Three New Lead (Pb) Benchmark Experiments Performed Using Plutonium and Different Enrichments of Uranium

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Three New Lead Experiments

- Over the past five years, a series of experiments containing lead have been performed.
  - HEU/Pb
  - “LEU”/Pb
  - Pu/Pb
- In addition to finding critical configurations, lead-void reactivity worth measurements were the focus.
- These have been performed in collaboration with JAEA and with funding from the NA-232 Office of Nuclear Material Removal.
- All experiments were performed on the Comet critical assembly.

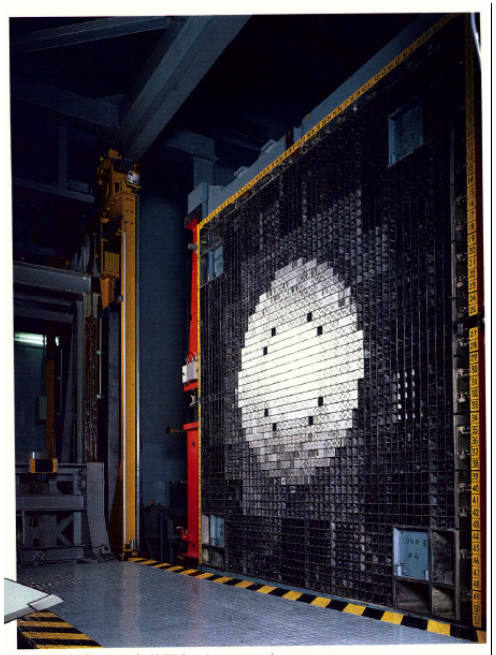
Benchmark Evaluations

- To preserve the valuable data generated in these experiments, benchmark evaluations are in progress
- Plan to submit for the 2019 ICSBEP Handbook
- Evaluations prepared by:
  - Kelsey Amundsen, DNFSB intern at UC Berkley - HEU/Pb
  - Akito Oizumi, Researcher at JAEA FCA - “LEU”/Pb
  - Alex McSpaden, LANL NEN-2 R&D Engineer - Pu/Pb

Fast Critical Assembly (FCA) in Japan

FCA did not return to operation following the 2011 tsunami

- Accelerated shipping schedule returned HEU and Pu fuel from FCA to US under Remove Program.
- Many planned experiments in support of an accelerator driven system to transmute minor actinides (Np, Am, Cm) could not be performed.
- HEU and LEU cores were planned to emphasize differences in Pb cross sections at energy above 1 MeV.
- Lead void measurements are important for regulatory approval of system with lead-bismuth coolant.



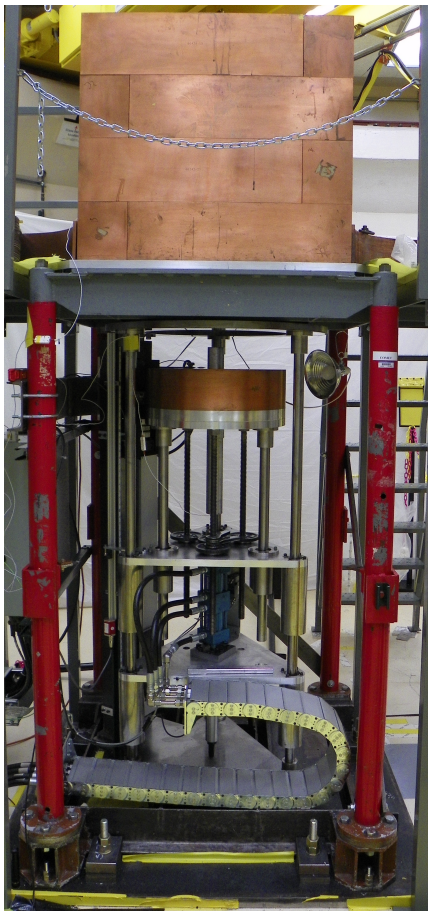
固定側½集合体密着面(51行×51列)

Cross section of fixed half assembly (51 by 51 tubes)

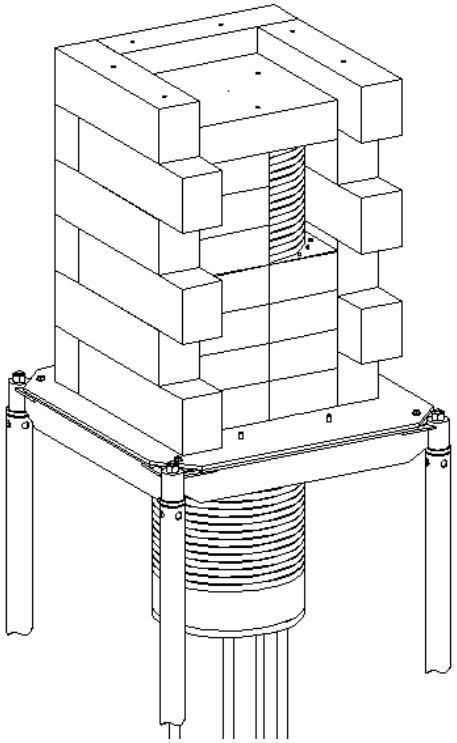
National Criticality Experiments Research Center (NCERC) in Nevada

