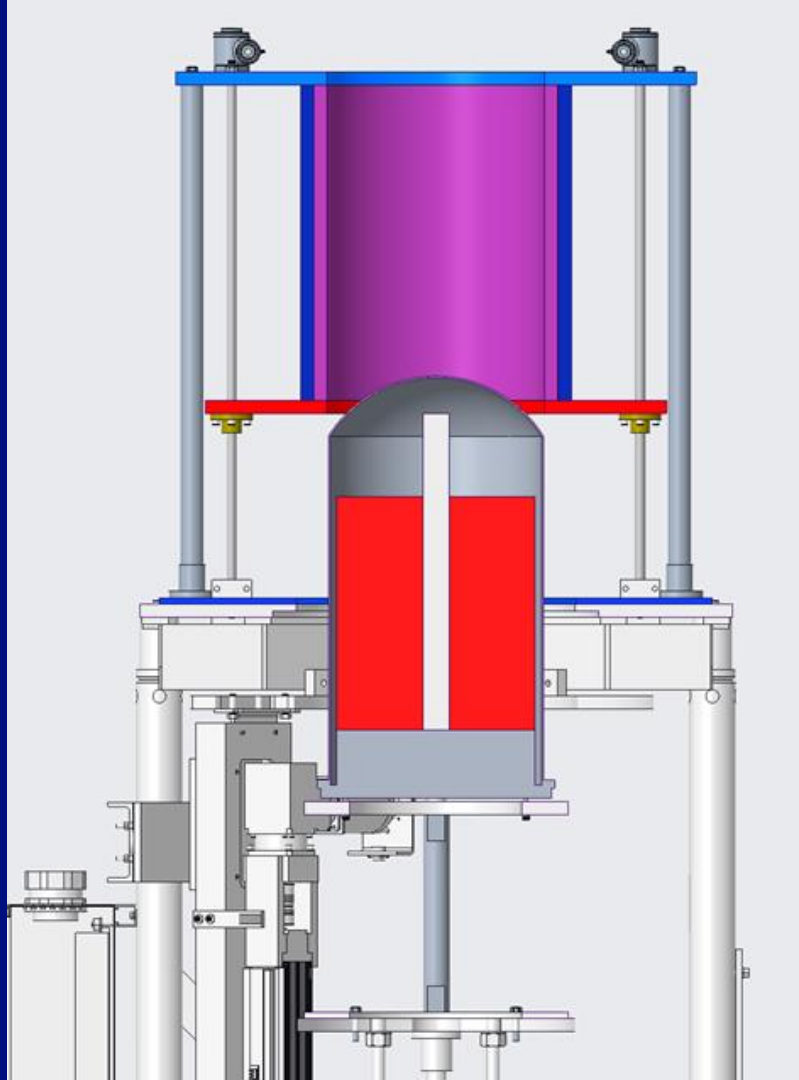
Background

- Low temperature (min -40 °C) critical experiment on Comet
- Vacuum chamber contains cooled stack of Jemima plates and interstitial material
  - Chamber reduces condensation at low temperatures
  - Will examine several temperatures
  - Reflector is at room temperature
- Design collaboration between LLNL and LANL
- Criticality is approached by driving vacuum chamber into variable height polyethylene reflector



Background

- IER 479 is a complex project
  - Vacuum chamber and equipment
  - Cooling, coolant, and equipment
  - Additional temperature monitoring
  - Stack of material inside vacuum chamber borders on handstacking limit from ANS-1
- Many design questions
  - How to design vacuum/coolant interface for lines/hoses?
  - How to perform 1/M for parts inside of vacuum chamber?
  - How to perform 1/M for outer reflector?



Current Status

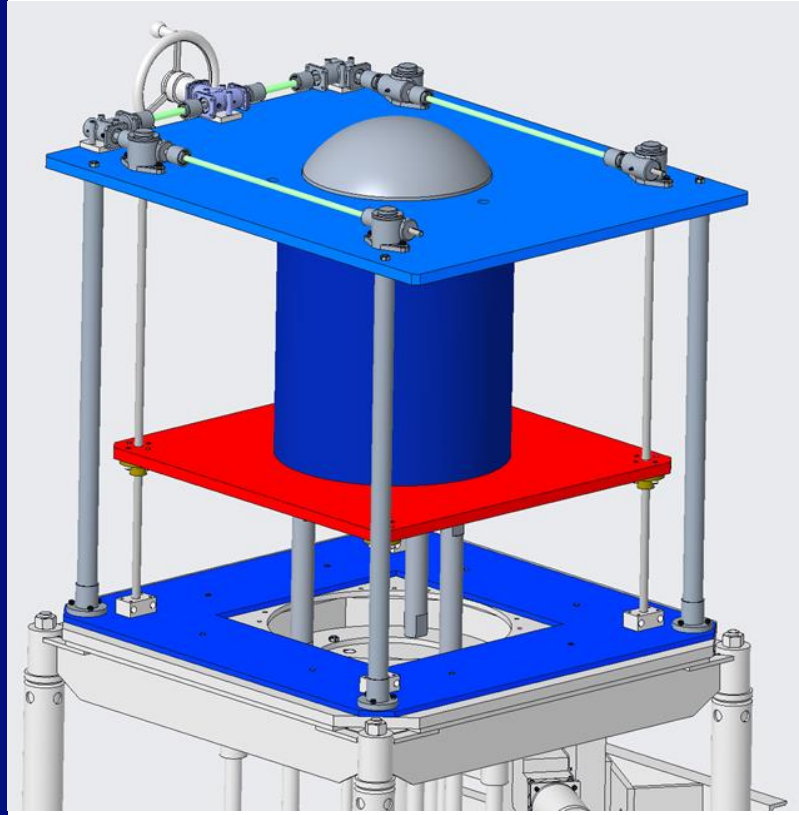
In CED-3A (finalizing design), with plans to complete in FY25.

