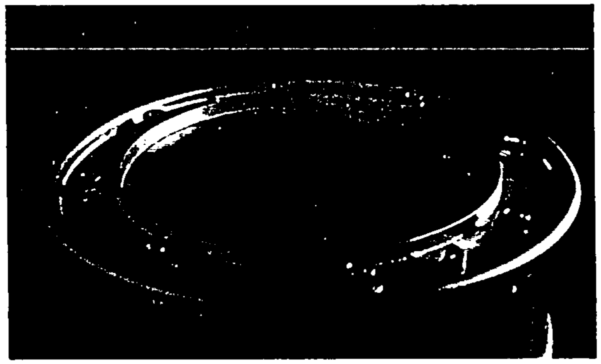
ES-3100 Shipping Package
Category 1 Meeting
Docket 71-9315



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Holder: U.S. Department of Energy

August 9, 2006

U.S. Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

BWXT Y-12 | Y-12 National Security Complex | NNSA National Nuclear Security Administration

Enclosure 3

Meeting objectives

- Review of topics in upcoming amendment
- Provide clarification as needed
- Discuss amendment submittal format
- Discuss amendment submittal schedule

Amendment topics

1. Revised equipment specifications for Kaolite and 277-4 casting
2. Revised calculation of total "off-gassing" material in CV
3. Increased moisture in oxide contents
4. Increased Np-237 concentration
5. Revised definition of pyrophoric uranium metal
6. Add air transport of the ES-3100
7. Add another CSI --- 3.2
8. Revised working data on 277-4 moisture content
9. Increased carbon content in HEU oxide contents
10. Confirmed that U/Al and U/Mo alloys are covered under HEU metal contents
11. Added U/Zr hydride and U carbide as content forms

Presenters

Kaolite and 277-4 specs	Arbital
Off-gassing materials and moisture in oxide	Arbital
Increased Np-237	Arbital
Pyrophoric uranium definition	Schmidt
Air transport	DeClue
Increased CSI to 3.2	DeClue
Revised moisture in 277-4	DeClue
Increased carbon in oxides	DeClue
Alloys and other uranium content forms	DeClue
Amendment submittal details	Arbital

Equipment specifications

- Revised specs for Kaolite and 277-4 casting
- No material property changes
- Changes were only for manufacturing efficiency
- Kaolite 1600™ spec is now Revision C
- 277-4 spec is now Revision E
- Detail of changes will be pointed out in the amendment submittal

Off-gassing materials

- Adds material over the previously submitted amendment
- Increased quantity of polyethylene bagging to 500 grams for each configuration
- Other materials are poly bottles, Teflon bottles and silicone pads
- Teflon FEP bottle off-gassing rates determined from testing; data on other materials already in SAR
- Pressure calculations revised in Appendices 3.6.4 (NCT) and 3.6.5 (HAC) to cover total mass of material
- Pressures are all below ASME code analysis value 101 psig at 300°F
- Revised regulatory leakage rate criteria in Containment Section of SAR
- Revised containment vessel stress analyses in Structural Section of SAR for both NCT and HAC

Increased moisture in oxide

- Moisture content increased from 3 wt% to 6 wt% in oxide contents
- Bagging of material and convenience containers minimize corrosion and galvanic reaction issues
- Boiling point of water is not reached during NCT and HAC temperature and pressure conditions
- Therefore, pressure increase from additional moisture content will not occur

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Increased Np-237 concentration

- Np-237 concentration increased to 0.025 g/gU (up from 0.003 g/gU in initial SAR)
- All shielding calculations were rerun with this one change only
- The gamma ray source increased by a factor of ~3, all below the 0.5 MeV energy range
- No change in the neutron source (neutrons contribute very little to the dose rates in this case)
- The package and contents provide adequate shielding with the increased Np-237

Results of increased Np-237

- Dose rate calculations are conservative

Maximum dose rates assuming 36 kg of HEU metal contents

Location	Regulatory Limit	Previous Dose (mR/hr)	New Dose (mR/hr)
NCT – Side surface of drum	200 mR/hr	65.9	94.0
NCT - 1 meter from drum side	10 mR/hr	4.4	6.5
HAC - 1 meter from CV side	1000 mR/hr	7.5	11.2

Additional Np-237 considerations

- Thermal analysis for HAC and NCT not revised
  - Decay heat limit maintained at 0.4W
- Total A_2 calculations will be revised
  - No safety implications

Revised Definition of Pyrophoric Uranium Metal

Current pyrophoric definition in CoC

"Uranium metal and alloy pieces must have a surface-area-to-mass ratio of not greater than 1.00 cm^2/g or must have a mass not less than 50 g, whichever is the most restrictive. Powders, foils, turnings, wires, and incidental small particles are not permitted, unless they are restricted to not more than 1 percent by weight of the content per convenience can, and they are either in a sealed, inerted container or are stabilized to an oxide prior to shipment."

Proposed replacement definition

"Uranium metal and alloy pieces must have a surface-area-to-mass ratio of not greater than 2.00 cm^2/g or must not pass freely through a mesh size 8 sieve (0.00238 m). Metal powders, foils, turnings, wires, and incidental small particles are not permitted, unless they are either in a sealed, inerted container or are stabilized to an oxide prior to shipment."

Major changes

- Eliminate 50 g minimum piece size
- Add mesh size 8 limit
- Increase Specific Surface Area limit from 1 cm^2/g to 2 cm^2/g
- Eliminate 1% limit on inerted material

Justification for changes

- The 50 gram minimum piece size is overly restrictive
  - Pieces less than 1 gram in mass can meet either the 1 cm^2/g or 2 cm^2/g surface area limit
  - The surface area limit is sufficient to prevent spontaneous ignition
  - The 50 gram limit places undue restrictions on normal operations

Justification for changes

- The mesh size 8 test is simple and effective
  - The test can be quickly and inexpensively performed at the work station
  - Mesh size 8 (0.00238 m) effectively implements a 2 cm^2/g specific surface area limit

