GE Hitachi Nuclear Energy

Optimum UO_2 Particle Size Determination Using GEMER Monte Carlo Code

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Overview

- Introduction
- Methodology
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Introduction

- Latticing of low enriched uranium (< 10 wt% ^{235}U) can reduce the critical mass of a homogeneous system due to the strong absorbing characteristics of ^{238}U in the resonance region for fission neutrons slowing down in the moderator [LA-10880-MS].
- Slow neutrons entering the fuel from the moderator are absorbed near the surface of the fuel, resulting in the interior region of the fuel to be shielded by the outside layer.
- The shielding of interior region of the fuel results in increased resonance escape probability due to the decrease in the number of neutrons which would otherwise be absorbed in the resonance region.

Introduction (cont)

- Global Nuclear Fuel - Americas (GNF-A) fuel fabrication facility involves in production, processing, handling, and storage of uranium oxide powder enriched to $\leq$ 5 wt% ^{235}U.
- Criticality safety of activities involving significant quantities of uranium oxide powder requires:

1) Identification of key powder properties that have major effects on neutronic behaviors,
2) Quantification of such effects for various powder properties in terms of effective neutron multiplication factor.

Introduction (cont)

UO_2 Powder

UO_2 Pellets

Introduction (cont)

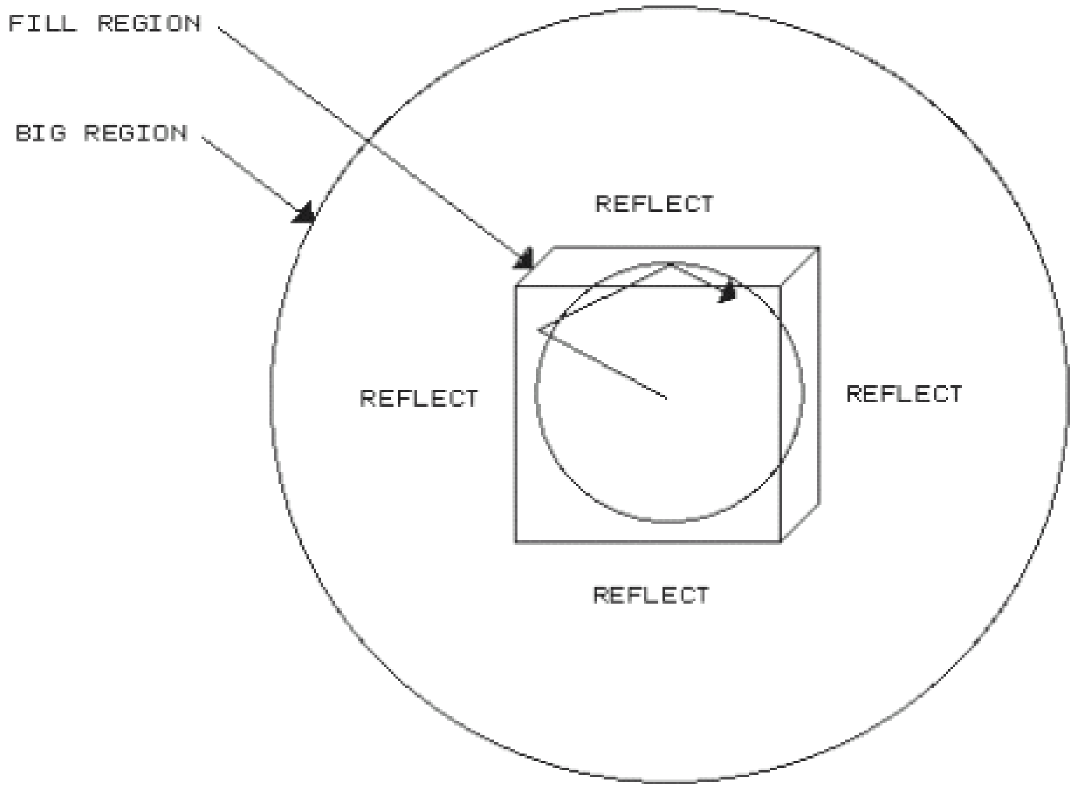
- The reactivity of uranium oxide powders depends on the following key powder properties:
  - Enrichment
  - Moderation
  - Geometry
  - Powder Density
  - Particle size
  - Porosity
- Monte Carlo neuron transport method has proven to be an effective approach in quantifying the effects of powder properties on the neutron multiplication factor.

