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7. Abstract <p>This CSER qualifies use of a 5% borated, lead foil lined polyethylene 1" annulus as a bucket and in a small carrier to move sealed containers of plutonium. The containers are Oversize Cans or smaller containing plutonium limited in mass and H/Pu ratio by PFP storage and transportation CPS's. These ALARA shielding units reduce personnel exposure to the radiation from the containers as they are moved for assay and other required activities.</p>		
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CSER 95-002

Title: ALARA SHIELDING FOR IAEA SNM CONTAINER MOVEMENT

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1.0 INTRODUCTION

The Plutonium Finishing Plant (PFP) has a commitment to turn over control of numerous Special Nuclear Material (SNM) items currently in storage in Vault 3 of the 2736-Z building to the International Atomic Energy Agency (IAEA). In support of this work, vault technicians and engineers are required to handle many of the items stored in the vaults in 2736-Z. To reduce personnel radiation exposure to AS LOW AS REASONABLY ACHIEVABLE (ALARA), a hand held shielding bucket has been designed and a rollable PORTA-PIG¹ carrier is being customized. Both shielding units can accommodate containers up to and including the PFP Oversize Can whose dimensions are: 12.07 cm diameter by 17.15 cm tall (4-3/4 inches diameter by 6-3/4 inches high). These shielding units need to be analyzed to establish their criticality safety. This Criticality Safety Evaluation Report (CSER) analyzes the shielding units for conformance to the criticality safety program at the Hanford site established by WHC-CM-4-29.

¹ Registered trademark of REACTOR EXPERIMENTS, Inc.

2.0 SUMMARY AND LIMITS

This CSER qualifies the shielded bucket described in Section 3.1 and the PORTA-PIG described in Section 3.2 to transport sealed containers of plutonium within limits listed below.

- Only one container allowed in shielding units at a time
- Only containers that fit into the shielding bucket well (Oversize Cans and containers of smaller volume)
- Only PORTA-PIGS drilled to allow drainage per Section J of CPS-Z-165-80010, Rev./Mod. C-2 and lined with a shielding bucket size liner
- Only containers of plutonium that meet the following material description and mass limits specified for the Fixed Array Wagon on page 10 in CPS-Z-165-80100, Rev./Mod. J-1.

<u>MATERIAL Description</u>	<u>Maximum Mass Limit</u>
H/Pu no more than 2	2500 grams
H/Pu no more than 20	1500 grams
H/Pu unrestricted and volume no more than 0.5 l	1500 grams
H/Pu unrestricted	400 grams

Containers are to be sealed in plastic or canned to maintain geometric control of the fissile material. Other fissile isotopes may be transported in the shielding units at equivalent limits as specified in Section 5.2.1.4 of Chapter 2 of WHC-CM-4-29, the Nuclear Criticality Safety Manual. Transportation of non-standard storage containers smaller than Oversize Cans may be approved by the PFP Criticality Safety Representative (CSR).

3.0 DESCRIPTIONS

3.1 Bucket

The shielding bucket is a one inch thick annulus with a 3.175 cm (1.25 inch) thick bottom constructed of borated (5% by volume) polyethylene as shown in Figure 1. Its inside dimensions are 12.07 cm (4.75 inch) diameter by 15.88 cm (6.25 inch) tall providing a total volume of slightly more than 1.8 liters. This inside well has a diameter only slightly larger than an Oversize Cans and a volume that is less than an Oversize Can. The inside diameter is still significantly less than the geometrically safe limit of 6 inches for cylinders containing plutonium solutions. The outside dimensions of the shielding bucket with its one-inch thick walls and bottom are 17.15 cm (6.75 inch) diameter by 18.42 cm (7.25 inch) high. Inside the polyethylene annulus and next to the canned item in the bucket is a 0.159 cm (1/16 inch) lead (Pb) foil. This foil covers only the sides of the container and is not placed in the bottom. A heavy gauge wire bail allows the operator to carry the shielding bucket conveniently and at a distance from the plutonium in the container. The lead foil, borated polyethylene, and bail serve to reduce the dose received by the operator, especially his extremities, during transport of cans containing SNM.