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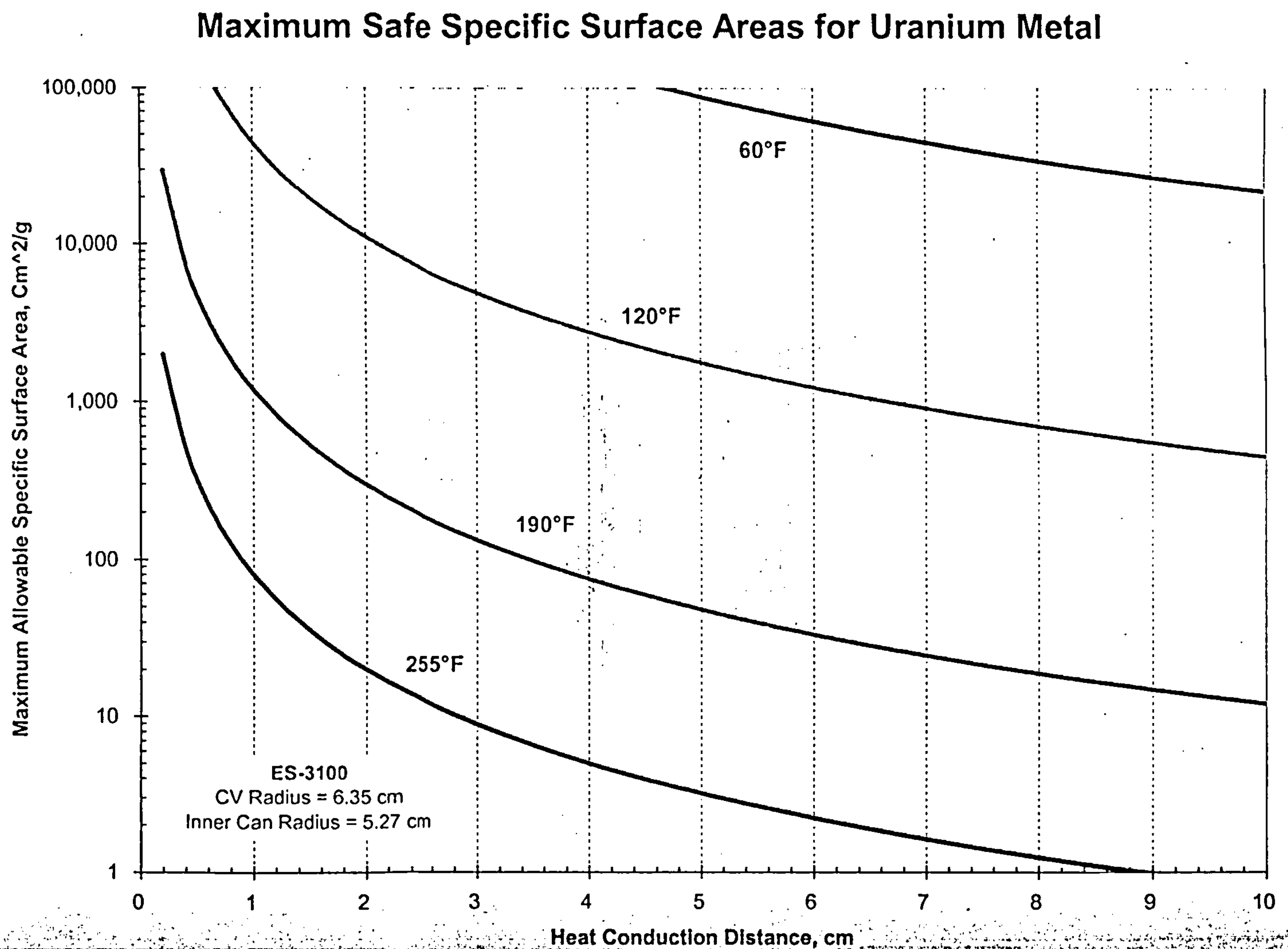
Justification for changes

- A limit of 2 cm^2/g will effectively prevent self-ignition under all conditions in the ES-3100
  - Pyrophoricity evaluated over a range of conditions including the maximum temperatures experienced under HAC
  - Evaluation methodology based on recent work that provides a solid computational basis to screen uranium for pyrophoric behavior under specific conditions:
    - "Uranium Pyrophoricity Phenomena and Prediction"; SNF-6192-FP; M. Epstein, B. Malinovic, M. G. Plys; April 28, 2000; issued by Fluor Hanford (public domain)

Evaluation results



Justification for changes

- The 1% limit on inerted material is not needed:
  - Items stabilized by oxidation are in no danger of spontaneous ignition
  - Items sealed in an inert container are in no danger of spontaneous ignition
  - The size of the containment vessel limits the maximum amount of oxygen present to the amount needed to oxidize 20 grams of uranium

Criticality Safety Analyses

Air transport of the ES-3100

- HAC for air transport mode are significantly more severe than for surface transport mode
- Package performance requirements are more stringent
- Performance requirements address separate aspects of the accident assessment and apply only to the criticality evaluation of an individual package under isolation (TS-G-1.1)
- 10 CFR 71.55(f) requires the criticality evaluation demonstrate:
  - A package be subcritical assuming reflection by 20 cm of water (7.9 in.)
  - No water inleakage
  - When subjected to the sequential application of:
    - HAC free drop of 10 CFR 71.73(c)(1)
    - HAC crush tests of 10 CFR 71.73(c)(2)
    - modified puncture of 10 CFR 71.55(f)(1)(iii)
    - modified thermal tests of 10 CFR 71.55(f)(1)(iv)
  - Subcritical under impact tests (90 m/s) of 10 CRF 71.55(f)(2)

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Air transport of the ES-3100

- Problem
  - The physical testing for Type-B fissile material packages transported by air have not been conducted for the ES-3100
- Proposed Solution
  - Demonstrate compliance of the package with more stringent requirements imposed by the IAEA for situations where the conditions of the fissile material package following the tests cannot be demonstrated (TS-G-1.1, Sect. 680.2)
- How
  - Analytic methods are used in lieu of testing to demonstrate compliance of the ES-3100 package with the requirements than 10 CFR 71.55(f)
- Rationale
  - Given that the requirements of 10 CFR 71.55(f) mirror the IAEA requirements of TS-R-1 Sect. 680 for Type B(U)F packages, we assume this approach will be acceptable