Methodology

- GEMER is a patented multigroup Monte Carlo code used at GNF-A. The GEMER code and its modeling capability for complex geometries have been previously presented at ANS meetings.
- The *Virtual Fill Option* (VFO) in GEMER allows the user to automatically fill a region (big region) with a virtual representation of another region (fill region).
- The fill region must be enclosed in a cuboid with mirror-reflecting surfaces.
- Since the fill region is virtual, there is no limit on the number of fill regions that would be required to fill the big region.

Methodology (cont)

Virtual Fill Option Illustration



Methodology (cont)

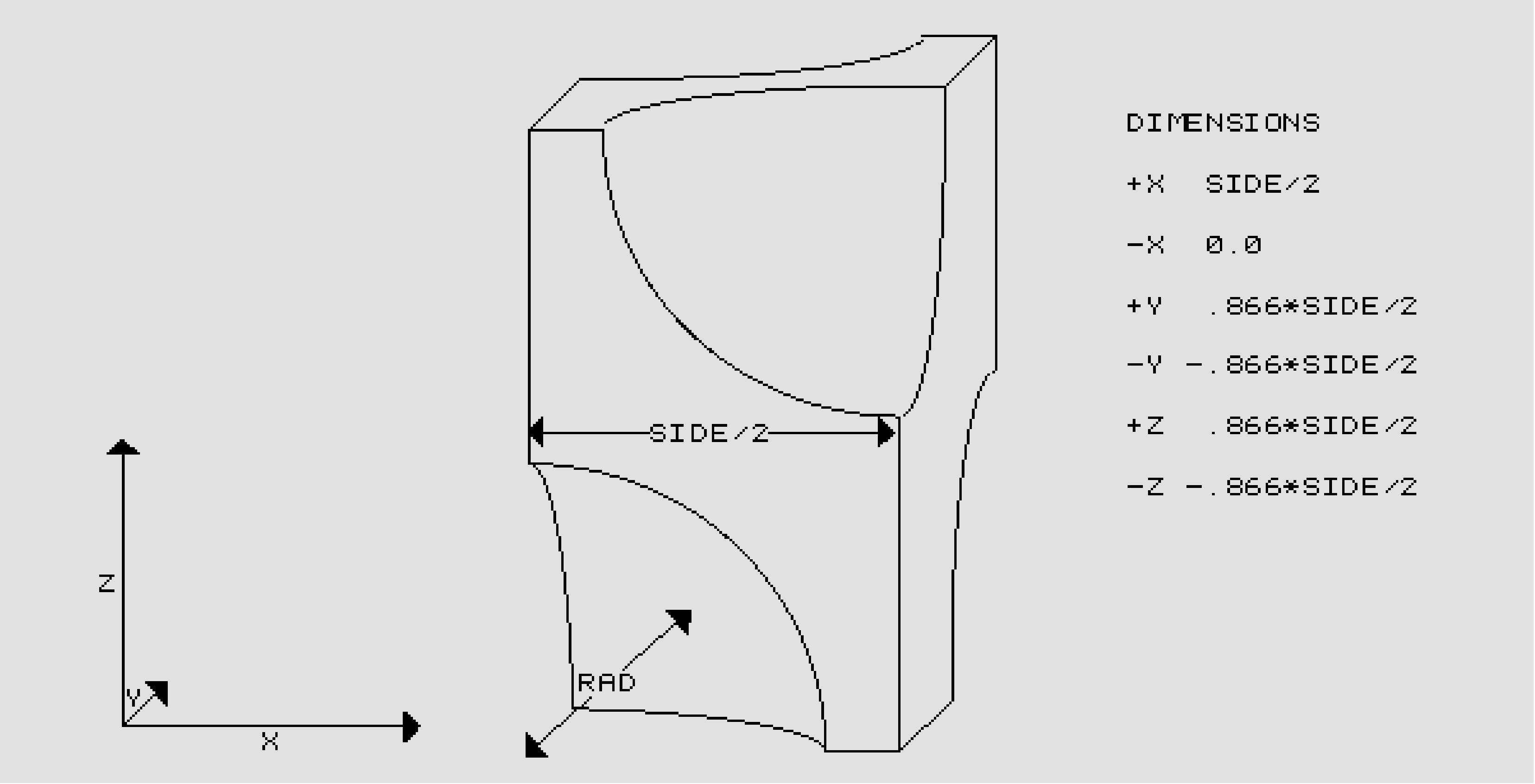
- When a neutron enters the big region, the fill region is randomly placed in the big region. This maintains the randomness in position of the fill region in the big region.
- When a neutron starts in the big region, the fill region is centered at the neutron starting position.
- VFO tracks the neutron among the mirror-reflecting boundaries of the fill region and keeps track of the neutron position within the big region.
- If the neutron reaches the boundary of the big region prior to the next collision in the fill region, it exits the big region.

