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K Basins Consolidated Fuel Storage and Handling Criticality Safety Evaluation

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Abstract: The bases for safe storage of irradiated N Reactor and Single Pass Reactor (SPR) fuel in the Hanford K Basins, as derived from existing criticality safety evaluation reports, have been consolidated in one supporting document.

K BASINS CONSOLIDATED FUEL STORAGE AND HANDLING CRITICALITY SAFETY EVALUATION

M. A. Jensen

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K BASINS CONSOLIDATED FUEL STORAGE AND HANDLING CRITICALITY SAFETY EVALUATION

1.0 INTRODUCTION

The 100 K fuel storage basins, designated K East and K West, were constructed in the 1950s for initial storage and cooling of irradiated fuel from the K Reactors prior to shipment for plutonium extraction. The reactors and basins were shut down and deactivated in the early 1970s. Subsequently the basins, first K East, and later K West, were reactivated to store N Reactor fuel.

Current K Basin fuel handling and storage criticality safety limits are derived from a large number of criticality safety evaluations dating from 1969. In many cases, these documents were written to cover an aspect of operations (for example, N Reactor fuel storage) that are no longer applicable; however portions of the analyses are being used to support K Basin limits. In some cases the bases for storage or handling are not clearly defined or were derived from erroneous assumptions or misinterpretations of earlier analyses.

This evaluation consolidates the existing bases for fuel handling and storage in the K Basins and provides bases for currently-used limits in those cases where the derivation of the limits are unclear. It does not perform new analyses nor does it incorporate evaluations for fuel encapsulation, sludge cleanup, or plutonium accumulations in filtration components. Recent, detailed analyses using modern computer codes have been performed for these operations and conditions. Additionally, it does not provide a basis for eliminating the older CSERs. This document provides a summary of existing analyses and provides a means for applying them to facility operating limits, and provides bases for existing limits that do not have clearly-defined bases.

1.1 Note on English vs. Metric Units

N Reactor and SPR fuel were manufactured to English dimensions. The reported fuel lengths, e.g. 26 inches, are nominal values. All previous documentation relating to the fuel, as well as accountability records, use English dimensions. Appendix A provides both metric and English values for the lengths, diameters, and factor weights.

Most of the facility limits for fuel storage and handling are based on English units. Although the metric equivalents are stated in the text of this document, with the English values given parenthetically, it must be understood that the English values, in most cases, are the actual limits, as derived from the applicable criticality safety evaluations and applied in Process Standards.

1.2 Note on Existing Criticality Safety Evaluations

Several criticality safety evaluations have been prepared in the past in support of N Reactor and K Basins fuel storage. These evaluations assume that stored fuel is unirradiated and therefore contains the original amount of ^{235}U; no credit is taken for burnup or the presence of fission product poisons. Although the effect of this assumption is that ^{239}Pu is not considered, the typical irradiation history of the fuel ensures that irradiated fuel is less reactive than unirradiated fuel. This was demonstrated by a subcritical experiment using both unirradiated and irradiated fuel (Toffer 1976). Calculated critical masses for both irradiated "safe exposure" and irradiated "average discharge exposure" were considerably higher than calculated critical masses for unexposed fuel. Thus the evaluations summarized in this document provide substantial conservatism.

2.0 DESCRIPTION OF SYSTEM AND FACILITY

K Basins consists of two large water-filled basins (K East and K West) used to store irradiated fuel discharged from the N Reactor (see Figure 1 in Appendix B). Small amounts of unirradiated N Reactor fuel are also stored in the basins. Small amounts of fuel from the Hanford Single-Pass Reactors (SPR) are also stored at each basin. The storage basins are subdivided into three storage bays, designated East, Center, and West. The bays are separated by concrete walls approximately 0.6 meters (two feet) thick.

N Reactor fuel consists of an annular outer tube and an annular inner tube of zirconium-clad uranium. A fuel assembly consists of an inner tube inserted into the outer tube. Outer tubes or inner tubes by themselves are called "fuel elements" or "outers" and "inners" respectively. The fuel elements come in several different lengths (from 30.5 to 66 cm or 12 to 26 inches) and in three different predominant enrichments (natural uranium, or 0.71 wt% ^{235}U, 0.95 wt% ^{235}U, and 1.25 wt% ^{235}U). For purposes of criticality safety and convenience in handling, 0.71 wt% ^{235}U fuel is treated as if it were 0.95 wt% fuel. Enrichments between 0.95 and 1.25 wt% also exist; these are handled as 1.25 wt% enriched fuel. 1.25 wt% assemblies (also known as MK IA assemblies or "spike" assemblies) have outer elements with a 1.25 wt% enrichment and inner elements with a 0.95 wt% enrichment. 1.25 wt% fuel is stored only at the K West basin. The majority of 0.71 wt% and 0.95 wt% fuel assemblies are designated as "MK IV" assemblies, however some earlier fuel assembly designs (0.71 wt% MK IB assemblies and 0.95 wt% MK IC assemblies) exist in the basins. A complete list of fuel lengths, types, enrichments, factor weights (weight of uranium in the fuel element or assembly excluding weight of cladding, support clips, etc.), and diameters is given in Appendix A in both English and metric units.

Both basins contain "scrap" fuel, which is defined as small pieces of fuel that cannot be packaged with the associated fuel assemblies or elements.