Working on finalizing design to send for procurement

- Anticipate procurements out in Q2

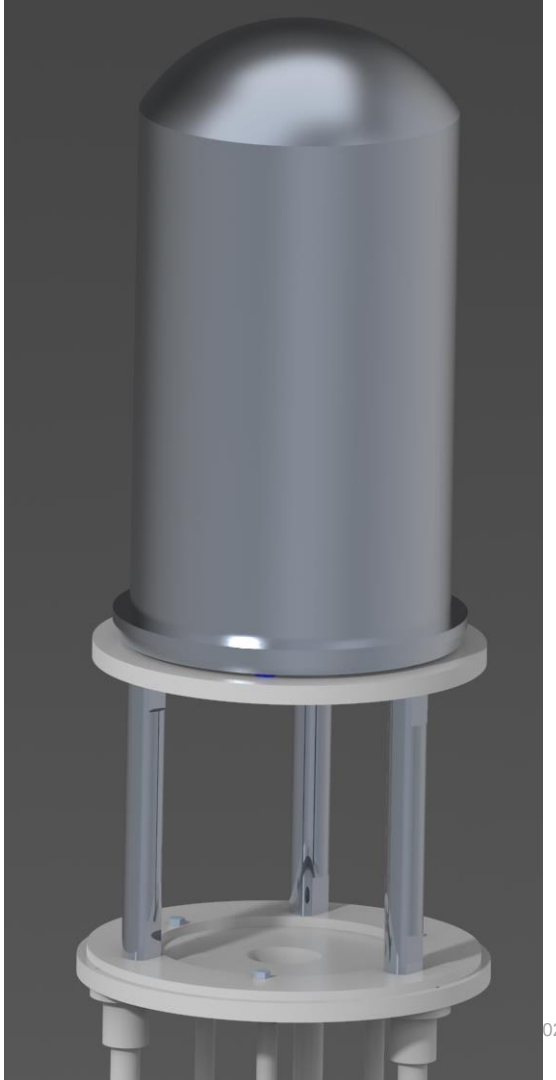
Concurrently working on experiment plan

- Plan to send to Criticality Experiments Safety Committee in Q2/3.



Vacuum Chamber Standoff

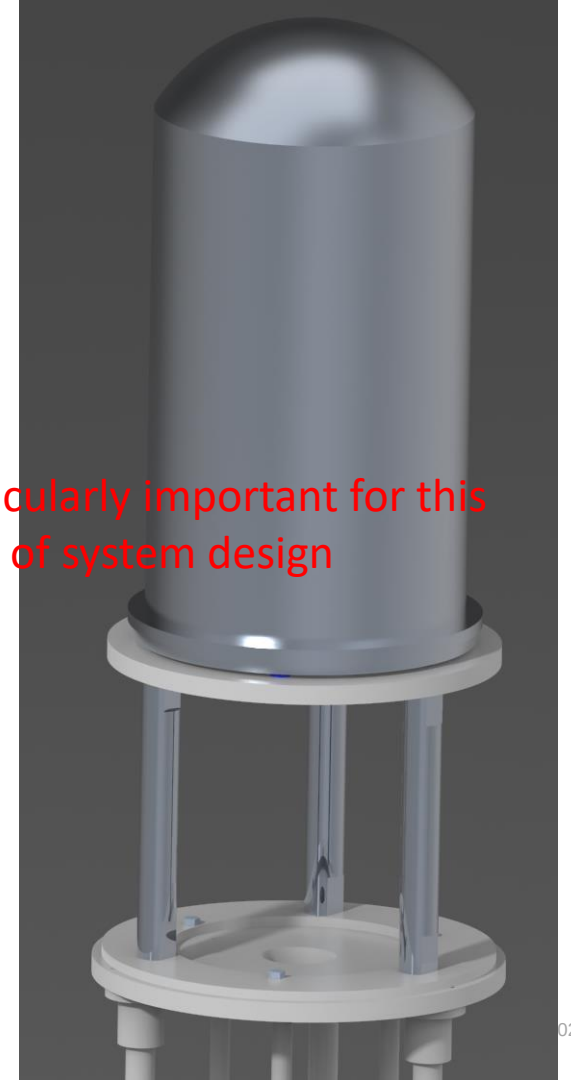
- Bottom clearance required for vacuum and chiller line connections
- Connects to Comet platen and vacuum chamber mounting holes