Methodology (cont)

- Advanatages of VFO
  - eliminates the presence of partial fill regions near the big region boundary.
  - allows easy creation of different heterogeneous models, including square- or triangular-pitch array, simple cubic, body centered cubic, or face-centered cubic array of spheres, and triangular lattice of spheres using predefined lattice geometry constructs.
  - eliminates the need for lengthy and complex input files.
  - results in faster run time.

Methodology (cont)

TRITERS Geometry Construct

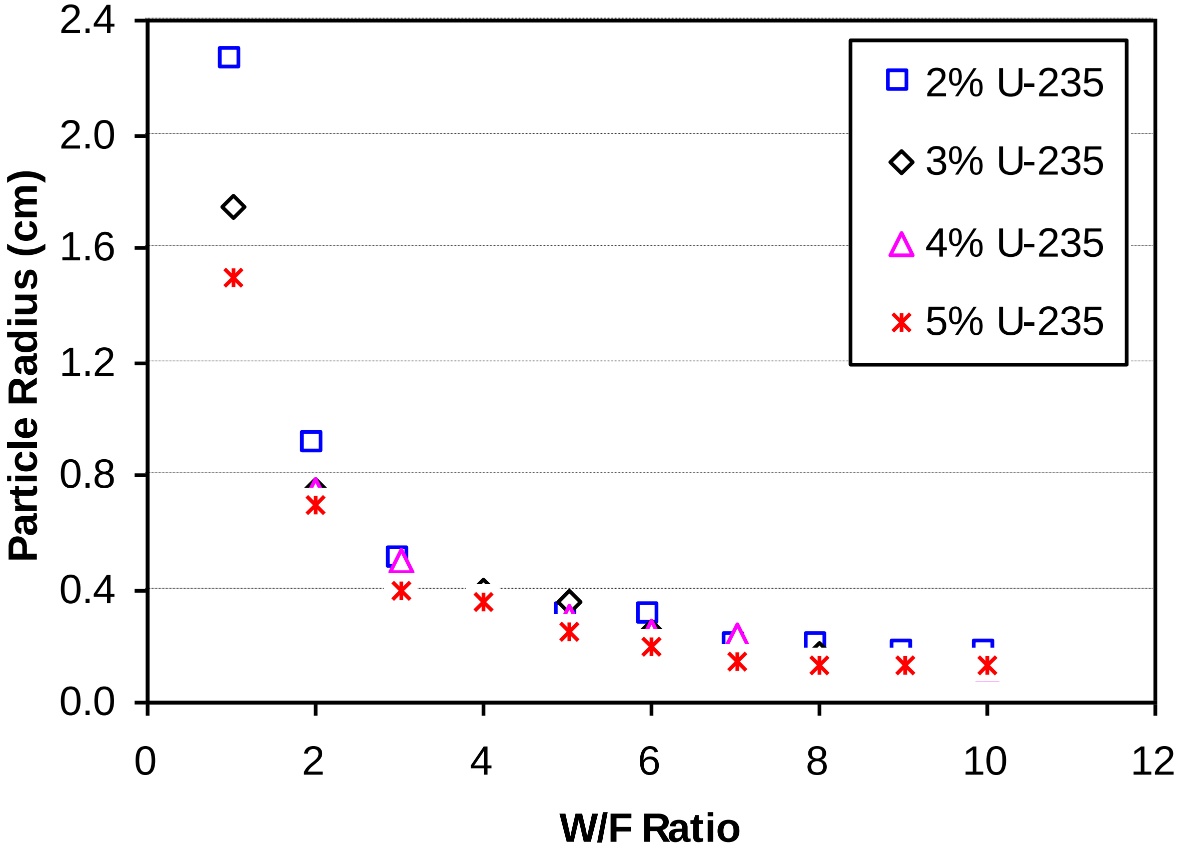


Methodology (cont)

