Effects of Particle Size and Density on Reactivity

Low Enriched UO_2 Systems

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Global Nuclear Fuel

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Background

Heterogeneous Systems - Particle Density Effect

- Particles ~ 1000 μm and 4.5 g/cc modeled as homogeneous at GNF-A
- Particles > 127 μm are heterogeneous (TID-7016)
- Non-conservative?

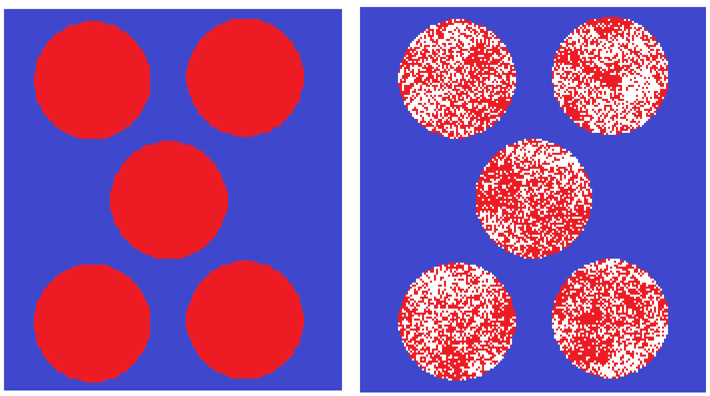
Homogeneous Systems - Bulk Density Effect

- Optimal Reactivity occurs at ~ 50 wt.% H_2O for a fixed mass of LEU.
- Is it credible that we can get 50 wt.% H_2O?
- Too conservative?

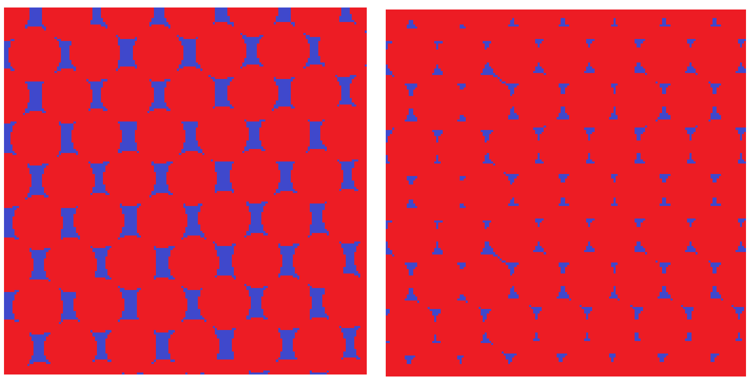
Introduction

Goal

To determine the effect of particle size and density on reactivity for low enriched UO_2 - H_2O systems



Particle Density
Heterogeneous Systems



Bulk Density
Homogeneous Systems

Heterogeneous Systems

The effect of particle size and density

Optimum Particle Size

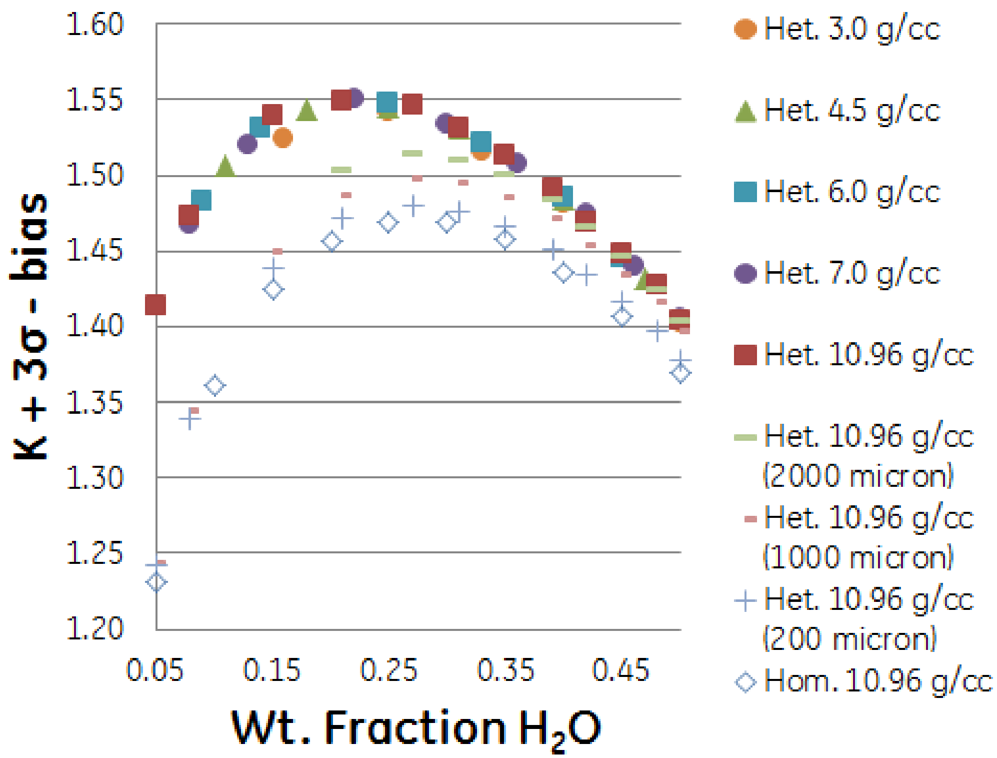
$$Wt. Fraction\ H_2O = \frac{W/F}{\frac{W}{F} + \rho_{fuel}}$$

