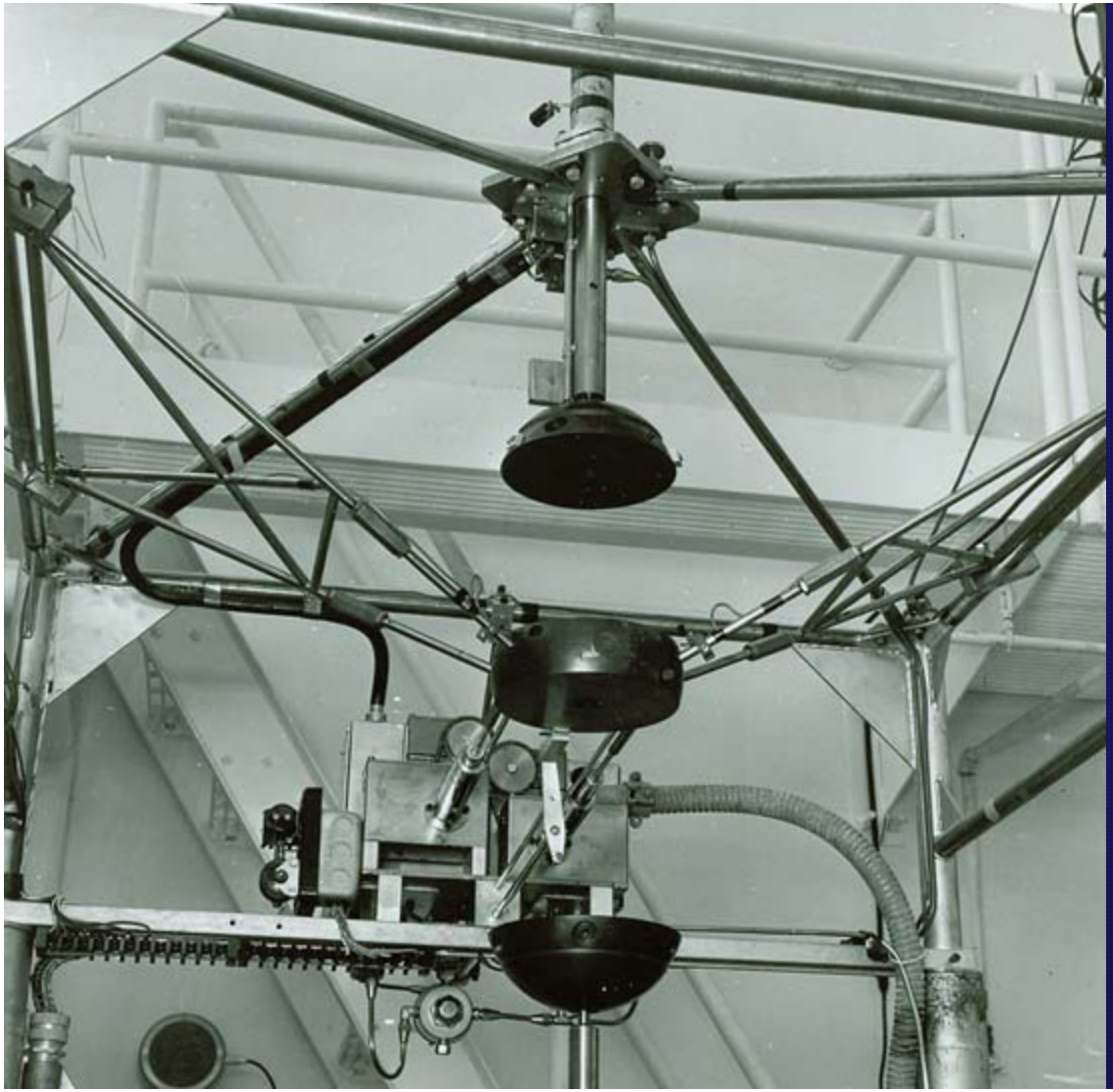

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NNSA
National Nuclear Security Administration