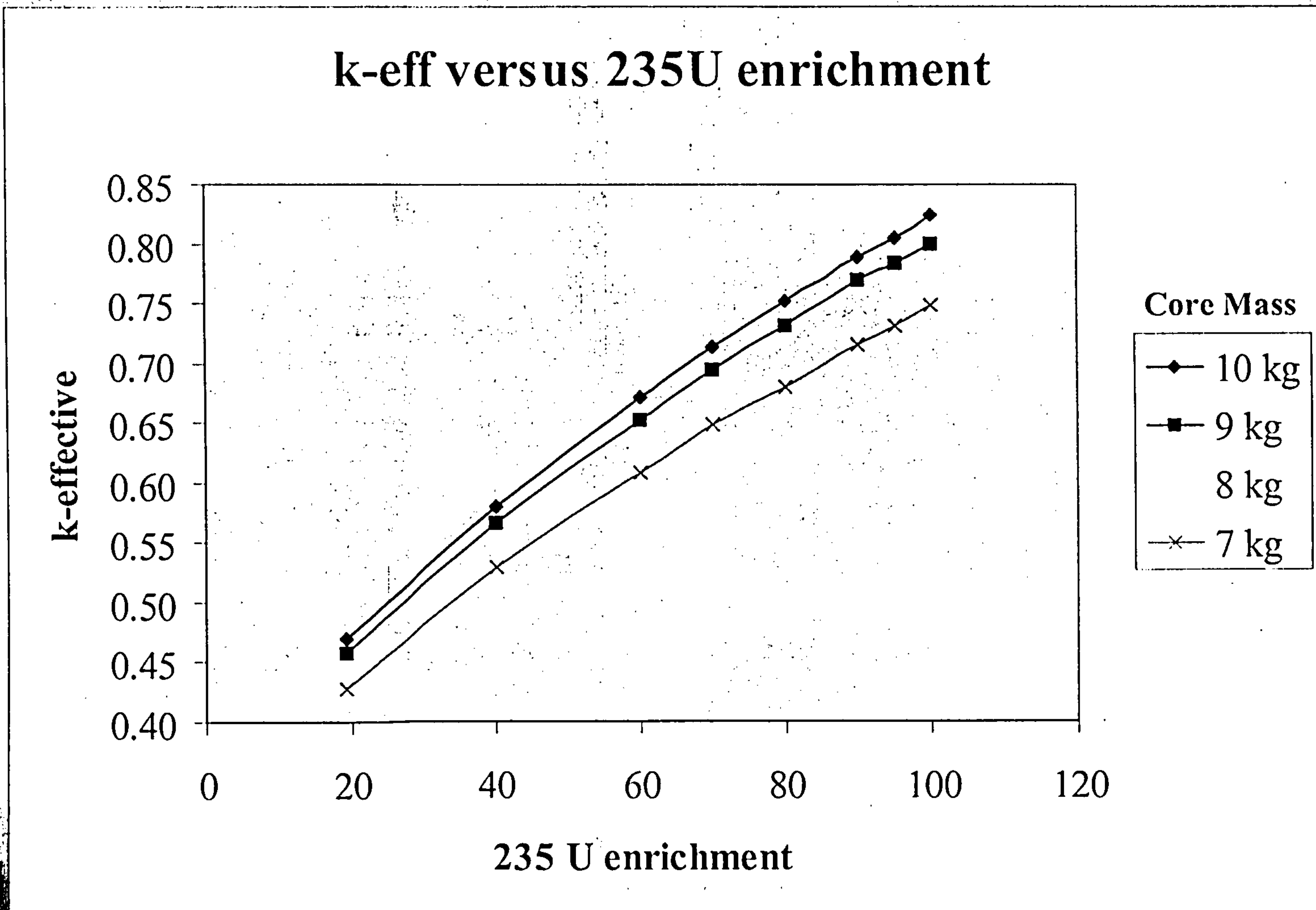
Method of analysis

- Worst case assumptions should be made in the criticality evaluation regarding the geometric arrangement of the package and contents taking into account all moderating and structural components of the packaging
- The assumptions should be in conformity with the potential worse case effects of the mechanical and thermal tests, and all package orientations should be considered for the analysis
- Subcriticality must be demonstrated after due consideration of such aspects as:
  - the efficiency of moderator,
  - loss of neutron absorbers,
  - absence of neutron poisons,
  - rearrangement of packaging components and contents,
  - geometry changes and temperature effects

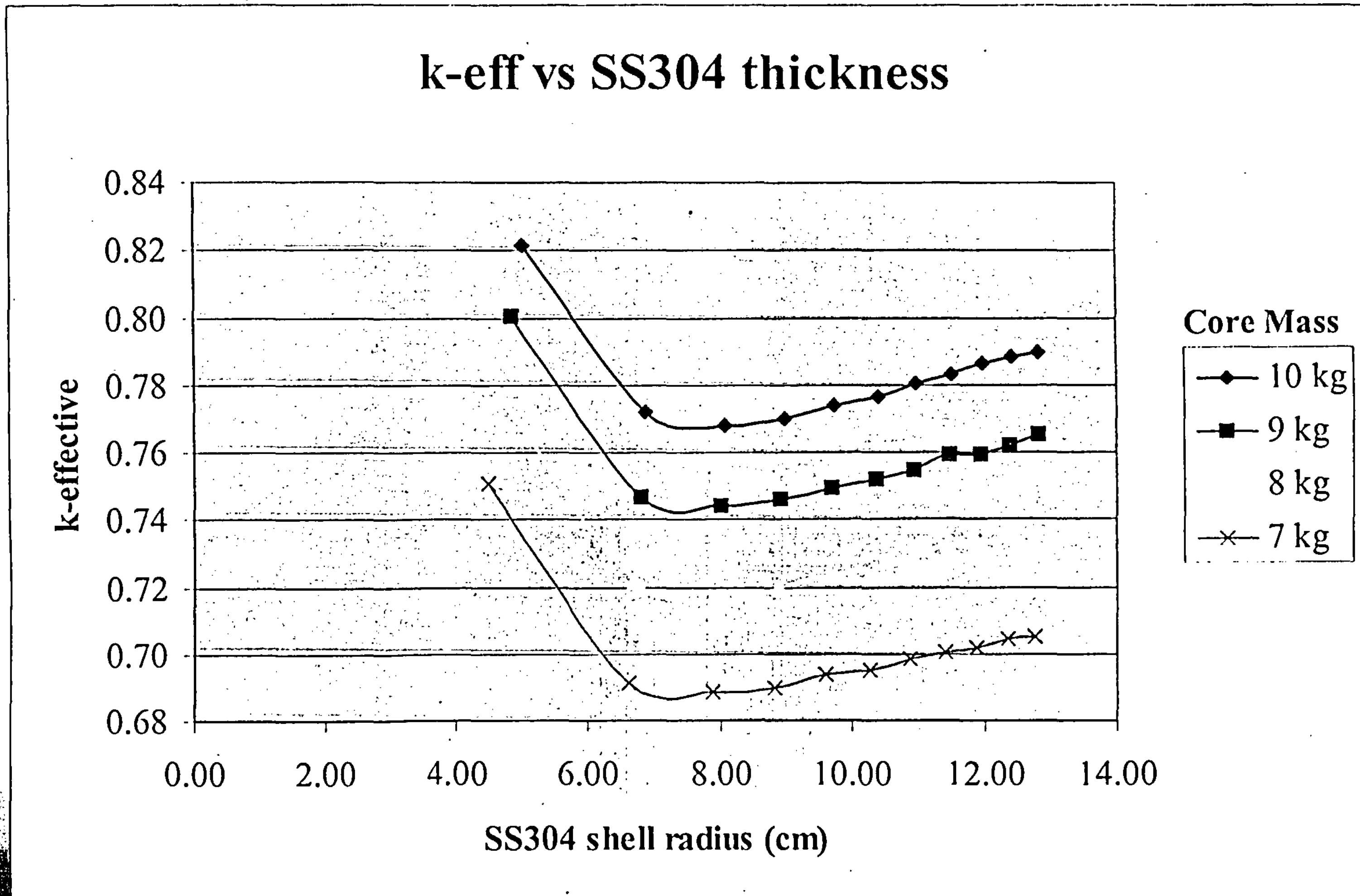
Spherical geometry models with 20 cm water reflection