SPR fuel is in the form of aluminum-clad solid slugs or single annular aluminum-clad tubes. K East enrichments are 0.71 wt% and 0.95 wt%. K West contains depleted uranium SPR with enrichments of 0.141 wt% and 0.22 wt% and "undetermined" enrichment (although no more than 1.25 wt% equivalent). The K West depleted SPR fuel is handled and stored as 0.95 wt% SPR and the undetermined enrichment SPR is handled and stored in a manner similar to that of 1.25 wt% scrap fuel. SPR fuel ranges from 12.7 to 20.3 cm (five to eight inches) in length and the weight varies from 2.1 to 3.86 kg (4.60 to 8.52 lbs). Appendix A contains a listing of SPR fuel types currently stored in the basins.

Both basins have water filtration systems consisting of cartridge filters, a sand filter, and ion exchange modules. These components filter uranium, plutonium, and fission products from the basin water and may contain a measurable inventory of plutonium/uranium. The source of the uranium and plutonium is suspended and dissolved material from corroded fuel assemblies. Fuel at K East is stored in open canisters which allows uranium and plutonium corrosion products to become suspended in the basin water. Fuel at K West is stored in closed canisters and very little uranium or plutonium has leached into the basin water. Historical center-of-basin water samples show that the basin water plutonium concentration at K East is approximately three orders of magnitude higher than at K West.

Fuel is stored in double-barrelled canisters which hold a maximum of seven assemblies per barrel. Canisters are placed in racks (53 cm x 27 cm or 21" x 10.6") installed on the basin floor. Each rack can contain a maximum of one canister. Stacking is not allowed nor is it physically possible with the existing rack design. Both basins have equipment in place to suspend canisters over the racks in a "one over three" arrangement but this storage arrangement is not in use and is prohibited by the facility Process Standards. A small amount of SPR fuel stored in K East is in baskets rather than canisters. This fuel is stored in the Technical View pit which is adjacent to the main storage basin.

3.0 REQUIREMENTS DOCUMENTATION

This evaluation is being prepared in accordance with the requirements for criticality safety evaluations in WHC-CM-4-29, *Nuclear Criticality Safety Manual*, chapter 4.0.

4.0 FUEL STORAGE LIMITS

Fuel storage in floor racks, suspended storage, west bay storage, and storage of 1.25 wt% scrap and single pass reactor fuel are discussed in this section.

4.1 Floor Rack Storage

A series of criticality evaluations (Toffer 1975, Toffer 1976, Toffer et al 1980), culminating in an evaluation of full-density storage with suspended fuel storage (Toffer and Eaves, 1981) were performed to determine the safety of fuel storage in the floor racks. It was determined that full-density floor storage (every storage location filled), with full-density water reflection, has a k_{eff} of 0.755 for MK IA fuel. For optimum moderation, the k_{eff} increased to 0.939. Optimum moderation requires a partial drain of the basin water, an unlikely condition. For a dry basin (water in canisters only) the k_{eff} is 0.876. As MK IV fuel is less reactive, this analysis is bounding for all types of N Reactor fuel.

The initial calculations were verified by performance of subcritical experiments with unirradiated and irradiated N Reactor fuel (Toffer 1976). Finally, subcritical experiments for storage configurations for MK IA fuel (which are bounding for less-reactive MK IV fuel) were performed to verify the safety of fuel storage in K West (Roblyer 1982).

4.2 Suspended Fuel Storage

Suspended fuel storage in a "one over three" arrangement was analyzed in Toffer and Eaves (1981). The worst-case single contingency accident involved spilling all suspended fuel alongside floor-stored canisters at optimum lattice pitch with full-density basin water. The k_{eff} in this case was 0.936, which is less than the safety factor of 0.98. A "one over two" array had a k_{eff} of 0.992 for the same accident; thus this method of suspended storage is not allowed. The analysis assumes both floor-stored and suspended fuel is MK IA in aluminum canisters. Substituting either MK IV fuel in place of MK IA fuel or stainless steel canisters in place of aluminum canisters reduced k_{eff} significantly. Suspension of 1.25 wt% scrap canisters or suspension of fuel of any enrichment over 1.25 wt% scrap canisters is not allowed (Tollefson 1983).

4.2.1 Storage in the West Bays

The K Basins Operational Safety Requirements (Jensen 1996) prohibits storage of 1.25 wt% enriched fuel in the west bay of K West (1.25 wt% fuel is not allowed anywhere in K East). Suspended fuel of any enrichment is not allowed in the west bay of K West or K East. A runaway train transporting a full load of fuel could crash into the basin and take any suspended fuel with it into the fuel stored on the basin floor. This accident is similar to a suspended fuel failure in the "one over two" mode, which was shown to exceed a k_{eff} of 0.98 (Toffer and Eaves, 1981). Thus neither suspended fuel nor 1.25 wt% fuel are allowed in the west bay of either basin.

4.3 1.25 wt% Scrap Canisters

1.25 wt% scrap is more reactive than 1.25 wt% assemblies because the scrap fuel more closely approaches an optimum geometry. In order to maintain equivalent reactivity between a scrap canister and an assembly canister, it is necessary to restrict the mass of scrap to the same percentage of the hemispherical critical mass as that of a canister of assemblies.

