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7. Abstract

This Supporting Document analyzes the various fissile material configurations in the 105-K East and K West fuel storage basins to determine the proper firefighting category. Firefighting categories are assigned to fissionable material facilities to provide guidance to firefighters in the allowable uses of water and other extinguishing materials to prevent inadvertent rearrangement of fissile materials or addition of neutron moderators which could lead to a criticality. This document concludes the appropriate category is B, which does not impose any restrictions on the use of water for firefighting purposes.

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BASIS FOR CRITICALITY CATEGORY B FIREFIGHTING DESIGNATION FOR K BASINS

1.0 INTRODUCTION

The Nuclear Criticality Safety Manual (WHC-CM-4-29 Section 13, Firefighting) requires assigning a criticality safety firefighting category to each facility containing fissionable materials. The purpose of this category is to define the allowable uses of water for firefighting purposes so that the risk of an accidental criticality due to the addition of moderator or the rearrangement of material into a more reactive geometry is minimized. The categories are listed as A, B, C, and D in ascending order of restrictions. Category A does not restrict firefighting methods in any way, Category B notes that use of full-stream water may violate a criticality safety limit such as spacing requirements but otherwise imposes no constraints on water use, Category C excludes solid water streams, and Category D excludes water use entirely.

The purpose of this evaluation is to determine the proper criticality safety firefighting category for the K Basins.

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. Small amounts of fuel from the Hanford Single-Pass Reactors (SPR) are also stored at each basin.

N Reactor fuel consists of an annular outer tube and an annular inner tube. 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 just "outers" and "inners". The tubes come in several different lengths (from 12 to 26 inches) and in three different 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, natural uranium assemblies and elements are treated as 0.95 wt%. For 1.25 wt% fuel, only the outers are enriched to 1.25 wt% ^{235}U. The inners are enriched to 0.95 wt%. 1.25 wt% fuel is stored only at the K West basin. 0.71 and 0.95 wt% fuel assemblies are also known as "MK IV" assemblies. 1.25 wt% assemblies are also known as "MK 1A" assemblies.

Both basins also contain "scrap" fuel, which is defined as pieces of fuel that cannot be packaged with the associated fuel assemblies or elements. 1.25 wt% scrap is significantly more reactive than the associated elements or assemblies due to its being in a geometric form more conducive to criticality. It is stored with more restrictive limits (180 lbs. per canister; Reference 3) than for assemblies. 0.95 wt% scrap is also more reactive than 0.95 wt% assemblies but a mass equivalent to that of 14 assemblies (approximately 724 lbs.; Reference 3) may be stored in a canister without restriction because this represents the same percentage (approximately 7%) of a critical mass as a canister of 1.25 wt% scrap. See Table 5.2 for a list of hemispherical critical masses of various fuel configurations.

SPR fuel is in the form of an aluminum-clad solid slug or a single annular tube of uranium. Enrichments are 0.71 wt% and 0.95 wt% at the K East basin and "undetermined" (although no more than 1.25 wt% equivalent) at K West. The K West SPR fuel is handled and stored as if it were 1.25 wt% scrap fuel (Reference 3). SPR fuel ranges from five to eight inches in length and the weight is slightly more than five pounds.

Both basins have a water filtration system consisting of cartridge filters, a sand filter, ion exchange columns, 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 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.

3.0 REQUIREMENTS DOCUMENTATION

This evaluation is being performed to satisfy the requirements of Section 13.0, "Firefighting", of the Nuclear Criticality Safety Manual (Reference 1).

4.0 METHODOLOGY

Previous criticality safety evaluations have determined the critical masses of fuel stored in the K Basins. The methodology of this analysis will be to analyze the various storage configurations and determine the appropriate firefighting category as detailed in Section 13 of Reference 1. Credible accident scenarios that could either lead to a fire or occur in conjunction with a fire are reviewed to determine if unrestricted firefighting could rearrange the fissile material into a critical configuration. Unless otherwise stated, each scenario assumes the longest (and therefore most massive) fuel assemblies for the type of fuel under consideration are involved in the contingency.

5.0 CONTINGENCY ANALYSES

5.1 Underwater Fuel Storage

Each basin contains approximately 1000 metric tons of fuel stored under approximately 16 feet of water. A fire is not a credible event for normal fuel storage and no contingencies are analyzed. None of the firefighting categories listed in the Nuclear Criticality Safety Manual are directly applicable; however the most appropriate choice is clearly not Category A (little or no fissionable material present) or Category D (exclusion of moderators required). Category C is also inappropriate because a fire is impossible and thus it is not possible to rearrange the fuel into a more reactive geometry by addition of water. Category B is the only remaining choice. Category B is defined in Section 6.0 of this document.