3.2 PORTA-PIG

The PORTA-PIG is a carbon steel cylinder welded to a plate mounted on rubber wheels and guided by a handle that steers the third wheel. The cylinder is 0.794 cm (5/16 inch) thick, 20.161 cm (7-15/16 inch) inside diameter, 25.718 cm (10-1/8 inch) tall with a 0.318 cm (1/8 inch) thick lid and bottom. The carbon steel cylinder is to be drilled to allow drainage per Section J of CPS-Z-165-80010, Rev./Mod. C-2, so it will not be a container. The cylinder and lid are to be lined with a 0.318 cm (1/8 inch) layer of lead. A shielding bucket annular liner is installed inside the lead lining of a PORTA-PIG cylinder to complete the unit. The immediate use of the PORTA-PIG is to shield operators moving samples of stabilized sludge in sample bottles sealed in plastic from Room 230A & B to the labs in the 234-5 Building.

3.3 Operations

Plutonium is stored in multiple canned and/or plastic sealed containers that must be moved for assay, storage, and examination. The shielding bucket is intended for moving cans of Plutonium metal and oxide stored in the vaults of 2736-Z building. And the PORTA-PIG is to be used to move sealed samples of stabilized sludge from Room 230A & B to the labs in the 234-5 Building. These two shielding units are being analyzed for criticality safety on the basis of the amount and

FIGURE 1

Inside Dimensions: 4.75" by 6.0"

Material: 1" Polyethylene w/ 5% Barium
1/16" lead foil inside walls
1" Polyethylene only on Bottom

H/Pu ratio of plutonium in a container and volume of the container. Qualified on this basis, the shielding unit may be allowed to be used for diverse tasks approved in Criticality Prevention Specifications (CPS's).

3.4 Fissile Material

The PFP CPS for storage (CPS-Z-165-80100, Rev./Mod. J-1) and transportation (CPS-Z-165-80110, Rev./Mod. C-1) limit the mass of plutonium in a single container by the degree of moderation. There are three hydrogen to plutonium (H/Pu) ratios used. Up to 2500 grams are allowed for dry materials ($H/Pu \leq 2$), up to 1500 grams of plutonium for slightly moderated material ($H/Pu \leq 20$), and up to 400 grams of plutonium for unrestricted moderation. A half liter container is allowed to contain up to 1500 grams with unrestricted moderation. The shielding units need to be evaluated for safe transport of each of these four categories of fissile material moderation. Note that if unit masses are shown to be critically safe for greater moderation or volume up to optimal moderation, the listed unit masses would be critically safe.

All fissile material is treated as Pu-239 in this analysis. Treating Pu-240 as Pu-239 is conservative. Other fissile material is allowed at equivalences defined in Sections A.4 and A.5 of the PFP General Limits CPS-Z-165-80010, Rev./Mod. C-2 and Section 5.2.1.4 of Chapter 2 of WHC-CM-4-29, the Nuclear Criticality Safety Manual.

Page 11 of the PFP General Limits CPS (CPS-Z-165-80010, Rev./Mod. C-2) lists routinely handled materials for each H/Pu category. Plutonium metal and dry oxide are expected to comprise most of the dry material ($H/Pu \leq 2$); plutonium oxalate and waste from rooms and hoods comprise much of the fully moderated material. Only floor sweepings from dry gloveboxes and sludge dried on a hot plate are listed for slightly moderated materials ($H/Pu \leq 20$).

3.4 Fissile Material Packaging

The bucket has an inside diameter of 12.07 cm (4.75 inch) and the pig carbon steel holder cylinder has an inside diameter of about 20.32 cm (8 inch). A shielding bucket annular liner is installed into the PORTA-PIG and restricts containers to those that fit in a 12.07 (4.75 inch) inside diameter well. The shielding units are to carry only sealed containers to prevent contamination and to maintain control of the fissile material. Containers transported in the shielding units are to be standard storage cans with diameters and volumes equal to or smaller than Oversized Can (4-3/4 inch diameter, 1.8 l). Other small containers may be used when approved by the PFP CSR.

