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ABSTRACT

An updated criticality study has been prepared for the SRE Core I and Core II fuel, to be used as a basis for a nuclear safety analysis for the decladding, cleaning, and repackaging of this fuel. The NSA has been reviewed for conformance to this Criticality Study and found to be satisfactory.

REV	SUMMARY OF CHANGE	APPROVALS AND DATE
A	A review of the Nuclear Safety Analysis (NSA 704-990-001) is presented in Appendix A. All fuel locations and operations are in conformance with the criticality study.	R.J. Seattle 2/10/75 M.E. Remley 10.5.675 REL. DATE 2-11-75 10147

I. INTRODUCTION

Criticality studies have been prepared previously for operations with SRE Core I fuel (1) and Core II fuel (2). These studies do not adequately cover the operations planned for the Decontamination & Disposition (D&D) Program. In addition, the Core II study is out-of-date with regard to methods and was not related directly to verified criticality data.

In this study, results presented in the Core I study are repeated and expanded to provide guidance for packaging of multiple containers. It is shown here that results derived for Core I fuel provide more conservative limits for Core II fuel.

This study provides additional interpretation to the Core I study; it replaces the Core II study.

II. CORE I FUEL

SRE Core I fuel consists of 2.78% enriched uranium metal. Fuel elements were constructed of seven rods, each containing 12 slugs, 6-in. long by 0.75-in. diameter. Because of the Core I melt-down incident, the size and integrity of these slugs cannot be assured and so optimum piece size was assumed in the criticality study. Changes in composition due to burn-up were neglected since these changes are small, and the plutonium produced is approximately one-half the U-235 consumed(3).

Table I
Core I Safe Values

Parameter	Safe Value	% of Critical Value
Mass (kg U-235)	1.14	45
Infinite cylinder diameter (in.)	9.1	85
Spherical volume (liter)	21.8	67
Infinite slab thickness (in.)	4.3	80

At 2.78% enrichment, the mass limit is equal to 41 kg. of fuel material.

For grouping of cylindrical containers, the criterion that the total transverse cross sectional area of the fuel regions of the group must not exceed that of the infinite cylinder has been used. Application of this criterion gives the safe diameters for cylinders in groups, shown in Table II.

Table II

Safe Cylinder Diameters For Groups

Number of cylinders in group	Safe diameter (in.)
1	9.1
2	6.4
3	5.2
4	4.5
5	4.0
6	3.7
7	3.4

Relation of the limits to process operations as discussed in the referenced Core I study (1) continue in effect.

III. CORE II FUEL

SRE Core II fuel consists of Th-7.6% U (highly enriched) alloy. Fuel elements were constructed of five rods, each containing 12 slugs, 6-in. long by 0.75-in. diameter. In contrast to the Core I fuel, this material is in good condition. Changes in composition due to burnup are insignificant and may be neglected.

No definitive information on criticality safeguards for Th-U alloy fuel was found. The criticality study performed for the fabrication of this material was based upon hand calculations using diffusion theory, with some experimental data taken from slightly enriched uranium-water lattices for the fast fission effect, migration area, and reflector savings. These results appear to be excessively restrictive.

For the present study, the equivalent enrichment and density have been found in order to relate this material to that of Core I. Typical composition is:

Th	92.4%	0.0285 atoms/b-cm
U-235	7.1%	0.00215 atoms/b-cm
U-238	0.5%	0.00016 atoms/b-cm

The thermal absorption cross section of Th is considerably greater than that of U-238. The ratio (Th/U-238) is 7.4/2.73 = 2.71 (4). Thus, for thermal absorption, each Th atom is equivalent to 2.71 U-238 atoms. On this basis, the composition is:

	U-235	2.7%	0.00215 atoms/b-cm
equivalent	U-238	97.3%	0.0774 atoms/b-cm

This equivalent enrichment of 2.7% is just slightly less than the 2.78% of Core I. The fast fission factor for Core II fuel (1.010, Ref. 5) is less than for Core I fuel (1.043, Ref. 6) while the resonance escape probability for Core II is somewhat larger (0.879,Ref. 5) than for Core I (0.854, Ref. 6). The fast effect is predominantly dependent upon fuel piece composition and size. Resonance escape depends also upon the surrounding material and would be expected to be different for water moderation compared to graphite moderation. The value calculated for optimum water moderation (.8900, Ref. 2) is close to the value (also calculated) for SRE Core II, and so in terms of resonance and fast neutron reactions, the Core II fuel may be considered to be closely similar to Core I fuel.

This similarity, and an indication of the conservatism in assuming similarity, is demonstrated by the critical masses of the two cores. Core I required 42.4 kg. of U-235 (6), while Core II required 62 kg. of U-235 (5).

On this basis, it is concluded that criticality safety limits established for Core I fuel provide even more safety margin for Core II fuel.