5.2 Plutonium/Uranium in Filtration Components

An accident during the handling of the ion exchange components (IXMs or IXCs) or the cartridge filters could result in a drop that ruptures the component and spills its inventory onto the floor. If the accident caused a fire or occurred concurrently with a fire, firefighting activities could rearrange the material into a more favorable geometry. The sand filter is not removed and replaced as are the other components; however an accident during lid removal operations could cause the lid to fall onto the filter and possibly rupture it. Again, if this accident caused a fire or occurred concurrently with a fire then firefighting activities could have consequences similar to those for the other components.

The filtration components are administratively limited to a total of 200 grams of plutonium per component (Reference 3). This value is 40% of the minimum critical mass for plutonium (Reference 4). The use of water to put out a fire in any component could not rearrange the material into a critical geometry since the minimum critical mass is based on optimum geometry, moderation, and reflection. The impact of washing fissile material from the filtration components into the main basin is minimal. The material is not pure Pu or U but rather relatively small amounts of Pu, U, and fission products mixed with the filter media (ion exchange resins or sand). This material would be added to a very large water inventory (more than 300,000 gallons of water in one bay of the basin) which would drive the H/U very much past a point (H:U = 28) at which k_{inf} cannot exceed 1.0 for normal ratios of Pu to U in the basins(reference 6). Addition of a few hundred grams of material to a total basin inventory of several tons of fissile material would also be insignificant.

The appropriate fire-fighting category for the basin filtration components is B.

5.3 Fuel Transportation

Both basins have the capability to ship fuel to other sites or to accept shipments of fuel. An accident during the shipment of fuel could cause a spill onto the transfer area floor. A fire could occur in the spilled fuel or the spill could occur concurrently with a fire in the general area.

Fuel has in the past been shipped in specially-designed railroad well cars, each holding three casks. Each cask holds up to three fuel canisters. Each fuel canister can hold up to fourteen fuel assemblies; thus the maximum amount of assemblies in a well car is 126. The longest MK IV assembly (0.95 wt% ^{235}U) weighs 51.72 lbs; a well car could contain 6517 lbs. of fuel. The longest MK 1A assembly (1.25 wt% ^{235}U) weighs 36.55 lbs.; a well car could contain 4605 lbs. Fuel weights are from Reference 3. The following table breaks down the distribution:

Table 5.1 Total Fuel Inventories in Well Cars, lbs.

MK IV Fuel		MK 1A Fuel	
Total	6517	Total	4605
Outers	4438	Outers	3078
Inners	2079	Inners	1527
Scrap (equivalent to 14 assemblies)	6517	Scrap (180 lbs./canister)	1620

Values are derived from factor weights for assemblies, inners, and outers as given in Reference 3.

An accident during shipping operations could result in a spill of fuel from one or more casks. Only one cask at a time is handled so if a cask is spilled during transfer to or from the basin shipping operations would halt until the spilled fuel is returned to the canisters or the cask. A full well car could be overturned by a seismic event and spill all 126 assemblies onto the transfer area deck. This is three times the fuel in one cask. Only one well car is allowed in the transfer area at any one time (References 3 and 5); thus a "double-batch" of fuel from two well cars is not credible. The well car accident will be evaluated because the conclusions will be bounding for the cask spill which does not contain as much fuel.

Calculated critical masses for N Reactor fuel are presented in Reference 2, and are based on unirradiated fuel. N Reactor and SPR fuel have been irradiated and are less reactive than unirradiated fuel. The most likely spill geometry is a hemisphere, and the hemispherical critical masses are reproduced in Table 5.2.

Table 5.2 Hemispherical Critical Masses for N Reactor Fuel, lbs.

Fuel Form	MK IV	MK 1A
Assemblies	27709	7080
Outers	18787	4109
Inners	15207	15583
Scrap	10525	2584

The most serious accident, from a potential criticality standpoint, is a spill of all nine canisters from a well car in which all of the fuel is ejected from the canister. Furthermore, the fuel becomes disassembled and the most reactive elements (outers for MK 1A fuel) are pushed together into a hemisphere. Although highly unlikely, this could occur as the result of using water for firefighting. The following table compares the actual fuel masses from the spill with the calculated critical masses:

Table 5.3 Comparison of Actual Fuel Mass From One Well Car with Hemispherical Critical Mass (HCM), lbs.