The hemispherical critical mass for 1.25 wt% assemblies is 3211 kg (7080 lbs) and is 1172 kg (2584 lbs) for scrap (Schwinkendorf 1994). A canister loaded with fourteen "M" length (53 cm or 21 inch) 1.25 wt% assemblies has a mass of 233 kg (514 lbs) which is 7.3% of 3211 kg. Limiting the scrap canisters to no more than 85.0 kg (187 lbs) will maintain the scrap canisters at approximately the same reactivity as the assembly canisters. Process Standards limits 1.25 wt% scrap canisters to 180 lbs (approximately 82 kg).

Because of the potentially higher reactivity of the scrap fuel, Tollefson (1983) required a nominal 0.3 meters (one foot or one empty storage rack) isolation for each two scrap canisters from all other fuel. A concrete wall, such as those dividing the basin into the three bays, is considered to provide equivalent neutronic isolation. If 1.25 wt% scrap fuel is spilled during transport in the basin, no other fuel movements within 3.0 meters (10 feet) are allowed until the fuel is recovered. Criticality calculations indicate a reactivity increase of up to 150 mk for such a spill. It should be noted that Tollefson appears to assume the canisters contain a mass of scrap roughly equivalent to 14 1.25 wt% assemblies (about 233 kg or 514 lbs) because no mass limits for the scrap canisters are given in the CSER. The spacing restrictions will not be changed by this document.

4.4 SPR Fuel of Unidentified Enrichment

K West basin contains a small amount (47 pieces) of unidentified SPR fuel. This fuel was retrieved from the cleanout of the C Reactor basin and is most likely 0.95 or 0.71 wt% enriched. However, the fuel has not been positively identified. C Reactor occasionally used a fuel model ("J" metal) with a 93 wt% ^{235}U-aluminate matrix fuel design that had an effective enrichment of 1.25 wt% ^{235}U; i.e., the fuel has the same reactivity as 1.25 wt% SPR fuel. The cylindrical critical mass of this fuel is approximately 54.4 kg (120 lbs) or 100 pieces (Kupinski and Toffer, 1970). The spherical and hemispherical critical masses were not calculated for this fuel. A conservative approach is to limit the number of pieces per canister to 30% of the critical mass; this equals 30 pieces. Thus a canister may contain no more than 30 pieces of unidentified SPR fuel.

In order to isolate this potentially more reactive fuel from other fuel, each canister must be stored with a nominal 0.3 meter (one foot) (one empty storage rack or one concrete wall) separation from all other fuel, including other canisters of unidentified SPR. This conservative approach prevents inadvertent intermixing of different fuel types which would require further analysis to determine the impact on basin or subarray reactivity.

If this fuel is positively identified (for example, by actual piece weight; J metal weighs 0.54 kg vs. between 2.1 and 3.6 kg for typical SPR fuel) then the SPR requirements of the following section apply.

4.5 SPR Fuel of Identified Enrichments

A total of 138 pieces of SPR fuel are stored in K East in three canisters and two baskets. 786 pieces are stored in K West in 20 canisters. Enrichments are 0.71 wt% (natural uranium) and 0.95 wt% at K East and 0.141 wt% and 0.0673 wt% (depleted uranium) at K West. All of the fuel is handled as if it were 0.95 wt%. The spherical critical mass for 0.95 wt% SPR fuel is 4944 kg or 10,900 lbs (Chitwood 1969). Although a hemispherical spill is more realistic than a spherical spill, the hemispherical critical mass is not available. The intent is to limit the amount of SPR in a container such that a spill will have a reactivity effect similar to that of a spill of N Reactor fuel. A canister of "E" length (66 cm or 26 inches) 0.95 wt% assemblies weighs 327.68 kg (722.40 lbs). The spherical critical mass for the assemblies is 7795 kg or 17,184 lbs (Schwinkendorf 1994); one canister contains 4.2% of a critical mass. A convenient percentage of the SPR critical mass that approximates the reactivity of a canister of N Reactor fuel is five percent. Therefore an SPR container may hold no more than 247 kg (545 lbs).

Due to the potentially higher reactivity of SPR fuel and the lack of knowledge regarding mixtures with N Reactor fuel, SPR fuel requires a 0.3 meter (one foot) or empty rack or concrete wall isolation from all other fuel.

The SPR container in K East with the most fuel contains approximately 167 kg (368 lbs) or 3.4% of a critical mass. In K West, the canister with the most fuel contains 179 kg (395 lbs) or 3.6% of a critical mass.

5.0 FUEL HANDLING AND MOVEMENT

This section discusses moving canisters on hoists in the main basin, handling in the event of fuel spills, amount of fuel allowed per container, canister decapping at K West, and fuel shipments to and from the basins.

5.1 Canisters on Hoists per Storage Bay

Process Standards limits the number of canisters out of storage and on hoists to three per bay, with the further limitation that only one scrap canister may be out of storage anywhere in the basin. The canisters are required to be separated by at least 0.9 meters (three feet) while in transit. Toffer (1975) determined that a spill of one canister into a six canister subarray has a minimal reactivity perturbation. With the canister rack dimensions of 53 cm x 27 cm (21" x 10.6") a six canister subarray is 160 cm x 81 cm (63" x 31.8" or 5.25' x 2.7'). A 0.9 meter separation for the canisters assures that a multiple spill from the hoists will not drop more than one canister into the six canister subarray. This accident is also simulated by a drop of suspended fuel in the one-over-three arrangement; canisters suspended fuel in this arrangement would be approximately 0.9 meters apart.