IV. SUMMARY

For operations with either Core I or Core II fuel, including the possibility of water moderation and reflection, the following safe limits apply.

Mass (kg. U-235)	1.14
Infinite cylinder diameters (in.)	
1	9.1
2	6.4
3	5.2
4	4.5
5	4.0
6	3.7
7	3.4
Spherical volume (liter)	21.8
Infinite slab thickness (in.)	4.3

V. REFERENCES

1. N. Ketzlack, "Criticality SRE Fuel Repackaging," TI-599-240-001, April 4, 1972

2. K. E. Buttrey, "Fabrication of Thorium-Uranium Fuel Rods For The SRE," TDR-2205, October 28, 1957.

3. J. Kinzer, A. C. Crawford, "Calculation of Uranium and Plutonium Inventories in the SRE First Core Fuel Loading," TDR-5301, May 16, 1960.

4. J. R. Stehn, et al., "Neutron Cross Sections," BNL-325, Second Edition, Supplement No. 2, Vol III, February 1965.

5. IAEA, "Directory of Nuclear Reactors," Vol. IV, P. 295, 1962.

6. IAEA, "Directory of Nuclear Reactors," Vol. I, P. 209, 1959.

APPENDIX A

Review of NSA 704-990-001 For Nuclear Safety

NSA 704-990-001, covering the SRE fuel decladding operations, was prepared on the basis of guidance established by this Criticality Study. The procedures and layout specified in the NSA have been reviewed for satisfaction of the criticality safety requirements; the review is summarized below according to work station and operation.

Work Station	Description	Controlling Variable	Basis
4-3S	Loaded storage cans in rack; ID = 3.25 in.	Geometry	Area (24.9 $in.^2$) less than 65 $in.^2$
4-3S	SRE storage can; ID < 3.2 in.	Geometry	Area (8.0 $in.^2$) less than 65 $in.^2$
4-3S	Interaction - loaded storage cans, SRE storage can	Geometry	Area (32.9 $in.^2$) less than 65 $in.^2$
4-3	Water tank; ID=6 x 6 in.	Geometry	Area (36 $in.^2$) less than 65 $in.^2$
4-3	Interaction - water tank, SRE storage can	Geometry	Area (44 $in.^2$) less than 65 $in.^2$

Work Station	Description	Controlling Variable	Basis
4-1, -2	Weld can; ID=3.25 in.	Geometry	Area (8.3 in.^{2}) less than 65 in.^{2}
4-2S	Clean batch store; ID=4.125 in.	Geometry	Area (40.1 in.^{2}) less than 65 in.^{2}
4-2S	Load can; ID=3.25 in.	Geometry	Area (8.3 in.^{2}) less than 65 in.^{2}
4-2S	Interaction - clean batch store, load can	Geometry	Area (48.4 in.^{2}) less than 65 in.^{2}
4-1, -2	Interaction - weld can, SRE storage can	Geometry	Area (16.3 in.^{2}) less than 65 in.^{2}
3-2S	Loaded storage cans; ID < 3.2 in.	Geometry	Area (24.0 in.^{2}) less than 65 in.^{2}
3-2	Element washing tank; ID=6 x 6 in.	Geometry	Area (36 in.^{2}) less than 65 in.^{2}
3-2	Element disassembly rack; ID $\leq$ 4 in.	Geometry	Area (12.6 in.^{2}) less than 65 in.^{2}

Work Station	Description	Controlling Variable	Basis
3-1	Rod disassembly rack	Quantity	Mass (≤550 g) less than 1.14 kg.
3-1	Rod washing tank	Quantity	Mass (≤550 g) less than 1.14 kg.
3-1S	Transfer cans; ID=4.125 in.	Geometry	Area (40.1 $in.^2$) less than 65 $in.^2$
3-1S	Sump, 5 gallons	Quantity	Volume (18.9 l) less than 21.8 l
3-2	Interaction - transfer can, element washing tank	Geometry	Area (49.4 $in.^2$) less than 65 $in.^2$
2-1, -2	Wash tray, 2 x 12 x 20 in.	Geometry	Thickness (2 in.) less than 4.3 in.
2-1, -2	Ultrasonic, 11 3/4 x 6 x 6 in.	Quantity	Volume (7 l) less than 21.8 l
2-3, -4	Nak distillation, ID=4.125 in.	Geometry	Area (13.4 $in.^2$) less than 65 $in.^2$

Work Station	Description	Controlling Variable	Basis
2-3, -4	Interaction - transfer can, NAK distillation	Geometry	Area (26.7 $in.^2$) less than 65 $in.^2$
2-1, -2	Interaction - transfer can, wash tray	Quantity	Volume (16.7 l) less than 21.8 l
2-1, -2	Interaction - transfer can, ultrasonic	Quantity	Volume (15.7 l) less than 21.8 l