1/M Approach to Critical Design Considerations

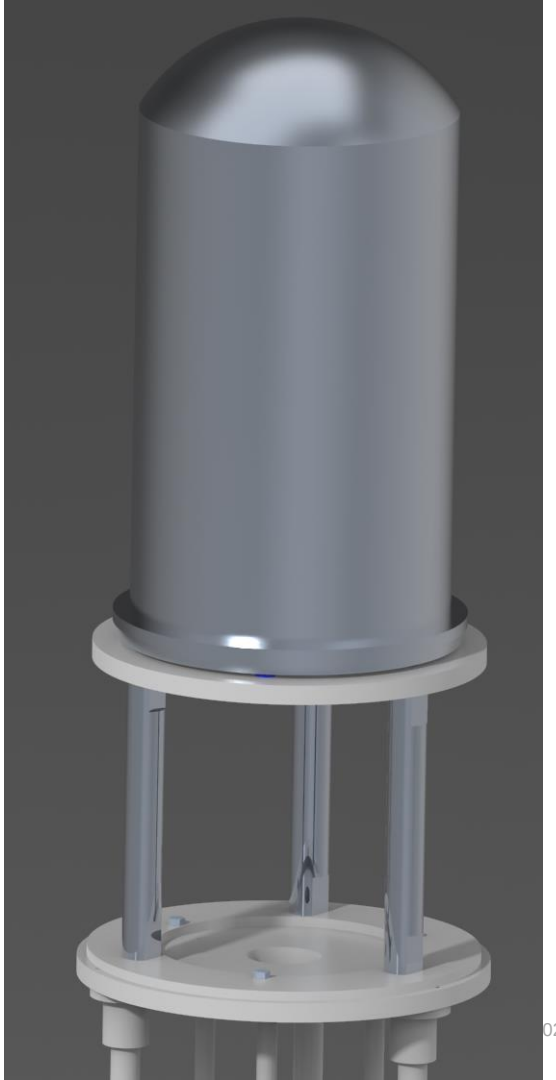
- Handstack Limit: Vacuum chamber with fuel and moderator needs to be k_{eff}<0.90
- Monotonic reactivity insertion as vacuum chamber is inserted into the upper reflector
  - System should not see an increase in reactivity when system is SCRAMed!
- SSM Subcritical Requirement: System should be subcritical when one Safety Shutdown Mechanism (SSM) is withdrawn
- Reactivity limit of $0.80

Particularly important for this type of system design



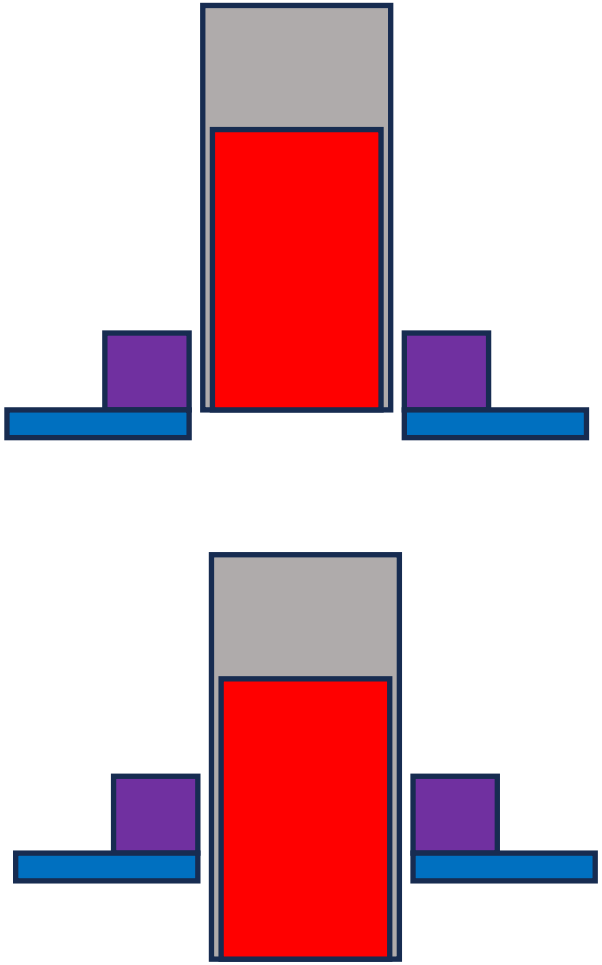
Handstack Limit

- Fuel/moderator in vacuum chamber just under k_{eff} 0.90
- 1/M Handstack is typically very conservative – will we reach the desired stacking inside the vacuum chamber before hitting our handstack limit?
  - Yes: Great!
  - No: Now what?
- Solutions (?):
  - Criticality safety documentation
  - Using calculated worths to demonstrate we are below $k_{eff} < 0.90$