- The TRITERS geometry construct represents a true triangular lattice of a spherical particle.
- The TRITERS geometry consists of a regular parallelepiped box in which two sets of opposite corners are cut out by 1/8th of a sphere at each of the corners.
- Dimensions of the sides are scaled such that when mirror reflected in the $\pm X$, $\pm Y$ and $\pm Z$ axes, the overall geometry becomes the original unbounded triangular lattice.

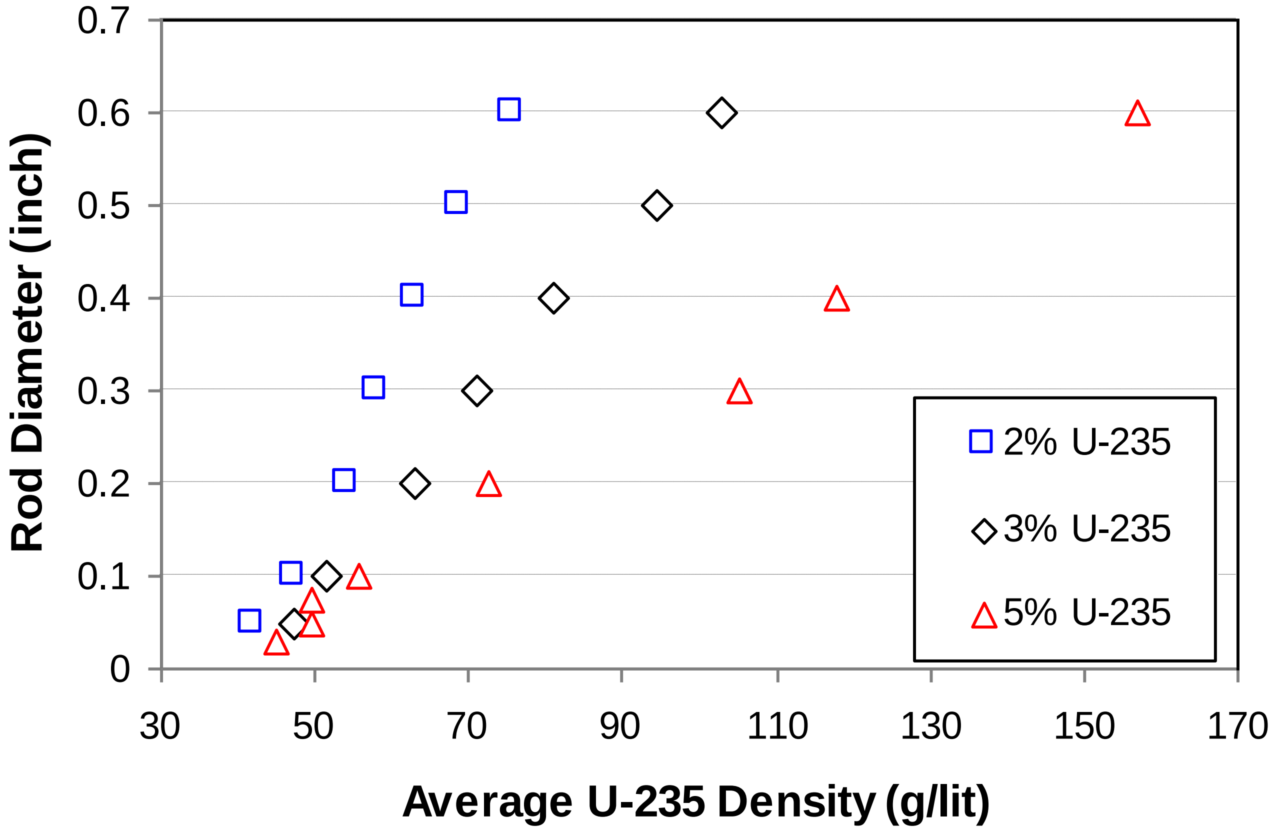
Results

UO_2 Particle Size Variation versus W/F Ratio



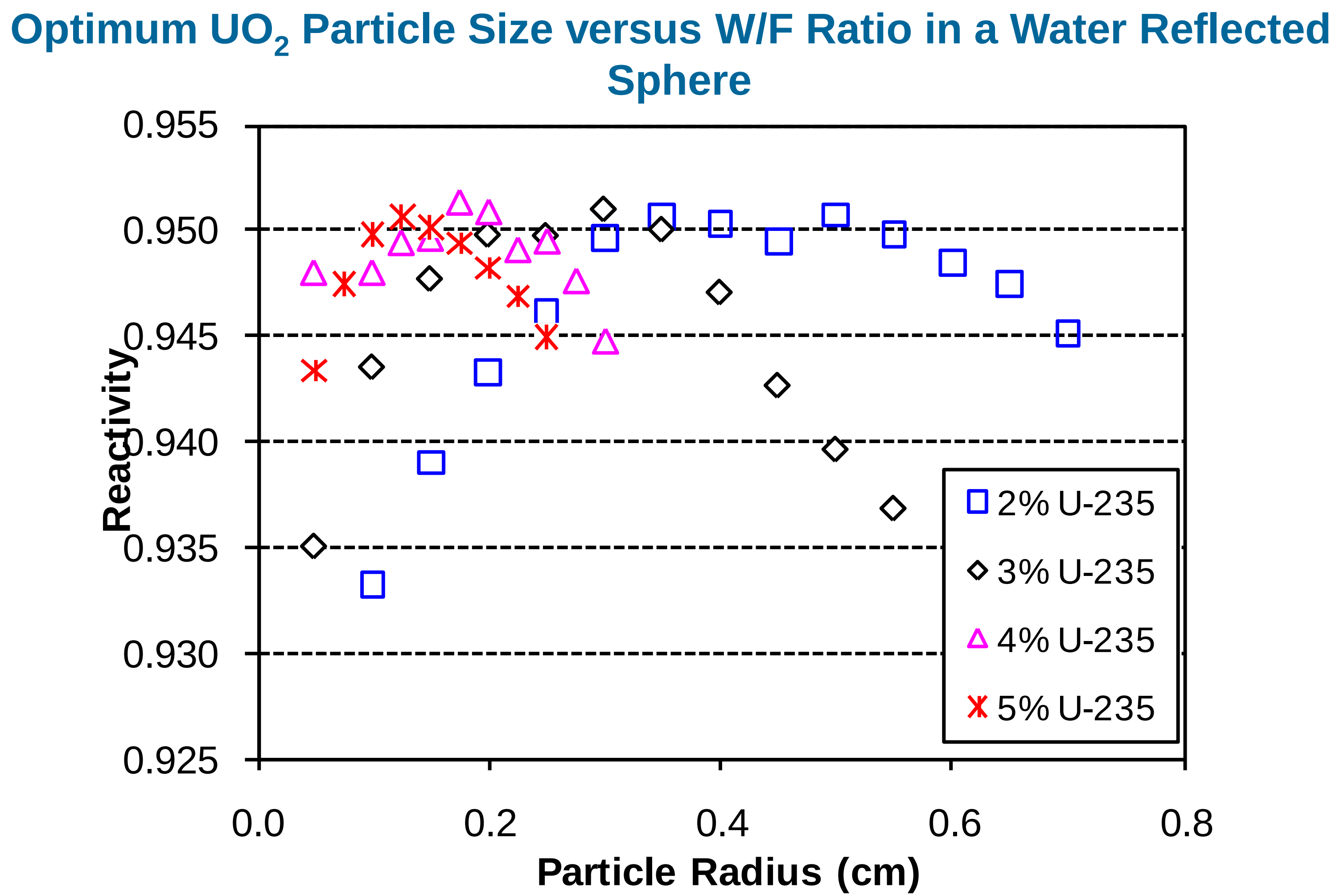
Results (cont)

