Transportation Implications of a Closed Fuel Cycle

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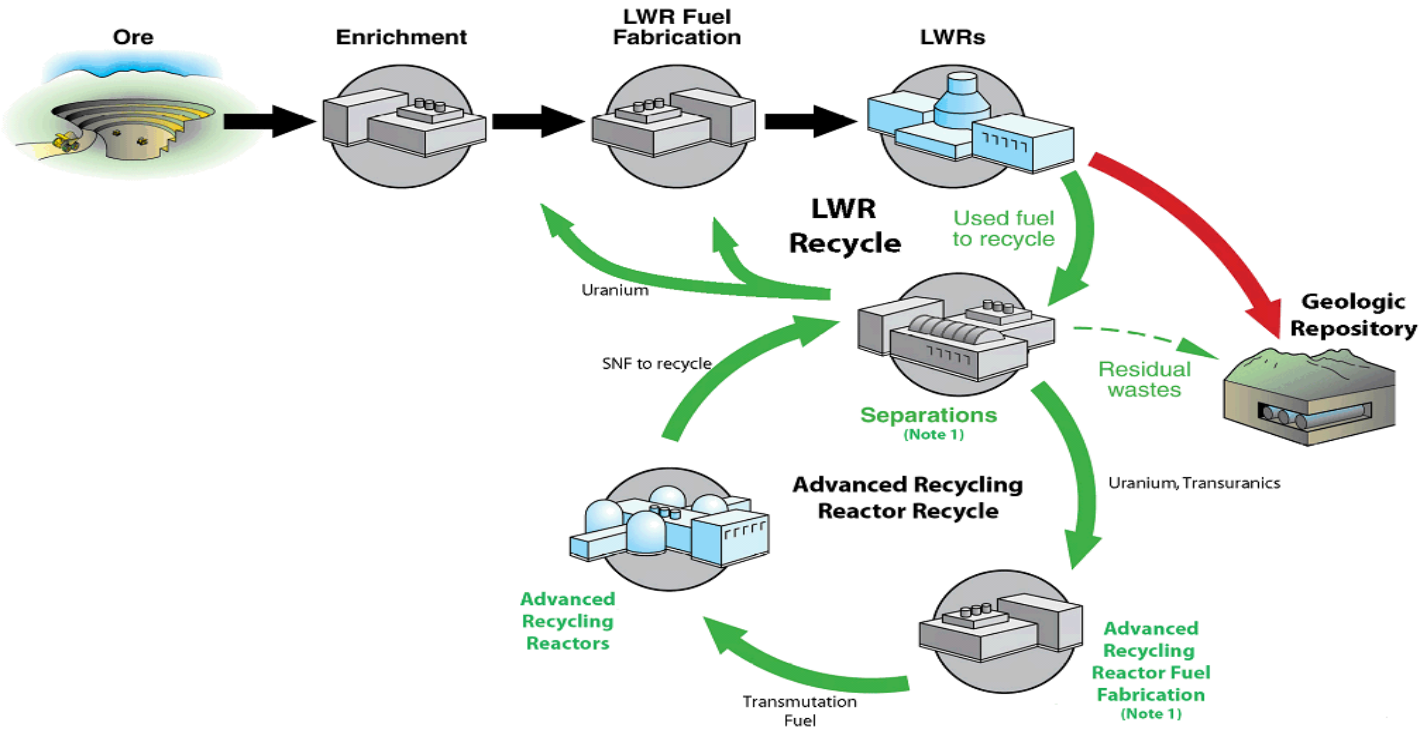
Baseline Fuel Cycle Scenario



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Mass Flow Supporting A 800-tonne Separations Plant