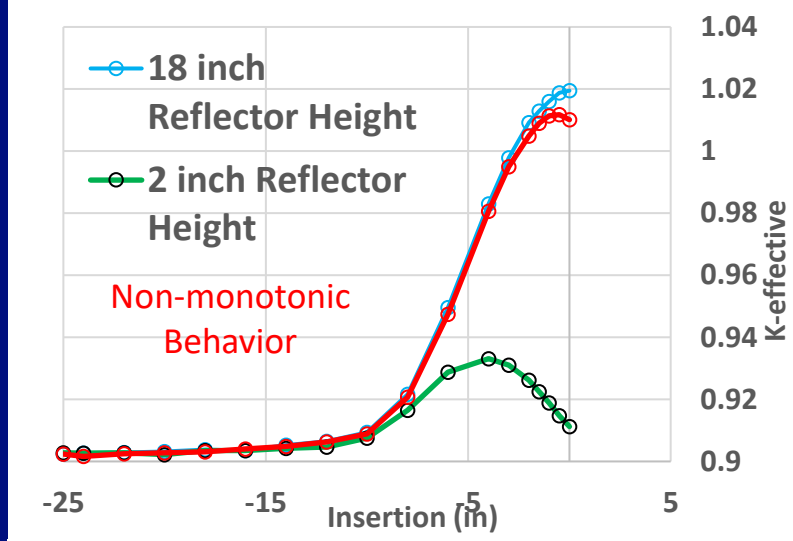
Reflector Worth

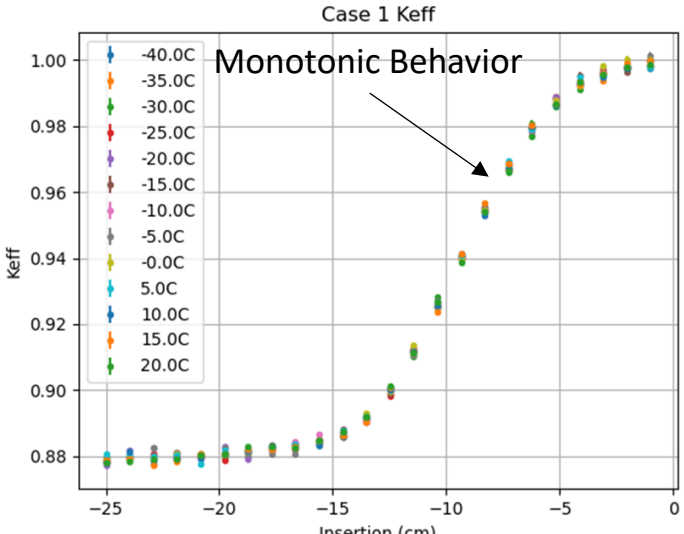
- If the reflector were to be built from the bottom up, during the 1/M the system would exhibit non-monotonic behavior (think Chernobyl or APRFR)
  - If we SCRAM the system, the reactivity increases!
  - So we have opted to build from the top down



Reflector Worth

- Building from the top down allows for this monotonic behavior that is desired, no matter the reflector height