Experiments at NCERC were designed to produce comparable data for JAEA

- First based on the Zeus Series of Experiments
  - Copper reflector
  - HEU fuel
  - Added lead to list of previously used interstitial materials (graphite, iron, poly)
- Expanded Zeus Series to include natural uranium (NU)
  - Allowed an “LEU” core to be created
  - Alternating NU and HEU with lead interstitial
- Designed Jupiter Experiment
  - Used ZPPR Pu plates and lead
  - Used same copper reflector

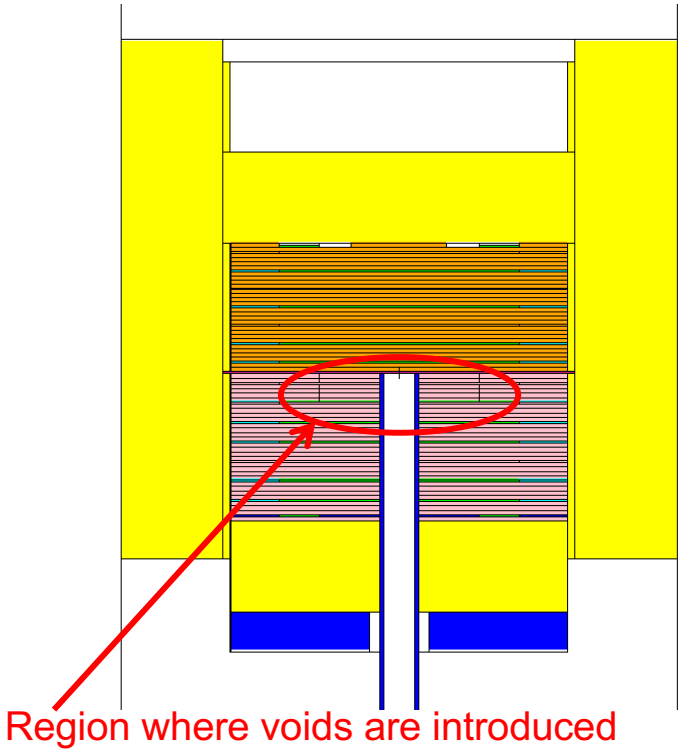


NCERC Experiments for JAEA Collaboration

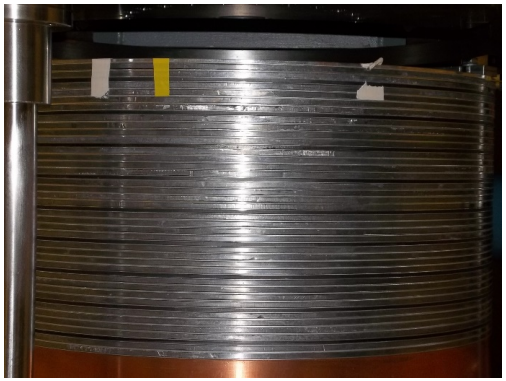


- Experiments performed on Comet over five years
- JAEA researchers visited NCERC to observe and record data
  - HEU/Lead Experiments
    - 2015-2016, 2018
  - LEU/Lead Experiments
    - 2016-2017
  - Pu/Lead Experiments
    - 2017, 2019
- Comet is a Vertical Assembly Machine -- a portion of the fuel is placed on the moveable platen and lifted towards the stationary upper fuel.
- These experiments have been the main activity on Comet except when KRUSTy was performed.