Model 1: Fissile material core		
	atd*f*r - air transport discrete *fissile material* reflected	(7-10 kg 235U)
Model 2: Fissile material core blanketed by reflecting material of packaging		
	atd*f*sr - air transport discrete *fissile material* stainless steel reflected	(0 to 66133g SS304)
Model 3: Fissile material core blanketed by moderating materials of packaging		
	atd*f*k1r - air transport discrete *fissile material* kaolite 1 reflected	
	kaolite 1 - variation of kaolite thickness in uniform mass (volume) increments	(0 to 128,034g Kaolite)
	kaolite 2 - variation of kaolite thickness in uniform thickness increments.	"
Model 4: Core of fissile material homogenized with moderators of package		
	ath*f*pkr - air transport homogenized *fissile material* poly kaolite reflected	(813g polyethylene, 0 to 2,204g H_2O of the Kaolite)
Model 5: Core of partial fissile material core homogenized with moderators of package, blanketed with residual fissile material		
	ath*f*pk*f*r - air transport homogenized *fissile material* poly kaolite *fissile material* reflected	

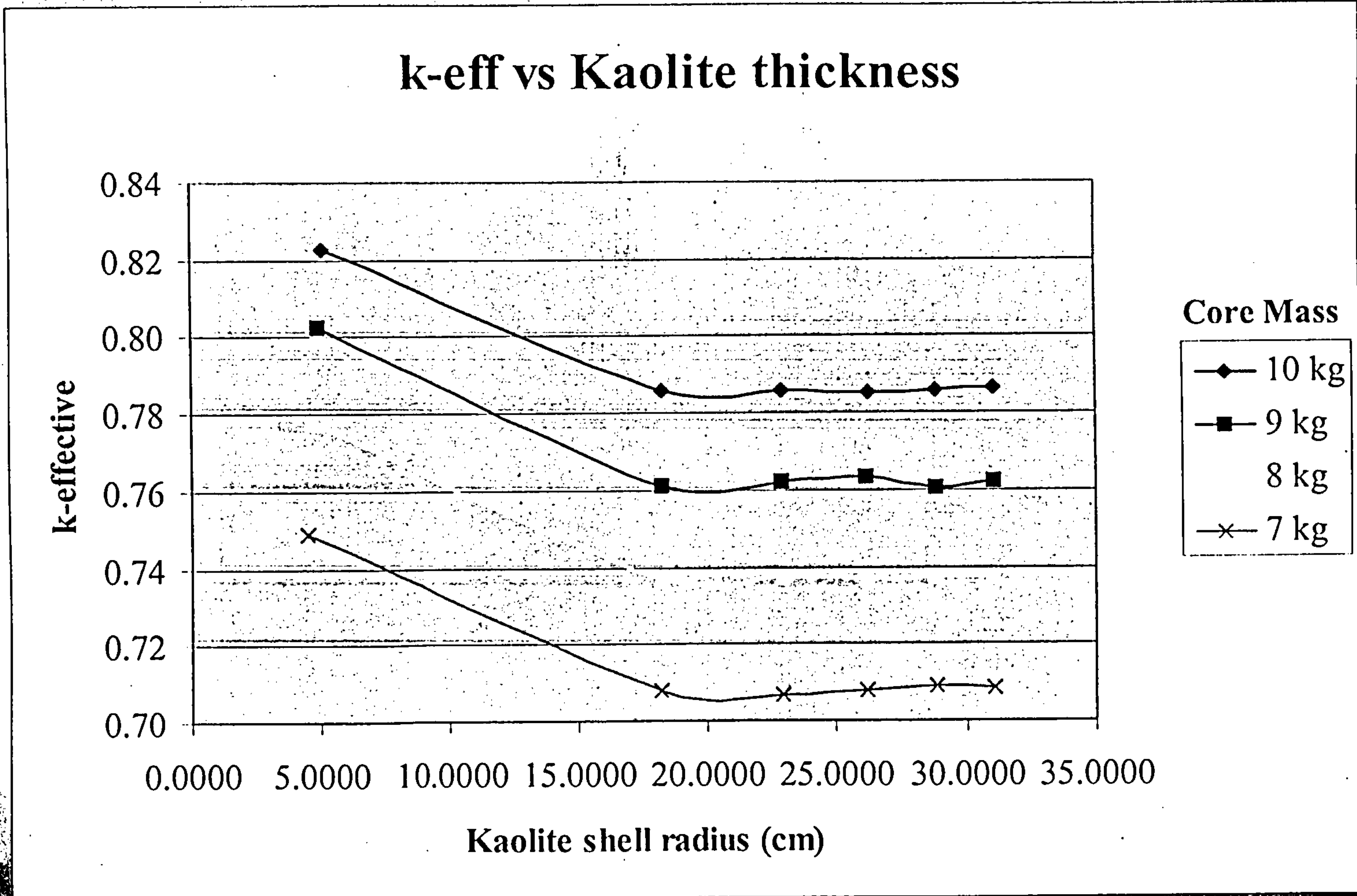
Model 1 *keff* increases with fissile mass