Steps of the Mass Flow	Material	Units	Quantity[a]
Mine to conversion	NU (U_3O_8)	Tonnes	8290
Conversion to enrichment	NU (UF_6)	Tonnes	10400
Enrichment to UOX fabrication	LEU (UF_6)	Tonnes	1180
Enrichment to reconversion	DU (UF_6)	Tonnes	9210
Reconversion to storage	DU (U_3O_8)	Tonnes	943
Fuel fabrication to LWR	UOX	PWR assemblies (65%)	1190
Used fuel pool to separations	Cooled used UOX	PWR assemblies (65%)	1190
Fuel fabrication to LWR	UOX	BWR assemblies (35%)	1610
Used fuel pool to separations	Cooled used UOX	BWR assemblies (35%)	1610
Separations to MOX fabrication	Recovered U-Pu	Tonnes	85
Separations to store to ABR fabrication	Recovered minor actinides	Tonnes	1.34
Separations to storage	Recycled U	Tonnes	671
Separations to disposal	Hulls waste	Tonnes GTCC	256
Separations to disposal	Fission products	Glass HLW canistered	42
MOX fab to LWR	Fresh MOX	PWR assemblies	195
Used fuel pool to separations	Cooled used MOX	PWR assemblies	195
MOX separations to ABR fab	Recovered U/TRU	Tonnes	18
Separations to storage	Recycled U	Tonnes	64
Separations to disposal	Hulls waste	Tonnes GTCC	27
Separations to disposal	Fission products	Glass HLW canistered	4.36
ABR fab to ABRs	U/TRU	Fresh ABR assemblies	277
ABR to ABR-separations	U/TRU	Used ABR assemblies	1980
Separations to disposal	Hulls waste	Tonnes GTCC	300[b]
Separations to disposal	Fission products	Glass HLW canistered	18
ABR-separations to ABR fabrication	Recovered U/TRU	Tonnes	112
ABR fabrication to ABR	U/TRU	Fresh ABR assemblies	1700

Principal Regulations For U.S. Radioactive Materials Transportation

CFR Section	Section Title or Description
10 CFR Part 71	Packaging and Transportation of Radioactive Materials
10 CFR Part 71 Subpart F	Package design tests for normal transport conditions and accident conditions
49 CFR Part 172	Table of Hazardous Materials including radioactive materials
49 CFR Part 173	Shippers: general requirements for shipments and packagings
49 CFR 173.401 to 476	General requirements for radioactive materials (HAZMAT Class 7) transportation
49 CFR Part174 Subpart K	Special requirements for transporting radioactive materials in or on railcars
49 CFR 172.800	Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements
49 CFR 177.842	Special requirements for transporting radioactive materials by motor vehicle on public highways
49 CFR Part 178, Subpart K	Manufacturing and testing specifications for packaging and containers used for commercial radioactive materials transportation
49CFR 178.350	Specifications for Type 7A containers
10 CFR Part 73	Physical protection and security of special nuclear materials transportation
10 CFR Part 74	Material Control and Accounting of Special Nuclear Material

Transportation Data For Shipments Of Yellowcake To Enrichment

Kilograms U_3O_8	8.29×10^6
Container	Drum (7A)
Payload/container	450 kg
Containers/truck	42
Number of truck shipments	439

Transportation of UF_6

Kilograms NUF_6	1.04×10^7
Kilograms DUF_6	9.21×10^6
Container	48X cylinder (Type B)
Payload/container	9540 kg
Containers per truck	1
Number of truck shipments NUF_6	1090
Number of truck shipments DUF_6	966
Containers per railcar	1
Containers per train	5
Number of rail shipments NUF_6	218
Number of rail shipments DUF_6	193
Kilograms reconverted U_3O_8	9430
Container	Drum (7A)
Payload/container	450 kg
Containers/truck	42
Number of truck shipments U_3O_8	17

Kilograms $LEUF_6$	1.18×10^6
Container	30B cylinder (Type B)
Payload/container	2280 kg
Containers per truck	2
Number of truck shipments	260
Containers per railcar	2
Containers per train	6
Number of rail shipments	87