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# Using Fast Burst Assembly Designs to Demonstrate Safe Assembly of KRUSTY Core Components

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Los Alamos NATIONAL LABORATORY EST. 1943

October 2017

National Nuclear Security Administration

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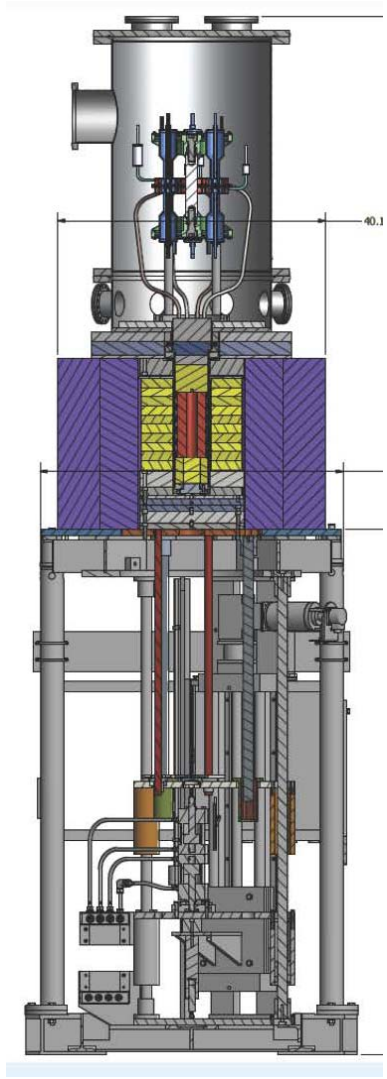
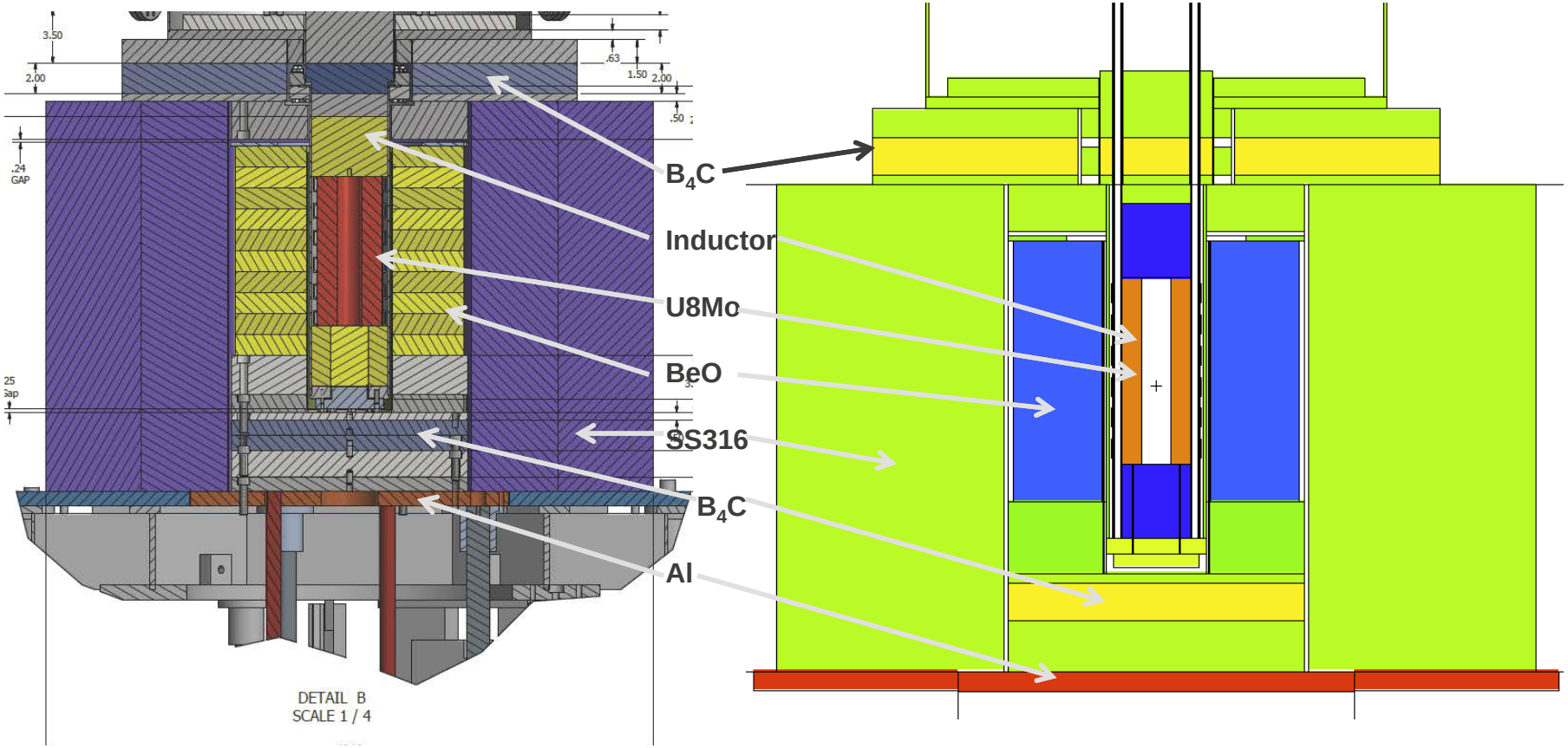
# Overview