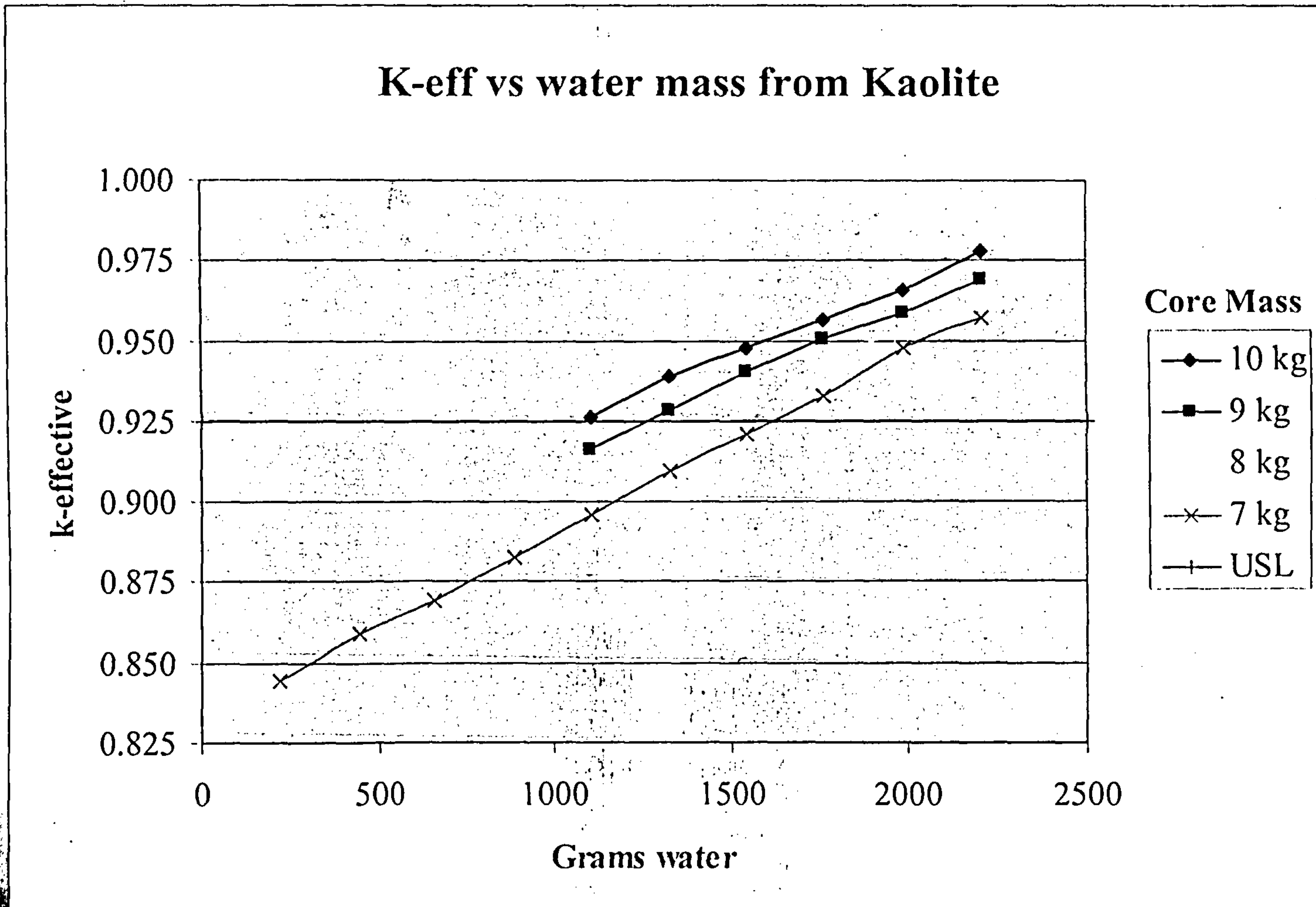
Model 2 *keff* decreases overall as mass of steel shell increases



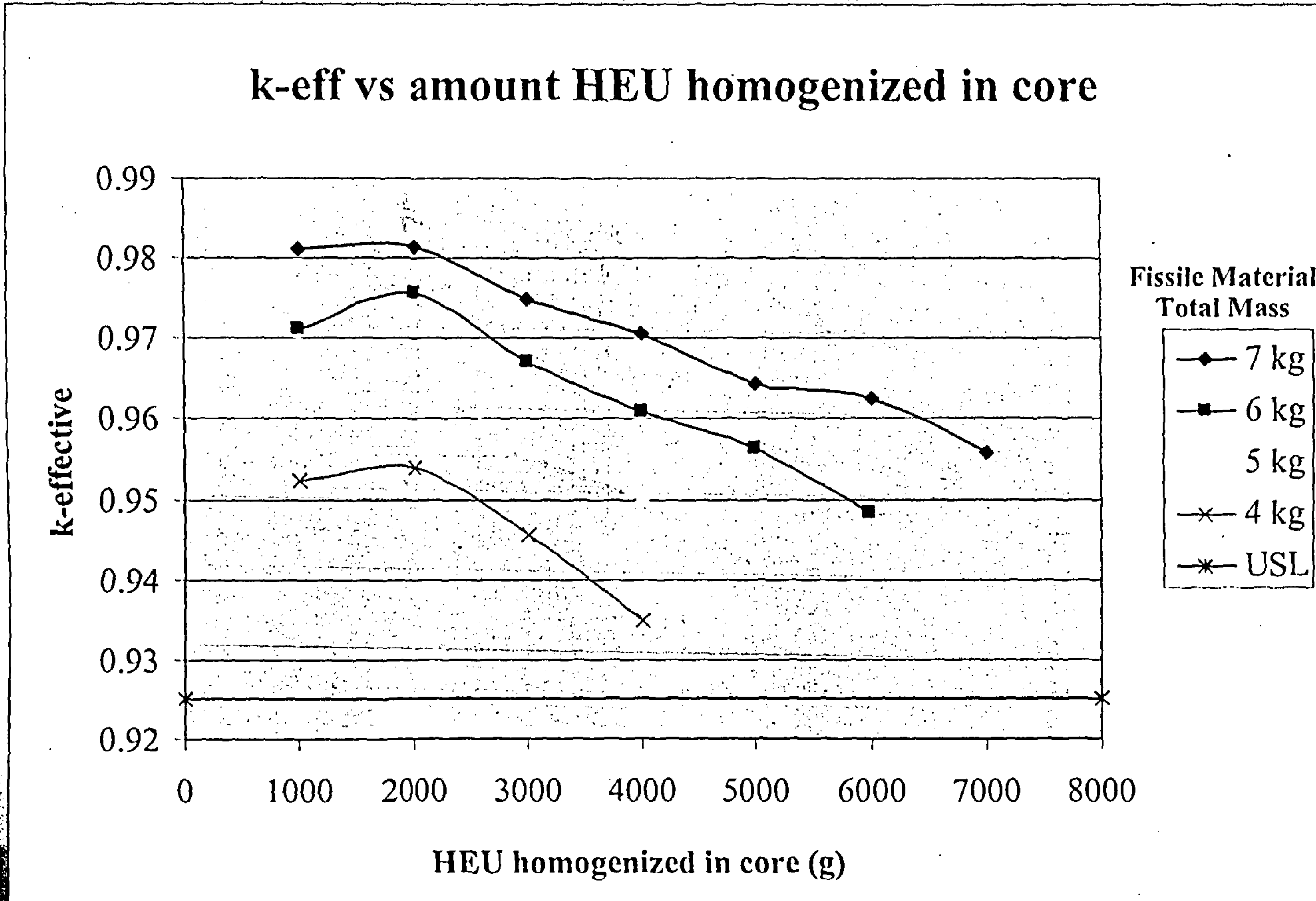
Model 3 *keff* decreases as mass of Kaolite shell increases



