NUCLEAR
DIVISION
Baltimore,
Maryland
21203

**MARTIN COMPANY**

In reply refer to:
ACC-312

July 9, 1964

U. S. Atomic Energy Commission
Division of Material Licensing
Washington 25, D. C.

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

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

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

Gentlemen:

We submit as Enclosure (1) our revised submission of proposed amendment No. 21 to Martin Marietta Special Nuclear Material License No. 53, which describes the fabrication steps and control criteria to be used in the fabrication of a nuclear core of tubular design employing approximately 5% enriched uranium dioxide pellets. Please consider this submission as a replacement for our submissions of April 1 and 24, 1964. The revised submission identifies the shipping and storage containers to be used for the receipt of the 5% enriched uranium oxide pellets at Martin, describes the cleaning operation in detail, and includes storage of fuel in the in-process storage area during fabrication processing.

We regret our delay in supplying this information, but believe that all aspects of shipping, storage, and processing are finally firm. We will appreciate receiving approval prior to our vacation shut-down scheduled to begin on July 27, 1964 and will be happy to discuss any questions which you may have on our submission. Thank you for your usual excellent cooperation in this matter.

Very truly yours,

C W Keller

B 25

C. W. Keller
Nuclear Accountability
& Licensing Representative

CWK/mc

Enclosure

A DIVISION OF
MARTIN MARIETTA

PROPOSED AMENDMENT NO. [illegible]

DOCKET NO. 70-58

SPECIAL NUCLEAR MATERIAL

LICENSE NO. [illegible]

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PROPOSED AMENDMENT NO. 21
TO SPECIAL NUCLEAR MATERIAL LICENSE NO 53

It is the purpose of this proposed Amendment No. 21 to SNM-53 to describe the process and control criteria, which will be used in the fabrication of a nuclear core of tubular design employing slightly enriched uranium oxide pellets.

Design and Nuclear Parameters:-

1. Core loading approximately 137 kgs. U-235.

2. Enrichment - 2 enrichments both less than 5%.

3. Fuel material - high density uranium dioxide.

4. Active length of core 36 inches.

5. Total core elements = 32.

6. Fuel Element loading = 3.7 kgs. to [illegible] kgs. U-235.

7. Fuel tubes per fuel element - 104.

8. Fuel tube diameter - maximum 1.5 inch.

9. Loading per fuel tube 36 to [illegible] gms U-235.

Process Description:-

The process for the fabrication of a tubular core using low enriched $UO_2$ pellets will follow these general steps:-

1. Receipt of loaded fuel tubes meeting specifications from off-site vendor in licensed shipping and storage container. Twenty-six tubes per container is established for receipt of material as discussed in this submission.

2. Storage of containers in the nuclear storage area in an array separated from other special nuclear material in accordance with AEC criteria

3. Transfer of individual licensed storage/shipping container to the welding work area. Transfer may also be made to in-process storage area for interim storage prior to fabrication.

4. Welding of end plugs in tubes.

5. Helium leak testing and radiography

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6. Dimensional inspection.

7. Cleaning.

8. In process storage of fuel tubes.

9. Assembly of fuel element

10. Storage of fuel elements.

Nuclear Safety - General Discussion

A work area is defined as any operational work location at which a specific fabrication step is performed. Each operational work area shall be separated from any other work area by a minimum distance of two (2) feet and shall be well defined and marked. Assembly work areas in which basic components are assembled into fuel elements shall be separated by a minimum distance of five feet. Transfers between work areas are affected by a trained courier, who shall be responsible to assure that work area limits are not exceeded. Mass and safe geometry criteria are used to establish the U-235 limits in any work area and for any operation.

The discussion in this submission will define the specific operations in more detail and include the pertinent nuclear safety evaluations. Figure 1 depicts the process flow and the U-235 limits assigned to each step.

Shipment of Tubes from Martin Vendor

Two basically similar shipping containers will be used for the shipment of the loaded tubes from the Martin Subcontractor, Nuclear Fuel Services, Erwin, Tennessee. The method and approval of the shipments, using these containers, will be obtained by the Nuclear Fuel Services.

These containers consist of a 4 inch inner diameter schedule 40 pipe fixed by welding in the center of a standard 18 gauge 55 gallon drum. The basic container, designated A, has been approved by the New York Operations Office for the shipment of 2 kgs U-235 as fuel elements or scrap material. A recent scrap shipment, using this container was made on the approval of AEC-NYOO.