5.2 Spilled Fuel

As previously mentioned (section 4.3), a spill of 1.25 wt% scrap requires a suspension of all fuel movement within 3.0 meters of the spill until the scrap fuel is recovered. Process Standards conservatively applies this restriction to spills of all types of fuel.

5.3 Amount of Fuel Per Container

Fuel canisters are limited to 14 fuel assemblies or the equivalent weight of disassembled fuel. Up to 327.7 kg (722 lbs) of 0.95 wt% scrap, which is equivalent to 14 of the longest 0.95 wt% assemblies, is allowed in one canister. This restriction does not include SPR fuel which is covered by different limits (see sections 4.3.2 and 4.3.3). This restriction assures that, in the event of a canister or multiple canister spill, no more fuel than the equivalent mass of 14 assemblies will be involved per canister. It also assures that a canister won't contain more fuel than is assumed for basin floor rack storage reactivity calculations (Toffer 1976).

5.4 Canister Decapping at K West

The K West decapping station is in the south loadout pit transfer channel. A maximum of four canisters are allowed in the transfer channel; a maximum of one may be out of the provided storage racks or the canister receptacle where the actual decapping takes place (Tollefson 1983). Four canisters of 1.25 wt% fuel contain 29% of the hemispherical critical mass (Schwinkendorf 1994). It would take the fuel from more than 13 canisters, spilled into an optimally-moderated and spaced hemisphere, to reach the hemispherical critical mass of 3211 kg (7080 lbs), and more than ten canisters to reach the hemispherical k_{eff} = 0.98 mass of 2464 kg (5433 lbs).

In addition to the four canisters allowed in the transfer channel, up to four additional canisters may be in the loadout pit itself. If the fuel from both locations were to spill into a single optimally-moderated and spaced hemisphere (again assuming 1.25 wt% fuel), there would be a total mass of 1866 kg (4113 lbs) or about 58% of the critical mass and 76% of the k_{eff} = 0.98 mass. More than two additional canisters would be required before the k_{eff} = 0.98 mass would be reached. Thus a single contingency (one additional canister in one of the two locations) will not exceed the basin control limit.

Once decapping operations have taken place in the K West decapping station, a sludge height limit of no more than 14.7 cm (5.8 inches) applies (Tollefson 1983). Safe slab heights are generally 45% of the minimum critical slab, which would be 32.7 cm (12.9 inches) in this case. K East does not have a similar sludge height limit due to the restriction against 1.25 wt% enriched uranium. Homogeneous hydrogenous uranium solutions with an effective enrichment of less than 1.0 wt% ^{235}U cannot be made critical (Neely and Handler, 1961).

Sludge heights are measured in the K West transfer channel by means of a four-legged pylon shaped like a jack or caltrop. Three legs of the pylon maintain contact with the transfer channel floor; the fourth extends straight up. Each leg is marked with the maximum sludge height so that no matter how the pylon is oriented on the floor the indicating leg marking is visible provided the sludge depth is within limits.

5.5 Fuel Shipments

Both K East and K West basins are designed to allow for shipments of fuel either to or from other Hanford locations. For shipments out of the basin, fuel is transported to the south loadout pit via the basin hoist and trolley system. Casks which can contain up to three canisters are loaded and removed from the pit by the building crane and placed into a railroad well car. The well car can contain three casks; thus a well car can transport up to nine canisters of fuel. Fuel shipments to the basin are accomplished in a similar manner--the well car casks are lowered one at a time into the loadout pit and the canisters are removed and stored in the basin. Fuel shipped to or from the basin in trucks rather than the standard well cars are administratively limited to contain no more fuel than would be allowed in a well car.

5.5.1 N Reactor Fuel Shipments

A well car containing nine canisters of 1.25 wt% fuel (M length; see Appendix A), holds 2099 kg (4627 lbs). This represents 65% of the hemispherical critical mass of 3211 kg (7080 lbs) (Schwinkendorf 1994). Westinghouse Hanford Company criticality control criteria state that the maximum acceptable k_{eff}, after any foreseeable contingency is less than or equal to 0.98 (WHC 1994). This CSER limits the number of loaded well cars in the facility to one and a well car cannot contain more than nine canisters; thus a double-batching accident following a well car spill is not credible.

If the fuel from one well car should spill in such a way as to cause the inners and outers to separate into distinct hemispheres, the pile of outers, which are more reactive, would have a mass of 1404 kg (3095 lbs) which is less than the k_{eff} = 0.98 mass of 1469 kg (3239 lbs). Thus after two contingencies (the rail car spill and the disassembly of fuel into two piles, one representing the most reactive configuration), the subcritical criteria is satisfied.

If the well car contains nine canisters of scrap, the total mass would be 763 kg (1683 lbs). This represents 81% of the hemispherical critical mass of 941 kg (2075 lbs) for 1.25 wt%

scrap; thus even with the more reactive scrap fuel a well car contains insufficient material to exceed a k_{eff} of 0.98.

Well cars containing 0.95 wt% fuel or scrap are bounded by the above analyses because the 0.95 wt% fuel and scrap is less reactive than 1.25 wt% fuel and scrap.