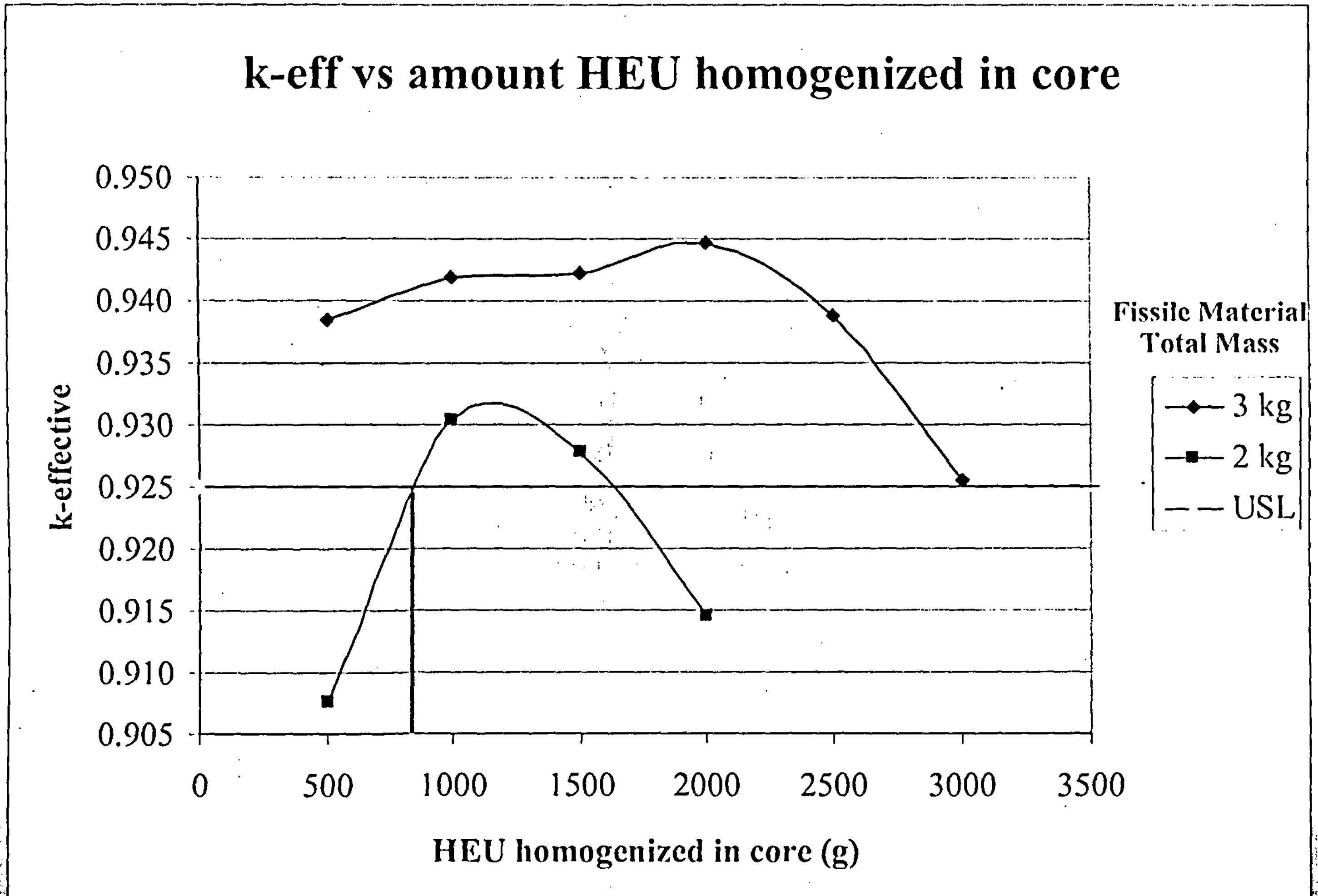
Model 4 keff increases as hydrogen content of homogenized fissile material increases



Model 5 keff decreases as h/x of homogenized fissile mass in the core decreases



Model 5 *keff* decreases as h/x of homogenized fissile mass in the core decreases (cont.)



