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SUPPLEMENT TO SAFETY ANALYSIS REPORT FOR PACKAGING STEEL BANDED WOODEN SHIPPING CONTAINERS FOR SLIGHTLY ENRICHED URANIUM METAL (NLCO-1107)

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June 20, 1979

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FROM: D. L. HONKONEN
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SUPPLEMENT TO "SAFETY ANALYSIS REPORT FOR PACKAGING, STEEL BANDED WOODEN SHIPPING CONTAINERS FOR SLIGHTLY ENRICHED URANIUM METAL"

INTRODUCTION

A total of 36 tons of slightly enriched uranium metal in the form of Mark VR, VE, and 15 slugs and cores is to be returned to NLO from Building 777-M. The most practical method of shipping this uranium is in the NLO wooden containers in which it was originally received (Reference 1). However, existing shipping regulations were written after this uranium was shipped and the Certificate of Compliance, COC, (Reference 2) does not authorize the shipment of this uranium in these boxes and the Safety Analysis Report for Packaging, SARP, (Reference 1) does not discuss this uranium. Therefore, this supplement to the SARP is intended to provide the basis for revision of the COC to permit shipping Mark VR, VE and 15 cores and slugs in NLO wooden containers.

SUMMARY

Mark VR, VE and 15 cores and slugs may be safely shipped in NLO wooden boxes by limiting the mass of uranium in each shipment as specified in Table 6. These limits ensure subcriticality even if all cores or slugs come out of the boxes and are arranged in the most reactive array in water.

DISCUSSION

The adequacy of NLO wooden shipping containers (boxes) for shipping other forms of slightly enriched uranium is described in reference 1. This discussion will cover only those aspects that are different.

Box Contents

The NLO boxes and their maximum contents are specified in Table 1. The material to be shipped is in the form of hollow cylinders of uranium metal with a thin nickel plate, bare cores, and with an additional aluminum cladding, canned slugs. These are described in Table 2.

Nuclear Criticality Safety

Nuclear criticality safety of each shipment of Mark VR, VE, and 15 will be ensured by shipping only a mass that can not be critical at the optimum arrangement in H_2O, i.e. it is assumed that in an accident the boxes would not maintain the slugs (or cores) at a close-packed, less reactive spacing. These safe masses were calculated by the MGBS, TCAN, and KEFF codes (Reference 3).

Mark VE Canned Slugs - The material bucklings of regular square lattices of Mark VE inner and outer canned slugs in water were calculated with the MGBS code for several lattice pitches. These bucklings were adjusted based on correlations of MGBS and experiments for Mark VE slugs in water (Reference 4). Extrapolation distances were calculated by TGAN, and finally, critical and safe masses were calculated by KEFF. Safe masses were defined as those corresponding to a $k_{eff} = 0.98$ (Reference 4).

The results of these calculations, given in Table 3, show that with full flooding the maximum safe mass of inner slugs is 3.4 tons and of outer slugs is 21.4 tons. However, subsequent calculations for Mark VR and Mark 15 outer slugs show that significantly lower masses occur if the axial cavity of the outer slugs contain no water, but there is water between the slugs, (References 5 and 6). Such a condition could occur with tightly fitting box lids that seal the axial cavity of the core or slug so that water only fills the space between the cores or slugs if the box is submerged. No such calculations were made for Mark VE outer slugs, but the maximum safe mass for Mark VE outer slugs can be conservatively chosen as the same as for Mark VE inner slugs, 3.4 tons. Calculations for Mark VR described below show that this provides a large margin of safety.

Mark VR Canned Slugs - Critical and safe masses of Mark VR slugs were calculated using the procedure described for Mark VE except that the outer slugs had H_2O between them but the axial cavity was void (Reference 5).

The results of these calculations, given in Table 4, show that the maximum safe masses of inner and outer slugs are 6.9 and 16.3 tons of uranium, respectively.

Additional calculations were performed to compare the safe masses calculated for square arrays with those calculated for triangular arrays and safe masses for fully flooded outers with those for axial cavity void outers. At each water to uranium volume ratio, square lattice arrays gave slightly lower safe masses than did triangular arrays; e.g. the maximum safe mass of inner bare cores was 5.56 tons for a square array, and 5.91 tons for a triangular array. The calculations show that fully flooded outer bare cores could not be critical (maximum $k_\infty = 0.988$), whereas 23 tons could be critical with the axial cavity void. Similarly, the maximum safe ($k_{eff} = 0.98$) masses are 153 and 13.8 tons for full flooding and with the axial cavity void, respectively.