- Background
- Description of the KRUSTY Experiment Design
- NCERC Material Handling/ Experiment Execution Process
- KRUSTY Fuel Component Description
- Lady Godiva Description
- Godiva II Description
- Moly-Godiva Description
- Godiva IV Description
- Parameters Important to the State of Criticality
- Use of **Experimental Data** to make a criticality safety case
- Conclusions/Recommendations
- Acknowledgements



# NASA Kilopower Zero-Power Critical Experimental Concept



# Experiment Execution at NCERC

**ANS-8 Standards Govern:**

- **Storage of materials in vaults**
- **Transport of Materials to Experiment buildings**
- **Staging of Materials in Experiment buildings**

**Transition to critical experiment assembly operations**

**ANS-1 Standards Govern:**

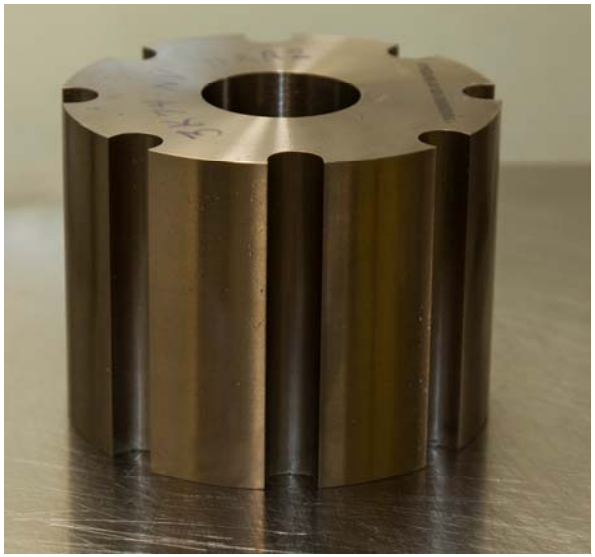
- **Critical experiment assembly operations**

  **Approach to Critical steps: half way rule, three quarter rule....**

**Disassembly Operations**

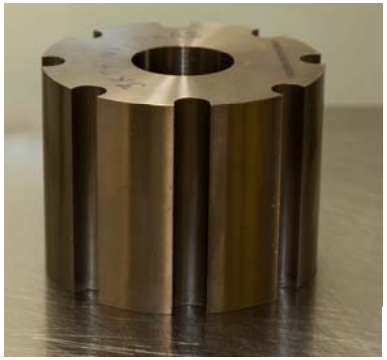
**Transition back to ANS-8 governed activities**