Basic container, designated B, has been approved in connection with Amendment No. 15 to Special Nuclear Material License No. 33, and we refer you to our submission dated May 2, 1962, to Mr. Nussbaumer from Mr. Wachtl. With reference to the strength analysis of the containers, we refer you to this submission which included a strength analysis to be applicable to both containers. We consider this analysis sufficient to support the integrity of containers A and B under the new strength criteria.

We are also investigating a reference supplied by a representative of the Bureau of Explosives, which we understand, describes the tests, indicating superior performance of this type container under drop test conditions in excess of the 30 foot drop.

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Storage of Loaded Tubes prior to Fabrication

Each container described in the preceding section received by Martin from the vendor will contain a maximum of 27 loaded tubes which represents one fourth of a completed fuel element. The total U-235 limit for each container will approximate 1.3 kgs U-235.

Upon receipt of the shipping containers, a thorough inspection of each individual container will be made by Martin Nuclear Materials Management. Any containers whose integrity is questioned will be separated immediately from the other containers and evaluated for health physics and criticality considerations. Excessive damage during normal shipment is not expected considering the strength of the shipping containers and in-leakage of water does not appear probable. In all actions, however, which may be necessary in handling damaged packages will be under the direct surveillance of Martin Health Physics.

The temporary storage of the shipping containers will be under the jurisdiction of Martin Nuclear Materials Management and will be made in the nuclear storage area which is depicted in the accompanying drawing. Spacing of the containers will be by the strict administrative control of the area which is maintained by Martin Nuclear Materials Management. Separation of the storage array from other special nuclear material will be in compliance with AEC criteria and as defined by the Martin Criticality Engineer. The following nuclear safety evaluation is presented for the storage of the fuel tubes prior to processing.

1. Storage of 72-55 gallon drums each with 27 fuel tubes (1 144 grams U-235) in storage area E

a) Drum Storage Volume $= \pi r^2 h$ $= \pi$ (5.0 cm)$^2$([illegible] cm)

$= 7,210$ cm$^3$

b) Fuel Pellet Volume $= \pi r^2 h$ $\pi$ ([illegible])$^2$(2.54)

[illegible]

c) Total Number Fuel Pellets = ([illegible]) ([illegible] tubes)

[illegible] pellets

d) Total pellet Volume = 2[illegible] cm$^3$

e) Total Moderator Volume = 4,[illegible] cm$^3$

f) Total Weight U-[illegible] = 1,21[illegible] [illegible]

g) Atom Ratio

$$\frac{N_H}{N_U} = \frac{(2)\left(\frac{4700}{7210}\right)/18}{\left(\frac{1280}{7210}\right)/235} = \frac{.0725}{.000755} = 96$$

h) *Allowable Mass for $\frac{N_H}{N_U} = 96$ is 800 gram U-235

i) U-235 Density

$$\frac{1280g}{7210cm^3} = 0.1775 \text{ g cm}^{-3}$$

j) *Effective Density for $\frac{N_H}{N_U} = 96$ is 0.270 g cm$^{-3}$

k) Since the actual density is less than the effective density, no density corrections can be used.

l) *Enrichment correction factor for 5% enriched fuel = 2.3

m) Corrected Allowable Mass = (800g)(2.3) = 1 840g U-235

Conclusion: An individual storage container is primarily safe from criticality by reason of mass control, and as a result, dictates an allowable solid angle of 2.5 for the array calculations.

An array calculation was performed for a rectangular array of 6 x 12 fuel containers with a minimum spacing of 30 inches center to center. Because of the array symmetry, Figure 5 illustrates only one-fourth of the total storage pattern. A "most central unit" outside the quadrant was chosen for the solid angle reference unit as shown. Pertinent statistics and calculations are tabulated in the Figure margin. Total calculated solid angle is 1.246 compared to the maximum allowable angle of 2.50.

Conclusion: This 30 inch center to center rectangular array is safe from criticality even when fully moderated and reflected.

*Reference - Nuclear Safety Guide, TID-7016, Revision 1.