HEU/Lead Core

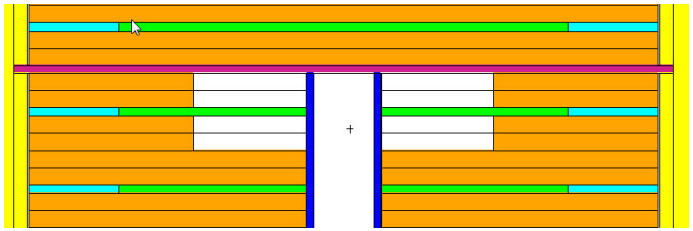


- Pb sandwiched between Al plates
- 9 units below, 6 above



HEU/Lead Void Experiments

HEU core (not to scale)
Void is 10” diameter

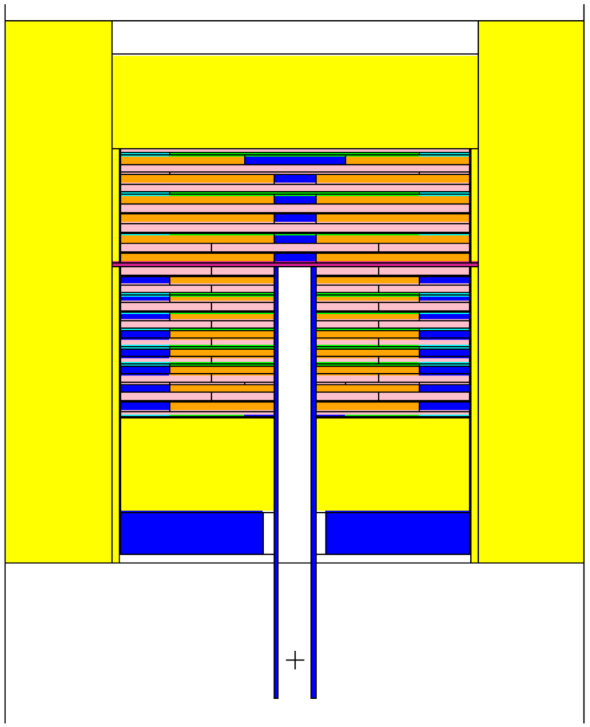


green/blue=HEU
orange=lead
yellow=copper
magenta=steel
blue=aluminum

2V case shown—
2 Pb plates removed above and 2 Pb plates removed below a U plate

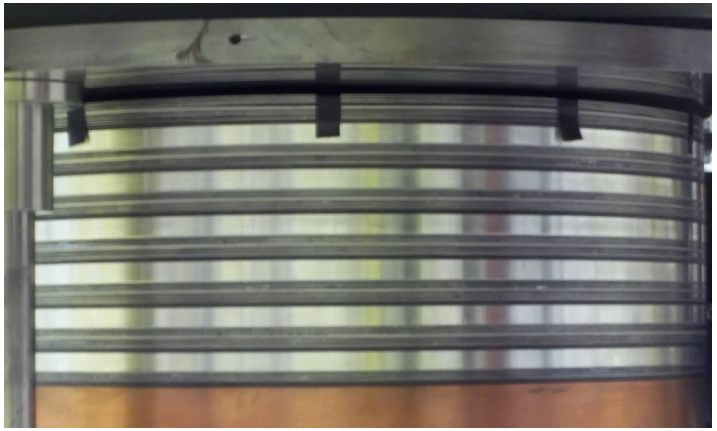
- Removed lead to measure change in reactivity
- Created voids in 2-8 units
- Spoked Al spacers used to maintain void space
  - Al spacer mass equal to mass of Al plates removed with Pb

“LEU”/Lead Core

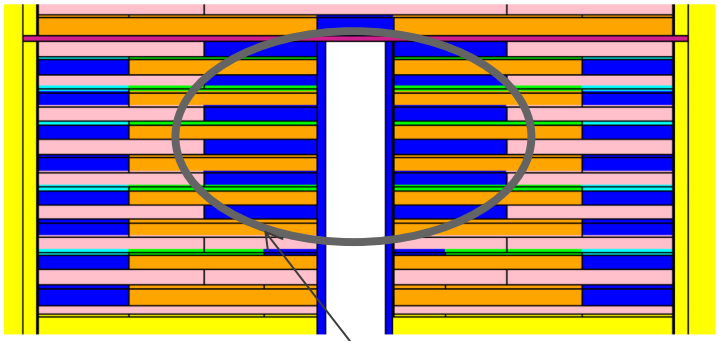


LEU core (to scale)

- Natural uranium plates alternating with HEU plates
- Effective enrichment ~21%
- Similar measurements to HEU core
- Some NU plates surrounded by Al rings to reduce weight