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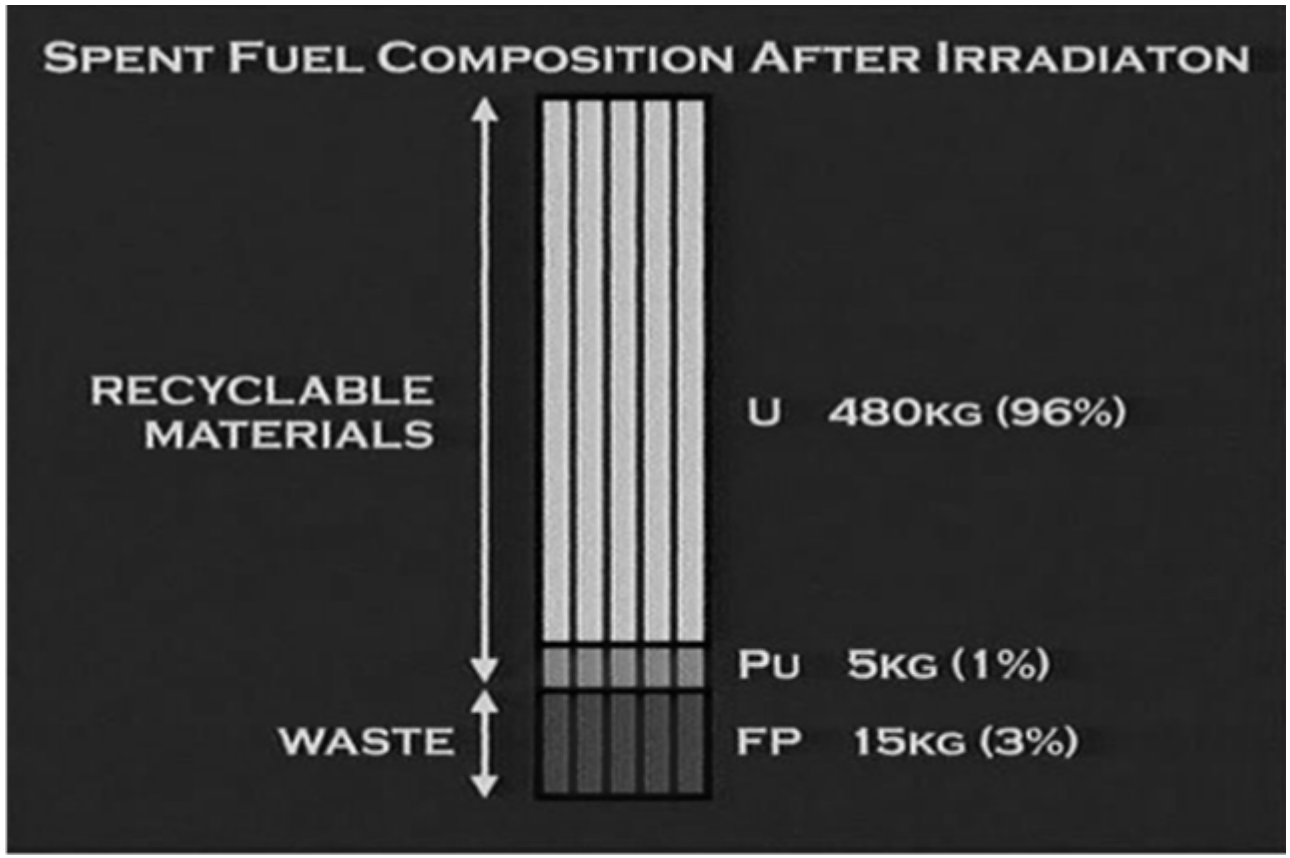
Transportation of UOX Used Fuel

Total assemblies	1190
Truck container	NAC-LWT (Type B)
Payload/container	One PWR assembly
Containers per truck	1
Number of truck shipments	1190
Rail container	HI-STAR 100 (Type B)
Payload/container	16 PWR assemblies
Containers per train	5
Number of rail shipments	15