W/F	Optimum Particle Diameter (µm)	10.96 g/cc fuel Wt. Fraction H_2O	4.5 g/cc fuel Wt. Fraction H_2O
0.577	70,000	0.05	0.11
1	30,000	0.08	0.18
2	14,000	0.15	0.31
3	8,000	0.21	0.40
4	7,000	0.27	0.47
5	5,000	0.31	0.53
6	4,000	0.35	0.57
7	3,000	0.39	0.61
8	2,500	0.42	0.64
9	2,500	0.45	0.67
10	2,500	0.48	0.69
11	2,000	0.50	0.71

Ref. "Optimum UO_2 Particle Size Determination," J. DeGolyer, and D. Eghbali, ANS June 2011

Infinite System

$$\frac{\Delta k}{k} = \frac{k_{het} - k_{hom}}{k_{hom}}$$



Optimum H_2O

Particle Diameter (μm)	Δk/k (%)
Optimum	5
2,000	3.0
1,000	1.8
200	0.6

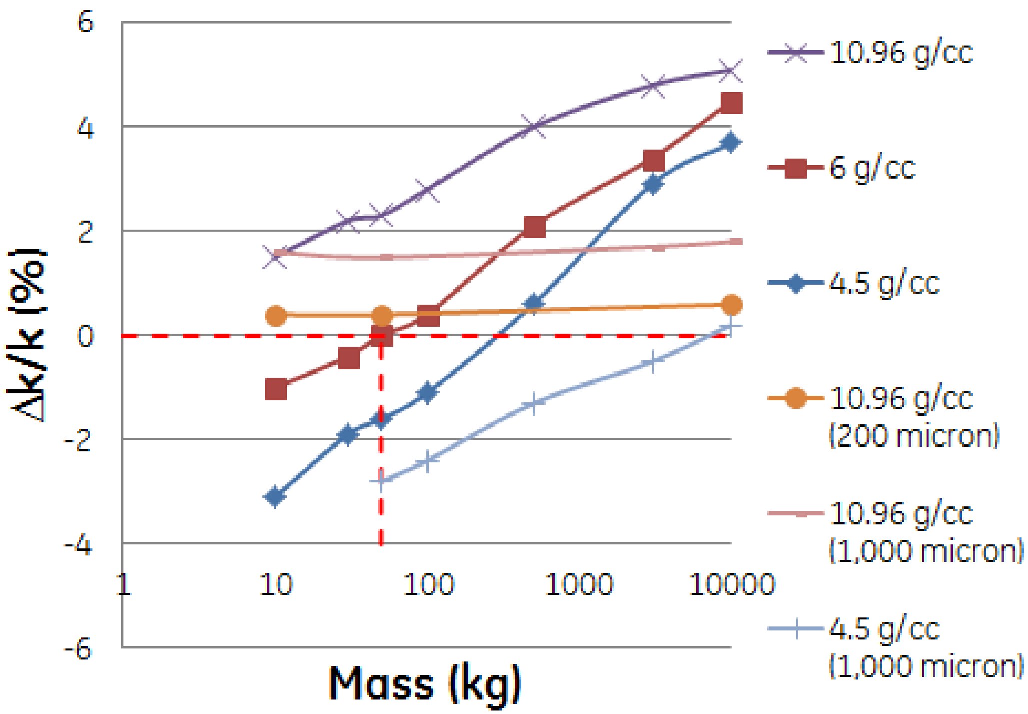
5 wt.% H_2O

Particle Diameter (μm)	Δk/k (%)
Optimum (2.75”)	15
12,700 (0.5”)	6
1,000	0.8

Heterogeneous effect is independent of density for infinite systems.