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Work Area Storage

Each work area shall be assigned a maximum of one storage rack, each containing two storage boxes. A drawing of the storage rack and boxes, which was approved in Amendment No. 18 to SNM-53 is included as Figure 6. Storage of fuel tubes in the storage boxes at the work area location shall be limited to 104 fuel tubes per two (2) storage boxes. An evaluation of the critical geometry was made to assure safety in storage of the 104 fuel tubes, the quantity contained in a fuel element, in any one storage box. Figure 7 depicts the storage of the fuel tubes in a storage box and the critical dimensions.

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In Process Storage

The in-process storage area approved for storage of highly enriched fuel, in connection with Amendment No. 18 to SNM-33, will be used for storage of tubular fuel tubes during the fabrication of a nuclear core of tubular design, employing slightly enriched uranium oxide pellets. The following nuclear safety evaluation defines the conditions for storage of the tubular elements.

[illegible]

## [illegible] CALCULATIONS FOR [illegible] STORAGE

A. [illegible] [illegible] safety for storage of fuel [illegible] storage area for the [illegible] Part B

B. [illegible] [illegible] calculations [illegible]
[illegible] per [illegible] = 2,216 [illegible]
[illegible] 14,000 [illegible]
[illegible] = 21,000 [illegible]
[illegible] 2.7 [illegible] 0.03 [illegible]
= 1.95 [illegible] 0.01 [illegible]
[illegible] 0.03 [illegible]

[illegible] of criticality [illegible]
[illegible] sphere [illegible]

[illegible]

[illegible]

SOLID ANGLE TABULATIONS

| Unit Number | Unit Area | Distance | (Distance)$^2$ | Unit | Total Unit |
|---|---|---|---|---|---|
| 23, 35 (1) | [illegible] | 27 | 730 | 0.295 | 0.730 |
| 28 | 216 | 20 | 400 | .540 | .540 |
| 22, 34 | 216 | 33.[illegible] | 1,130 | .191 | .3[illegible] |
| 40 | 216 | 60.[illegible] | 3,650 | .059 | .059 |
| 30 | 216 | [illegible] | 2,110 | .102 | .102 |
| 24, 3[illegible] | 21[illegible] | [illegible] | 2,[illegible] | .07[illegible] | .152 |
| 42 | 216 | 73.2 | 5,[illegible] | .040 | .040 |
| 21, 33, [illegible] | 216 | 70.7 | 5,000 | .0[illegible] | .12[illegible] |
| 25, 37, 45 | 216 | 7[illegible].3 | 5,[illegible] | .037 | .0[illegible] |
| 26, 38, 44 | 216 | 13[illegible] | 18,[illegible]00 | .011 | .033 |
| 3, [illegible], 13, 1[illegible], [illegible] 23, 5[illegible], [illegible] | [illegible]0 Avg. | 73 | 5,[illegible] | .01[illegible] | .1[illegible] |
| 2, 7, 12, 17, 4[illegible] 52, 5[illegible], [illegible] | [illegible]0 Avg. | [illegible] | [illegible],700 | .015 | .120 |
| 4, 9, 14, 1[illegible], [illegible] 5[illegible], [illegible] | [illegible]0 Avg. | [illegible] | [illegible],100 | .012 | [illegible] |
| 1, [illegible], 11, 1[illegible], [illegible], 20 15, 20, [illegible], 5[illegible] 57, 63, 49, [illegible] 61, [illegible], 67 | [illegible]0 Avg. | 97.2 | [illegible] | .010 | .1[illegible]0 |
| 50, [illegible], [illegible] | [illegible] Avg. | [illegible] | [illegible] | [illegible] | [illegible] |
| | | | Total [illegible] | | [illegible] (2) |

Figure[illegible] [illegible] [illegible] the [illegible] configuration for which [illegible] were calculated. The [illegible] [illegible] conservative since the [illegible] of [illegible] angle [illegible] out of [illegible] [illegible] [illegible] safety factor.

[illegible]

(1) [illegible]

(2) Units 21, 27, 31, 32 are [illegible] reference [illegible]

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Processing Criteria

For welding and inspection steps, a limit of 2400 gms U-235 has been established based on a flat array and a minimum critical slab thickness of 3.5 inches, as defined in TID-7016, Revision 1. Leak test operations are defined by the Chamber dimensions which comply with the always safe eight inch diameter criteria as depicted in the discussion of the storage boxes. Cleaning operations have been established according to the nuclear safety analysis following this discussion. 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 dissolution of any tube during cleaning is not possible since the cleaning acids are for the purpose of surface cleaning only. Use of HF which is necessary for dissolution of the stainless steel tubing shall be prohibited. A twelve inch fixed mechanical separation shall be provided between cleaning tanks as defined in the nuclear safety evaluation for the cleaning operation.