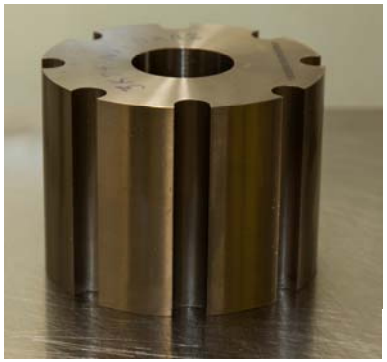
# Can you make the safety case for handling one component of KRUSTY Fuel without performing a validated simulation?



| | |
|---|---|
| Enrichment (wt % U-235) | 93.0 |
| Metal Density (g/cc) | 17.2 |
| Moly Alloy (wt %) | 8.0 |
| Total Metal Mass (kg) | 10.0 |
| U-235 Mass (kg) | 9.2 |
| ID (cm) | 4.0 |
| OD (cm) | 11.0 |
| Height (cm) | 8.3 |
| H/D | 0.8 |

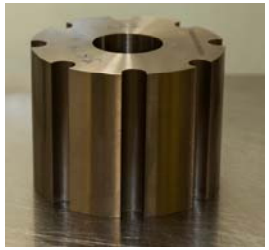
# Can you make the safety case for stacking two components of KRUSTY Fuel without performing a validated simulation?

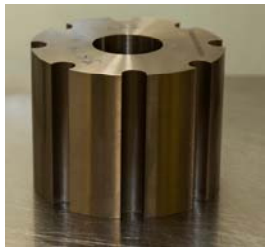


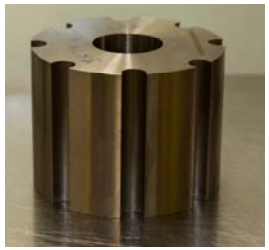


| | |
|---|---|
| Enrichment (wt % U-235) | 93.0 |
| Metal Density (g/cc) | 17.2 |
| Moly Alloy (wt %) | 8.0 |
| Total Metal Mass (kg) | 20.0 |
| U-235 Mass (kg) | 18.4 |
| ID (cm) | 4.0 |
| OD (cm) | 11.0 |
| Height (cm) | 16.7 |
| H/D | 1.5 |