Mark 15 Bare Cores - Safe masses were calculated for fully flooded Mark 15 inner cores and for Mark 15 outer cores with the axial cavity void (Reference 6). The results, summarized in Table 5, give a maximum safe mass of 1.34 and 4.19 tons of uranium for inner cores and outer cores, respectively.

Shipment Limits - The slugs and cores will be loaded, with their axes vertical, into the NLO boxes as specified in Table 1. The boxes will be sealed using steel bands, and then they will be loaded onto a truck in a single layer (no stacking will be permitted). The smallest safe masses of uranium from Tables 3,4, and 5 shall be the limits for each Fissile Class III shipment (Reference 4), as listed in Table 6. Only one material type, e.g. Mark VR inner canned slugs, may be in each shipment except that Mark 15 inner bare cores may be shipped with Mark 15 inner canned slugs and Mark 15 outer bare cores may be shipped with Mark 15 outer canned slugs.

Compliance with the above limits ensures that these shipments satisfy the "Specific Standards for a Fissile Class III shipment" (Reference 7).

- Two identical undamaged shipments in contact and closely reflected on all sides by water would be subcritical. The uranium in these two adjacent shipments would be in a layer (slab) whose thickness is equal to the length of the uranium. Results of calculations using the MGBS, TGAN, and KEFF codes show that the maximum safe ($k_{eff} = 0.98$) thickness of an infinite slab with these uranium cores and slugs at the most reactive spacing in water and with a close fitting water reflector on all sides is greater than the actual thickness (see Table 7). Thus, the two adjacent undamaged shipments in which the cores and slugs are not in water, a less reactive condition, are subcritical by a much larger margin than shown.

- No attempt is made to evaluate the safety of a shipment if the boxes of these slugs or cores are subjected to the hypothetical accident conditions specified in regulations (reference 8). Rather, it is assumed that all the cores or slugs would come out of the boxes and would be arranged in the most reactive array in water, full flooding for inner cores and slugs and the axial cavity of outer cores and slugs void. As discussed previously, the maximum masses to be shipped (see Table 6) would be subcritical under these conditions.

DLH:sgf
Attachments
SPR

References

1. D. L. Dunaway, "Safety Analysis Report For Packaging, Steel Banded Wooden Shipping Containers For Slightly Enriched Uranium Metal," NLCO-1107, National Lead Company of Ohio, July 1974.

2. Certificate of Compliance No. USA/5467/AF(ERDA-OR), Revision No. 3, NLO Wooden Containers, September 20,1976.

3. H. K. Clark, "Computer Codes for Nuclear Criticality Safety Calculations," DP-1121, November 1967.

4. H. K. Clark, "Comparison of VE Experiments and Calculations," DPST-63-297, June 12, 1963.

5. D. L. Honkonen, "Nuclear Safety Criteria for Unirradiated Mark V-R," RTR-794, Dec. 16, 1965.

6. Memo D. L. Honkonen to R. H. Dietz, R. M. Radford, and T. L. Evans, "Nuclear Criticality Safety Analysis No. 15, Revised Mark 15 Development Program," June 27, 1972.

7. 10 CFR 71 "Packing of Radioactive Material For Transport and Transportation of Radioactive Material Under Certain Conditions." Section 71.40

8. Ibid., Appendix B.

TABLE 1

NLO BOX CONTENTS

MATERIAL TYPE	BOX TYPE, NLO DRAWING NO.	NO. PER BOX, MAX.	MAXIMUM WEIGHT PER BOX, POUNDS NET	GROSS
Mark VR inner canned slugs	G-4214	105	1070	1125
Mark VR outer canned slugs	G-4214	45	650	705
Mark VE inner canned slugs	G-4214	105	1010	1065
Mark VE outer canned slugs	G-4214	45	610	665
Mark 15 inner bare cores	G-4292*	60	980	1080
Mark 15 inner canned slugs	G-4292*	60	1015	1115
Mark 15 outer bare cores	G-4292*	30	580	680
Mark 15 outer canned slugs	G-4292*	30	610	710

*A wooden false bottom will be placed in each box to reduce the inside useable height from 16 1/8 to 11 1/2 inches.

