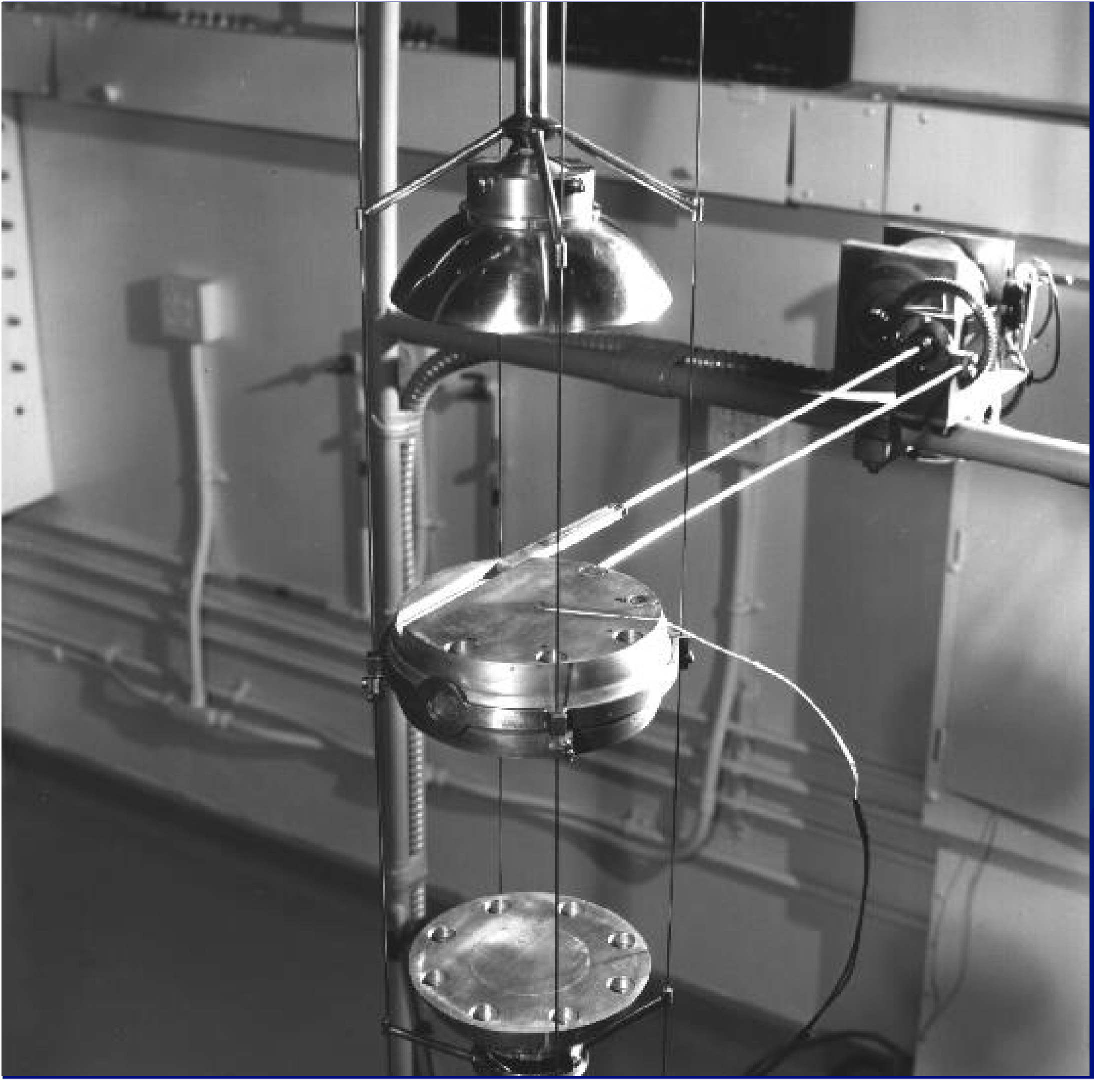

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IER 479: Technical Challenges of a Low Temperature Experiment and Proposed Solutions

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NCSP Technical Program Review

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IER-479 Summary

- Investigation of critical masses of uranium-fueled systems at and below room temperatures
  - 20 °C to -40 °C
- Address criticality aspects of transporting nuclear materials (waste, etc.) in very cold temperatures and associated criticality safety concerns
  - Integral experiment will help validate low temperature nuclear data (cross sections, S(α,β) or TSL, etc.)

Very challenging experiment!

