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1	1	Cog. Eng. E. M. Miller	<i>Edward M. Miller</i>	5/18/95							
1	1	Cog. Mgr. D. S. Leach	<i>D. S. Leach</i>	5/18/95							
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1	1	Peer Review J. L. Geiger	<i>J. L. Geiger</i>	5/18/95							
1	1	CSR R. M. Irwin	<i>R. M. Irwin</i>	5/18/95							

18. <i>Edward M. Miller</i> E. M. Miller Signature of EDT Originator Date 5-18-95	19. <i>D. S. Leach</i> D. S. Leach Authorized Representative for Receiving Organization Date 5/18/95	20. <i>D. S. Leach</i> D. S. Leach Cognizant Manager Date 5/18/95	21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
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7. Abstract

This CSER justifies storing 13 K Basin cartridge filters, each grouted in a culvert, under the limits in an existing criticality presentation specifications (CPS) because the fissile material inventory is less than 1/5 the CPS limit, the container is larger than allowed containers, and the container has adequate iron content to meet the CPS requirements.

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CSER 95-008

**Title: CRITICALITY STORAGE CATEGORY FOR GROUTED K BASIN CARTRIDGE FILTERS AT
CWC**

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Criticality Safety Representative, Solid Waste

Reviewed by: J. L. Geiger Date: 1995 May 18
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1.0 INTRODUCTION AND SUMMARY

This criticality safety evaluation report (CSER) justifies the use of the criticality limits for container 5, burial boxes, from Criticality Prevention Specification CPS-SW-149-00002 for storage of 13 K Basin cartridge filters grouted in culverts. These items total inventory of plutonium is measured at 77 grams of plutonium, with at most 16 grams in one container. The items also contain uranium but it is at most enriched to 1.15 wt%. At this enrichment, there is no limit on the amount of uranium that can be stored in a burial box. The smallest burial box has a 250 gram plutonium limit which is more than three times the total plutonium inventory in the 13 containers and 14 times that in a single container. The volume of the container is over three times that of the smallest burial box. For these reasons, the K Basin cartridge filter containers can be stored as separate items or all 13 as one "burial box" unit. This evaluation specifies that the K Basin cartridge filter containers are to be stored using the limits in CPS-SW-149-00002 for the 2.5 ft x 2.5 ft x 2.5 ft burial box fissile inventory of 250 grams and the array limits for type 5 containers, burial boxes.

2.0 DESCRIPTION OF CONTAINER

The 13 containers from K Basins hold one cartridge filter each. The filters removed solids from the K Basins water before the water went to air-cooled chillers. The filters are about 75.7 cm (30 inches) in diameter and 86 cm (34 inches) tall (based on an outline on drawing H-1-34709 (Reference 1)). This is a volume of 388 liters.

Drawing H-1-34709 (Reference 1) shows the configuration of the concreted 122 cm (48 inch) diameter culvert cut to 124 cm (49 inches) long and shows the imbedded steel. The culvert is 0.35 cm (0.138 inches) thick and has a volume of 1450 liters. There are four 127 cm (50 inch) long 2 inch by 3/4 inch steel bars and reinforcing steel in the container. The culvert and four bars weigh 169.6 kg. The cylindrical culvert is oriented vertically with an 11 gauge bottom plate welded on and then filled to 15 cm (6 inches) with grout. The cartridge filter, bagged in 20 mill plastic (Reference 2), is then placed in the center of the culvert and the culvert is filled with concrete. Four of the 13 culverts were then put vertically into 152 cm (5 foot) diameter culverts about 61 cm (2 feet) high, centered radially, and concreted into the larger base. The two configurations weigh about 3600 and 5400 kgs, respectively.

Reference 3 analyzed the 13 containers for transuranic fissile material content. Table 1 presents the masses of isotopes pertinent to this CSER from Reference 3. The reference calculated the masses using constants from Appendix C, "Calculational Methods, Fissile Materials - Equivalents and Conversion Factors", of WHC-IP-0063-4.

Reference 3 did not calculate the amount of uranium or its enrichment contained on the cartridge filters. The uranium on the filters would have the same ratio to plutonium as is found in the water of the east K Basin. Reference 4 gives the uranium concentration in the K East Basin of $4.62\text{E-}05$ grams/liter and the plutonium 239/240 as $2.62\text{E-}2$ uCi/liter. Using the amount of plutonium-239 and plutonium-240 from Table 1 and Ci/g values for the two plutonium isotopes from Reference 5, a value of 0.08497 Ci/g was calculated for the plutonium 239/240 in the K East Basin. This value gave a concentration of plutonium 239/240 in K East Basin water of $0.308\text{E-}6$ grams/liter. The ratio of uranium to plutonium 239/240 is then $(4.62\text{E-}05/0.308\text{E-}6)$ 150, which is reasonable for the amount of plutonium made from uranium in the Hanford stie reactors. Multiplying the 150 times the largest value of plutonium 239/240 in a container (14.7 grams plutonium 239/240 in cartridge filter CF71(KE)) gives a maximum uranium content for any container of 2.20 kg and a total uranium inventory for the 13 containers of 10.9 kg of uranium.