NAC-LWT

Used Fuel Composition



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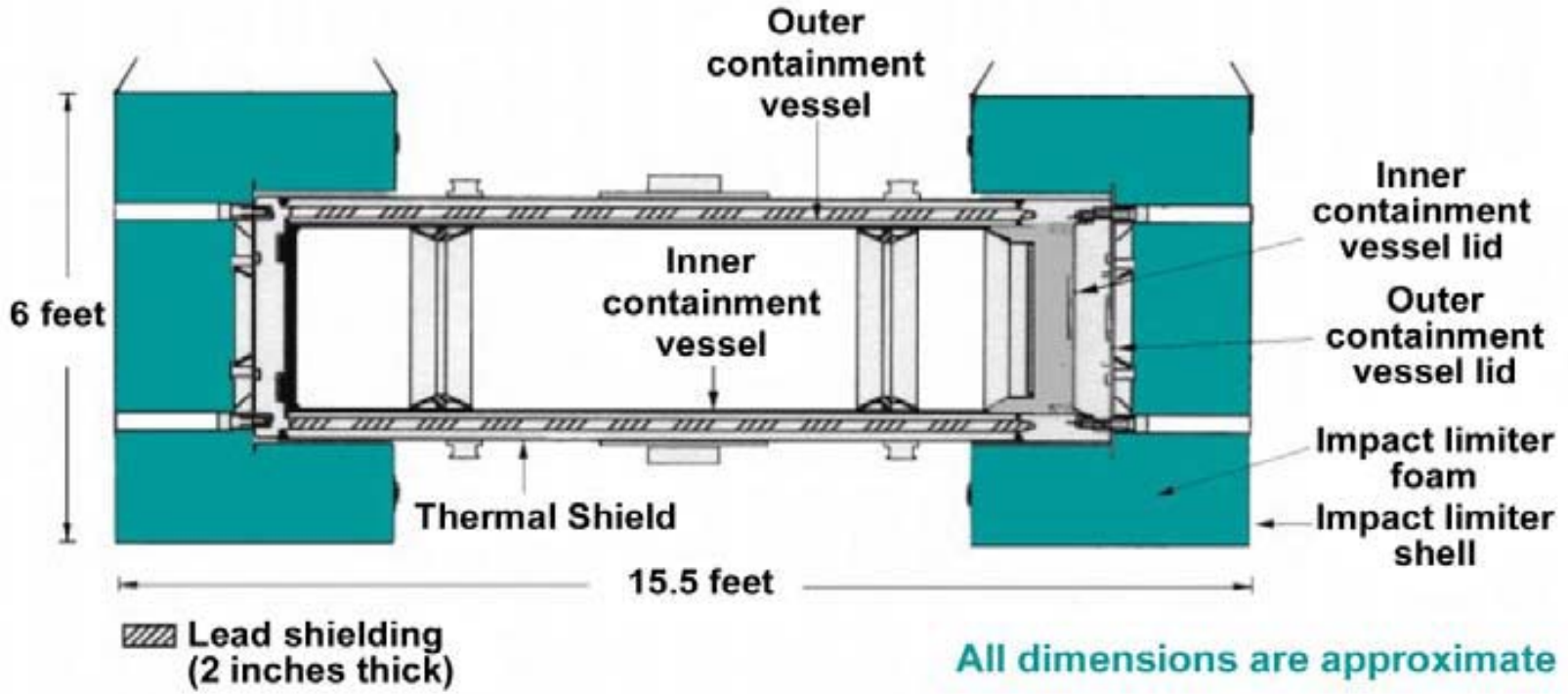
UREX Processes

PROCESS	PRODUCTS						
	1	2	3	4	5	6	7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	FP except Cs,Sr,Tc, Ln		
UREX+1a	U	Tc	Cs/Sr	TRU	FP except Cs,Sr,Tc,		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+ Ln	FP except Cs,Sr,Tc, Ln	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	FP except Cs,Sr,Tc	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	FP except Cs,Sr,Tc,

Transportation of U/TRU



Kilograms recovered U/TRU	1.30×10^5
Container	RH-72B (Type B) (derated)
Payload/container	558 kg
Containers per truck	1
Number of truck shipments	234

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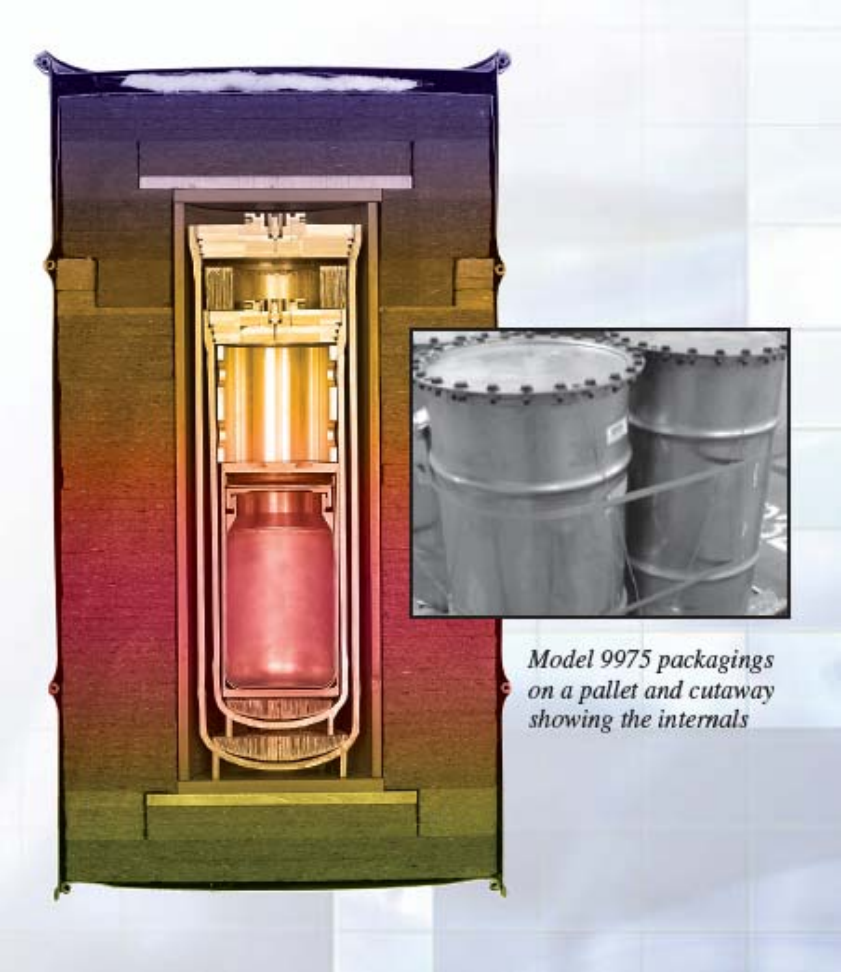
9975 Package for Transporting Mixed U/Pu Oxide and Other Actinides