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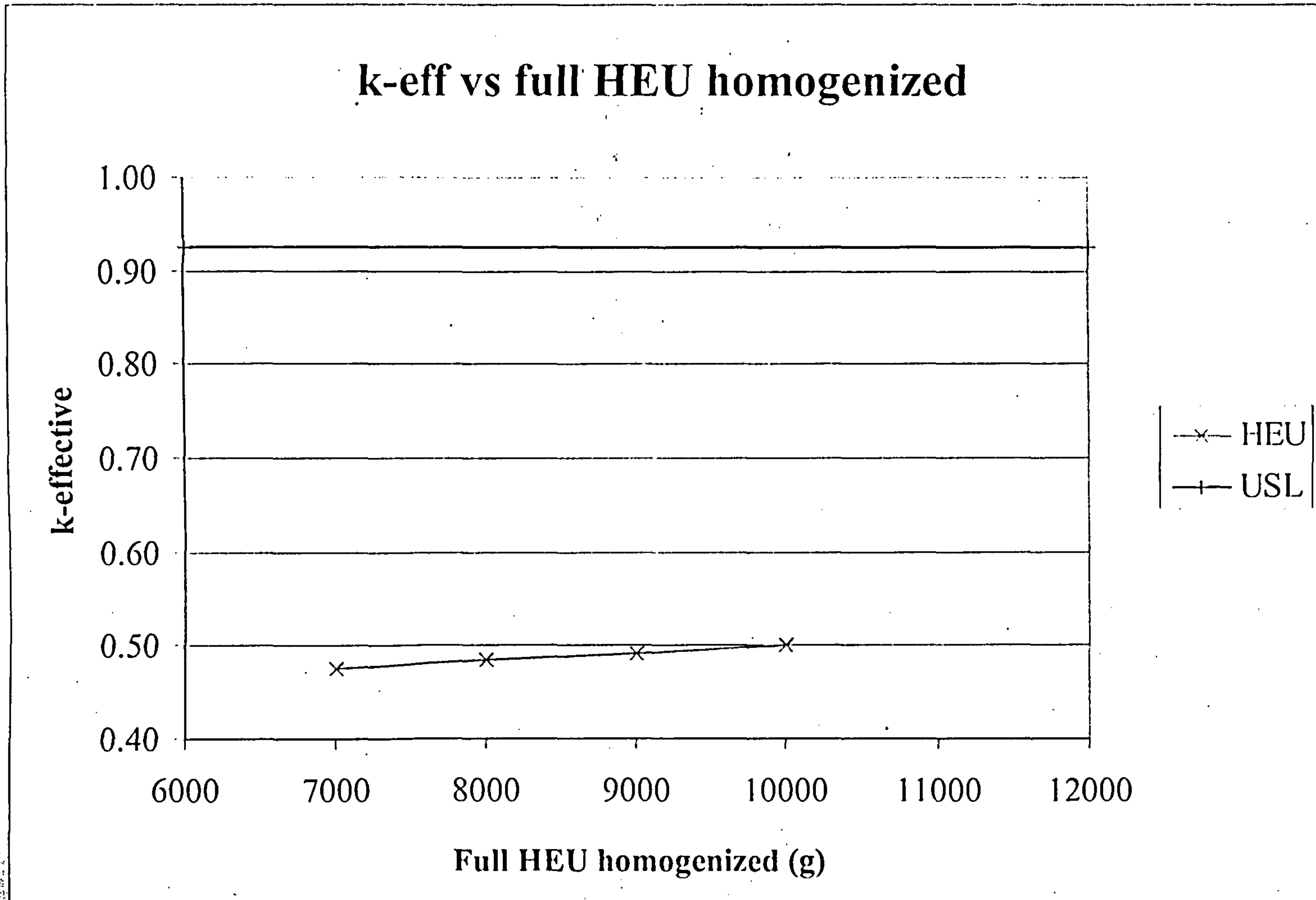
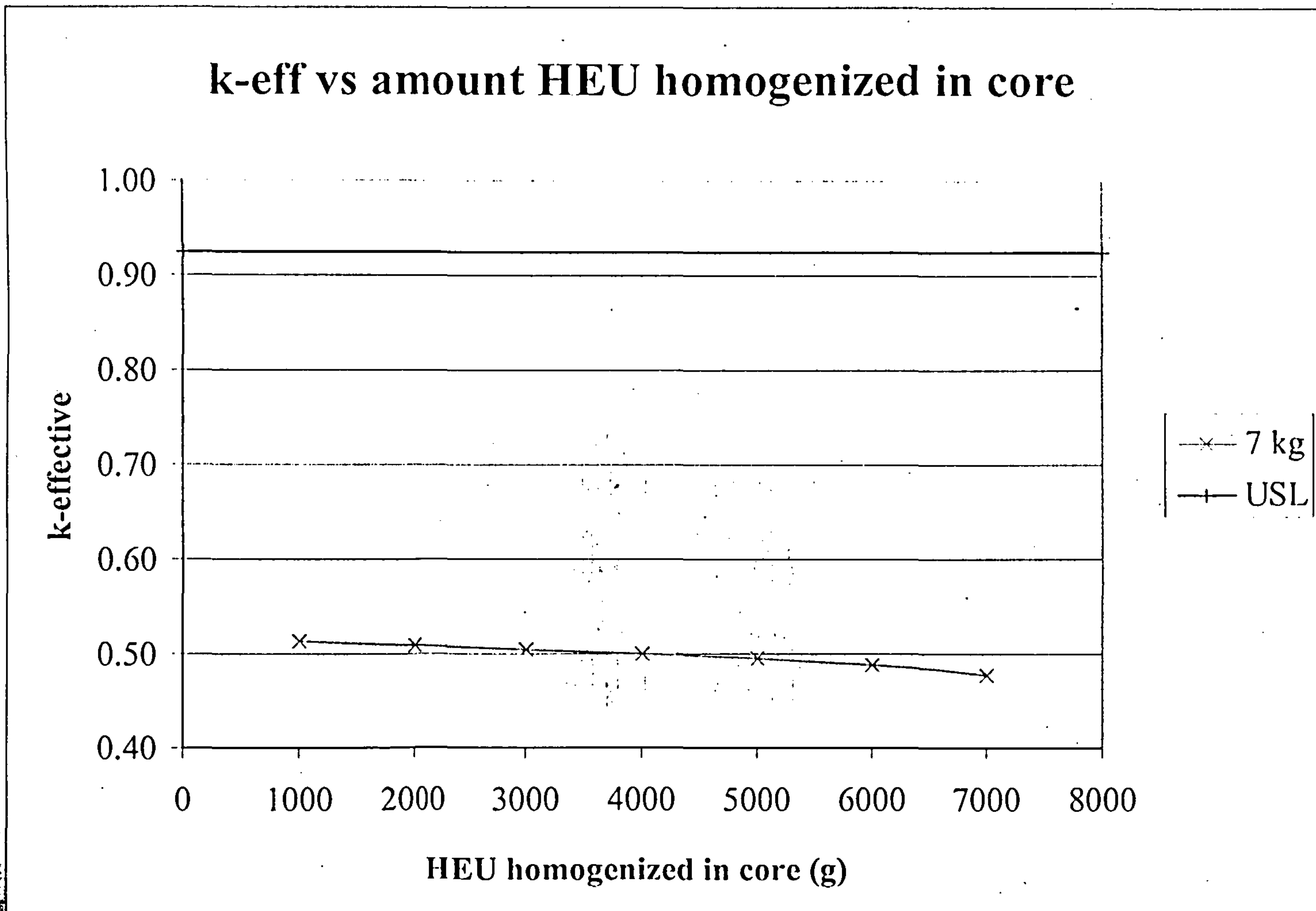
Observations

- Significance of previous figure: no more than 800g 235-U may be approved for air transport
- Reconfiguration of the ES-3100 package and fissile material content into an optimum geometric shape is conceivable
- Additional criteria may not be credible:
  - Selective removal of neutron absorbing material of package
    - (i.e., Kaolite and stainless steel)
  - Homogenization of volatile moderating materials with fissile material
    - (i.e., hydrogenous packing inside containment vessel and water of the Kaolite)
- Alternative models are proposed to Models 4 and 5, where total Kaolite is homogenized with fissile material in the core

Alternative Model 4 fissile material homogenized with 813 g poly and total Kaolite material



Alternative Model 5 fissile material homogenized with 813 g poly and total Kaolite material



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Proposed Criticality Evaluation for Air Transport

- Retain Models 1-3 but delete Models 4 and 5
- Adopt revised Models 4 and 5 based on positive feedback from NRC
- Re-evaluate for proposed loadings in 7-10 kg range for fissile contents

