Licensing Issues Associated with PuO_2 and Mixed Oxide Powder Processes

Workshop on the Need of Integral Critical Experiments with Low-Moderated MOX Fuels
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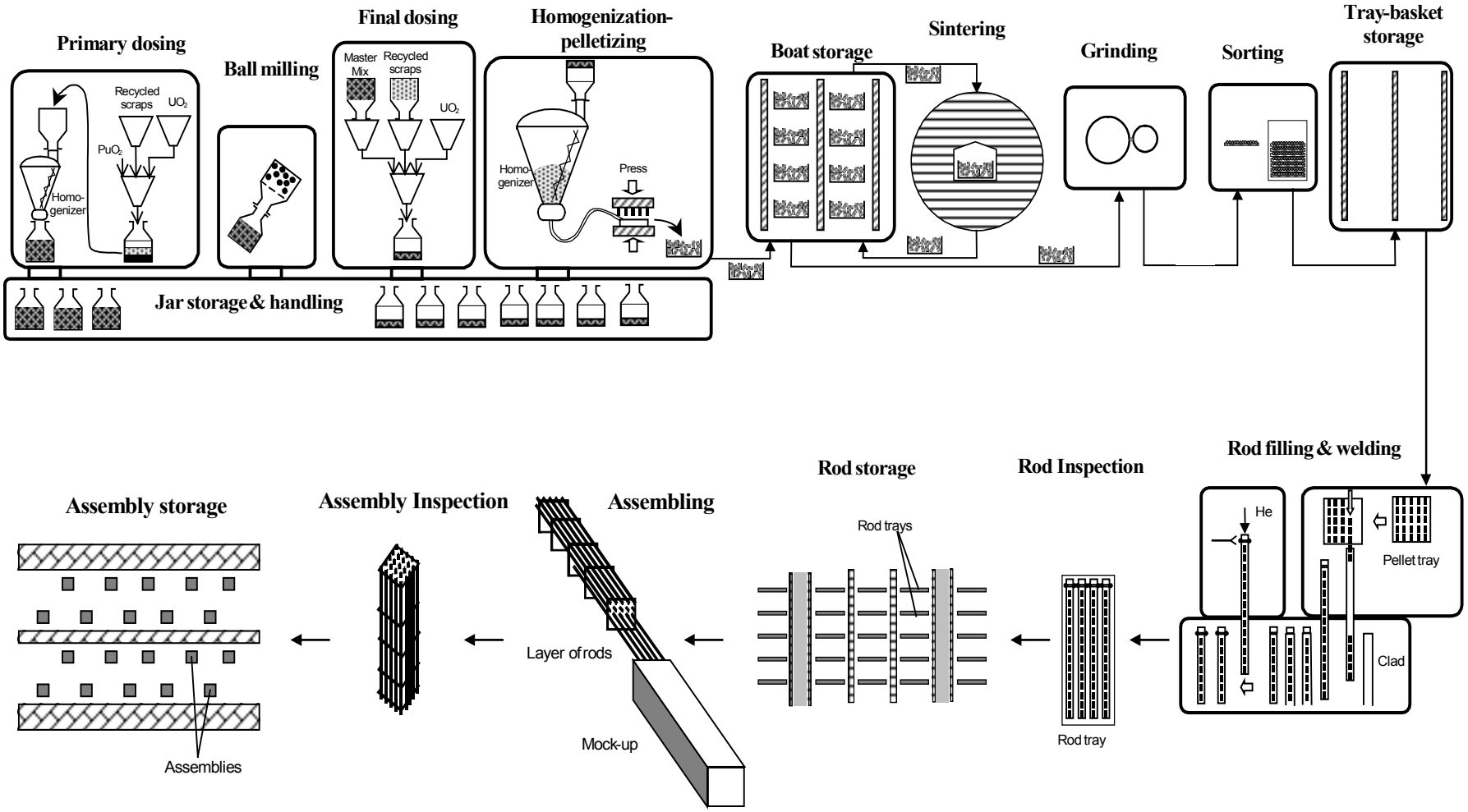
Unique Aspects: MOX/Pu