“LEU”/Lead Void Experiments



green/blue=HEU
orange=lead
yellow=copper
magenta=steel
blue=aluminum

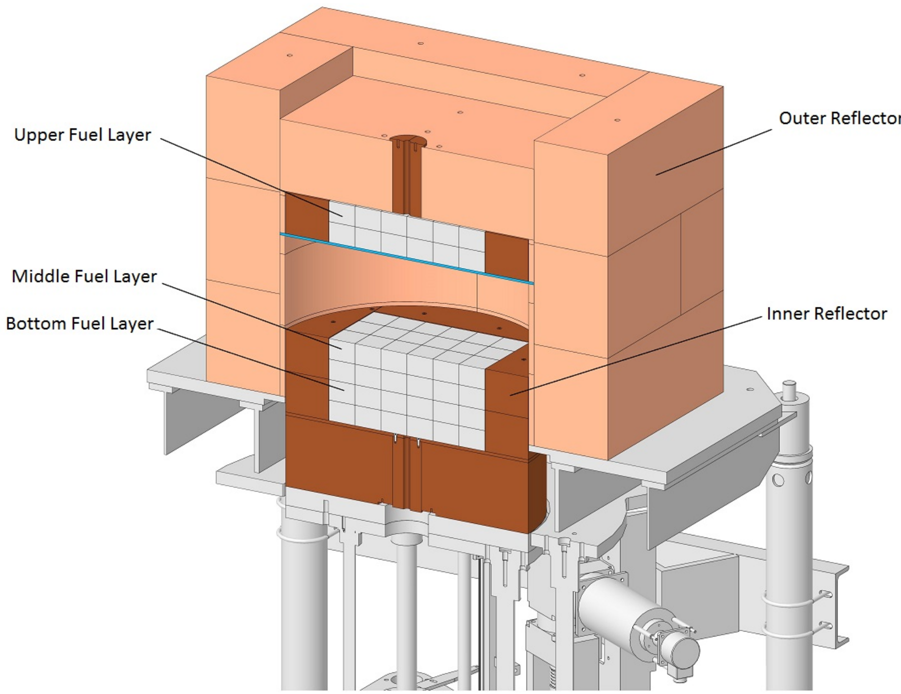
6V case shown—Each void consists of 2 Pb plates removed between an HEU and a NU plate

- Removed lead to measure change in reactivity
- Created voids in 2-6 units
- Spoked Al spacers used to maintain void space
  - Al spacer mass equal to mass of Al plates removed with Pb

Positive Lead-void Coefficient
(HEU system has negative coefficient)

Pu/Lead Core

- Pu ZPPR plates loaded into boxes with lead
- Boxes loaded into layers with additional inner reflector
- One layer on the stationary upper platform
- Two layers on the moveable, lower platform



Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu

Top Layer

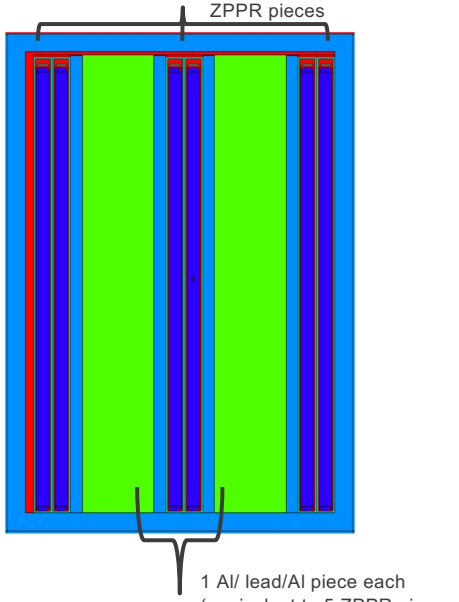
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	empty Al	Cu

Middle Layer

Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb
Cu	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	6 Pu 2 Pb	Cu
Cu	Cu	6 Pu 2 Pb	6 Pu 2 Pb	Cu	Cu

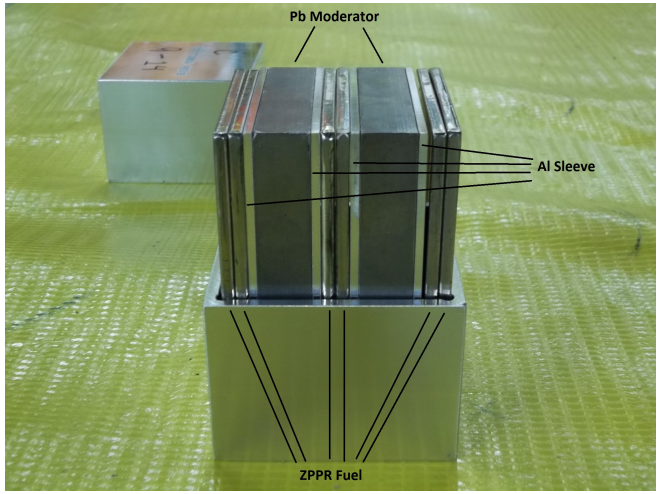
Bottom Layer

Pu/Lead Core: Unit Cell



dark blue=Pu; green= lead; light blue=Al plate or box; red= void

- ZPPR Pu fuel
  - Welded nickel-plated stainless steel
  - 3” x 2” x 0.25”



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