The plutonium stored in these canned containers in 2736-ZB building and elsewhere is actually triple sealed. For plutonium oxide, there are to be two mechanical seals (metal cans) and a sealed plastic bag. For plutonium metal, that are to be three mechanical seals. Plutonium metal is first put in a sealed in a Tuna Can (3-3/8 inch diameter x 2 inch tall, 0.25 lb). Plutonium oxide is first put in a 1 lb. Slip Lid Can (3-1/2 inch diameter x 3-1/2 inch tall, 0.5 lb) or a Purex Slip Lid Can (3-7/16 inch diameter x 5-5/8 inch tall, 0.8 lb) that is sealed with tape. The second step is sealing the can from the first stage in a plastic bag. At the third stage, the three types of primary cans sealed in plastic are mechanically sealed, canned, in a Purex Secondary Can (4-1/16 inch diameter x 6-1/4 inch tall, 1.3 lb), except the 1 lb. Slip Lid Can which also may be put in a Small Tomato Can (4 inch diameter x 4-5/8 inch tall, 0.9 lb). At the final stage, the double sealed container of plutonium is mechanically sealed in a 7-inch Can (4-1/4 inch diameter x 7 inch tall, 1.5 lb). Sometimes the double sealed container is wrapped in plastic or for other reasons it is mechanically sealed in an Oversize Can (4-3/4 inch diameter x 6-3/4 inch tall, 1.9 lb).

4.0 CONTINGENCY ANALYSIS

The acceptability of the plutonium loading in the allowed containers is demonstrated by referencing other analysis. These references have analyzed normal loading and double batching. One analysis used up to triple batching with single, double sized, arrayed, and adjacent containers. The analyses used the most reactive combinations of container and fissile material and moderator that fit in the containers. The containers also were given significant reflection by 6" of water, 12" of concrete, lead, and full water.

This CSER quotes the k-effectives applicable to the interaction of a container carried by the shielding bucket with other containers and full array wagons. Placing a shielding bucket on a full array wagon is the worst case scenario for a single contingency that is possible given the shielding bucket geometry. However, the analyses placed the most reactive containers next to one or two containers in an array or next to double batched containers with significant or full reflection. This exceeds the reactivity increase from two cans directly on top of each other that could be arranged with a shielding bucket.

The contingency cases analyzed for the shielding bucket are considered more severe than those that would involve the PORTA-PIG. The pig has a thick metal cylinder around a bucket that would decrease interaction by distance and absorption and the pig is heavy so it would not be put on other plutonium containers. The interaction analyses of the bucket conservatively covers the PORTA-PIG.

5.0 CALCULATIONAL METHODS

The analyses use the fissile units composed of the most reactive containers and fissile contents. The fissile material in the containers for normal and overbatching is constrained by dimensions of the containers. For water moderated plutonium oxide in containers smaller than 2 ℓ , the most reactive system uses the largest volume container. So the Oversize Can is used to define the most reactive plutonium oxide system. This is a conservative approach because the actual material is sealed several times over in much smaller containers. The plutonium metal is most reactive in a compact shape so the analysis has used the button in a Tuna Can. For fissile material with a volume less than that of an Oversize Can, the fissile material was modelled as an equilateral (diameter = height) cylinder to make the most reactive cylindrical geometry. The fissile units do not include the plastic and metal that seal and contain the plutonium. Dimensions are chosen for the containers to be conservative. Each CSER qualifies the codes used in its analysis, except Reference 3 (CSAR 87-002). The MONK5 code used in that analysis was qualified in Reference 2.

6. RESULTS

6.1 Most Reactive Plutonium Form in Containers and Two Stacked Container Contingency

Reference 1 has considered which fissile material type is the most reactive in containers that will fit in the polyethylene bucket. Section 3.4 names the cans and gives their dimensions. The largest outside dimensioned container used to can plutonium is the Oversize Can (4-3/4 inch diameter x 6-3/4 inch tall, 1.9 ℓ). This container was used in Reference 1 to model the maximum size container where volume is a constraint, such as plutonium oxide mixed with an unlimited amount of moderator. For plutonium metal buttons, where compactness and tight reflection increase reactivity, a Tuna Can (4 inch diameter x 2-1/2 inch high, 0.5 ℓ) was used.