TABLE 1 CALCULATED MASSES OF PLUTONIUM AND NEPTUNIUM

CARTRIDGE FILTER	Pu-239 (gm)	Pu-240 (gm)	Pu-241 (gm)	TOTAL Pu ¹ (gm)	Np-237 (gm)
CF69(KE)	2.233	0.362	0.088	2.736	0.660
CF70(KE)	6.103	0.989	0.240	7.479	1.805
CF71(KE)	12.652	2.050	0.497	15.506	3.742
CF72(KE)	5.210	0.844	0.205	6.385	1.541
CF73(KE)	9.725	1.576	0.382	11.918	2.877
CF74(KE)	5.210	0.844	0.205	6.385	1.541
CF75(KE)	3.870	0.627	0.152	4.743	1.145
CF76(KE)	11.908	1.929	0.468	14.594	3.522
CF21(KW)	0.248	0.040	0.010	0.304	0.073
CF22(KW)	0.298	0.048	0.012	0.365	0.088
CF23(KW)	0.397	0.064	0.016	0.486	0.117
CF24(KW)	3.473	0.563	0.136	4.256	1.027
CF25(KW)	1.191	0.193	0.047	1.459	0.352
TOTAL (gm)	62.518	10.129	2.458	76.6	18.5
FRACTION	0.816	0.132	0.032	1.00	---

Note 1: Minor fractional plutonium constituents; Pu-238: 0.001, Pu-242: 0.003, Am-241: 0.015. Total americium-241 is less than the 15 gram threshold for criticality consideration.

Reference 6 specifies that the K East Basin has a maximum uranium enrichment of 0.95 wt% and at K West Basin it is 1.15 wt%. K West Basin has fuel with enrichment of 1.25 wt%, but it is only the outer annular part of the MKIA fuel elements. The inner annulus has a 0.947 wt% enrichment. When averaged, the result is a maximum enrichment of 1.15 wt% of uranium corrosion products in the water from the thousands of fuel elements in the basin.

3.0 ANALYSIS

The K Basin cartridge filter containers are subcritical in all circumstances because there is so little fissile material in them. The sections below demonstrate that the containers are less reactive than burial boxes or 55 gallon drums containing the allowable limits of fissile material from CPS-SW-149-0002, Rev./Mod. B-1. Reference 7 analyzed an array of drums that established the adequate subcriticality of the limits for drums. This limit for drums was used to establish limits for burial boxes in Reference 8. The sections below show that the cartridge filter containers are significantly less reactive than the limits for the smallest burial box or a 55 gallon drum taken as a unit of 13 containers or each container taken individually.

3.1 TOTAL FISSILE MATERIAL

The cartridge filter containers hold plutonium and neptunium per Reference 1 and uranium per Reference 4. Only the plutonium would contribute to the reactivity of the containers. The uranium is less than 1.15 wt% enriched (Reference 6). At that enrichment, the uranium effect on reactivity is negligible. Neptunium is present on the cartridges in the amount of 18.5 grams total for all 13 containers. The largest amount on a single filter is 3.74 grams on filter CF71(KE). If only a little hydrogen is present ($H/Np > 5$), then $Np-237$ does not contribute to the reactivity (Reference 9). Since the cartridge was wet when bagged in plastic and is encased in concrete that retains significant water, the cartridge will continue to have an H/Np ratio greater than 5 and so can be considered exempt from criticality consideration. Even if dried in a fire, the total of 18.5 grams of $Np-237$ would be no more reactive than plutonium (Reference 9). The 18.5 grams added to the 76.6 grams of plutonium would still be less than 100 grams for all 13 containers combined. Even if all the material from all 13 containers were concentrated in less than 20 % of the area of a 55 gallon drum, the total equivalent plutonium inventory would be less than the limits for a single 55 gallon drum. Also, note that 100 grams is less than 1/5 of the minimum critical mass of plutonium-239, 530 grams (Reference 9). Therefore even if all the fissile material in the 13 containers were collected, optimally water moderated and fully reflected, a criticality would not be possible.

3.2 BURIAL BOX FISSILE MATERIAL LIMITS

CPS-SW-149-0002, Rev./Mod. B-1 specifies limits for burial boxes (container type 5). The criticality limits for the smallest type 5 container (burial box of 2.5 ft x 2.5 ft x 2.5 ft dimensions) is 250 grams of fissile material and allows an unrestricted amount of uranium when the maximum enrichment is no more than 1.15 wt%. The amount of fissile material (plutonium) and uranium for each individual cartridge filter or all 13 taken together as one unit are well within these limits for the smallest container type 5.

In addition, a cartridge container is larger than the smallest burial box. The burial box volume is 442 liters and the cartridge container volume is 1450 liters. The increase in volume would decrease the reactivity of the cartridge container when compared to a burial box, because the fissile material is at a lower density. Therefore, the CPS array limits for the burial boxes applied to the cartridge containers will mean greater conservatism for subcriticality.