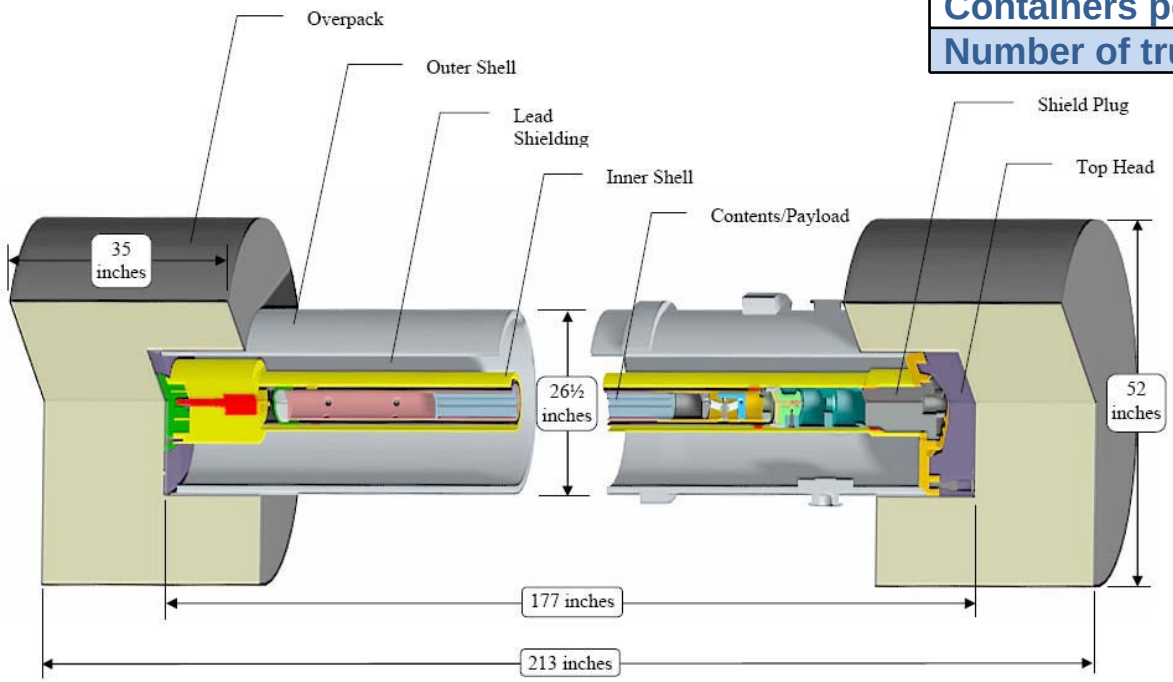


Model 9975 packagings on a pallet and cutaway showing the internals

Kilograms recovered actinides	1340
Container	9975
Payload/container	0.150 kg
Containers per truck	22
Number of truck shipments	405

T-3 Package For FFTF Used Fuel

Total assemblies	1977
Container	T-3 provisional (Type B)
Payload/truck container	One assembly
Containers per truck	1
Number of truck shipments	1977