Reference 1 evaluated the k_{eff} of each category of allowed plutonium material in allowed containers and for double batching. The results are reproduced in Table 6.1. This data shows that the normally loaded cases for Pu metal buttons, PuO₂ at H/Pu $\leq$ 2, and PuO₂ in unrestricted moderator have a maximum k_{eff} of about 0.7 for normal loading. For double batching, the plutonium metal has a significant higher k_{eff} of 0.887, but well below the allowable limit of 0.935. These results show that plutonium metal buttons are the most reactive of the categories of stored plutonium containers.

Reference 1 established in Figure 4.1 that putting a double batch (800 g of PuO₂) in an Oversize Can (Pu-150-1h) does not significantly increase reactivity. So the double batch for unrestricted moderation is actually two Oversize Cans on top of each other. The other double batchings are made by combining the same density and H/Pu ratio material in an equilateral (diameter = height) cylinder with the restriction that the largest container diameter is 4.75".

The seven double batchings (calrim0h, PuO₂-d-1, PuO₂-w-5h, PuO₂-w-2h, PuO₂-w-3h, PuO₂-w-4h, and P4-150-1h) show that for the most reactive cylindrical geometry (two containers stacked or merged to a diameter = height cylinder), the k_{eff} is in all cases acceptable. This is with full radial water reflection. Note that this analysis covered PuO₂ in polyethylene in containers larger than a 1/2 liter container. The 1/2 liter container is allowed to store plutonium plastic mixtures in gloveboxes. Plutonium mixed with plastic is not canned due to the generation of gases that would pressurize the stored cans.

Reference 1 also evaluated cans containing Plutonium metal buttons for several contingencies since that item was found to be the most reactive. Single and double batching with water reflector were modelled and the results shown in Table 6.2. These cases show that even two plutonium metal buttons on top of each other, the worst stacking case, is within allowables. Placing a shielding bucket on another container or a container put on top of a shielding bucket would be significantly subcritical.

Table 6.1 Normal and Double Batched Fissile Material in Storage Cans

INPUT FILE	DESCRIPTION	FISSILE DIMENSION (Dia. x Tall)	DENSITY (g/cc)	H/Pu	Pu (kg)	k _{eff}
Calrim0e	Pu Metal Button	2.8" x 1.277"	19.7	0	2.5	0.700
Calrim0h	2 Pu Metal Buttons	2.8" x 2.55"	19.7	0	5.0	0.887
pu02-d-1	PuO2	2.79" x 2.79"	11.3	0	2.5	0.525
Pu02-d-1	PuO2 in Water	2.79" x 2.79"	11.3	2	2.5	0.698
Pu02-d-1h	PuO2 in Water	3.39" x 3.39"	11.3	2	5.0	0.872
Pu02-m-1	PuO2 in Water	5.1" x 5.1"	1.11	3.346	1.5	0.309
Pu02-w-5	PuO2 in Water	4.54" x 4.54"	1.409	20	1.5	0.592
Pu02-w-5h	PuO2 in Water	4.75" x 8.31"	1.409	20	3.0	0.739
Pu02-w-2	PuO2 in Water	4.60" x 4.60"	1.51	20	1.5	0.640
Pu02-w-2h	PuO2 in Water	4.75" x 4.76"	1.51	20	3.0	0.775
Pu02-w-3	PuO2 in Water	3.66" x 3.66"	3.0	8.676	1.5	0.504
Pu02-w-3h	PuO2 in Water	4.45" x 4.45"	3.0	8.676	3.0	0.670
Pu02-w-4	PuO2 in Water	2.94" x 2.94"	5.8	3.834	1.5	0.470
Pu02-w-4h	PuO2 in Water	3.57" x 3.57"	5.8	3.834	3.0	0.618
P4-150-1	PuO2 in Polyethylene	4.75" x 6.75"	0.231	148.4	0.4	0.684
P4-150-1h	PuO2 in Polyethylene	4.75" x 13.5"	0.231	148.4	0.8	0.788

- Notes
- 1) All items were modelled centered inside a long 6.335 diameter cylinder of water as a reflector.
 - 2) All k-effective values have standard deviations of less than 0.0030.