- 2-6wt% Pu *vs.* ≤5wt% ^{235}U fuel
  - Lower critical mass/dimensions
  - Harder neutron spectrum
- Multi-isotope mixture (^{239}Pu, ^{240}Pu, ^{241}Pu, ^{235}U, ^{238}U & Pu/(U+Pu))
- Multiple valence states and chemical forms
  - Affects system reactivity (*e.g.*, $Pu(NO_3)_3$ *vs.* $Pu(NO_3)_4$)
  - Affects process flow (*e.g.*, purification cycle efficiency depends on Pu(IV) *vs.* Pu(III))

Unique Aspects: MOX/Pu

- Variability in powder density (3.5 – 11.46 g/cm^3)
- Computer code validation
  - AOA(1): Pu-Nitrate solutions
  - AOA(2): MOX pellets, rods & assemblies
  - AOA(3): PuO_2 powders
  - AOA(4): MOX powders
  - AOA(5): Miscellaneous Pu-compounds
- Few benchmarks available for AOA(3) & (4)

Risk-Significant Processes



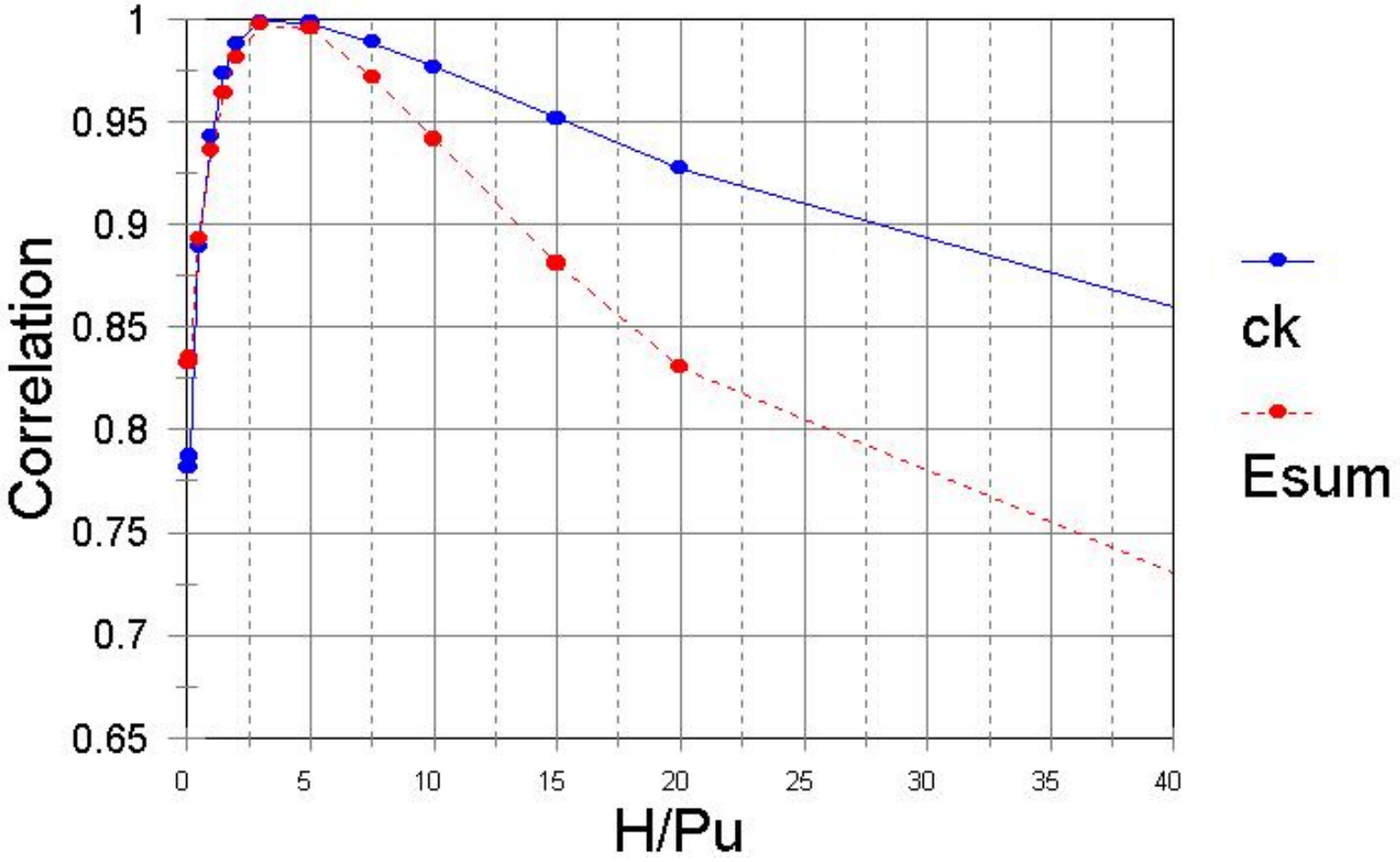
Parametric Significance Evaluation

- Characterize normal & abnormal conditions
- Identify parameters of greatest importance to benchmark applicability
- Determine screening criteria to select final set of benchmarks