3.3 ACCIDENT CONDITION

A possible off-normal contingency is that a cartridge filter is placed in an array of 55 gallon drums. CPS-SW-149-0002, Rev./Mod. B-1 specifies limits for 55 gallon drums (container type 1) based on Reference 7. The CPS allows 200 grams of fissile material in a 55 gallon drum if the material occupies more than 20% of the drum volume and 100 grams if the material occupies less than 20% of the drum volume. No cartridge container contains more than 20 grams of fissionable material so the cartridge containers have a 10 or 5 factor of safety for the 200 gram and 100 gram drum limits. The small amount of fissile material would make the array less reactive than fully loaded drums.

The cartridge filter container is three times larger than a drum, and if substituted for drums in an array would decrease the array reactivity. The reactivities of two arrays are roughly proportional to the ratio of the two fissile densities raised to the 1.5 power. As the volume of items in an array increases and the amount of fissile material per item remains constant, the reactivity of the array decreases.

Reference 7 shows that the reactivity of an array of 55 gallon drums was strongly dependent on the mass of iron of the drums. The more iron in a drum the lower the reactivity of the array. An allowed 55 gallon drum has to have a minimum of 23 kg of iron and has a volume of about 217 liters. The K Basin cartridge filter container has an iron content greater than 169.6 kg and a volume of 1450 liters. The density of iron in the container is 0.117 kg/liter and that in a drum is 0.106 kg/liter. The cartridge container has adequate iron content to substitute for that in displaced drums to maintain the subcriticality of an array of waste drums.

3.4 CONTAINER ISOLATION

Reference 1 shows that there is at least 15 cm (6 inches) of concrete around each filter cartridge. When two containers are adjacent, at least 30 cm (12 inches) of concrete separate the fissile material. 30 cm (12 inches) is enough to neutronically isolate the fissile material of each container, so the containers would not act as an array but as a separate unit even when stacked as close together as possible. No limits are needed on the arrangement of the 13 cartridge filter containers.

4.0 REVIEWER COMMENTS

J. L. Geiger of the Criticality Analysis Team of Consequence Analysis performed the independent technical review of CSER 95-008: "Criticality Storage Category for grouted K Basin Cartridge Filters at CWC." The reviewer provided the following comments.

The analyst demonstrated the criticality safety of the grouted filter unit by comparing it to the PUREX TRU HEPA filter burial box containing HEPA filters. A grouted filter unit is larger than a filter burial box, and contains less fissile material than allowed in the filter burial box.

Concerns about storing this waste form with others were addressed by a further comparison with the 55-gallon drums commonly used for fissile waste storage. The total fissile content of the thirteen filter units could be stored in a single drum and stacked with other such drums without violating the envelope of criticality safety. Furthermore, each of the thirteen filter units contains more iron absorber than a single drum, and takes up more space. This comparison shows the extreme safety of these thirteen waste units.

5. REFERENCES

1. WHC drawing "FILTER BURIAL CONTAINER", H-1-34709, Sheet 1: Rev. 7, Sheet 2: Rev. 3, Sheet 3: Rev. 3.
2. UNI-3388, Rev. 1-C, "SAFETY ANALYSIS REPORT FOR PACKAGING OF K AREA SPENT FILTER CARTRIDGE CONTAINER", Romano, T., June 7, 1994.
3. WHC Internal Memo 95SPB.005 from C. L. Bennett of Technical Safety group to C. D. Lucas, "CARTRIDGE FILTER CALCULATIONS", April 10, 1995.
4. Personnel communication from C. L. Bennett to E. M. Miller of a "SAMPLE STATUS REPORT FOR E", dated 3-15-95 giving the concentration of constituents in K East Basin water.
5. WHC-EP-0063-3, "HANFORD SITE SOLID WASTE ACCEPTANCE CRITERIA", Willis, N. P. and Triner, G. C., September 1991.
6. WHC-SD-NR-CSER-015, Rev. 0, "CRITICALITY SAFETY EVALUATION REPORT FOR MKIA FUEL PERTAINING TO CONSOLIDATING FUEL STORAGE", Schwindendorf, K. N., October 26, 1994.
7. SD-SQA-CSA-20121, Rev. 0, CSAR 80-021: "PACKAGING, STORAGE, AND DISPOSAL OF SOLID WASTE (55-GALLON DRUMS, UNRESTRICTED H/Pu ONLY)", Carter, R. D., January 26, 1981.
8. SD-SQA-CSA-20129, Rev. 0, CSAR 82-001: "TRANSPORTATION AND BURIAL OF PUREX BURIAL BOX", Carter, R. D., February 22, 1982.
9. ARH-600, "CRITICALITY HANDBOOK", Carter, R. D., Kiel, G. R., and Ridgeway, K. R., Atlantic Richfield Hanford Company, original issued June 28, 1968, latest update June 15, 1980.