Table 6.2 Plutonium Metal Buttons with Varying Water Reflection

INPUT FILE	DESCRIPTION	WATER REFLECTION	Pu (kg)	k _{eff}
Calrim0e	1 Pu Metal Button (2.8" Dia. x 1.277" high)	6.335" Dia. tube	2.5	0.700
Calrim0i1	" " " " "	4" Dia. x 2-1/2" Hi	2.5	0.730
Calrim0j1	" " " " "	2.8" Dia. x 1.277"H	2.5	0.777
Calrim0h	2 Pu Metal Buttons (2.8" Dia. x 2.55" High)	6.335" Dia. tube	5.0	0.887
Calrim0m1	2 Pu Metal Buttons stacked with 0.7" space between	2.8" Dia. x 3.25" H	5.0	0.860

1) k-effective standard deviations are all less than 0.0030

6.2 A Sixth Container Added to A Fixed Array Wagon

The previous section found stacked storage cans of plutonium were safely subcritical. This section reviews the subcriticality of a container from a shielding unit put in a Fixed Array Wagon. Figure 6.1 shows three views of Fixed Array Wagons. Reference 2 analyzed the reactivity of the 5-position Fixed Array Wagon with one of the 5 containers double batched and, in another case, for a sixth container in the array wagon. Up to a 1/2" lead reflector was also considered around each container. The type of containers, the plutonium mass limits, H/Pu limits, and container volume limits analyzed in Reference 2 are the same as considered for transport in the shielding units. These containers are specified in Section 3.4 above. The analysis considered full reflection of individual containers and of the loaded Fixed Array Wagon. Reference 2 concluded that a double batched container in the most reactive of the five positions or a sixth container in a loaded wagon was subcritical by a wide margin. K_{eff} for conditions relevant to the shielding units never exceed 0.9.

The k_{eff} 's for some of the cases analyzed with 2.5 kg plutonium buttons in the 5-position array wagon were: (1) for full, close reflection around the wagon (water on three sides and concrete on the other three sides) - 0.72; (2) for a sixth button in the most reactive position in the array wagon with full, close reflection around the wagon (water on three sides and concrete on the other three sides) - 0.77; (3) for a double batched container in the most reactive position and with full, close reflection around the wagon (water on three sides and concrete on the other three sides) - 0.79; and (4) for two adjacent wagons arranged so one double batched container is separated from a normally loaded container by less than two inches - 0.80. The second case listed above is significantly worse than putting a Shielding Bucket on a Fixed Array Wagon. The container is closer to other containers in the Fixed Array Wagon than a Shielding Bucket would allow and the wagon was modelled as collapsed into a concrete corner with water on the other three sides. This configuration is a conservative case for the shielding units. The third case listed above puts the sixth button in the center container on top of the button in that position. This is a worse configuration than putting the shielding bucket on top of a container in the array wagon. The fourth case listed above puts a container closer to a double batched container than the shielding bucket and Fixed Array Wagon hardware would allow. Even dropping a container out of the bucket on to a Fixed Array Wagon would be less severe. These runs show that a shielding unit would be safely subcritical in any geometrically possible configuration of an array wagon and bucket.

Figure 6.1 Three Views of Fixed Array Wagons (Formerly
Plutonium Transfer Wagons)

Photo 1 - Four Empty
Plutonium Transfer Wagons.

Photo 2 - Plutonium
Transfer Wagon Showing
the Five Fixed Storage
Positions.

Photo 3 - Close View of
Storage Positions.

A run putting 7-inch Cans (4-1/4 inch diameter x 7 inch tall, 1.5 l) filled with 400 grams moderated plutonium in the same configuration as Case 1 above had a lower k_{eff} , 0.605. So the 7-inch Can would also be acceptable in the shielding units. And Reference 3 has shown that 1500 grams of plutonium in half liter container is less reactive than a 400 gram, moderated fissile unit in a 1.5 l or a 4.7 l container. So the 1/2 liter container is also acceptable in the shielding units.

Reference 2 also analyzed the reactivity of the PUREX (2 lb) Slip Lid Can (3.5" dia. x 5.63" tall, 0.83 l measured) filled with 2.5 kg plutonium as PuO₂ at 3.0 g PuO₂/cc. The plutonium oxide is canned dry (H/Pu = 0) so moderation is a contingency. An array of 12 5-position wagons filled with the container containing dry plutonium has a k_{eff} of 0.35 with 6 inch water reflection on five sides. With 6 inches of water reflection on all six sides, the k_{eff} increases to 0.66. Moderating the plutonium oxide in the containers with water (H/Pu = 6.9), k_{eff} increases significantly to 0.87. These results show that even for two contingencies, moderation and reflection on all sides, this container and plutonium loading is significantly subcritical.