  - NUREG/CR-6698, Table 2.3 (industry consensus)
  - Qualitative judgment ⇒ traditional trending parameters
  - ORNL Sensitivity/Uncertainty Code (TSUNAMI)

Parametric Significance Evaluation

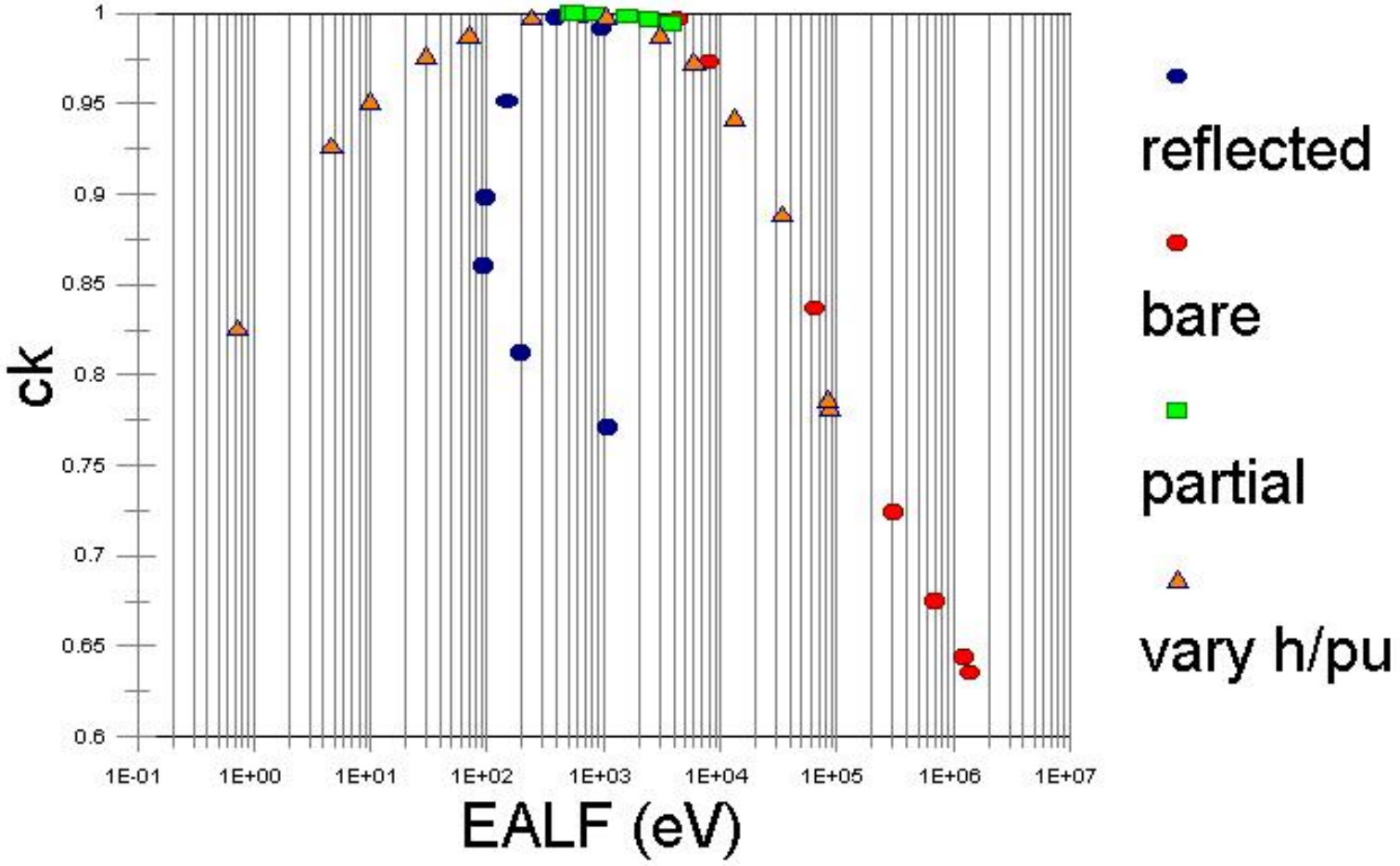
- **Primary**
  - Moderator-to-fuel ratio (H/Pu, H/X, v^m/v^f)
  - Total Pu-content (wt% Pu/(U+Pu))
  - Isotopics (^{239}Pu, ^{240}Pu, ^{235}U, ^{238}U…)
  - Neutron energy (thermal fission, AEG, EALF…)
- **Secondary**
  - Density
  - Geometry
  - Physico-chemical form