5.5.2 SPR Fuel Shipments

SPR fuel may be shipped in two ways. Canisters limited to 247 kg (545 lbs) may be shipped three per cask and nine per well car. The total mass in a well car is 2225 kg (4905 lbs) or 45% of the critical mass of 4944 kg (10,900 lbs). Alternatively, fuel may be received or shipped in a special SPR basket, traditionally used for fuel shipments during the operation of the single pass reactors. Each basket can hold approximately 240 pieces of fuel. At a maximum mass of 3.86 kg per piece (8.52 lbs), the basket could hold about 928 kg (2045 lbs) or about 19% of a critical mass. Baskets are larger than canisters and only one can fit into a cask. Thus the total well car loading is three SPR baskets or about 2783 kg (6135 lbs). This is about 56% of the critical mass; thus although a well car of SPR fuel in baskets contains more fuel than a well car containing canisters, the total mass is still bounded by the limits for 1.25 wt% fuel. There are only two canisters of "unidentified" SPR fuel with a total piece count of 47. This fuel requires careful separation from all other fuel and thus may not be shipped in combination with any other fuel. One shipment containing both canisters would contain at most about 47% of the critical amount (approximately 100 pieces) and a spill will not cause a criticality.

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Appendix A

Factor Weights and Dimensions for N Reactor and Single Pass Reactor Fuel

English Factor Weights for N Reactor Fuel in K Basins (Doriss, 1970 and Locati, 1986)[1]				
Description	Fuel Type	Fuel Code	Factor Weight, lbs.	Enrichment wt% ^{235}U
26" spike outer		A12E	30.69	1.25
26" spike inner		N09E	15.33	0.95
26" spike assembly	MK IA	A12NO9E	46.02	
21" spike outer		A12M	24.56	1.25
21" spike inner		N09M	12.16	0.95
21" spike assembly	MK IA	A12N09M	36.72	
19.5" spike outer		A12T	22.99	1.25
19.5" spike inner		N09T	11.38	0.95
19.5" spike assembly	MK IA	A12NO9T	34.37	
15" spike outer		A12F	17.39	1.25
15" spike inner		N09F	8.60	0.95
15" spike assembly	MK IA	A12FN09F	25.99	
26" standard outer		B09E	35.10	0.95
26" standard inner		X09E	16.50	0.95
26" standard assembly	MK IV	B09X09E	51.60	
24.5" standard outer		B09S	32.98	0.95
24.5" standard inner		X09S	15.52	0.95
24.5" standard assembly	MK IV	B09X09S	48.50	
23" standard outer		B09A	31.12	0.95
23" standard inner		X09A	14.64	0.95
23" standard assembly	MK IV	B09X09A	45.76	
23" standard outer		A09A	27.95	0.95
23" standard inner		N09A	13.96	0.95
23" standard assembly	MK IC	A09N09A	41.91	
22" standard outer		B09R	29.45	0.95
22" standard inner		X09R	13.90	0.95
22" standard assembly	MK IV	B09X09R	43.35	
19" standard outer		A09P	22.18	0.95
19" standard inner		N09P	11.07	0.95
19" standard assembly	MK IC	A09N09P	33.25	

English Factor Weights for N Reactor Fuel in K Basins				
Fuel Description	Fuel Type	Fuel Code	Factor weight, lbs.	Enrichment, wt% ^{235}U
17" standard outer		A09C	20.29	0.95
17" standard inner		N09C	10.13	0.95
17" standard assembly	MK IC	A09N09C	30.42	
17" standard outer		B09C	23.19	0.95
17" standard inner		X09C	10.91	0.95
17" standard assembly	MK IV	B09X09C	34.10	
12" standard outer		A09D	13.35	0.95
12" standard inner		N09D	6.65	0.95
12" standard assembly	MK IC	A09N09D	20.00	
26" natural outer		B07E	35.10	0.71
26" natural inner		N07E	16.50	0.71
26" natural assembly	MK IVB	B07N07E	51.60	
23" natural outer		B07A	31.12	0.71
23" natural inner		N07A	14.64	0.71
23" natural assembly	MK IVB	B07N07A	45.76	
20" natural outer		A07B	24.01	0.71
20 natural inner		N07B	11.99	0.71
20" natural assembly	MK IB	A07N07B	36.00	
21" special outer		B15M	28.11	1.15
21" special inner		X09M	13.10	0.95
21" special assembly	MK IVC	B15X09M	41.21	1.085 average
Enrichment Tester Standards[2]				
6" outer				0.71
6" outer				0.95
6" outer				1.25
Possibly in the Basin(s)[3]				
17" natural outer		B07C	23.19	0.71
17" natural inner		X07C	10.91	0.71
17" natural assembly		B07X07C	34.10	

English Dimensions for N Reactor Fuel (Bergsman 1994)			
Mark Letter	Piece	o.d. (inches)	i.d. (inches)
A	Outer	2.40	1.77
B	Outer	2.42	1.70
N	Inner	1.25	0.44
X	Inner	1.28	0.48

English Dimensions for K Basins SPR Fuel (Doriss, 1968)				
Model	Factor Weight, lbs.	Length, inches	Enrichment, wt% ^{235}U	Piece Count
K5AD	8.52	8.0	0.14	532
K5D	7.86	8.0	0.14	245
K1D	6.74	7.0	0.22	2
W1D	7.86[4]	8.0	0.0673	786
C2N	7.36	8.0	0.71	2
K5N	7.86	8.0	0.71	42
K4N	7.28	8.0	0.71	3
K4W	5.21	6.0	0.71	1
O3N	7.42	8.0	0.71	15
C3E	5.29	6.0	0.95	42
K5E	5.50	6.0	0.95	29
O3E	5.36	6.0	0.95	4
K5A	4.60[5]	5.0	1.25	47

