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NUCLEAR
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Baltimore,
Maryland
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In reply refer to:
ACC-325

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Mail No. 845
August 4, 1964

Division of Materials Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

DOCKET NO. 70-58

Attention: Mr. Donald A. Nussbaumer, Chief
Source & Special Nuclear Materials Branch

File Copy

Subject: Proposed Amendment No. 21 to Special
Nuclear Material License No. 53

Enclosure: (1) Proposed Amendment No. 21 to
SNM-53 (six copies)

Gentlemen:

We are pleased to again submit a revised submission of the proposed Amendment No. 21 to Martin Marietta Special Nuclear Material License No. 53. The basic revisions from our July 9, 1964 submission are in our Nuclear Safety evaluations which result from discussions held with Messrs. Lauterbach and McCreless in our July 21, 1964 meeting at Bethesda. Included are other pages of our July 9, 1964 submission, with minor editorial changes, to present a complete picture of all aspects of our operation.

We appreciate the guidance given to us in Nuclear Safety aspects by Mr. McCreless and believe we have followed his suggestions in our re-evaluation. Approval of this proposed amendment will be needed by August 10 in order to enable us to start limited production shortly thereafter. We trust that our meeting on July 21 cleared up informative type questions, but please feel free to contact us if we can be of further assistance in this matter.

Very truly yours,

CWKeller

C. W. Keller
Nuclear Accountability and
Licensing Representative

CWK:lnl

Encl.

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ACKNOWLEDGED

A DIVISION OF MARTIN MARIETTA

PROPOSED AMENDMENT NO. 21

TO

SPECIAL NUCLEAR MATERIAL File Copy

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[illegible] NO. 21
TO [illegible] NO. 53

It is the purpose of this proposed Amendment No. 21 to [illegible] to describe the [illegible] and control criteria, which will be used in the [illegible] of [illegible] of tubular design employing slightly [illegible]

[illegible]

1. [illegible] approximately 127 [illegible] 0.23%.

2. [illegible] than 5% (0.65% and 1.07%)

3. [illegible]

4. [illegible]

5. [illegible]

6. [illegible]

7. [illegible]

8. [illegible]

9. [illegible]

[illegible]

[illegible]

[illegible] specifications [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

7. [illegible]

8. [illegible] of [illegible]

9. [illegible] of fuel ele[illegible]

10. [illegible] of fuel element

[illegible] - [illegible]

A work area is defined as any [illegible] at which a specific fabrication step is performed. [illegible] shall be separated from any other [illegible] by [illegible] or two (2) feet and shall be well defined [illegible] rooms in which [illegible] components are assembled into fuel elements shall be separated by a uniform distance of five feet. [illegible] are [illegible] by a trained courier, who shall be responsible to ensure that [illegible] limits are not exceeded. [illegible] criteria are used to establish the U-235 limit in [illegible] for any operation.

The discussions in this [illegible] will [illegible] in [illegible] and include the [illegible] safety [illegible]. Figure 1 [illegible] the process flow and the U-235 limits [illegible] to each step.

Page 5 redacted for the following reason:

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Shipment [illegible]

[illegible] Ceroide.

[illegible]

[illegible] this [illegible]

[illegible] under [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Conclusions

[illegible] primarily [illegible]

[illegible] array of [illegible] Figure 5 [illegible] 1.95 [illegible]

* [illegible] - Proposed Amendment to 10 CFR, Part 70.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

In-Process Storage

The in-process storage area approved for storage of highly enriched fuel, in connection with Amendment No. 22 to SNM-33, will be used for storage of [illegible] fuel during the fabrication of a [illegible] core of [illegible] design, employing highly enriched uranium oxide pellets. The following nuclear safety evaluation defines the conditions for storage of the [illegible] elements.

The in-process storage area (Figure 2) is approximately 26 ft. wide by 35 ft. long or 910 square feet. This area is located in the Nuclear Manufacturing area (about 35,000 sq. ft.) and is thus in part of "B" building which is approximately 170,000 sq. ft. in area. Flooding of the in-process area is highly improbable since over 2.5 million gallons of water would be required to cover the entire building floor area to a depth of one foot and, since there are a multitude of drainage facilities and doors separating the particular areas (none of which are water-tight), an accumulation of water due to

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] the welding, leak detecting and inspection [illegible], a limit of [illegible] (U-233 and U-235) has been established. This limit is well within [illegible] for [illegible]. Cleaning operations have been [illegible] according to the nuclear safety analysis following this [illegible]. Since accountability for each tube is necessary from a production standpoint in the assembly of specific tubes in a fuel element, strict accountability is required during cleaning operations. However, possibility of [illegible] of any [illegible] during cleaning is not possible since the cleaning [illegible] are for the purpose of surface cleaning only. Use of [illegible] which is necessary for [illegible] of the stainless steel tubing shall be prohibited. A [illegible] fixed mechanical separation shall be provided between cleaning tanks as defined in the nuclear safety evaluation for the cleaning operation.