# Can you make the safety case for stacking three components of KRUSTY Fuel without performing a validated simulation?

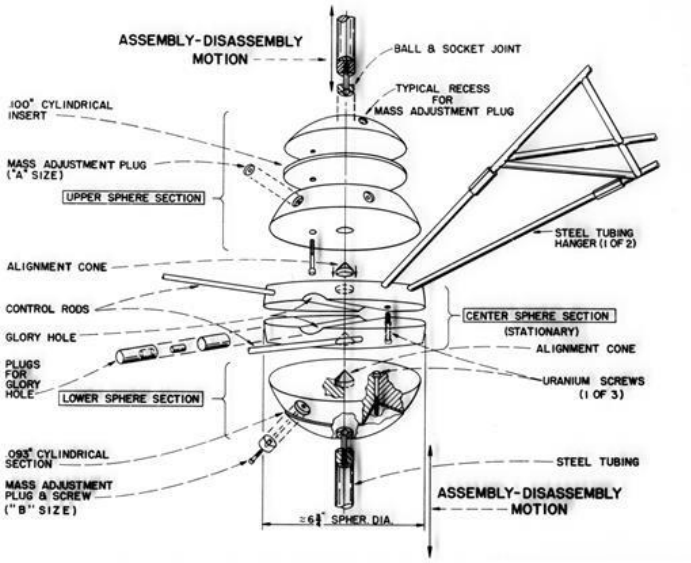




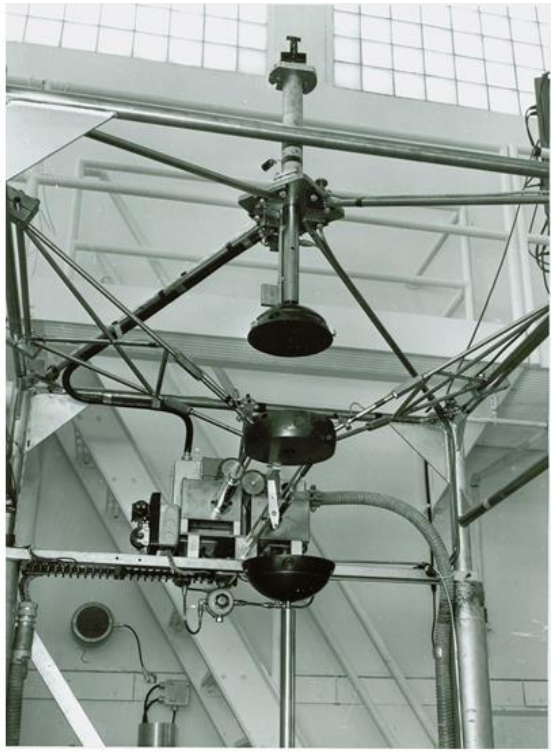


| | |
|---|---|
| Enrichment (wt % U-235) | 93.0 |
| Metal Density (g/cc) | 17.2 |
| Moly Alloy (wt %) | 8.0 |
| Total Metal Mass (kg) | 30.0 |
| U-235 Mass (kg) | 27.6 |
| ID (cm) | 4.0 |
| OD (cm) | 11.0 |
| Height (cm) | 25.0 |
| H/D | 2.3 |

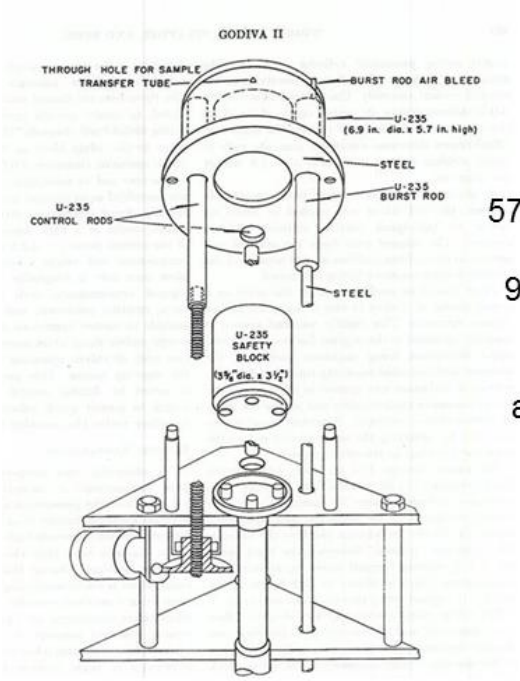
# Lady Godiva (Circa 1951)




52.8 kg of Bare Uranium
Un-alloyed Uranium Metal
93.7 wt % enriched in U-235
critical mass measurements
Neutron irradiation source (pulsed and steady-state)