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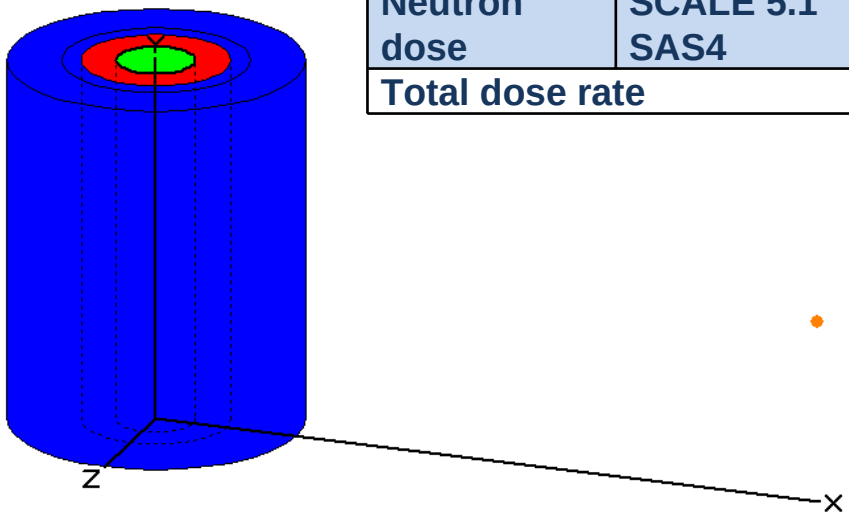
Microshield Model For 3 ABR Fuel Assemblies, 5 Year Cooled; Dose Point At 2 Meters From Cask Outer Surface

	Analysis program	Dose rate at 2 m (mrem/hr)	Shield thickness (cm)
Gamma dose	MicroShield 7.01	1.6	7 (lead)
Neutron dose	SCALE 5.1 SAS4	6.7	20 (NS-4-FR)
Total dose rate		8.3 mrem/hr	



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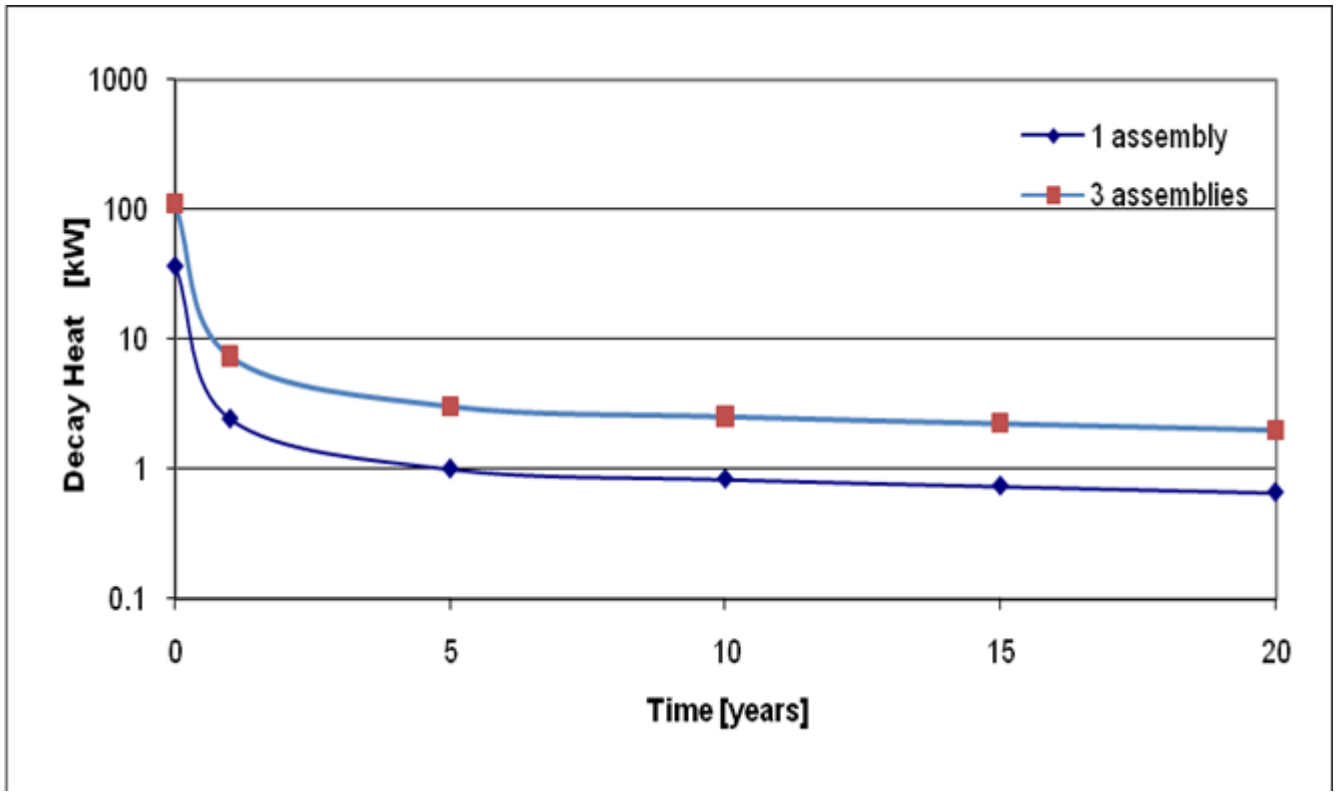
Decay Heat As A Function Of Cooling Time For 130 GWD/MTU ABR Fuel