[illegible]
[illegible]

A. Problem — Fifty-two fuel elements will be [illegible] in a water trough 12x12x96 inches long during the cleaning operation of the fuel element fabrication process. The fuel elements will be loaded on two racks, 26 fuel elements per rack, separated by a 12-inch fixed mechanical spacer. What is the K_{eff} of this reflected system as shown in Figure 10. ([illegible] homogeneous solution is assumed for some of the following equations; however, correction for low enriched heterogeneity is incorporated in the determination of [illegible].)

B. Given — Weight of U-235 per element = 10.968 gms.
Weight of U-238 per element = 181.032 gms.

C. Analytical Models — The calculations were based on a unit cell 1.0 x 1.75 x 36 inches long. Twenty-six unit cells made up the active fuel volume analyzed. These unit cell dimensions were based on the spacing of fuel elements on the rack in the cleaning trough. The rack is shown in Figure 10.

Material	Volume (Cm^3)	Volume Fraction	Σ_a (Ref. 1) (Cm^{-1})	Homogenized Σ_a (Cm^{-1})
H_2O	23,745	.8646	.0221	.01955
U-235	57	.00212	[illegible].70	[illegible]
U-238	1,225	.04564	.128	.00584
347 SS	536	.01938	.268	.00535
Oxygen & Impurities	1,228	.04577	0	0
Void	50	.00185	0	0

D. For the age diffusion method of calculating steady state reactor conditions, the standard effective multiplication factor for a light water moderated system is given by:

$$k_{eff} = \frac{k_{\infty}}{(1 + L_1^2 B^2)^2 (1 + L_2^2 B^2) (1 + L^2 B^2)}$$ (Ref. 2)

where $k_{\infty} = \epsilon p f \eta$

and
- ϵ = Fast fission factor
- p = Resonance escape
- f = Thermal utilization
- η = Neutrons liberated per thermal neutron absorbed in fuel.

E. The fast-fission for slightly enriched uranium dioxide in water can be approximated by:

$$\epsilon = 1 + \frac{0.196}{1 + 0.69\rho_w\left(\frac{V_w}{V_u}\right) + 0.208\left(\frac{V_c}{V_u}\right)} \qquad \text{(Ref. 3)}$$

where ρ_w is the density of water in g/cc, V_w/V_u is the volume ratio of the water to uranium, and V_c/V_u is the volume ratio of the cladding to uranium.

$$\epsilon = 1 + \frac{0.195}{1 + (0.69)(1.0)(19.53) + 0.208(\text{[illegible]})}$$

$$\epsilon = 1.012$$

The fast fission factor as a function of slug radius for natural uranium is shown graphically in Reference 4. Using this data $\epsilon \cong 1.015$.

F. The resonance escape probability for a heterogeneous system can be approximated by:

$$p(E) \cong \exp\left(-\frac{f_r}{1 - f_r}\right) \qquad \text{(Ref. 5)}$$

$$\text{where } \frac{1}{f_r} \cong 1 + \frac{V_1}{V_0}\,\frac{\Sigma_{a_1}}{\Sigma_{a_0}}\,F_m + (E_m - 1), \quad \frac{V_1}{V_0} = 9.46 \qquad \text{(Ref. 6)}$$

$$\Sigma_{a_1} = \frac{\xi\Sigma_{s_1}}{\ln(E_1/E_2)} = \frac{1.58}{\ln(E_1/E_2)} \qquad \text{(Ref. 7)}$$

The values of $\xi\Sigma_s$ were obtained from the Nuclear Engineering Handbook by Etherington, pages 2-9, Table 12.

$$\Sigma_{a_0} = \frac{N_0\left(a + b\sqrt{S/M}\right)}{\ln(E_1/E_2)}$$

$$= \frac{0.023(11.0 + [\text{[illegible]}][\text{[illegible]}])}{\ln(E_1/E_2)} = \frac{0.434}{\ln E_1/E_2} \qquad \text{(Ref. 8)}$$

where a = 11.0 and b = 24.5 for uranium dioxide.

$$F_m \cong 1 + \frac{(K_0 r_0)^2}{8} - \frac{(K_0 r_0)^4}{192} \cong 1.004 \qquad \text{(Ref. 9)}$$

where K_r = 0.31 cm^{-1} for uranium dioxide

a_0 = .380 cm

$$E_r = 1 + \frac{(K_r a_0)^2}{2}\left[\frac{a_1^2}{a_1^2 - a_0^2}\ln\frac{a_1}{a_0} + \frac{1}{4}\left(\frac{a_0}{a_1}\right)^2 - \frac{3}{4}\right] \quad \text{(Ref. 9)}$$

$$E_r = 1 + 1.097 \left[\frac{3.225 \times 1.185}{3.225} + .0281 - .75\right] = 1.117$$

where K_1 = .835 cm^{-1} for uranium dioxide

E_1 = 1.896

thus $\frac{1}{f_r} = 1 + 9.46\left(\frac{1.896}{.835}\right)(1.03) + (1.117 - 1)$