# I MH-1A CRITICALITY ANALYSIS

## $K_{eff}$ Calculation

A. Problem: Fifty-two fuel elements will be submerged in a water trough 12 x 12 x 96 inches long during the cleaning operation of the fuel element fabrication process. Due to screens securely anchored in the trough, the active volume that the elements shall occupy is 8 x 10 x 76 inches. What is the $K_{eff}$ of this reflected system, as shown in Figure II? (A homogeneous solution is assumed.)

B. Given: Weight of U-235 per element = 43.2 g, per 52 elements = 2,246 g

Weight of U-238 per element = 358 g, per 52 elements = [illegible]

Volume displacement of 52 elements = 6,560 $cm^3$

Volume of critical system = 100 000 $cm^3$

Volume of water moderator = 93,440 $cm^3$

U-235 density = [illegible] x $10^{-2}$

U-238 density = [illegible] x $10^{-1}$

$H_2O$ density = [illegible]

$\Sigma$ [illegible] x $10^{-2}$ $cm^{-1}$

$\Sigma_a$ [illegible] x $10^{-3}$ $cm^{-1}$

$\Sigma$ [illegible] $H_2O$ [illegible] x $10$ [illegible] $cm^{-1}$

[illegible] $\rho$ = Density, $N_0$ = Avogadro's Number, $\sigma_a$ = Absorption Cross Sec., $M$ = Molecular Weight

C. For the [illegible] of calculating the $K_{eff}$ [illegible] the [illegible] multiplication factor [illegible] system [illegible] given by

(Ref. 1)

$$K_{eff} = k_{\infty} [illegible] (1 + L^2 B^2)(1 + \tau B^2) \quad (1.0)$$

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

[illegible] $\epsilon$ = Fast Fission Factor (2.0)

$p$ = Resonance escape

$f$ = Thermal utilization

$\eta$ = Fast fission neutrons

(Ref. 2)

$$B^2 = \left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2 + \left(\frac{\pi}{c}\right)^2 \text{ — Geometric buckling} \quad (3.0)$$

(Ref 3)

$$L_c^2 = L_m^2 / E+1 \text{, thermal neutron diffusion length in core} \quad (4.0)$$

(Ref 4)

$L_1 = 4.49$ cm.
$L_2 = 2.45$ cm.
$L_3 = 2.05$ cm.
$L_4 = 1.00$ cm.

experimental spatial distribution for fast neutrons in ordinary water.

D. Equation (2.0)

(Ref 5)

(1) $\epsilon = 1.015$ based on an element radius of 0.63 cm.

(Ref 6)

(2) $\eta = \nu \times \frac{\Sigma_f}{\Sigma_a} = 2.5 \times \frac{(549)}{650 + (19.6)(2.8)} = \nu \times \frac{\sigma_{f\,235}}{\sigma_{c\,235} + \frac{N_{238}}{N_{235}} \sigma_{c\,238}}$

$\eta = 1.95$

(Ref 7)

(3) $f = 1 / 1 + \frac{\Sigma_{a\,H_2O}}{\Sigma_{a\,235} + \Sigma_{a\,238}} = 1 / 1 + \frac{0.0206}{.0374 + 0.00316}$

$f = 0.635$

(Ref. 8)

(4) $p = e^{-\left[\frac{3.9}{\xi}\left(\frac{N_u}{N_{H_2O} \times \sigma_{s\,H_2O}}\right)^{0.585}\right]}$

where: $\xi = 1$ for water (ordinary)

$\sigma_s$ = scattering cross section = 38 for water (Hydrogen)

$N_u$ = N235 + N238 = 0.00187 + 0.000088 = 0 001971

$N_H$ = 0.1035

$$p = e^{-\left[3.9\left(\frac{0.001971}{0.1035(38)}\right)^{0.585}\right]} = e^{-3.9(0.0118)}$$