TABLE 2

DESCRIPTION OF SLIGHTLY ENRICHED URANIUM SLUGS

		NOMINAL DIMENSIONS, INCHES					
MATERIAL TYPE	^{235}U Content, WT %	CLAD,*OD	Bare,** OD	BARE,** ID	CLAD,* ID	BARE**LENGTH	CLAD*LENGTH
Mark VR outer	0.86 ± 0.006	3.074	3.016	2.460	2.402	8.442	8.840
Mark VR inner	0.86 ± 0.006	1.972	1.914	1.226	1.168	8.442	8.840
Mark VE outer	0.947 ± 0.006	3.076	3.016	2.460	2.400	8.030	8.400
Mark VE inner	0.947 ± 0.006	1.974	1.914	1.226	1.166	8.040	8.400
Mark 15 outer	1.100 ± 0.006	3.700	3.640	3.165	3.105	11.11	11.5
Mark 15 inner	1.100 ± 0.006	2.665	2.605	2.018	1.958	11.11	11.5

* Canned slugs are clad with aluminum

** 0.0003 inch Nickel bonding layer on all uranium surfaces.

TABLE 3

CRITICAL AND SAFE* MASSES OF MARK VE CANNED SLUGS IN A SQUARE LATTICE IN H_2O

TYPE SLUG	TYPE FLOODING	LATTICE PITCH, IN.	V_{H_2O}/V_u	TONS OF U	
				Critical	Safe*
Inner	Full	1.97	1.0	38.7	15.4
		2.13	1.5	7.4	4.6
		2.32	2.0	5.2	3.4
		2.50	2.5	8.5	4.7
Outer	Full	3.08	2.75	475	25.6
		3.18	3.00	242	21.4
		3.27	3.25	376	22.2

* Corresponds to a $k_{eff} = 0.98$. The smallest of these values is the maximum safe mass.

TABLE 4

Critical and Safe* Masses of Mark VR Canned Slugs in Square Lattice in H_2O

Type Slug	Type Flooding	Lattice Pitch, in.	V_{H_2O}/V_u	Tons of U	
				Critical	Safe*
Inner	Full	1.99	1.158	43.7	16.4
		2.04	1.282	28.1	12.3
		2.23	1.757	13.2	7.0
		2.32	2.012	13.6	6.9
		2.42	2.278	17.8	8.1
		2.61	2.843	409.5	25.3
Outer	Between Slugs (axial cavity void)	3.19	1.161	56.8	30.0
		3.29	1.424	34.9	19.8
		3.39	1.694	28.7	16.3
		3.58	2.263	72.3	26.7

* Corresponds to a $k_{eff} = 0.98$. The smallest of these values is the maximum safe mass.

TABLE 5

Critical and Safe* Masses of Mark 15 Bare Cores in Square Lattice in H_2O

Type Core	Type Flooding	Lattice Pitch, in.	V_{H_2O}/V_u	Safe* Mass Tons of U
Inner	Full	2.605	2.19	1.48
		2.692	2.40	1.42
		2.846	2.80	1.34
		2.920	3.00	1.36
		3.062	3.40	1.49
		3.131	3.60	1.63
		3.455	4.60	4.39
Outer	Between Cores (axial cavity void)	3.770	1.50	6.10
		3.935	2.00	4.45
		4.000	2.20	4.24
		4.062	2.40	4.19
		4.124	2.60	4.29
		4.245	3.00	4.99

* Corresponds to a $k_{eff} = 0.98$. The smallest of these values is the maximum safe mass.

TABLE 6

Shipping Limits for Slightly Enriched Uranium

Piece Designation	Type	Maximum Amount of Uranium per Shipment, Tons
Mark VR Canned Slugs	Inner	6.9
	Outer	16.3
Mark VE Canned Slugs	Inner	3.4
	Outer	3.4
Mark 15 Bare Cores & canned slugs	Inner	1.3
	Outer	4.1

TABLE 7

Maximum Safe* Thickness of An Infinite, Fully Water Reflected Slab

Material Type	Type Flooding	Maximum Safe* Slab Thickness, in.	Actual Slab Thickness, in.
Mark VE inner canned slugs	Full	17.4	8.04
outer canned slugs	Between slugs (axial cavity void)	17.4	8.03
Mark VR inner canned slugs	Full	21.7	8.44
outer canned slugs	Between slugs (axial cavity void)	34.0	8.44
Mark 15 inner bare cores	Full	12.3	11.11
canned slugs		13.1	11.11
outer bare cores	Between cores (axial cavity void)	22.1	11.11
canned slugs		23.1	11.11

*Corresponds to a $k_{eff} = 0.98$