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MARTIN COMPANY

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August 19, 1964

Refer to: ACC-322
Mail No. 845

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

Attn: Mr. Kenneth Lauterbach

Subj: Additional Information for Proposed Amendment No. 21 to SNM-53

Gentlemen:

We have considered the points of discussion of our meeting in Bethesda on August 14, 1964 and, with further guidance from Mr. McCreless, are resubmitting our nuclear safety evaluation for the in process storage of the fuel tubes. Our evaluation is included with this letter and involves the k_{eff} and solid angle calculations.

In connection with the cleaning of the welded tubes, we shall prepare a composite sample of the cleaning baths each week during initial production. If a significant quantity of special nuclear material (.2 gm U/liter) is detected in the composite, a sample from each bath will be analyzed. Relaxation of the sampling may be effected if the analytical results of a number of the weekly composites indicates uranium quantities below the significant amount. Immediate sampling of a bath will be made, of course, if the operator observes any condition which indicates any loss of integrity in the completed tubes.

We anticipate a minimal quantity of scrap generation as a result of the fabrication of tubes at the Martin facility. Although we will possess a slight excess of loaded fuel tubes for use as substitutes for tubes which may be rejected, we do not expect to generate any significant quantity of rejected fuel pellets. We also do not envision any appreciable quantity of uranium bearing solution which might result from our quality control effort. In any event, whether pellets or solution, an always safe limit of 350 gms U-235 per container shall

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be enforced for any scrap type material which may be generated. It is the present plan to ship any excess fuel, after obtaining appropriate AEC approval, to a reprocessor for ultimate return of the special nuclear material to the AEC.

We trust that this discussion will permit you to grant approval of the proposed amendment No. 21 to SNM-53 by August 25, 1964. Thank you for your effort in this matter.

Very truly yours,

CWKeller

C. W. Keller
Nuclear Accountability
and Licensing Representative

CWK:jn

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19 August 1964

Nuclear Safety Evaluation

In Process Storage Area

Introduction:

A nuclear safety analysis has been completed for the MH-1A fuel tube in-process storage. The in process storage area (Figure 1) is approximately 24 ft. wide by 36 ft. long. This area is located in the Nuclear Manufacturing area of "D" building. Fifty-two MH-1A fuel tubes will be loaded into a storage box which in turn will be stored on spaced limited racks in the in-process storage area. (Figure 1) A typical storage box and in-process storage rack is shown in Figure 2.

The analysis consists of calculating the neutron multiplication factor (k) for an individual storage box and the total solid angle subtended at the most central storage box in the array.

Neutron Multiplication Factor Calculations

Material	Volume (cm^3)	Volume Fraction	Σ_a (Ref.1) (cm^{-1})	Σ_a Homogenized (cm^{-2})
H_2O	22,223.07	.784805	.0221	.01734
U-235	113.98	.004025	32.70	.13163
U-238	2,449.93	.086519	.128	.01107
347 SS	1,072.82	.037886	.268	.01015
Oxygen & Impurities	2,456.93	.086765		~0

The total volume was based on a 6" x 8" x 36" active fueled region containing 52 MH-1A fuel tubes. The calculations were made for the 4.65% enriched fuel. Each tube contained 40.97 g of U-235 and 881 g of U-238.

The effective multiplication factor was calculated by the age diffusion method for a light water moderated system assuming steady state reactor conditions.

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

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

<u>Fast Fission Factor</u>

$$\epsilon = 1 + \frac{0.156}{1 + 0.62 \rho_W \left(\frac{V_W}{V_u}\right) + 0.288 \left(\frac{V_c}{V_u}\right)} \qquad \text{(Ref. 3)}$$

$$= 1 + \frac{0.156}{1 + (0.62\ (1.0)\ (9.071) + (0.288)\ (.4379)}$$

$$= \underline{1.023}$$

<u>Resonance Escape</u>

$$p\ (E) \simeq \exp\left(-\frac{fr}{1-fr}\right) \qquad \text{(Ref. 4)}$$

where $\frac{1}{f_r} = 1 + \frac{V_1}{V_0}\frac{\Sigma_{a1}}{\Sigma_{a0}} F_r + (E_r - 1)$

$$\frac{V_1}{V_0} = 4.426$$

$$\Sigma_{a1} = \frac{\xi \Sigma_{s1}}{ln\,(E_1/E_2)} = \frac{1.38}{ln\,(E_1/E_2)}$$

$$\Sigma_{a0} = \frac{N(a + b\ S/M)}{ln\,(E_1/E_2)} = \frac{.02309\,(11.0 + 24.5 \times .378)}{ln\,(E_1/E_2)} = \frac{.468}{ln(E_1/E_2)}$$

$$F_r \simeq 1 + \frac{(K_o r_o)^2}{8} - \frac{(K_o r_o)^4}{192} \simeq 1.004$$

where $K_o = 0.31\ cm^{-1}$ for uranium dioxide

$r_o = .580$ cm

$$E_r \simeq 1 + \frac{(K_1 r_1)^2}{2}\left[\frac{r_1^2}{r_1^2 - r_o^2} \ln \frac{r_1}{r_o} + \frac{1}{4}\left(\frac{r_o}{r_1}\right)^2 - \frac{3}{4}\right] \simeq 1.210$$

where $K_1 = .885$ for uranium dioxide

$r_1 = 1.377$ cm.