Low-Moderated PuO_2 System: H/Pu Correlation vs. H/Pu (H/Pu app=3.79)



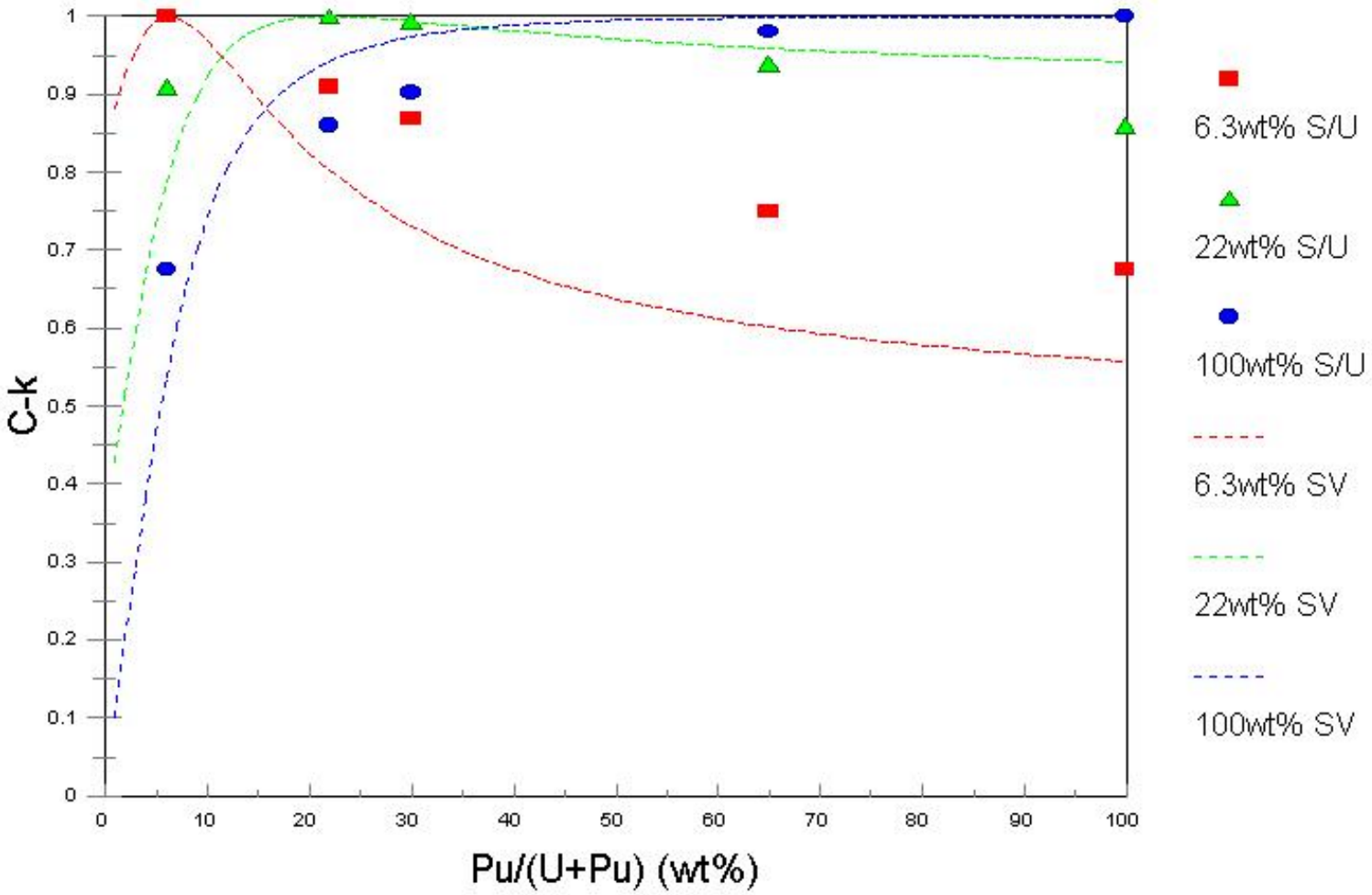