Varying the contingencies in the following cases does not change the conclusion that this container and loading are safe. Using 12 inches of concrete reflection on three sides in place of 6" of water on those three sides with the remaining three sides still reflected by 6" of water, increases k_{eff} to 0.90. Interspersed water moderation does not increase k_{eff} significantly. A 1/2 inch thickness of lead wrapped around each container in the array does increase the k_{eff} from 0.87 to 0.89, but 1/4 inch of lead does not increase k_{eff} . The 1/8 inch or less thick lead used in the shielding units would not have a significant affect under contingency conditions on the critical safety of the units.

If the triangular array is changed to a square array of 64 moderated containers with a pitch of 7.9 inches, the k_{eff} is 0.879. Putting an extra container in the center of the middle four in the array, raises k_{eff} only to 0.880. Putting an extra container in the array between two others (0.4 inch edge-to-edge spacing for three containers instead of the array spacing of 2.15 inch edge-to-edge) raises the k_{eff} to 0.89. For a 4x4 array of these containers, the k_{eff} is 0.83. With an extra container at the center, k_{eff} is 0.84. This reduced spacing contingency is shown to be critically safe for the Purex Slip Lid Can loaded with 2.5 kg of plutonium oxide.

Reference 2 found the 2.5 kg plutonium buttons and 2.5 kg of plutonium oxide to be the two most reactive unit masses carried by Fixed Array Wagons and listed in Section 2. Even these more reactive unit masses that are packaged to fit in shielding units are shown by the Reference 2 analyses to have a significant margin of safety, even with the following

contingencies: a thin lead collar, moderated contents, multiple array wagons, incredible reflection (6" of water all around) and misplacement of the carried container. Since these are subcritical in these contingencies analyzed above, then smaller containers and containers with less plutonium are also safe. Section 3.4 gives the size container plutonium oxide is actually put in. It is smaller than the container analyzed here.

6.3 0.5 Liter Containers

The criticality potential of plutonium oxide in the 1/2 liter polyjar has been examined in Reference 4. The determinations made in that CSER will be used here to show that these containers are critically safe in the two shielding units. The results for 1/2 liter polyjars are also applicable to 1 lb. Slip Lid Cans which also have a volume of a 1/2 liter and have only a 1/4 inch larger diameter (3.5 inch diameter).

Plutonium oxide is normally about 3 g PuO₂/cc at PFP. Page II.C.-2 of Reference 5 shows that for metal and some compounds burned at high temperatures, a higher density can be achieved. The 1500 g plutonium limit is imposed to administratively exclude completely filling a 1/2 liter container with PuO₂ from burned plutonium metal. The density could also be increased by compaction. However, 1/2 liter polyjars are not used to store pure PuO₂, but contain floor sweepings or other dry plutonium waste which would have considerable non-fissile material in it. Further, the jars would not normally be completely filled. At 3 g PuO₂/cc, a full 1/2 liter polyjar could contain 1500 g PuO₂ or 3000 g PuO₂ per liter. This is the maximum loading a 1/2-liter container is allowed at PFP.

The small diameter and volume of the 1/2 liter polyjar make it geometrically safe. Figure III.A.4-1 in Reference 5 shows that a 3-1/4 inch diameter infinite cylinder of plutonium-239 in water, fully water reflected is subcritical for all plutonium densities less than 5 g Pu/cc. For 1500 g Pu-239 in water, Figure III.A.9(100)-4 in Reference 5 shows a volume of more than 6 liters is needed for a criticality of 1500 grams of plutonium. In both cases, less than full reflection would mean the assembly would be more subcritical. This data establishes that for plutonium compounds confined to 1/2 liter polyjars, criticality is not possible regardless of the fissile material density, the quantity of water moderation, or the degree of reflection.