$$\frac{1}{f_r} = 1 + (4.426)\ (2.949)\ (1.004) + (1.210 - 1)$$

$$\frac{1}{f_r} = 14.314$$

$$p(E) \simeq \exp\left(- \frac{.06985}{.93015}\right) = \underline{.928}$$

Thermal Utilization

$$f = \frac{\Sigma_a^{Fuel}}{\Sigma_a^{Fuel} + \Sigma_a^{H_2O} + \Sigma_a^{SS}} = \underline{.838}$$

Neutrons Liberated

$\eta = \underline{1.928}$ (Ref. 5)

Infinite Multiplication Factor

$$k_\infty = \epsilon p f \eta$$

$$k_\infty = (1.023)\ (.928)\ (.838)\ (1.928) = \underline{1.534}$$

Reflector Savings

$$\delta(\text{cm}) = 7.2 + 0.10\ (M^2 - 40.0) = 7.11\ \text{cm}$$ (Ref. 6)

where $M^2 = L^2 + \tau$ and $\tau = 31$ cm

$L = 2.85$ cm

Buckling

$a = 36 \times 2.54 + 7.11 = 98.55$ cm

$b = 6 \times 2.54 + 7.11 = 22.35$ cm

$c = 8 \times 2.54 + 7.11 = 27.43$ cm

$$B^2 = \left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2 + \left(\frac{\pi}{c}\right)^2 = \underline{.03390}$$

Effective Multiplication Factor

$L_1^2 = 2.625$

$L_2^2 = 26.539$ (Ref. 7)

$$L^2 = L_m^2 (1 - f) = 1.312$$

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

$$k_{eff} = \frac{1.534}{(1.1859) (1.8997) (1.0445)}$$

$$\boxed{k_{eff} = .652}$$

The solid angle (Ω) between units was calculated according to procedures discussed in proposed revision of 10 CFR Part 70 section 70.52. Two expressions were employed for determination of the solid angle.

(1) $$\Omega = 4 \sin^{-1} \frac{(a/2)(b/2)}{\sqrt{(\frac{a}{2})^2 + h^2} \sqrt{(b/2)^2 + h^2}}$$

(2) $$\Omega = \frac{\text{Cross Sectional Area}}{(\text{Separation Distance})^2}$$

The nomenclature and storage rack array used for the solid angle calculations is shown in Figures 3 and 4.

Solid Angle Tabulations Using Equation 1

Rack No.	a (in.)	b (in.)	h (in.)	Ω per Rack	Ω Total
23 & 35	36	8	27.25	.32116	.64232
28	36	6	29.25	.21408	.21408
30	36	6	56.0	.06516	.06516
53 & 8	8	6	90.0	.00592	.01184
				(Total)	0.93340

Solid Angle Tabulations Using Equation 2

Rack No.	Unit Area (inches)^2	Distance^2 (inches)^2	Ω per Rack	Ω Total
22 & 34	316.8	1598.1	.19823	.39646
24 & 36	316.8	3878.6	.08167	.16334
40	316.8	4161.8	.07612	.07612
42	316.8	6442.3	.04917	.04917
21 & 23	316.8	7925.1	.03997	.07994
39	316.8	10488.8	.03020	.03020
25 & 37	316.8	8708.1	.03637	.07274
43	316.8	11271.8	.02810	.02810
26 & 38	316.8	27393.1	.01156	.02312
44	316.8	29956.8	.01057	.01057
52 & 7	100.8	6084.0	.01656	.03312
46,58,2 & 12	100.8	6826.6	.01476	.05904
64 & 17	100.8	9390.3	.01073	.02146
54 & 9	136.8	8317.4	.01644	.03288
48,60,4 & 14	136.8	9060.0	.01509	.06036
66 & 19	136.8	11623.7	.01176	.02352
55 & 10	163.2	12814.2	.01273	.02546
49,61,5 & 15	163.2	13556.8	.01203	.04812
67 & 20	163.2	16120.5	.01012	.02024
51 & 6	172.8	26244.0	.00658	.01316
45,57,1 & 11	172.8	26986.6	.00640	.02560
63 & 16	172.8	29550.3	.00584	.01168
56	184.8	30415.4	.00607	.00607
50 & 62	184.8	31157.9	.00593	.01186
68	184.8	33721.6	.00548	.00548
			(Total)	1.32781

The combined total solid angle is 2.26.

Conclusion:

The maximum total allowable solid angle is equal to 9 minus 10 k or 2.48 steradians. Thus, the in-process storage area presents no potential nuclear safety hazards for storage of the MH-1A fuel tubes.

Pages 10 through 13 redacted for the following reasons:
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