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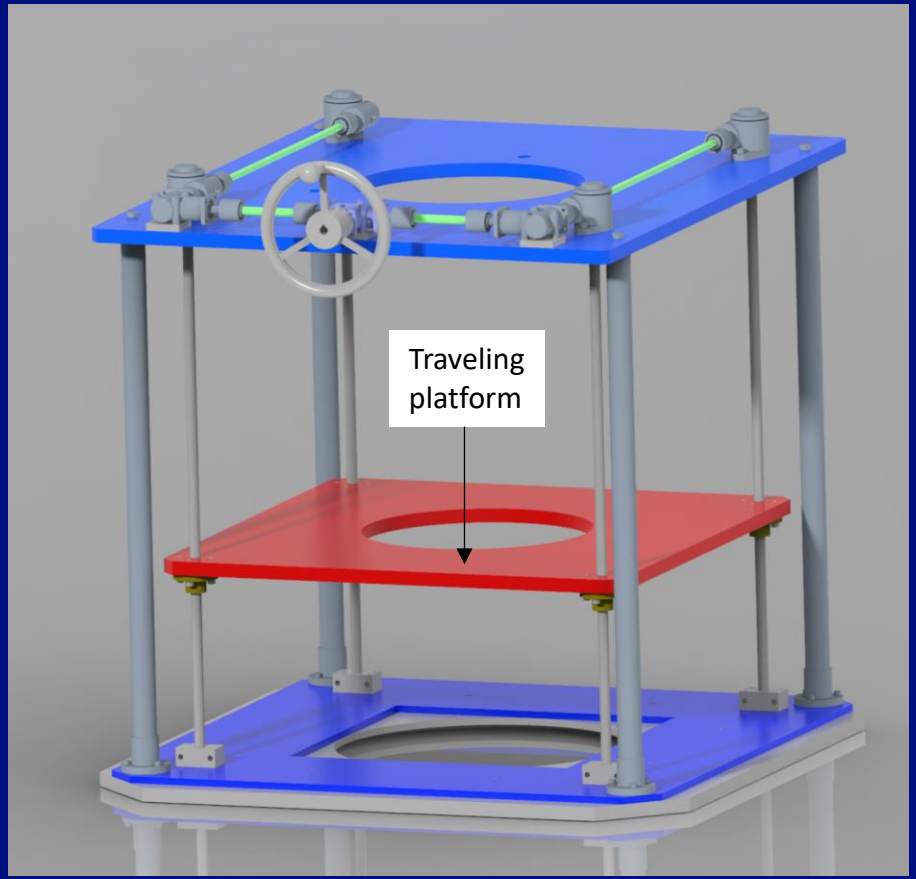
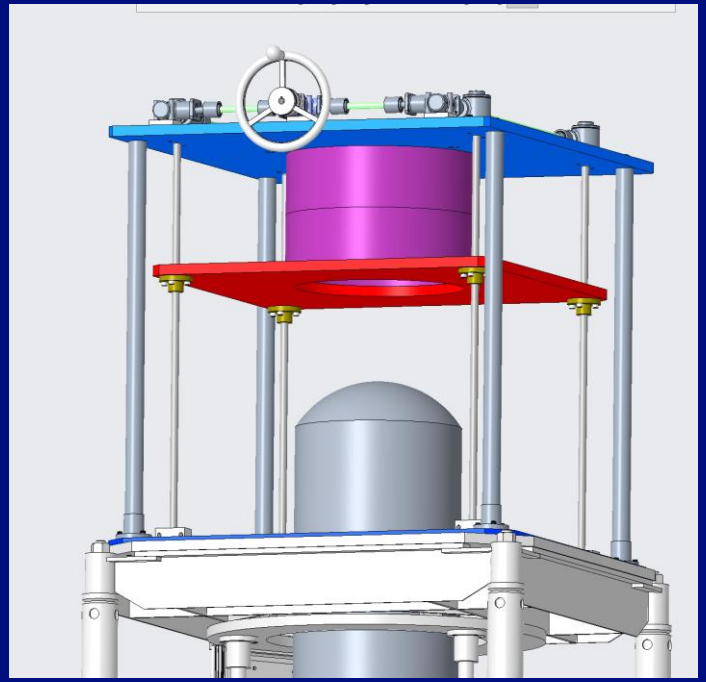
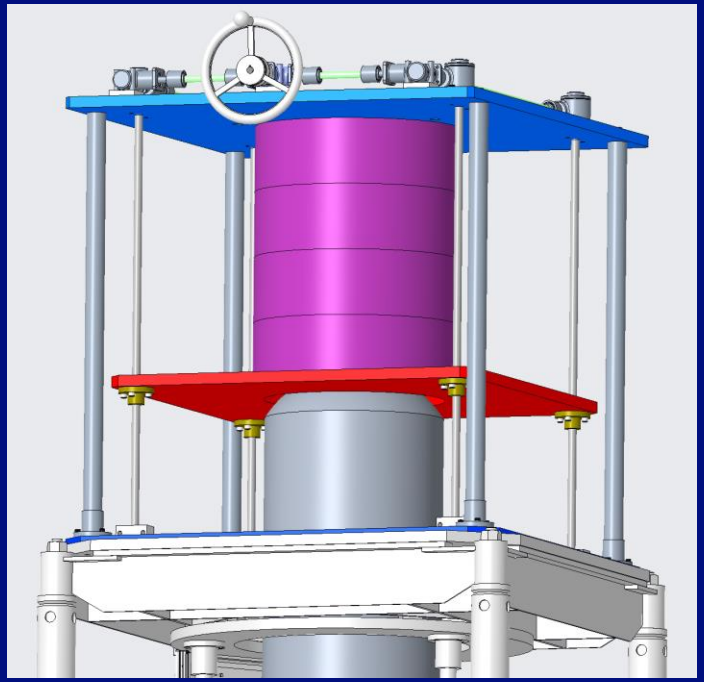
Reflector Support

- With a stationary reflector support, local criticality maximum before full insertion
  - Significant for first radial layer of reflector
- First layer of reflector must be built “top down”
- Traveling platform is required