- Close collaboration between LANL and LLNL necessary to ensure experiment can be executed safely and efficiently

Current Status: Nuclear Design

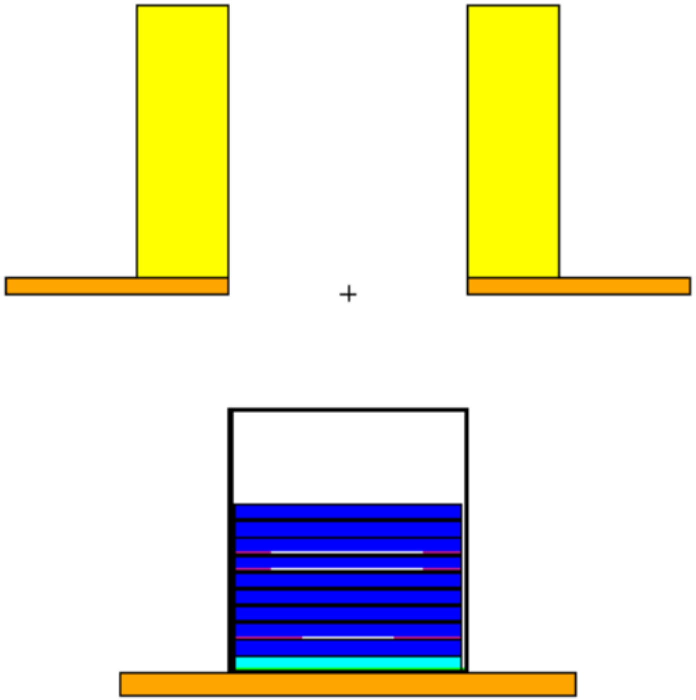
- LLNL has modeled 5 configurations spanning different energy regimes
- LANL has been working on the experimental process including
  - approach to critical,
  - integration with DAF safety basis, and
  - ANS-1 requirements.

Current Status: Engineering Design

- LLNL has worked with commercial vendor to acquire vacuum chiller system
  - This system is currently undergoing rigorous engineering testing before being utilized for an experiment.
  - Some results presented by LLNL at this meeting.
- LANL has also been generating the overall engineering design package including drawings, component fabrication, and component management level determination.
  - All of which requires close collaboration with LLNL.
- The team has been working toward CED-3a completion in FY25

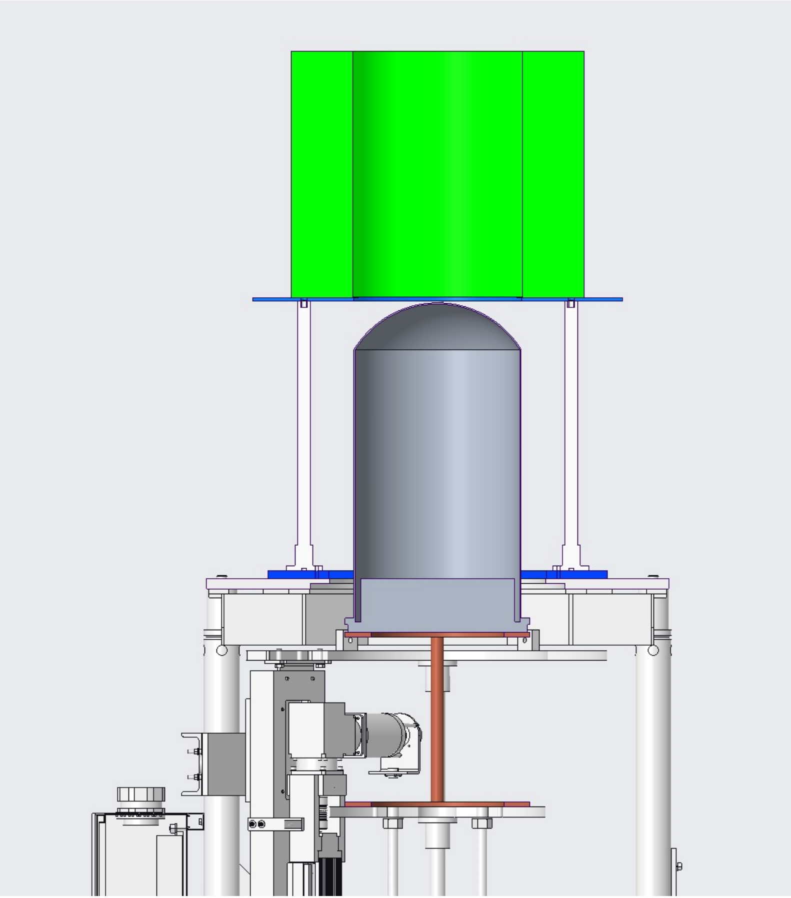
IER-479 Description

- Experiment designed for Comet critical assembly at NCERC
- Stacks of HEU and HDPE plates in a vacuum chamber
- Air evacuated from chamber and a cooler/chiller cools the system down to chosen temperature
- Vacuum chamber/stack is then inserted into reflector and measurement of criticality/reactivity is taken
- Repeat for various temperatures and configurations