Low-Moderated PuO_2 System: EALF

ck vs. EALF

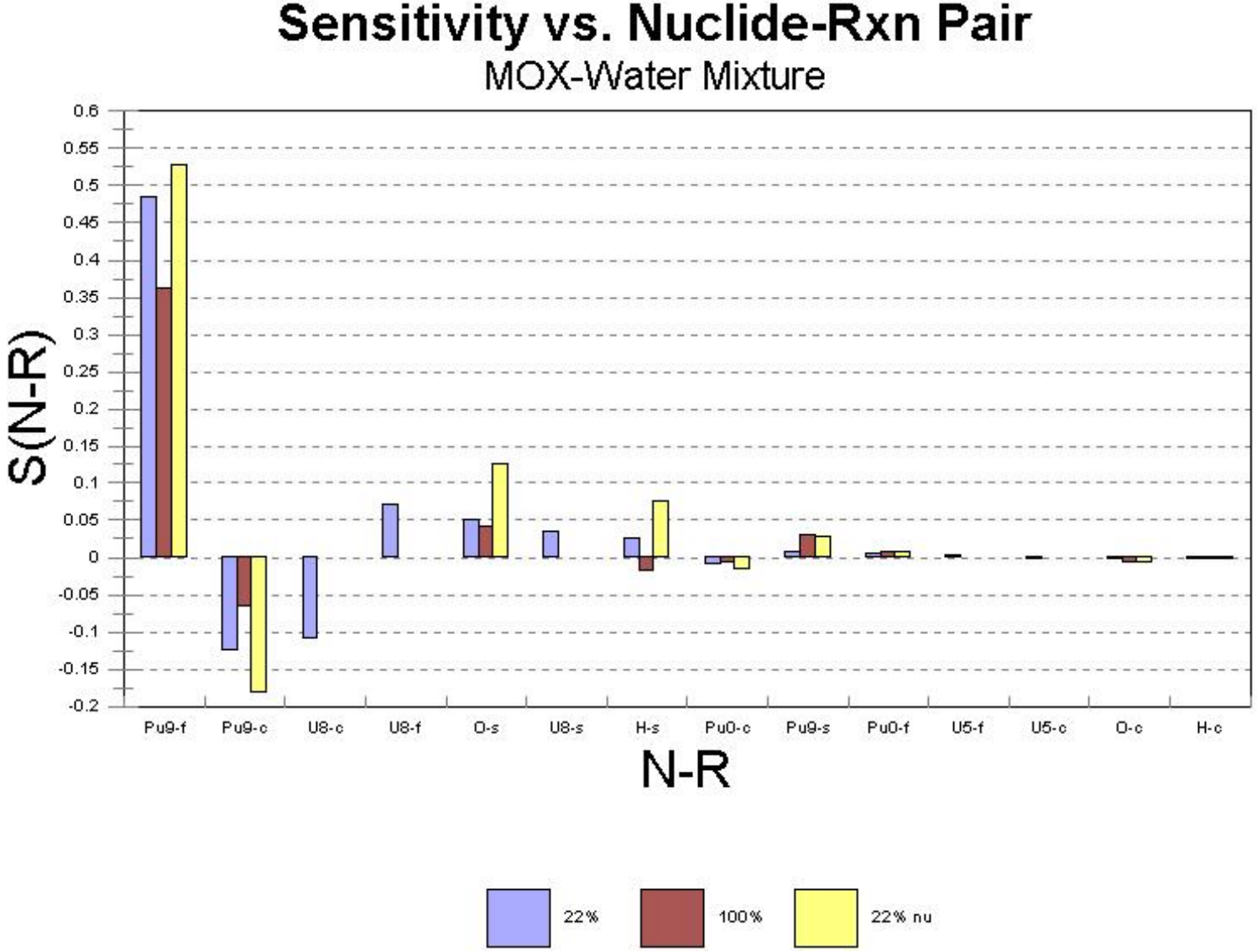


Low-Moderated MOX System: Pu/(U+Pu)