Reflector Support: Continued



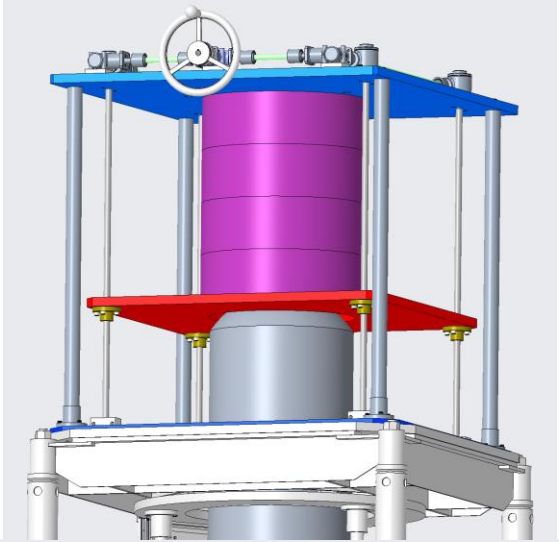


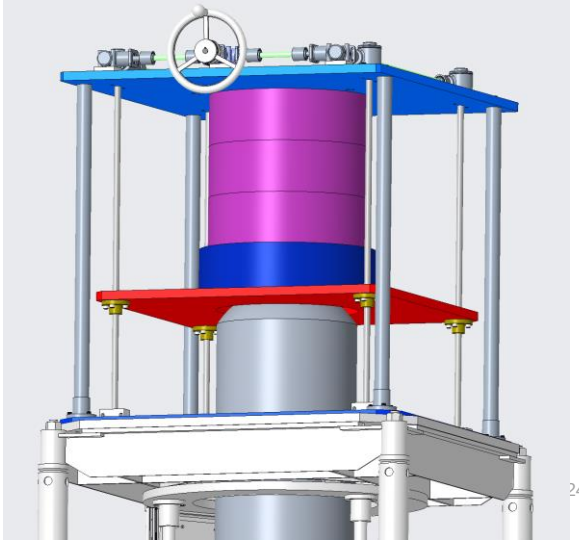
Reflector

- HDPE
  - 24” max height
  - Pins for alignment
  - Gap compression from reflector support
  - Located against top plate
- Approach to critical by a single radial layer (pink) to height from the top down
- If needed: Then moving to the next radial layer (blue) building up from the bottom

Reflector Worth

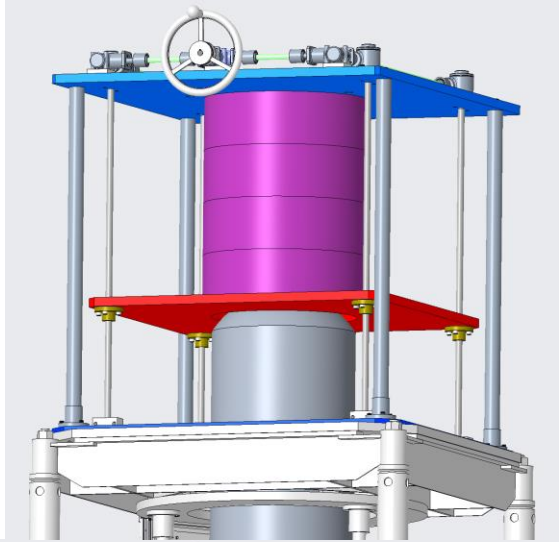
- The modeling indicates that the reflector exhibits diminishing efficiency as you expand radially (think about the BeRP ball demo), so after the first ~2” this effect is counteracted by the insertion
  - This allows us to build bottom up for any second layers