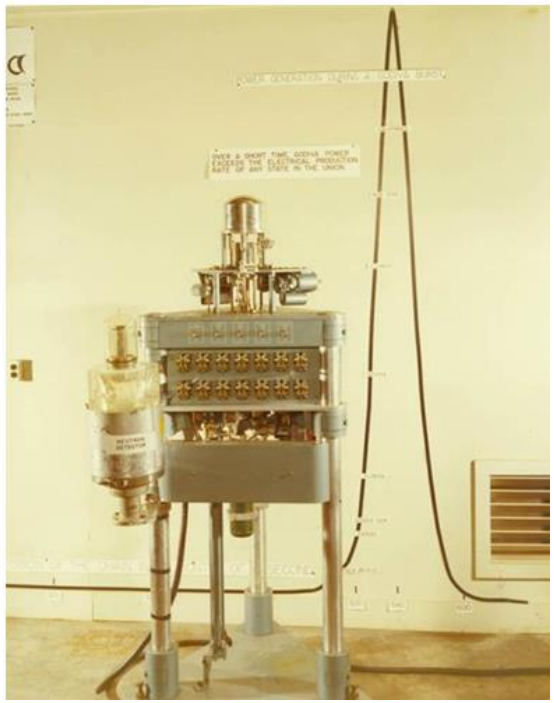


# Godiva II (Circa 1957)

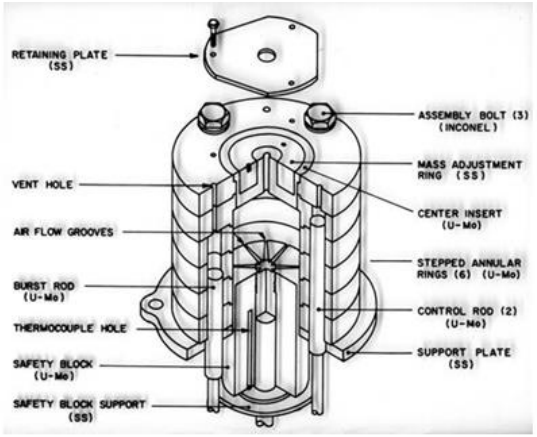



57.7 kg of Nickel Clad Uranium
Unalloyed Uranium Metal
93.5 wt.% enriched in U-235

Designed to be used as
a neutron irradiation source
(pulsed and steady-state)

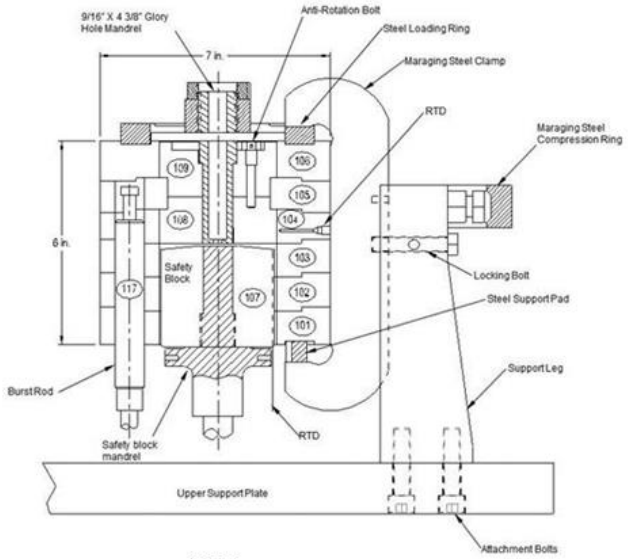


# Moly-Godiva (Circa 1963)

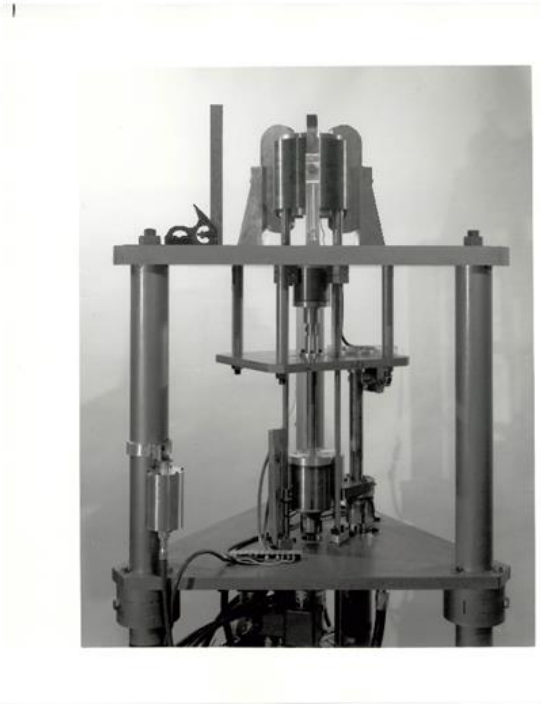



97 kg
U-Mo alloy (10 wt. % Mo) metal
U content 93 wt. % enriched in U-235
Aluminum Ion plated parts
Pulsed and steady-state operations
for various applications