Metric Factor Weights for N Reactor Fuel in K Basins				
Description	Fuel Type	Fuel Code	Factor Weight, kg	Enrichment wt% ^{235}U
66 cm spike outer		A12E	13.92	1.25
66 cm spike inner		N09E	6.95	0.95
66 cm spike assembly	MK IA	A12NO9E	20.87	
53 cm spike outer		A12M	11.14	1.25
53 cm spike inner		N09M	5.52	0.95
53 cm spike assembly	MK IA	A12N09M	16.66	
49.5 cm spike outer		A12T	10.43	1.25
49.5 cm spike inner		N09T	5.16	0.95
49.5 cm spike assembly	MK IA	A12NO9T	15.59	
38 cm spike outer		A12F	7.89	1.25
38 cm spike inner		N09F	3.90	0.95
38 cm spike assembly	MK IA	A12FN09F	11.79	
66 cm standard outer		B09E	15.92	0.95
66 cm standard inner		X09E	7.48	0.95
66 cm standard assembly	MK IV	B09X09E	23.40	
62 cm standard outer		B09S	14.96	0.95
62 cm standard inner		X09S	7.04	0.95
62 cm standard assembly	MK IV	B09X09S	22.00	
58 cm standard outer		B09A	14.12	0.95
58 cm standard inner		X09A	6.64	0.95
58 cm standard assembly	MK IV	B09X09A	20.76	
58 cm standard outer		A09A	12.68	0.95
58 cm standard inner		N09A	6.33	0.95
58 cm standard assembly	MK IC	A09N09A	19.01	
56 cm standard outer		B09R	13.36	0.95
56 cm standard inner		X09R	6.30	0.95
56 cm standard assembly	MK IV	B09X09R	19.66	
48 cm standard outer		A09P	10.06	0.95
48 cm standard inner		N09P	5.02	0.95
48 cm standard assembly	MK IC	A09N09P	15.08	

Metric Factor Weights for N Reactor Fuel in K Basins				
Fuel Description	Fuel Type	Fuel Code	Factor weight, kg	Enrichment, wt% ^{235}U
43 cm standard outer		A09C	9.20	0.95
43 cm standard inner		N09C	4.59	0.95
43 cm standard assembly	MK IC	A09N09C	13.79	
43 cm standard outer		B09C	10.59	0.95
43 cm standard inner		X09C	4.95	0.95
43 cm standard assembly	MK IV	B09X09C	15.47	
30.5 cm standard outer		A09D	6.06	0.95
30.5 cm standard inner		N09D	3.02	0.95
30.5 cm standard assembly	MK IC	A09N09D	9.08	
66 cm natural outer		B07E	15.92	0.71
66 cm natural inner		N07E	7.48	0.71
66 cm natural assembly	MK IVB	B07N07E	23.41	
58 cm natural outer		B07A	14.12	0.71
23" natural inner		N07A	6.64	0.71
23" natural assembly	MK IVB	B07N07A	20.76	
51 cm natural outer		A07B	10.89	0.71
51 cm natural inner		N07B	5.44	0.71
51 cm natural assembly	MK IB	A07N07B	16.33	
53 cm special outer		B15M	12.75	1.15
53 cm special inner		X09M	5.94	0.95
53 cm special assembly	MK IVC	B15X09M	18.69	1.085 average
Enrichment Tester Standards				
15 cm outer				0.71
15 cm outer				0.95
15 cm outer				1.25
Possibly in the Basin(s)				
43 cm natural outer		B07C	10.52	0.71
43 cm natural inner		X07C	4.95	0.71
43 cm natural assembly		B07X07C	15.47	

Metric Dimensions For N Reactor Fuel			
Mark Letter	Piece	o.d. (cm)	i.d. (cm)
A	Outer	6.10	4.50
B	Outer	6.15	4.32
N	Inner	3.18	1.12
X	Inner	3.25	1.22

Metric Dimensions for K Basins SPR Fuel				
Model	Factor Weight, kg	Length, cm	Enrichment, wt% ^{235}U	Piece Count
K5AD	3.86	20.3	0.14	532
K5D	3.57	20.3	0.14	245
K1D	3.06	17.8	0.22	2
W1D	3.57	20.3	0.0673	786
C2N	3.34	20.3	0.71	2
K5N	3.58	20.3	0.71	42
K4N	3.30	20.3	0.71	3
K4W	2.36	15.2	0.71	1
O3N	3.37	20.3	0.71	15
C3E	2.40	15.2	0.95	42
K5E	2.49	15.2	0.95	29
O3E	2.43	15.2	0.95	4
K5A	2.09	12.7	1.25	47

References:

Bergsman, K.H., 1994, WHC-SD-SNF-TI-001 Rev 0, *Hanford Spent Fuel Inventory Baseline*, Westinghouse Hanford Co., Richland, WA.

Doriss, C.P., 1968, *DUN Conventional Reactors Fuel Element Factor Weights*, memo of March 14, 1968.