$p = 0.955$

## MSR-1A CRITICALITY ANALYSIS

### $K_{eff}$ Calculation

**E. $B^2$ Equation (3.0)**

The container dimensions for the system volume are 20.3 x 25.4 x 163 cm. To include the effect of reflector savings ($\delta$), these dimensions are increased by 6 cm to 26.3 x 31.4 x 169 cm. Where:

$$\delta = \frac{D_c}{D_r} L_r \; \frac{[illegible]}{0.8} \; [illegible] \text{ cm} \qquad \text{(Ref 9)}$$

≈ 3 cm. per side thickness or 6 cm total

$D_c$ - Diffusion coefficient of system (core)

$D_r$ - Diffusion coefficient of reflector

$L_r$ - Reflector thermal neutron diffusion length

## CRITICALITY ANALYSIS -

## Keff CALCULATION

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

where a, b, & c are the critical dimensions which include reflector savings. (26.3 x 31.4 x 199 cm resp.)

$$\boxed{B^2 = 0.0245}$$

F. $L_c^2$, Equation (49)

$$L_c^2 = \frac{Lm^2}{Z+1}$$

where Lm = 2.88 cm. Moderator thermal neutron diffusion length.

$$Z = \Sigma a_u / \Sigma a_{H_2O}$$

$$Z = \frac{.0374 + .0032}{.0206} = 1.97$$

$$L_c^2 = \frac{8.3}{2.97}$$

$$\boxed{L_c^2 = 2.8}$$

G. The denominator of equation (1.0) can now be determined -

$$(1 + L_c^2 B^2)\ (1 + L_1^2 B^2)\ (1 + L_2^2 B^2)\ (1 + L_3^2 B^2)\ (1 + L_4^2 B^2)$$

$$(1.0686)\ (1.493)\ (1.147)\ (1.105)\ (1.0245) = \boxed{2.07}$$

H. and the Keff of the system is

$$K_{eff} = \frac{1.20}{2.07} = \boxed{0.58}$$

(Ref. 10)

I. Based on this Keff the total interaction steradians ($\Omega$) allowed for an array calculation is (9 - 10K) or $\boxed{3.20}$

J. References.


(1) Principals of Nuclear Reactor Engineering, Glasstone, Equation
(1) Principals of Nuc. Reactor Engr., Glasstone, Equation 3.162.1
(2) " , Section 3.116
(3) " , Equation 3.147.2
(4) " , Section 3.162
(5) " , Figure 3.17
(6) " , Section 3.130
(7) " , Section 3.133
(8) " , Section 3.135
(9) " , Equation 3.213.2
(10) Nuclear Safety Guide TID-7016, Rev.1(1961), Figure 26

# CRITICALITY ANALYSIS -
# ARRAY CALCULATIONS

A. PROBLEM: A maximum of 104 fuel elements will be allowed in the cleaning room at one time, and will be loaded in four [illegible] racks as shown in the sketch. Determine the maximum interaction [illegible] angle possible for these racks in the cleaning room.

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Obviously, the [illegible] in [illegible] 2,3, [illegible] tank [illegible] 2, [illegible] is 360 in$^2$. [illegible] The distance [illegible] of rack 1 [illegible] to [illegible] 2, 3 [illegible] the total interaction [illegible]

$$\Omega_T = [illegible] \; [illegible] \; [illegible] = [illegible]$$

C. CONCLUSION: This configuration [illegible] if [illegible] 12 inch [illegible] distance [illegible] maintained [illegible] within a given tank by mechanical means, i.e., a divider [illegible] only. (This [illegible] distance [illegible] common to all array calculations.)

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Fuel Element Assembly

When a set of 104 fuel tubes have been accepted for use in a fuel element, they will be assembled into the grid structure to form a completed fuel element. Figure 12 illustrates the positioning of the fuel tubes in the grid structure and tabulates the minimum critical dimensions. As in the case of the storage boxes, safe geometry is the controlling factor. A limit of one element per work area shall be permitted and transfer of the completed element to storage will be effected prior to the fabrication of another fuel element.

Completed fuel elements will be stored in the nuclear storage area in the D Building. Since safe geometry is the controlling factor for individual elements, a maximum total solid angle of 1.0 steradians is required. Vertical storage of the elements on five foot centers will be maintained by Martin Nuclear Materials Management, which has jurisdiction over the storage area. Calculation of the storage array is presented in Figure 13.

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