# Godiva IV (Circa 1967)




65 kg
U-Mo alloy (1.5 wt. % Mo) metal
U content 93 wt. % enriched in U-235
Aluminum Ion plated parts
Pulsed and steady-state operations
for various applications



# Parameters of Importance to Criticality

**Anything that affects the global battle between absorption and leakage will affect $k_{eff.}$**

- **Mass**
- **Competing materials (materials that absorb but do not fission)**
  - poisons are a class of these.
- **Moderation**
- **Shape (geometry)**
- **Size (volume)**
- **Density and/or concentration**
- **Nearby fissionable material (spacing, interaction)**
- **Enrichment**
- **Reflection**

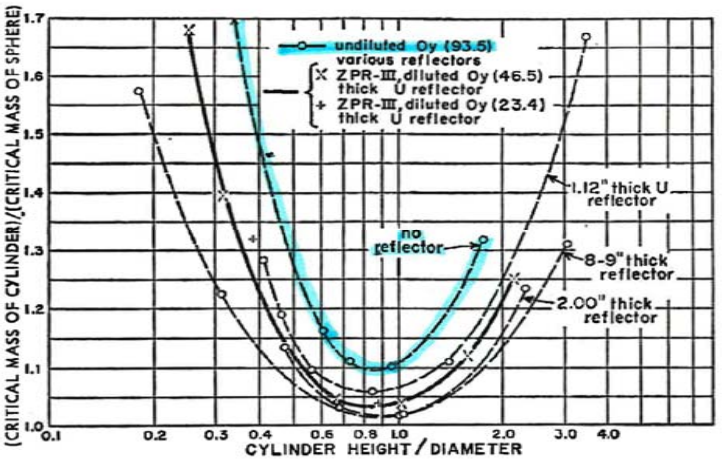
**Note that the parameters are somewhat interdependent.**

**Changing one often changes others.**

# Now can you make the safety case for stacking three components of the KRUSTY Fuel without performing a validated simulation?

| Assembly | U-Mo Alloy (Mo wt. %) | Critical Mass (kg) | 3/4 critical mass estimate (kg) |
|---|---|---|---|
| Lady Godiva | 0.0 | 52.7 | 39.5 |
| Godiva II | 0.0 | 57.7 | 43.3 |
| Godiva II (H/D near 2.0) | 0.0 | 68.5 | 51.4 |
| Moly-Godiva | 10.0 | 97 | 72.8 |
| Godiva IV | 1.5 | 65 | 48.8 |

| | |
|---|---|
| Enrichment (wt % U-235) | 93.0 |
| Metal Density (g/cc) | 17.2 |
| Moly Alloy (wt %) | 8.0 |
| Total Metal Mass (kg) | 30.0 |
| U-235 Mass (kg) | 27.6 |
| ID (cm) | 4.0 |
| OD (cm) | 11.0 |
| Height (cm) | 25.0 |
| H/D | 2.3 |




L.J. Koch and H.C. Paxton, "Fast Reactors," Annual Review of Nuclear Science, Vol. 9, pp. 437-472, (1959).

# Conclusion/Recommendation

**If you want to learn more about how to make a criticality safety case without having to perform a validated simulation, then come and sign up for one of the Department of Energy's Nuclear Criticality Safety Program's training and education classes.**

**For more information check the website:**

https://ncsp.llnl.gov/training.php

**ps. You will learn a bunch more about criticality safety related topics and get some "hands on" lessons too!**

# Acknowledgments


- **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.**

# Any Questions or Comments?

# Extra Slides