Doriss, C.P., 1970, DUN-6926, *Factor Weights for NPR Fuel Elements*, Douglas United Nuclear Inc., Richland, WA.

Locati, V.K., 1986, UNI-278 Rev 12, *Factor Weights for N Fuel Elements Effective October 1, 1986*, UNC Nuclear Industries, Richland, WA.

Notes

1. The source for the listing of fuel currently stored in the K Basins is from the 5/1/89 issue date of Process Standard C-300 (WHC-NR-M-2 Vol. 3).

2. Enrichment standards were used during the fuel segregation project at K East (circa 1983) and were not a fuel type for reactor use.

3. The factor weight for this fuel model is given in UNI-278 Rev12 but is not listed in the 1989 Process Standard C-300.

4. Safeguards and Security has assigned the W1D designation for this fuel. The actual depleted uranium SPR fuel models were K1D, K2D, K4D, K5D, K5AD, and O3D. The factor weight and length assigned by Safeguards is equivalent to the K5D model; the enrichment is the estimated ^{235}U content after irradiation.

5. Dorriss (1968) lists the K5A factor weight as 4.96 lbs. The Metal Accountability record (MAC) states that a total of 47 pieces are in K West with a total weight of 216.20 lbs. This is an average of 4.60 lbs. per piece.

Appendix B

Figures

Figure 1 K Basin Plan (Typical)