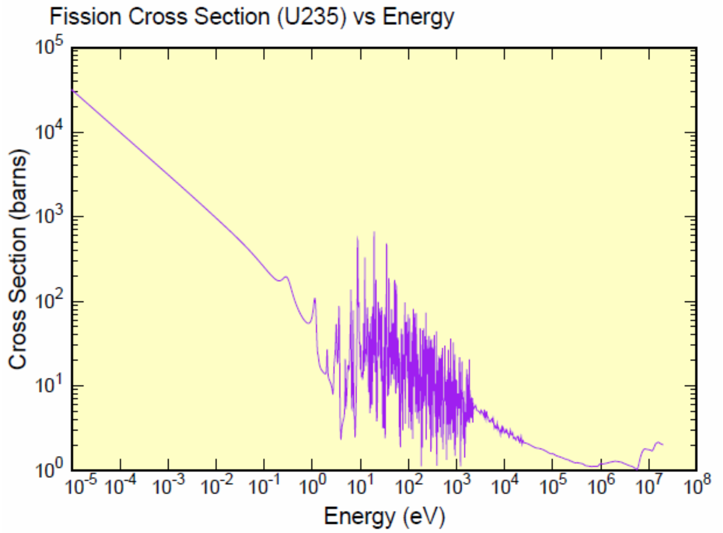
IER-479 Technical Challenges

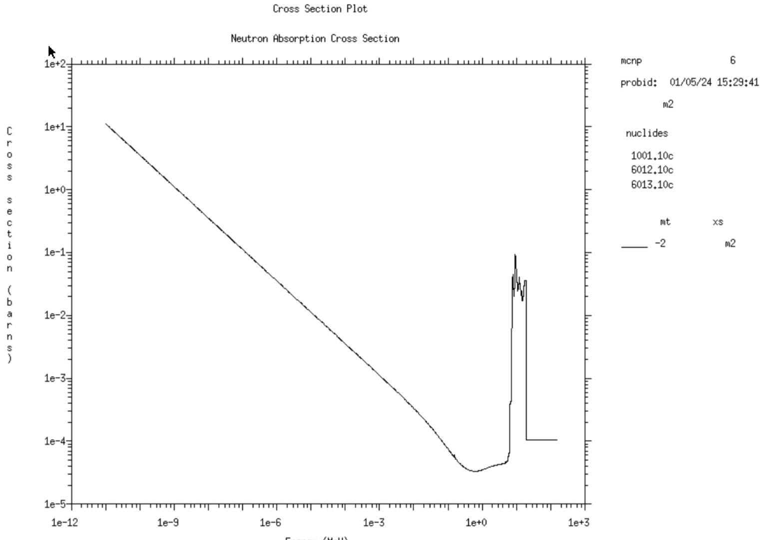
- Vacuum chamber and cooler/chiller design has proven complicated.
  - See LLNL talk.
- Sparse nuclear data at low temperatures means large unknowns and requires larger margins.
- Extensive modeling is needed to plan approach to critical and ensuring the design meets experimental requirements (safety basis, ANSI/ANS-1, etc.)