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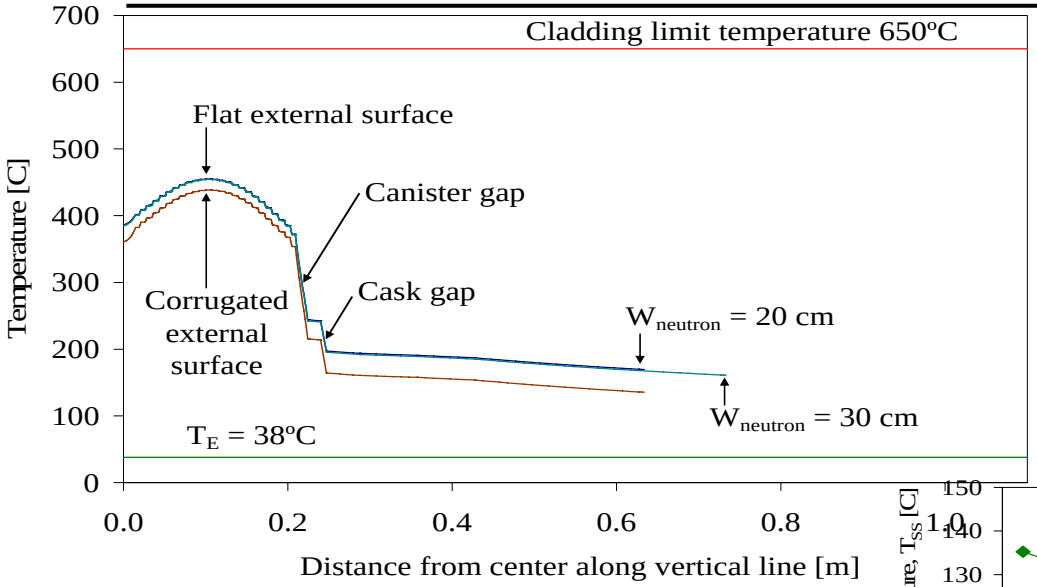
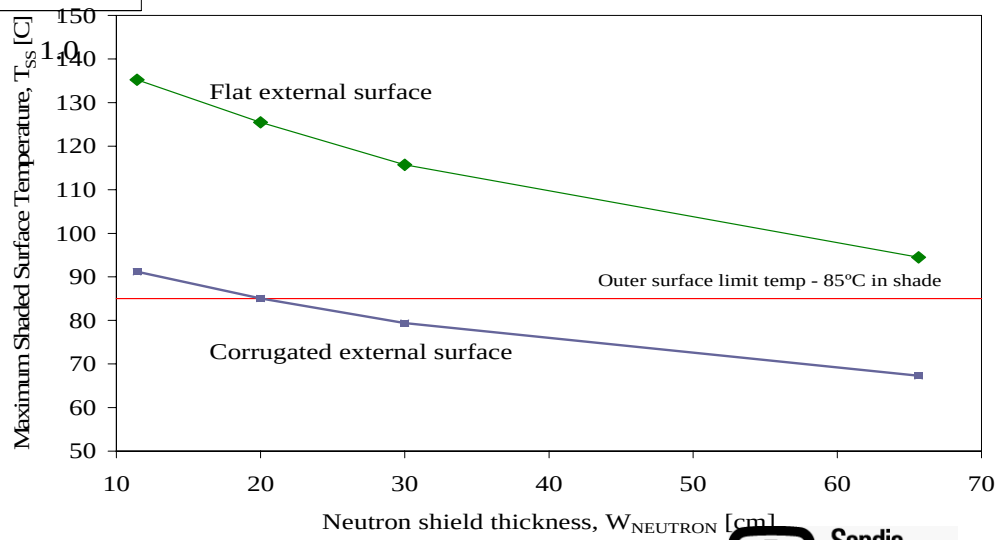
Temperature



Surface temperature of a shaded cask as a function of neutron shield thickness.