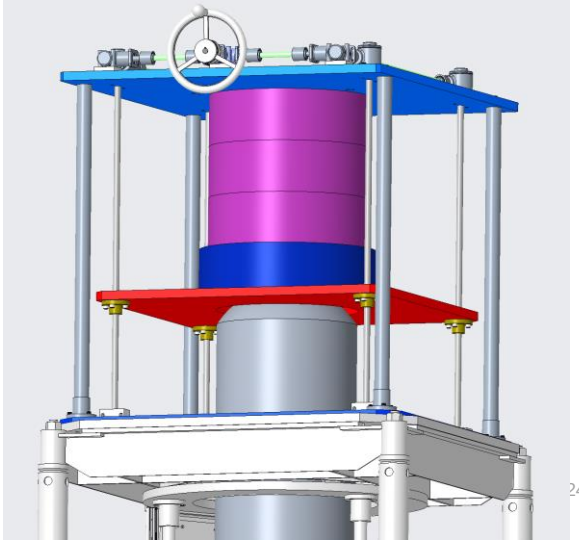




SSM Subcritical Requirement

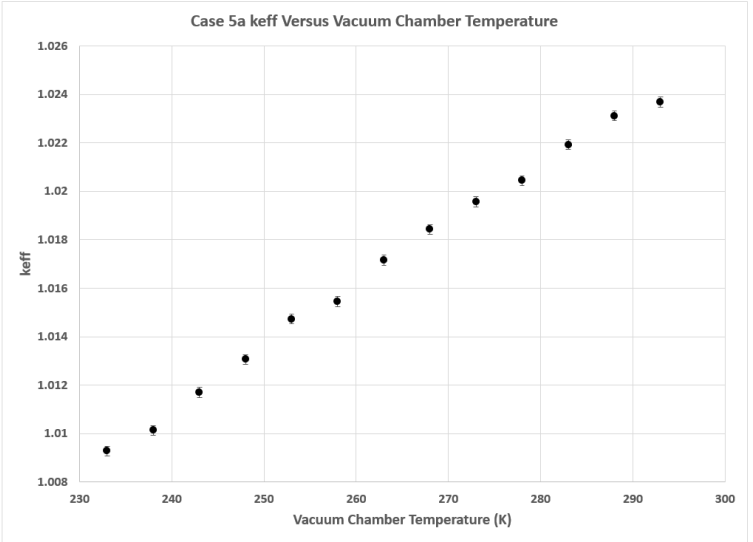
- System should be subcritical upon the withdrawal of one Safety Shutdown Mechanism (SSM)
- System design has reactivity/criticality worth similar to a control rod (S curve)
- If system is too far up on the S curve (where it levels off), SSM withdrawal will not change reactivity/criticality much
- Comet SSM: 1.5”
- Planet SSM: 2.0”





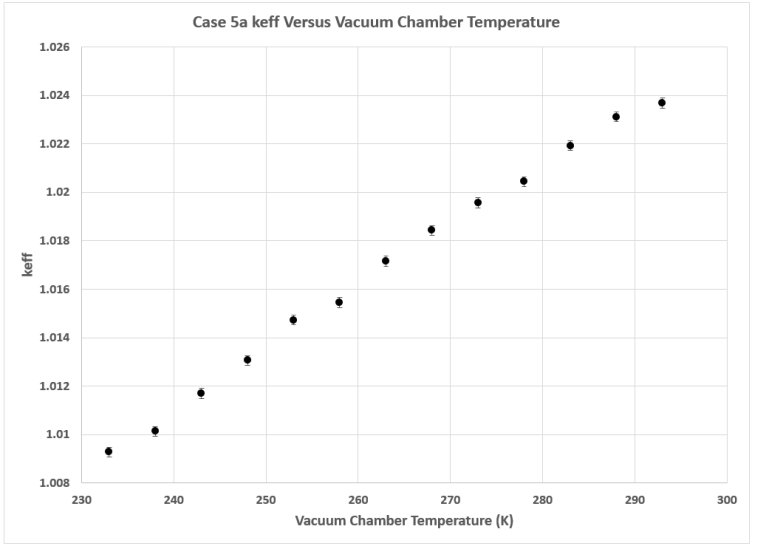
Temperature Approach to Critical

- In CED-2, the extreme temperatures of 20 °C and - 40 °C were examined
- To ensure there are no odd effects in between, cross sections were made in 5 °C increments
- Case 1 (unmoderated): Reactivity increased as temperature decreased
  - Lower uranium density → higher uranium fission
- Case 5a (largest moderation): Reactivity decreased as temperature decreased
  - Lower thermal neutron energy → higher hydrogen absorption



Temperature Approach to Critical

- 1/M Plan:
  - Meet reactivity requirements at room temperature
  - Slowly decrease temperature and remeasure reactivity
  - Compare results to simulations for trending
  - Start off with enough reactivity to decrease temperature as much as possible
    - Case 1: Lower initial reactivity
    - Case 5a: Higher initial reactivity



Loss of Vacuum

- One of the potential upset conditions for IER 479 is a loss of the vacuum system
  - Will cause warming, due to air influx
  - Allows moisture (condensation) into chamber near fuel
  - Large temperature gradients can cause permanent (plastic) deformation
- Not able to be easily tested without potential to damage system
- Conservative engineering calculations agree that potential ΔT is less than 10 °C
- LLNL and LANL agree effects are not detrimental to personnel or SMN assets