IER-479 Modeling

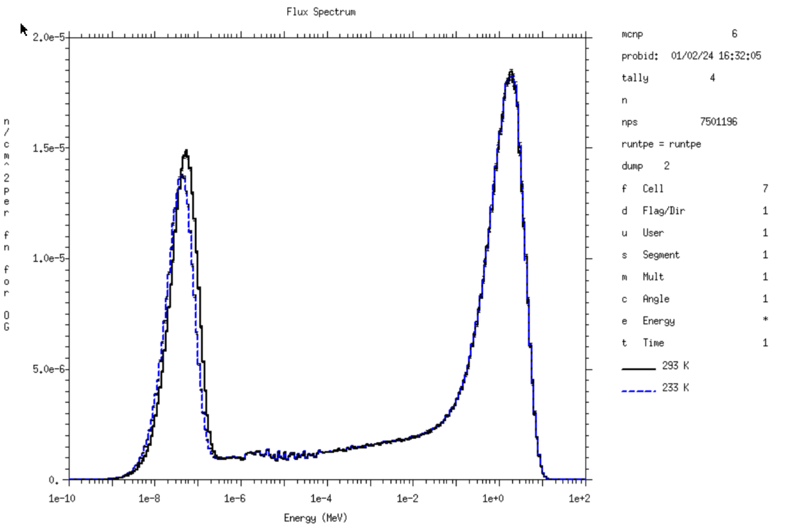
- Modeling in CED-2 indicates that as temperature decreases the k_{eff} of the system decreases
  - Not intuitive
  - Independently confirmed by LANL
  - Competing effects from neutron absorption in HEU (positive reactivity effect) versus neutron absorption in HDPE (negative reactivity effect)

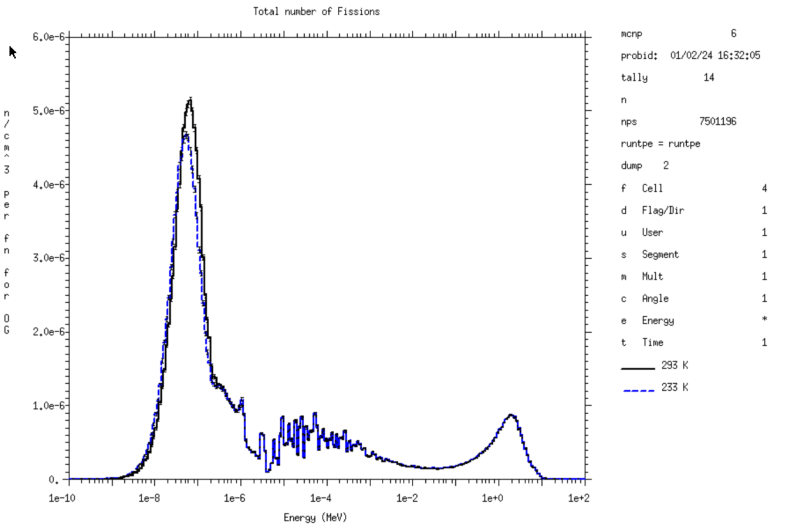




IER-479 Modeling

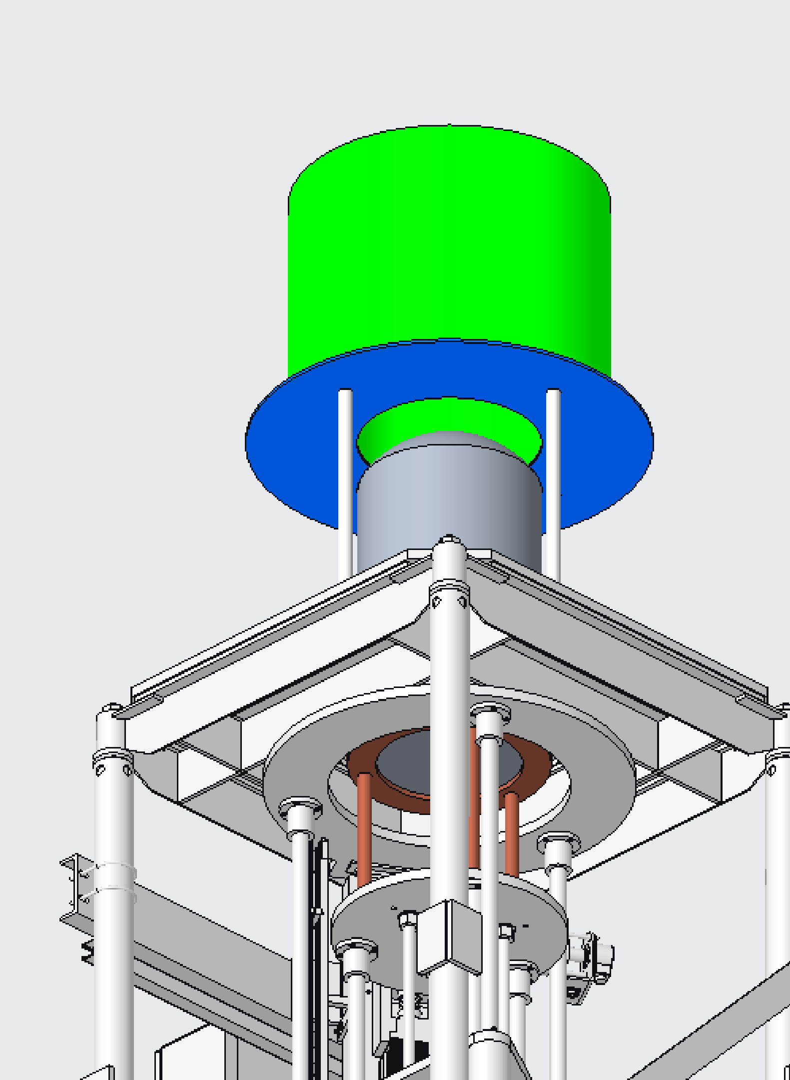
- The top plot shows the neutron spectrum for both the room temperature (black) and -40 degree cases (blue).
  - Slight shift of energy for blue spectrum can be seen on lower peak from temperature change, lower peak height due to polyethylene absorption.
- The bottom plot shows the total number of fissions for both cases (same color scheme).
  - The lower peak here illustrates the same absorption that the flux spectrum above does.