Peak clad temperature as a function of neutron shield thickness .



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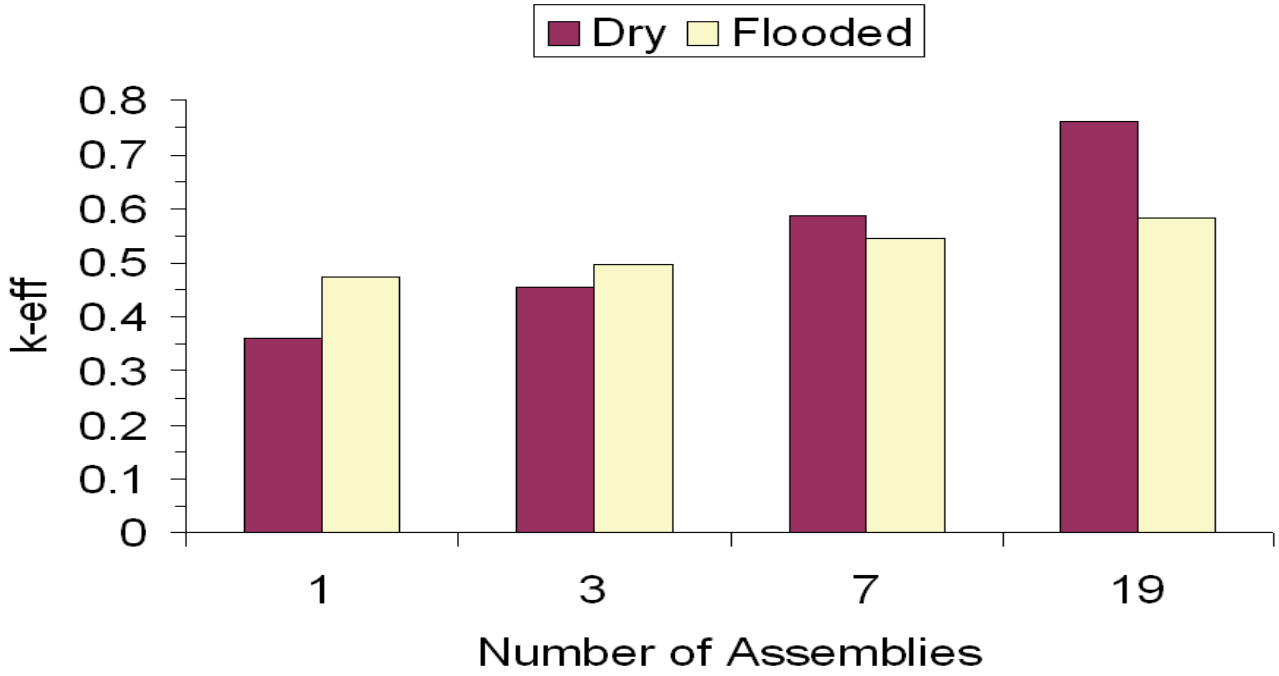
Criticality



Reactivity of different numbers of ABR used fuel assemblies under dry and fully moderated conditions

Economics: Total Estimated Cost For Three Scenarios

Scenario	Truck Transport	Rail Transport	Cost ($Million)
1	U_3O_8, UF_6, used and fresh fuel, U/TRU, U/Pu, RU, MA	Hulls, fission products	248
2	U_3O_8, $LEUF_6$, used and fresh fuel, U/TRU, U/Pu, RU, MA	NUF_6, DUF_6, hulls, fission products	227
3	U_3O_8, fresh UOX fuel, U/TRU, U/Pu, RU, MA	UF_6, used/fresh MOX, ABR fuel, hulls, fission products	158

Observations

- **Certified transportation containers exist for most steps in this fuel cycle.**
- **High burnup fuel, advanced burner reactor fuel, and similar fuels may be difficult to transport because of heat and neutron emissions.**
- **Rail transportation can achieve significant cost savings if it is maximized.**