Mass Limited System

$$\frac{\Delta k}{k} = \frac{k_{het} - k_{hom}}{k_{hom}}$$

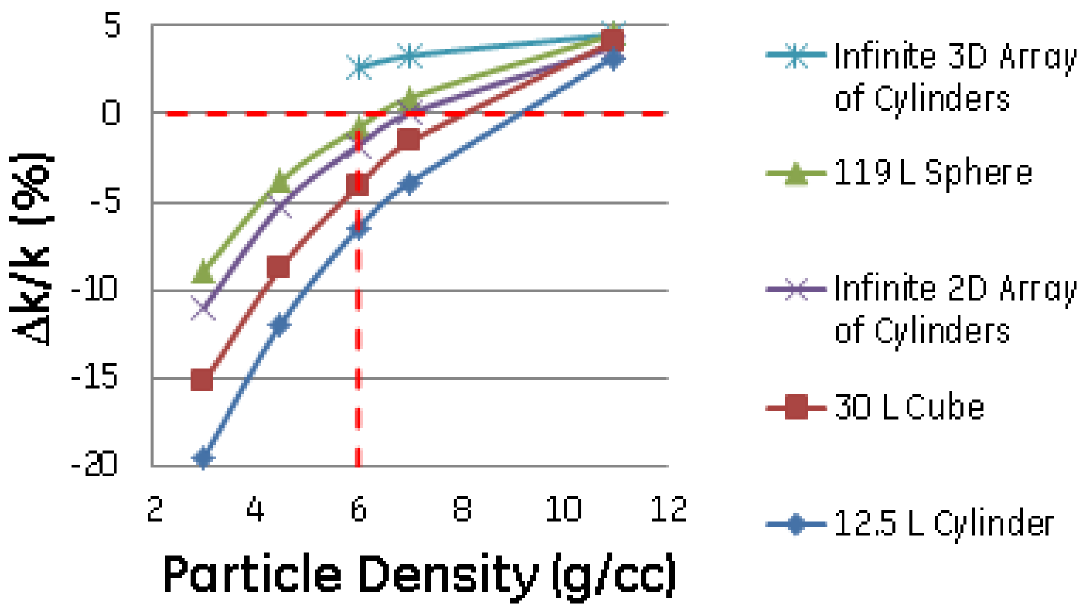


For 1,000 µm particles ≤ 4.5 g/cc, homogeneous is bounding up to 10,000 kg.

For 1,000 µm particles = 10.96 g/cc, heterogeneous effect is independent of mass.

Particle Density is important because leakage is important!

Geometry Limited System



$$\frac{\Delta k}{k} = \frac{k_{het} - k_{hom}}{k_{hom}}$$

For heterogeneous particles ≤ 6 g/cc, homogeneous is bounding up to 119 L or infinite 2D array.

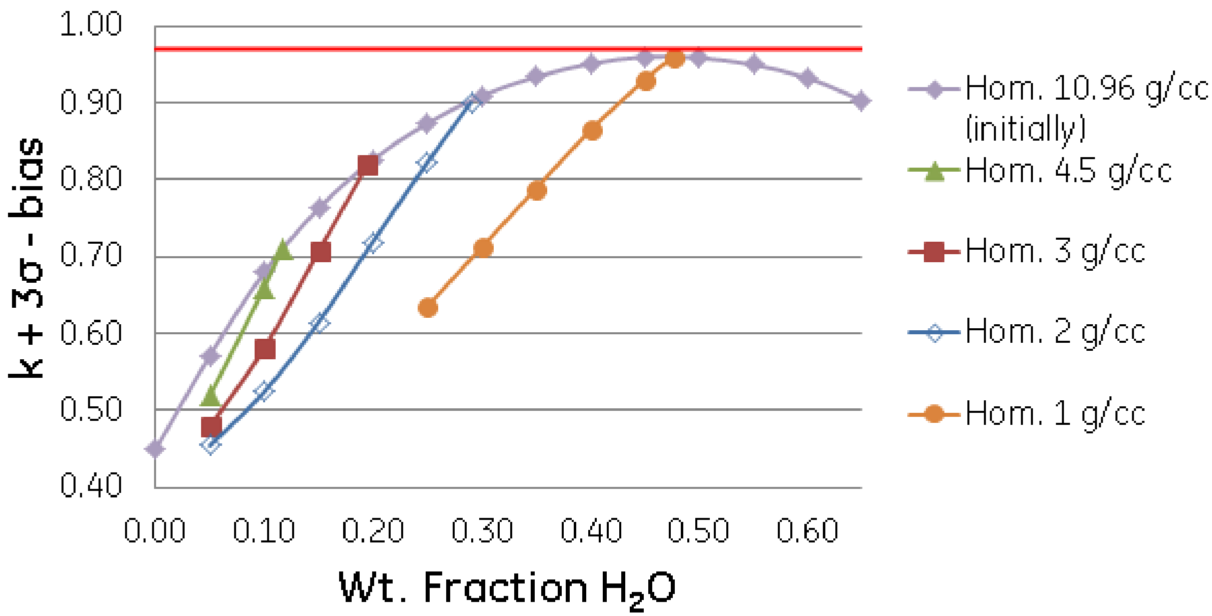
Heterogeneous effect is density and geometry dependent for geometry limited systems.