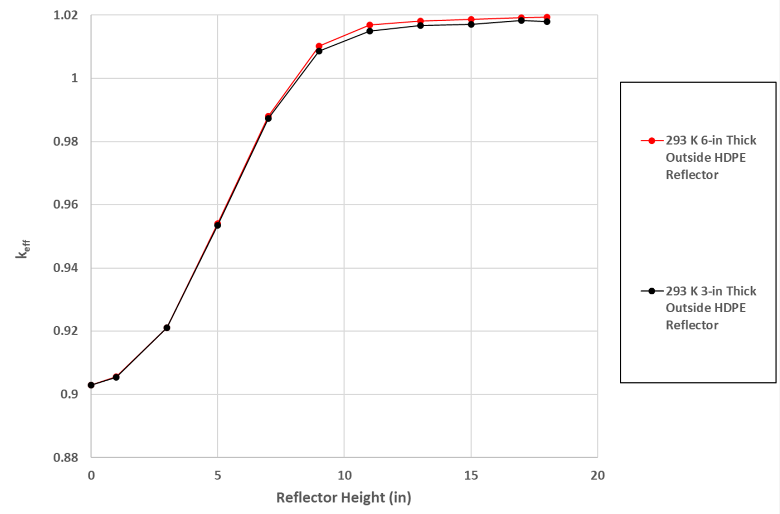
Approach to Critical: Central Fuel Column

- Challenging because central column has very high mass and multiplication.
  - Most stacks model at or above k_{eff}= 0.90 which may push the limits of the 1/M approach method.
  - Worth of vacuum chamber will need to be determined or the chamber needs to be emplaced during the entire set of approach measurements.
  - Approach will either take place with the chamber for each unit or a fixture will be designed and the addition of the chamber will happen remotely using Comet



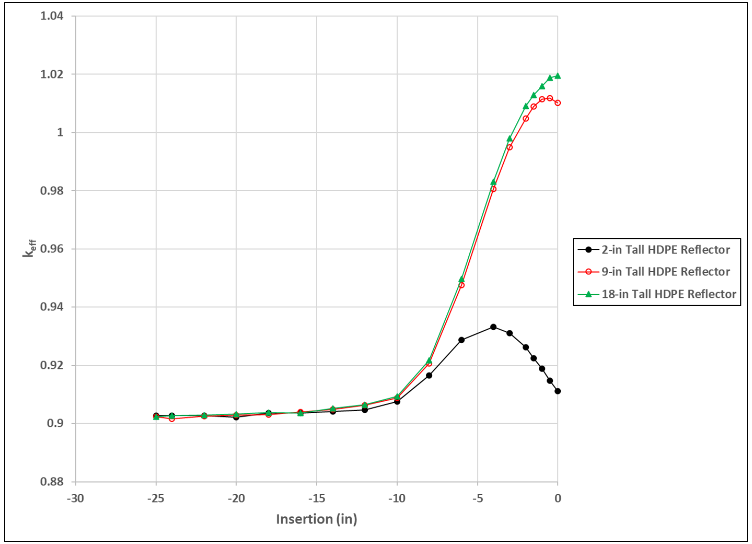
Approach to Critical: Outer Reflector Height

- Can approach on reflector thickness or height.
  - Approach to critical by height is shown in the figure,
  - Red points show reactivity with 6 in. of radial reflector and the black dots show reactivity with 3 in. of radial reflection at room temperature
- Addition of the outer reflector can be performed remotely
  - Each of the points shown would be measured at the end of an approach to critical on insertion…