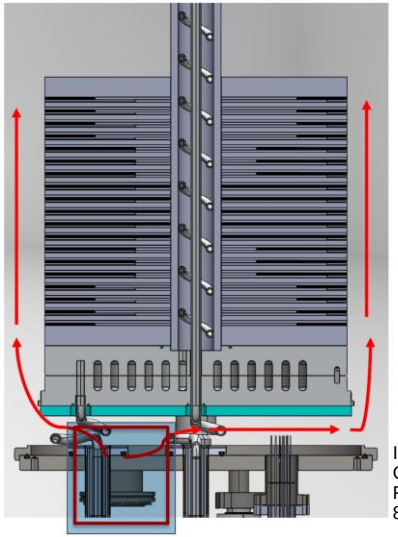
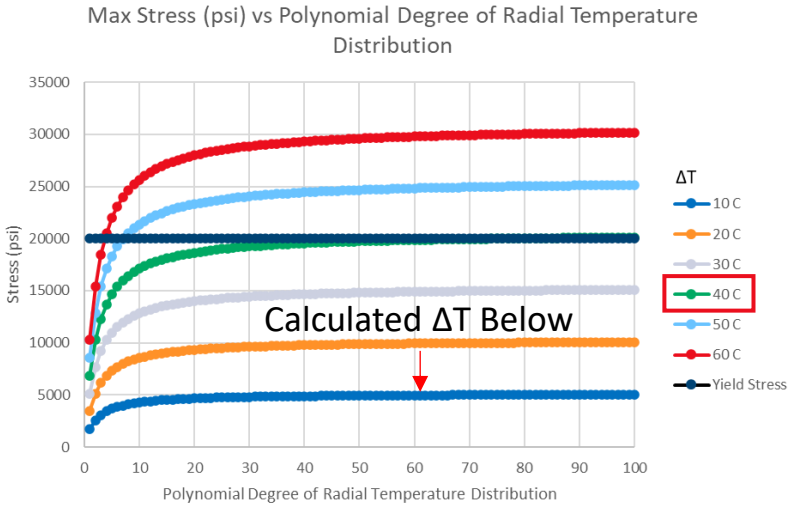


Image from: Jacob Glesmann and Dan Flowers LLNL-PRES-870525



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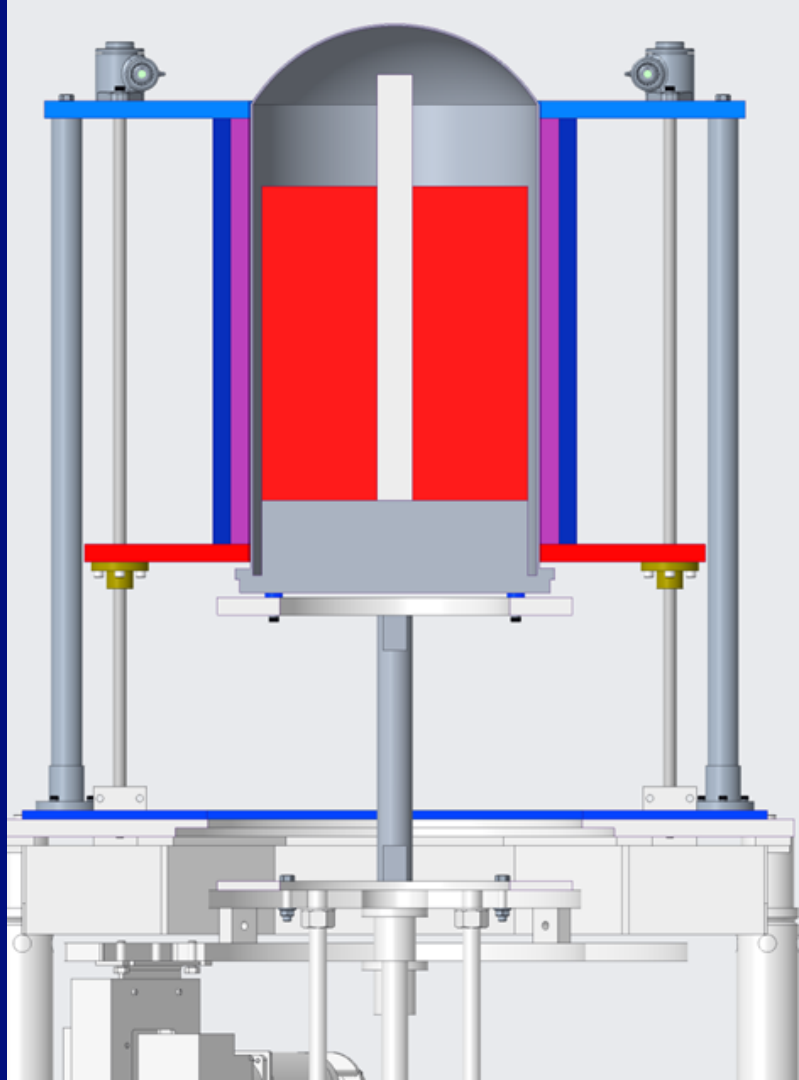
Future Work

- Finalize reflector design and send for procurement
- Finalize design of structural components
- Component dimensional inspection
- Test fitting



Questions?

- This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.
- We would like to acknowledge the significant input to this design by our colleagues at LLNL, specifically Eric Aboud, Jacob Glesmann, Jesse Norris, and Catherine Percher
- We would also like to thank the design team at LANL for supporting these efforts, specifically Justin Lee, Rowan Johnson, Rene Sanchez, and Eric Williamson

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