Homogeneous Systems

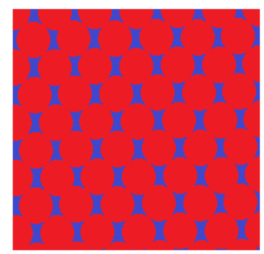
The effect of bulk density

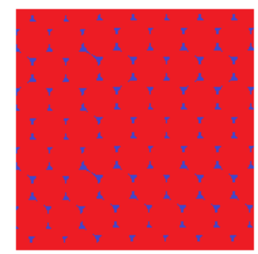
Mass Limited System

Homogeneous 31 kg UO_2 Sphere



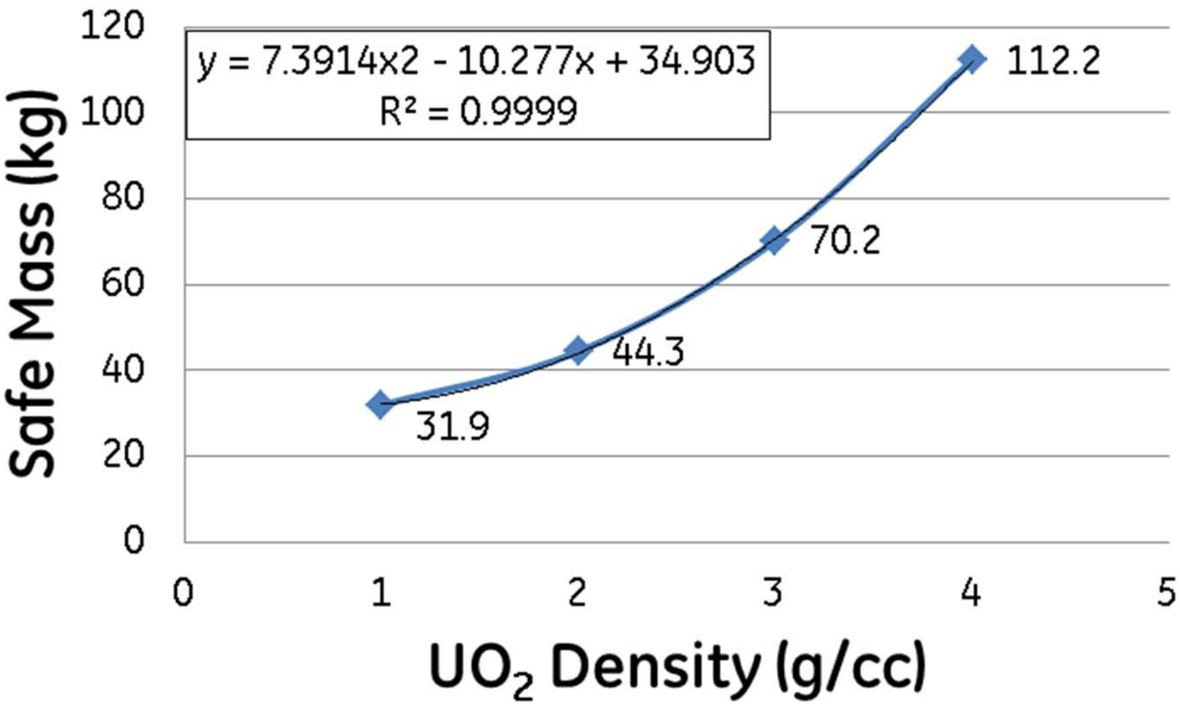
density (g/cc)	saturation wt. % H_2O
1	47.6
2	29.0
3	19.5
4.5	11.6
10.96	0.0





High density powder has less void space for water to occupy.

Density Dependent Safe Mass Limits



Higher safe mass limits can be developed for systems of a known density if agitation is not credible.

Conclusion

Effect of Particle Size and Density on Heterogeneous Systems

Infinite

- No density effect
- Large particle size effect

Mass and Geometry Limited

- Homogeneous bounds heterogeneous (≤ 6 g/cc) for systems with a high leakage component (≤ 50 kg, 119 L)
- 1,000 μm particles ≤ 4.5 g/cc are effectively homogeneous

Effect of Bulk Density on Homogeneous Systems

- Higher safe mass limits can be developed for systems of a known density if agitation is not credible.