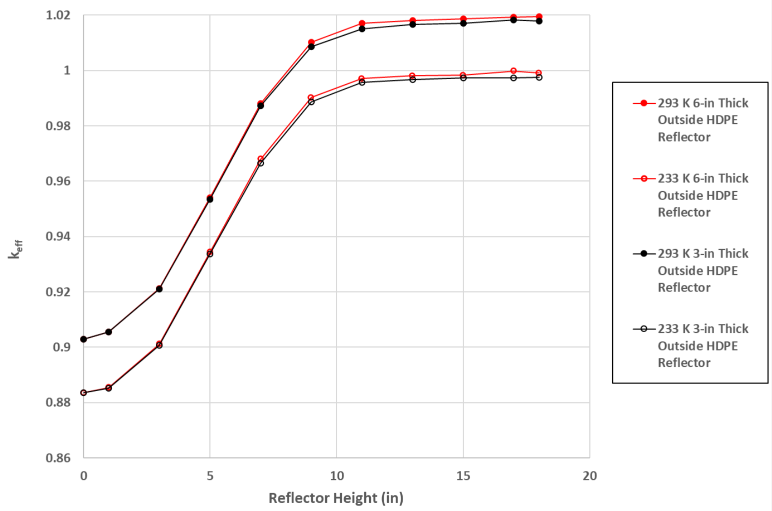
Approach to Critical: Insertion in Outer Reflector

- The challenge with the upper reflector will be building a system that has a monotonic worth, meaning that the reactivity won't increase when SCRAM'd.
  - Non-monotonic worth as shown in the figure, is caused by asymmetry in the core and reflector.
  - We propose to address this issue with spacers to better center the reflector at each reflector height, with concurrence from LLNL



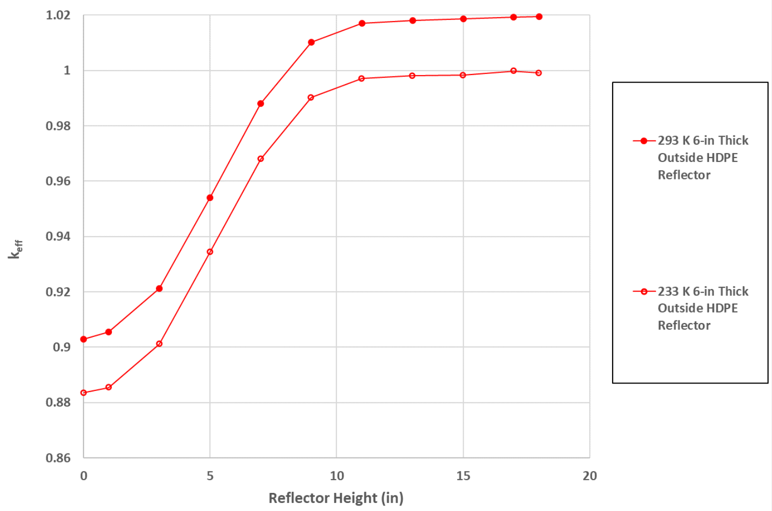
Approach to Critical: Temperature

- Will perform reactivity measurements at intermediate temperatures on way down to -40 ºC.
  - Potential to benchmark these cases also.
  - The difference between room temperature and -40 is shown in the figure from solid circles to open circles.
  - Suggest something along the lines of 20 ºC, 0 ºC, -20 ºC, -40 ºC, or even more frequent stops along the way.



Approach to Critical: Temperature

- The plot on the right shows the most drastic reactivity drop among the five proposed cases.
  - The reactivity drops nearly three dollars for this temperature change
  - Adding this much excess could pose a problem for emergency situations if the system were to warm up
    - Could require safety basis mod as mentioned as a possibility in CED-2 or subcritical measurements of some kind
    - With 80 cents of excess reactivity we could reasonably achieve a temperature reduction of about 15 degrees (from 20 ºC to 5 ºC).



Conclusions and Continuing Work

- IER 479 is a very challenging experiment!
- Continue calculations to determine the “best” (most efficient) sequence for performing the experiment.
  - 1/M prediction of fuel stack,
  - reactivity worth versus reflector thickness and height,
  - reactivity worth versus insertion,
  - temperature coefficient of reactivity calculations, etc.
- The approach to critical steps, especially cooling, will be time consuming and the experiment can become very expensive.
- Continue design work for overall design including addressing challenges

Acknowledgements

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