Fuel Rod Size Variation versus ^{235}U Concentration



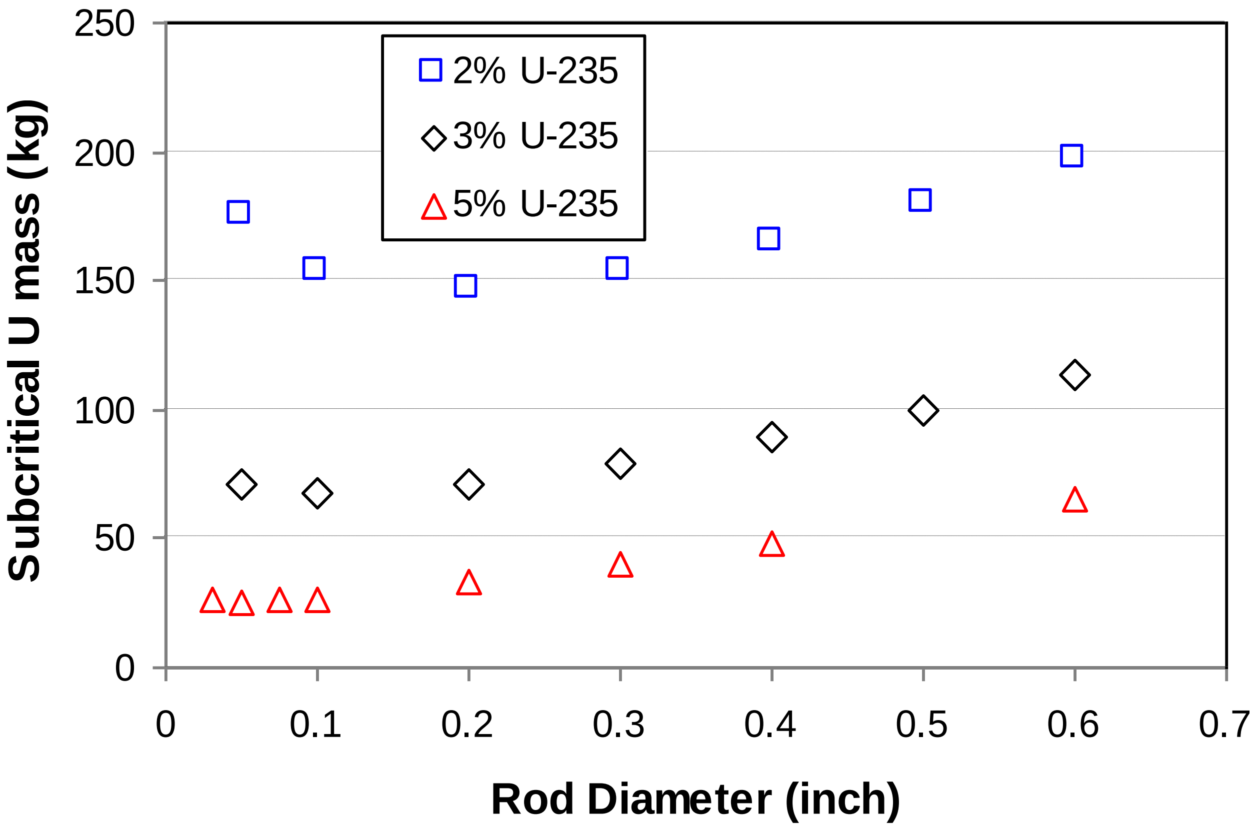
Uranium metal rods in water, DP-1014, H. K. Clark

Results (cont)



Results (cont)

Subcritical Uranium Mass versus ^{235}U Concentration



Uranium metal rods in water, DP-1014, H. K. Clark

Conclusions

- Criticality safety of fissionable material powder requires identification of key powder properties that have major effects on neutronic behaviors and quantification of such effects in terms of effective neutron multiplication factor.
- For uranium enrichment below 5 % ^{235}U the optimum particle size varies significantly with enrichment and the lattice water to fuel ratio.
- Heterogeneous advantage over homogenous must be quantified based on the powder properties that have major effects on neutronic behaviors.