Putting eight polyjars in a tight circle (4-9/16 inch radius to polyjar centers) like items in a Lazy Susan is a worst configuration than any of the arrangements possible with the shielding units. Table 6.3 lists the results found in Reference 4 for five densities of plutonium-239 in water inside the eight polyjars with the outsides flooded with water. The plutonium uniformly occupies each 1/2 liter polyjar at a conservative density of 19.8 g/cc with the

remaining polyjar volume filled with water. Even at 1500 g Pu per polyjar (3000 g Pu/l), the grouping has a k_{eff} of less than 0.9. This is adequately below the allowable limit of 0.935. These results show that a single 1/2 liter container in the bucket or pig is a safe configuration of 1/2 liter containers and that the misplacement of the bucket with five 1/2-liter containers in a Fixed Array Wagon or another 1/2-liter container is also critically safe even with a contingency of water reflection.

TABLE 6.3 k_{eff} for a Ring of 1/2 Liter Containers

INPUT FILE	Pu DENSITY (g Pu/l)	TOTAL Pu (kg)	k_{eff}	SD
ha23s01	100	0.4	0.669	0.0031
ha23s02	250	1.0	0.745	0.0033
ha23s03	400	1.6	0.770	0.0032
ha23s04	1000	4.0	0.809	0.0032
ha23s05	3000	12.0	0.898	0.0032

Reference 3 determined that 1/2 Liter Polyjars and 1 lb. Slip Lid Cans (0.5 l volume) with unrestricted moderation and a plutonium loading limit of 1500 grams are less reactive than the following volume-mass limit combinations; 400 g Pu in a 1, 1.2, 1.5, and 4.7 l volume, 800 g Pu in a 1 l volume, 1500 g Pu in a 2.7 l volume, and 2500 g Pu in a 2.7 l volume. The 1/2 liter container limit was found to be less reactive than these seven sets of limits for the four following conditions: (1) normal plutonium limit loaded in a single container volume; (2) double plutonium loading in a single container volume (double batching); (3) two normal plutonium loadings in a double container volume (spacing violation); and (4) a double volume containing three normal plutonium loadings (double batching and spacing violation). The containers are modelled as spheres with water moderation and full water reflection. The three "containers" of specific concern in this analysis are the containers with limits of 2500 grams of plutonium in 2.7 l, 1500 grams of plutonium in 2.7 l, and 400 grams of plutonium in 4.7 l. These three "containers" cover the three limits of plutonium mass reviewed in this analysis, but the "containers" have larger allowable volumes than the cans holding the plutonium to be handled by the shielding units. A larger volume allows a smaller minimum critical mass and so can be more reactive. Reference 3's conclusions are conservatively applicable to the containers under consideration in this CSER.

7. REVIEWER'S COMMENTS

T. Chiao of Criticality Radiological Analyses carried out the independent, technical review of "CSER 95-002, ALARA SHIELDING FOR IAEA SNM CONTAINER MOVEMENT" and provided the following comments.

The criticality safety evaluation was reviewed for technical adequacy for Criticality Safety considerations. The reviewer agrees with the author's conclusions summarized in the CSER and believes the Shielding Bucket and rollable PORTA-PIG can be operated safely according to standards established by WHC-CM-4-29. The references and logic were also confirmed to establish the intended conclusions.

Some comments and suggested clarifications were discussed with the author of this CSER and these comments were incorporated into the text of this CSER.

8. REFERENCES

1. WHC-SD-SQA-CSA-20384, Rev. 0, entitled "ADDENDUM 3 TO CSAR 80-027: USE OF CALORIMETER 109B FOR FISSILE MATERIAL MEASUREMENT", Tang Chiao, December 5, 1994.
2. SD-SQA-CSA-064, Rev. 0, entitled "CSAR 87- 004: PLUTONIUM TRANSFER WAGONS", C. L. Brown, August 14, 1987.
3. SD-SQA-CSA-058, Rev. 0, entitled "CSAR 87-002: SUBSTITUTION OF HALF-LITER UNIT MASSES FOR OTHER UNIT MASSES", R. D. Carter, August 13, 1987.
4. WHC-SD-SQA-CSA-20347, Rev. 0, entitled "CSER 91-007: USE OF CAROUSEL PALLETS TO STORE HALF-LITER POLYJARS IN PFP GLOVEBOX HA-23 S", E.M. Miller, July 14, 1992.
5. ARH-600: CRITICALITY HANDBOOK, R.D. Carter et. al., Atlantic Richfield Hanford Co., May 23, 1969.