Re-evaluation of 277-4 effectiveness based on updated moisture data

- Original calculations performed with conservative estimate of moisture in 277-4, and resulted in bias correction factors
- All KENOV.a criticality calculations rerun with revised moisture data
- 277-4 neutron poison material used in ES-3100 is a formulation of Cat 277-0 dry mix, a boron carbide additive, and water
- 277-4 elemental composition data are derived from Loss on Drying (LOD) test data published in DAC-PKG-801624-A001, Rev. A
- Table 5 from DAC -- as-manufactured neutron absorber material composition data derived from basic data for 277-4 at 100 lb/ft^3 and 31.8% LOD
- Table 11 from DAC -- composition reduced for NCT minimum density at minimum hydrogen content (95.39 lbs/ft^3 and 25.15 % LOD after 168 hours at 250°F)
- Table 12 from DAC -- composition reduced for HAC minimum density at minimum hydrogen content (94.59 lb/ft^3 and 27.90% LOD after NCT and 4 hours at 320°F)
- NCT cases were rerun with "t11" data while HAC cases with "t12" data
- Re-evaluation provides verification that results of original criticality analyses were indeed conservative

Increase CSI to 3.2 for broken metal contents

CSI	NCT Array Size	N	HAC Array Size	N	Model	Units	Arrayed Units	Lines of coding	k_{eff}	σ	$k_{eff} + 2\sigma$	time sec
0	∞	∞	-	-	7.0% reduction on drum ID with conservation of mass adjustments	19	1	338	1.1099	0.0013	1.1125	296
0	∞	∞	-	-	Explicit Triangular Pitch	19	45	822	1.1107	0.0013	1.1133	356
2.0	7×7×3	29 (1.8)	5×5×2	25 (2.0)	7.0% reduction on drum ID with conservation of mass adjustments	19	2793	4212	0.9179	0.0012	0.9204	299
						19	950	4176	0.8849	0.0014	0.8877	366
3.2	27×3	16 (3.2)	16×3	24 (2.1)	Explicit Triangular Pitch	19	9576	1099	0.9225	0.0012	0.9249	328
						19	7182	1001	**0.9062**	**0.0014**	**0.9089**	318

13.8 kg approved under CSI = 2.0 increases to 24.9 kg under CSI = 3.2 for broken metal at 95 wt% 235-U

Increase carbon content in oxides

Skull oxide – oxidized uranium (U_3O_8) contaminated with graphite.

Units	wt %	wt %	µg/gU	µg/gU235			g	g	g
Statistic	**U**	**U-235**	**C**	**C/U235**	**Cycle**	**MF**	**NetWt**	**ElWt1**	**IsWt11**
Count	269	269	269	269			269	269	269
Max	84.52%	93.19%	171,000	252,861			7,072	5,938	4,165
Min	12.93%	20.28%	13	17			442	312	221
Median	81.66%	37.62%	5,590	13,910			4,448	3,541	1,414
Mean	79.64%	45.02%	16,968	41,333			4,419	3,532	1,563
Std Dev	6.87%	16.40%	24,304	59,027			745	698	606

Carbon-to-Uranium ratios

- Above 252,861 μgC/gU occurring in samples $\leq$221 g ^{235}U
- 12,600 – 18,600 μgC/gU occurring in samples with 93.2 wt% ^{235}U
- 3,231 – 87,720 μgC/gU occurring in samples with 60 -70.2 wt% ^{235}U
- 400 – 233,366 μgC/gU occurring in samples with 37 – 38 wt% ^{235}U
- Y-12 to evaluate skull oxide at mass limits currently in the SAR

Confirm U/Al and U/Mo alloys are bounded by HEU metal contents

U/Al cylinders

- Diameter 3.93 in + 0.03/ -0.04 in.
- Length: 9.5 in +/- 0.4 in.
- Average 0.94 kg U, 0.05 – 2.39 kg U
- Average 0.60 kg 235-U, 0.03 – 1.34 kg 235-U
- Average 4.07 kg Al, 1.14 – 4.96 kg Al
- Replacing scattering media (Al) with multiplying media (U)
- Alloy content conservatively assessed as 4.25-in. diameter HEU metal cylinders at 100 wt% 235-U

Mo material types

- 98.5 wt% U 1.5 wt% Mo. enrichment 92.65 – 92.94 wt% 235-U
- 90 wt% U 10 wt% Mo. enrichment 93.11 – 93.21 wt% 235-U
- Replacing scattering media (Mo) with multiplying media (U)
- Alloy content mass conservatively assessed as HEU at 95 wt% 235-U

Added U/Zr hydride as content forms

- Un-irradiated TRIGA fuel element
  - stainless steel clad
  - maximum overall length 29.68 in.
  - length of active region, 3 sections 15 in.
  - *diameter of each fuel section* ~1.44 in.
  - volume active fuel region 24.43 in3 (400.32 cm3)
  - maximum amount of 235-U occurs in 45 wt% stainless steel clad fuel element
  - mass of 235-U ~307 g
  - Enrichment 19.6795 wt%
  - mass of U 1,560 g
  - H/Zr ratio 1.6
  - mass of UZrHx 3466.67 g
- Uranium hydride does not form to any considerable extent.
- Uranium hydride has never been detected in the photo micrographic evaluations of TRIGA fuel

Case	np (in)	$UZrH_x$ (g)	^{235}U (g)	H2O (g)	h/x	mocfr	NCT k_{eff}	NCT σ	NCT $k_{eff}+2^*\sigma$	HAC k_{eff}	HAC σ	HAC $k_{eff}+2^*\sigma$
ncsrtriga_01_15_15	0.0	3467	307	9797	832.96	1.0E+00	0.29925	0.00098	0.30121	0.29785	0.00083	0.29950
ncsrtriga_02_15_15	1.4	3467	307	9184	780.80	1.0E+00	0.23620	0.00092	0.23805	0.23569	0.00070	0.23710

Case	np (in)	$UZrH_x$ (g)	^{235}U (g)	H2O (g)	h/x	mocfr	NCT k_{eff}	NCT σ	NCT $k_{eff}+2^*\sigma$
nciatriga_01_15_03	0.0	3467	307	9797	832.96	1.0E-04	0.31371	0.00107	0.31586
nciatriga_02_15_03	1.4	3467	307	9184	780.80	1.0E-04	0.25331	0.00079	0.25489

- Y-12 to evaluate TRIGA fuel at higher mass limits

Amendment format

- Cover letter with attachment that summarizes the topics of the amendment
- Complete SAR, Revision 1
- SAR Revision 1 will encompass:
  - Revision 0
  - All series of page changes
  - Amendments 1 and 2
- Not planning to highlight specific word changes in SAR Revision 1

Amendment schedule

- Submittal planned for around Sept 30.
- Potential for revising the CoC in phases
  - Phase 1
    1. Modified equipment specs
    2. Air transport
  - Phase 2
    1. All other topics