$\frac{1}{f_r}$ = 12.022

and f_r = .0832

therefore $p(E) = \exp\left(-\frac{.0832}{.9886}\right) = .963$

G. The thermal utilization for a homogenized system can be represented by:

$$f = \frac{\Sigma_a^{fuel}}{\Sigma_a^{fuel} + \Sigma_a^{H_2O} + \Sigma_a^{SS}} = \frac{.07527}{.07527 + .01955 + .00335}$$

= .791

H. The average number of neutrons, η, released for 4.65% enriched uranium is 1.928 (Ref. 10).

I. The reflector savings, δ, for low-enriched, light-water moderated cores can be calculated from the following expression:

$$\delta \text{ (cm)} = 7.2 + 0.10\,(M^2 - 40.0) = 7.11 \text{ cm} \qquad \text{(Ref. 11)}$$

where $M^2 = L^2 + \tau$ = 39.12

and

τ = 31

L = 2.85

The values of τ and L were obtained from the Nuclear Engineering Handbook by Etherington, pages 2-9, Table 13.

J. The buckling is calculated from the following expression:

$$B^2 = \left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2 + \left(\frac{\pi}{c}\right)^2 = .03[illegible]$$

where a = 36 x 2.54 + 7.11 = 98.55 cm

b = 7 x 1.0 x 2.54 + 7.11 = 24.89 cm

c = 4 x 1.75 x 2.54 + 7.11 = 24.89 cm

K. The thermal diffusion length is obtained from the following expression:

$$L^2 = L_m^2 (1 - f) = 2.019 \qquad \text{(Ref. 12)}$$

The thermal diffusion length, L_m, in water is equal to 2.85 cm. This quantity was obtained from the Nuclear Engineering Handbook by Etherington, pages 2-9, Table 13.

$$L_1^2 = 2.[illegible]$$

$$L_2^2 = 26.539 \qquad \text{(Ref. 13)}$$

The values of L_1^2 and L_2^2 are empirical constants derived from measurements on the slowing down of fast neutrons in water.

Therefore:

$$(1 + L_1^2 B^2)^2 = 1.1800$$

$$(1 + L_2^2 B^2) = 1.8726$$

$$(1 + L^2 B^2) = 1.0664$$

L. The calculated value for k_{eff} for the 26 fuel elements arranged as described in part C is:

$$k_{eff} = \frac{k_\infty}{(1+L_1^2B^2)^2(1+L_2^2B^2)(1+L^2B^2)} = \frac{(1.012)(.968)(.751)(1.928)}{(1.1800)(1.8726)(1.0664)}$$

k_{eff} = .602 (This K_{eff} value (< 1) is confirmed by HW-69273, Figure 13, which shows the minimum critical mass of 5% fuel and 0.5 inch diameter rods to be 3.75 kgs of U-235 under conditions of ideal spacing. Although the 26 tubes were known to be individually subcritical--as shown in HW-59273--the K_{eff} calculation was performed to determine the allowable solid angle.)

M. Based on this k_{eff}, the total interaction steradians (Ω) (Ref. 14) allowed for an array calculation is (9-10 k_{eff}) or <u>3.0</u>.

(b)(4)

[redacted]

Ex4

[illegible] when final reach 1, 2, 3, and 4 are in [illegible] The predicted curve of reach 2, 3, and [illegible] The distance from the center of [illegible] of reach 2, 3, 4 [illegible] 12, 30 and 35 inch [illegible] angle is

[illegible] 360/144 [illegible] 80/300 [illegible] 240/1,040 [illegible] 70

[illegible] configuration [illegible] 12 x 12 inch [illegible] distance [illegible] maintained between racks [illegible]

[illegible]

[illegible]

[illegible]

References:

(1) Nucleonics, Volume 20, No. 8 - August 1962, pp. 158-161.

(2) Glasstone & Sesonske, *Nuclear Reactor Engineering*, p. 187, Equation 4.59.

(3) Ibid, pp. 206-207.

(4) Murray, *Introduction to Nuclear Engineering*, p. 122, Figure 6.9.

(5) Glasstone & Sesonske, *Nuclear Reactor Engineering*, p. 195, Equation 4.72.

(6) Ibid, p. 190, Equation 4.65.

(7) Ibid, p. 195, Equation 4.70.

(8) Ibid, p. 196.

(9) Ibid, p. 192.

(10) HW-65273, p. 18, Appendix 1.

(11) [illegible], *Method for Analyzing Low-Enrichment, Light-Water Cores*, Reactor Science and Technology, Vol. 16, No. 4, pp. 166-175.

(12) Glasstone & Sesonske, *Nuclear Reactor Engineering*, p. 183, Equation 4.56.

(13) Ibid, p. 188.

(14) Nuclear Safety Guide, TID-7016, Rev. 1 (1961), Figure 26.

Pages 17 through 27 redacted for the following reasons:

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