MK IV		MK 1A	
Fuel Form	% HCM	Fuel Form	% HCM
Assemblies	24%	Assemblies	65%
Outers	24%	Outers	75%
Inners	14%	Inners	10%
Scrap	62%	Scrap	63%

SPR fuel is limited to 545 lbs. per canister for 0.95 wt% fuel. This is five percent of the minimum critical mass of 10,900 lbs. (Reference 5). A well car with nine canisters of 0.95 wt% SPR fuel will contain 45% of a critical mass and the same conclusions reached for N Reactor fuel apply. The relatively high percentages of the HCM for MK IA fuel is allowable because reference 1 (section 2.0, para. 5.1.2) defines an acceptable margin of subcriticality as 90% of a critical mass. Administrative controls on mass are acceptable if double-batching is not credible.

Future fuel transport operations may not use the casks and well cars previously used. However, the equipment used will be bounded by the same restrictions and in no case will a shipment contain more fuel than was transported in one railcar used in past operations.

6.0 SUMMARY AND CONCLUSION

Use of water to fight a fire in K Basins, in any amount and in any form, does not impact criticality safety. Fuel stored underwater cannot burn and no firefighting restrictions are appropriate. Basin filtration components contain insufficient fissile material for a criticality. Neither situation would require a firefighting category more restrictive than B. Any one well car, loaded with three fully-loaded casks, contains an insufficient amount of fuel for a criticality. The most reactive case, a spill of 1.25 wt% MK 1A fuel with the outer elements forming a hemisphere, will contain only 75% of a hemispherical critical mass. More reactive 1.25 wt% scrap fuel is administratively limited to 180 lbs. per canister and a well car with nine such canisters contains only 63% of a critical mass. Therefore, this document concludes that the firefighting category for the K Basins is Category B, which is defined in WHC-CM-4-29 as follows:

"Category B--An area in which the use of water to fight fires may violate a criticality safety limit (such as a spacing requirement), however double contingency will be maintained and criticality cannot occur. Water in any form may be used in any amount."

Posting for Category B is optional, and will not be used at the K Basins.

7.0 REVIEWER'S COMMENTS

E. M. Miller of Criticality Radiological Analyses carried out the independent, technical review of the CSER WHC-SD-SNF-CSER-001, Rev0, entitled "BASIS FOR CRITICALITY CATEGORY B FIREFIGHTING DESIGNATION FOR K BASINS" and provides the following comments.

The criticality safety evaluation setting the criticality category for firefighting at K Basins was reviewed for technical adequacy. The CSER conclusions are based on comparing the maximum fissile mass allowed under operating limits with the minimum critical mass for each category of fuel. The reviewer confirmed the bases for the operating limits and minimum critical masses. The CSER logic and acceptance criteria were reviewed and found to meet the requirements of the Nuclear Criticality Safety Manual (Reference 1). The reviewer agrees with the conclusions and that the accident scenarios were sufficiently extreme to cover all conceivable contingencies. The analysis has covered all applicable areas of the basins and all fuel types stored at K Basins. The analysis considers the largest fuel upset conceivable, the dumping of a full railroad well car, regardless of the low probability of the event. Yet even this large amount of fuel is not enough to exceed a minimum critical mass in any category of form or enrichment. The upset of a railroad well car full of fuel, then having firefighting water segregating the most reactive categories of inner and outer fuel parts into separate hemispheres is a limiting event. The only "less than most conservative approach" of the analysis is the use of the minimum critical mass of a hemisphere instead of the more limiting mass limit of a sphere. The minimum critical mass of the sphere is about 60% of that of a hemisphere. However, given the difficulty of forming a large number of fuel elements into a sphere, using the mass limit of a hemisphere is appropriate. Editorial comments and suggested clarifications were incorporated into to the text.

8.0 REFERENCES

1. WHC-CM-4-29, "Nuclear Criticality Safety Manual" Release 6, Westinghouse Hanford Co, May 23, 1994

2. WHC-SD-NR-CSER-010 Rev0, "Criticality Safety Evaluation Report for 300 Area N Reactor Fuel Fabrication and Storage Facility", KN Schwinkendorf, January 24, 1994

3. K Basins Process Standards Section C-303 "Fissile Material Control - KE and KW Storage", Westinghouse Hanford Company, June 15, 1994

4. UNI-1055, "Nuclear Criticality Evaluation Associated with Concentration of Dissolved Fissile Isotopes in K Reactor Basins", H. Toffer, September 12, 1978

5. WHC-SD-WM-OSR-006 Rev0, "Operations Safety Requirements - 100-KE and 100-KW Fuel Storage Basins", Westinghouse Hanford Company, Jan. 10, 1994

6. WHC-SD-NR-CSER-014 Rev0, "Criticality Safety Evaluation Report for the 100 KE Basin Sandfilter Backwash Pit", DG Erickson, March 8, 1994.