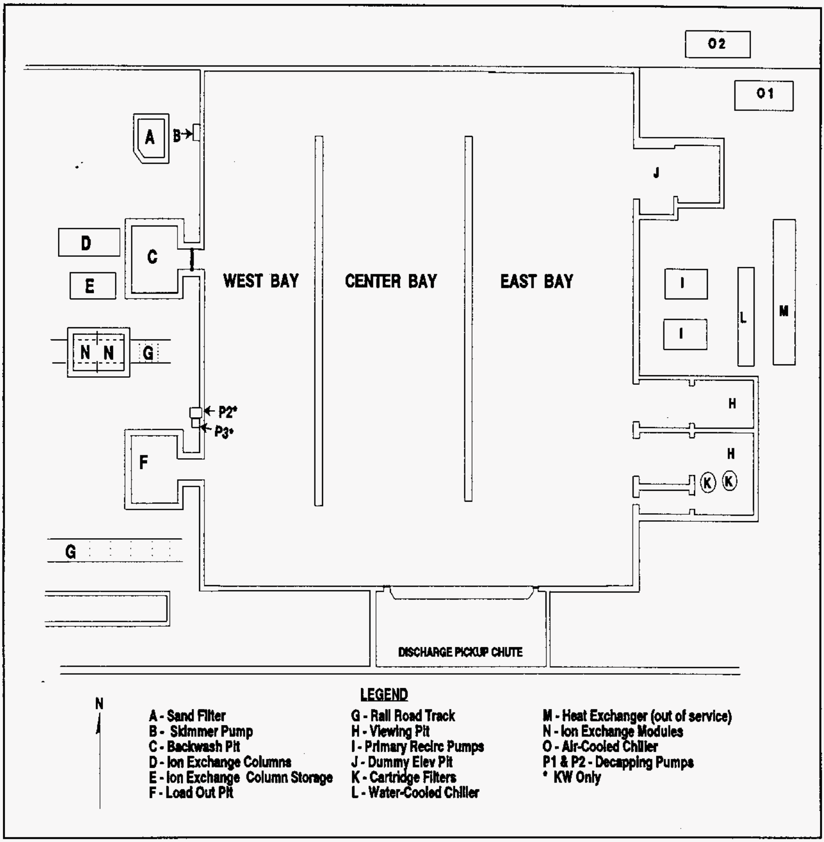


Figure 2 K Basin Fuel Storage Canisters

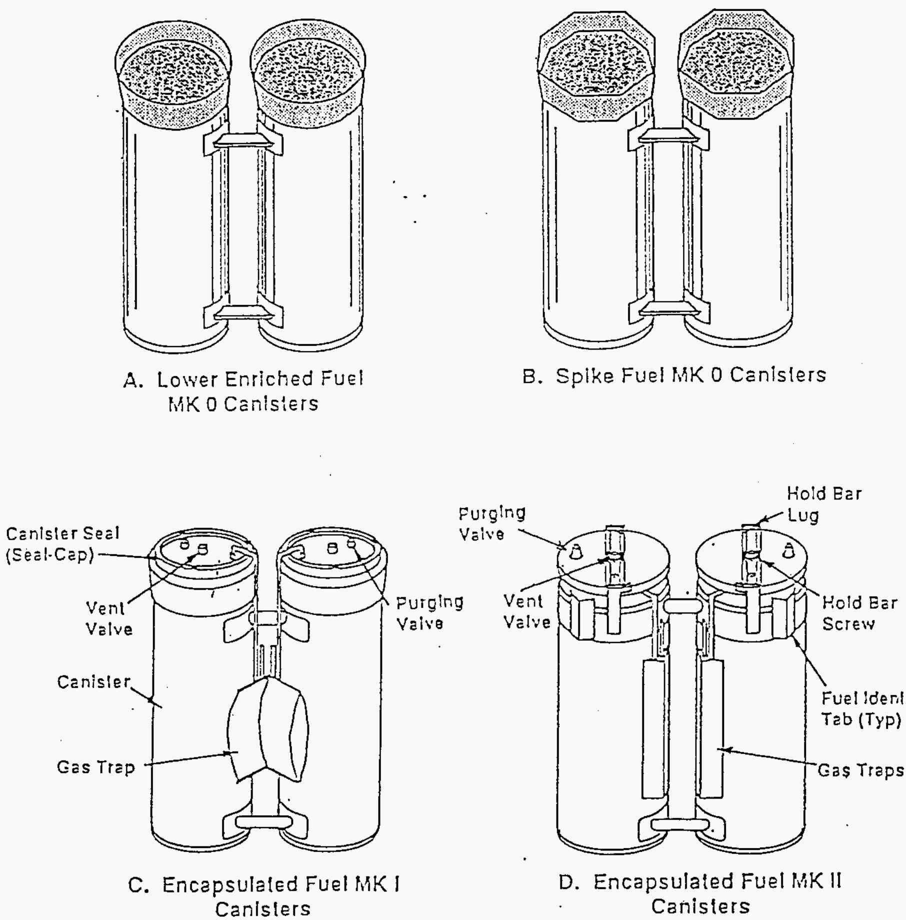


Figure 3 K Basin Fuel Storage Racks

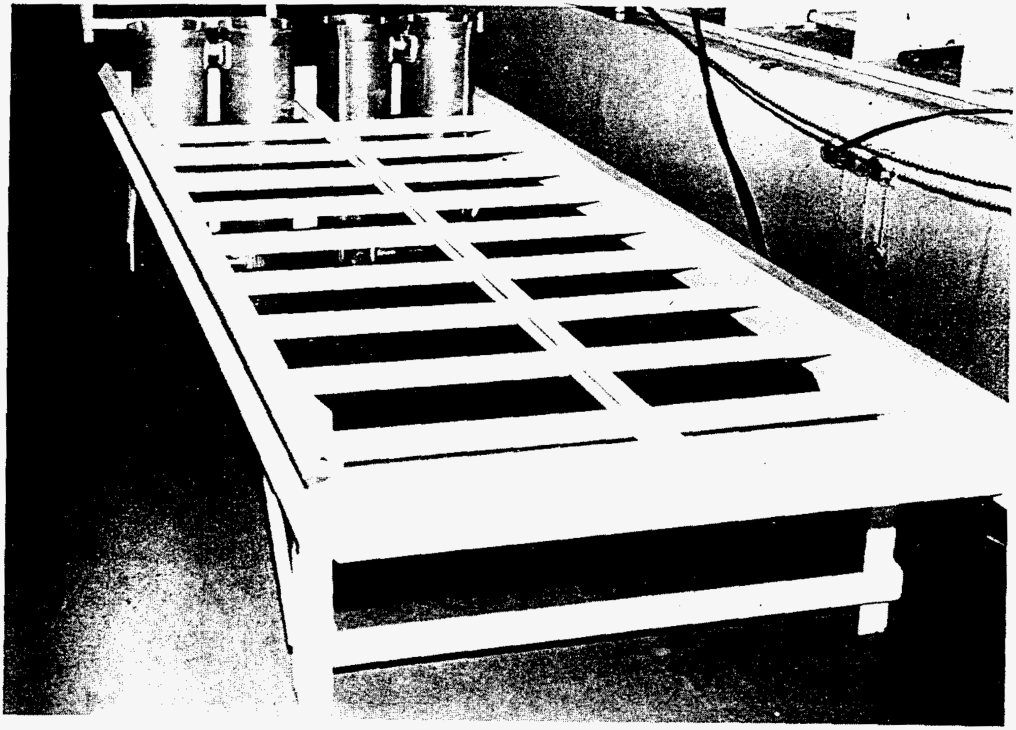
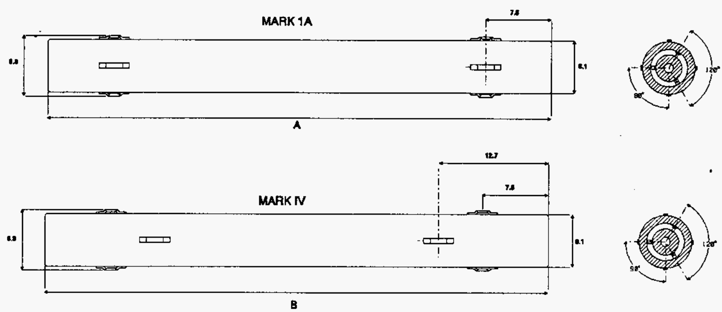


Figure 4 N Reactor Fuel Assembly



Appendix C

Technical Peer Review

Technical Peer Review

Technical review of this evaluation was provided by A. L. Hess of the Criticality Evaluation Team of the Nuclear Physics and Shielding section of Safety Analyses and Nuclear Engineering, who provides the following comments.

This report is found to be an accurate and concise summary of the evaluations reported in the past to support the criticality safety limits governing fuel storage in the K-basins, and of the defining calculated criticality parameters. Studies by this reviewer of the referenced evaluation reports, as part of technical reviews on other Criticality Safety Evaluation Reports (CSERs) pertaining to N-fuel element storage, have confirmed the adequacy of the safety margins for unburned fuel, and indicated the extra conservatism inherent to assuming green fuel in the K basins.

Comments submitted from reviews of earlier drafts of this document, including requests for further details of the stored fuel and the facilities, have been well accommodated in this final version.

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