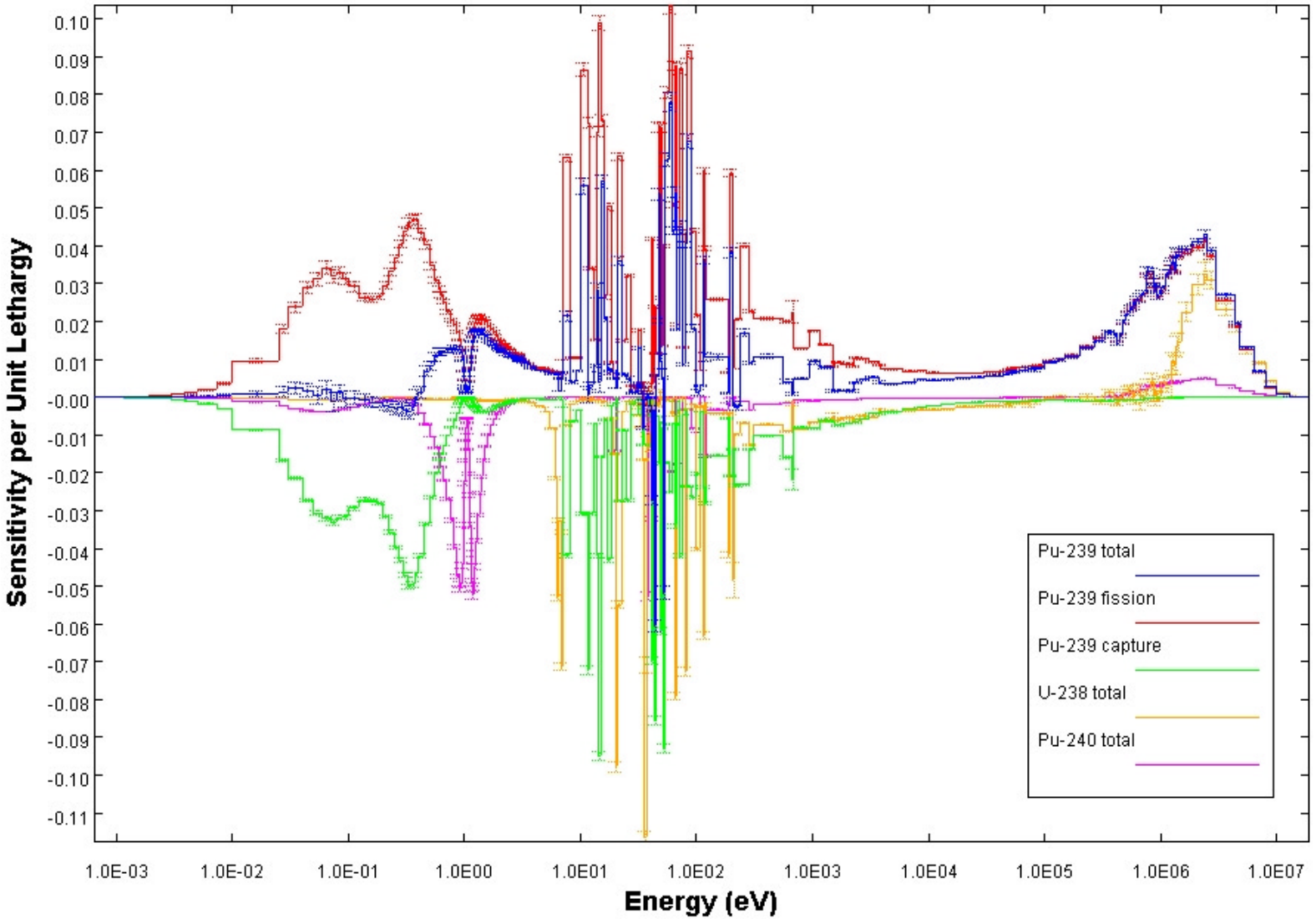
Ck vs. Pu-content: MOX-water spheres



^{239}Pu & ^{238}U Sensitivity Coefficients



^{239}Pu & ^{238}U Sensitivity Profiles



Summary of Parameters

	NUREG-6698	TSUNAMI	Design App.	Benchmarks
PuO_2				
H/X	0 – 19.8	0 – 25	0 – 16.5	0 – 15.1
Pu	90 – 100wt%	30 – 100wt%	100wt%	29.3 – 100wt%
^{240}Pu	0 – 8wt%	0 – 30wt%	4wt%	2.2 – 18.4wt%
EALF	1 – 2x10^{7} eV		3 – 2.66x10^{5} eV	4 – 1.25x10^{6} eV
MOX				
H/X	0.88 – 1.92		1.1 – 1.6	2.77 – 15.1
Pu	3.8 – 37	≤ 82wt%	6.3, 22wt%	8.1 – 100wt%
^{240}Pu	0 – 8wt%		4wt%	2.2 – 11.5wt%
EALF	0 – 10^{4} eV		0.28 – 850 eV	0.6 – 92.6 wt%

Conclusions

- PuO_2 & MOX powders are main areas in which more benchmarks are needed
- Particularly true in highly thermal range (expected under abnormal conditions)
- Limiting parameters appear to be H/X and total Pu-content.
- Geometry, density, and neutron energy appear to be secondary in importance.
- Decision about subcritical margin must consider risk, k_{eff} sensitivity, and parametric range of benchmarks as compared to normal and abnormal conditions.