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WHC-SA-3136-FP

Characterization of Hanford K Basin Fuel and Sludge: A Second Look

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Westinghouse
Hanford Company Richland, Washington

Management and Operations Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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WHC-SA-3136-FP

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Date Published
February 1997

To Be Presented at
American Nuclear Society
Waste Management '97
Tucson, Arizona
March 2 to 7, 1997

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CHARACTERIZATION OF HANFORD K BASIN FUEL AND SLUDGE: A SECOND LOOK

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ABSTRACT

Characterization of N Reactor metal spent fuel and associated sludge stored in the two Hanford K Basins has entered a more mature stage. Previous campaigns had consisted of top-view visual surveys of open fuel canisters, limited collection of gas and liquid from sealed canisters, detailed examinations of only a few fuel elements and collection of sludge from the floor of only one basin. More recent work has included lifting fuel elements from both Basins to ascertain bottom end and circumferential cracks. Sludge collection has now been performed for material residing inside of spent fuel canisters in both Basins. Finally the number of gas and liquid samples from sealed canisters has been greatly expanded leading to a maximum observed cesium-137 content ten times higher than previous reports. Characterization has been a challenge because of the age of the fuel materials, the water environment, and the radiation field.

INTRODUCTION

Over 2,100 tons of zirconium alloy clad uranium metal fuel from the Hanford N Reactor are stored in the water-filled Hanford K Basins. Half of this fuel is in open-top aluminum and stainless steel canisters (in K East Basin) and half is in sealed vented canisters (in K West Basin). There are 3,600 to 3,800 double barrel canisters in each Basin with up to seven fuel assemblies (14 elements) in each barrel. Fuel elements are roughly 0.6 m (2 ft) long with the tops of the elements 4 m (13 ft) under water. On the Basin floor and associated with this fuel is an accumulation of sludge containing fuel, fission products, and/or wind blown particulate debris.

Characterization is in progress for the fuel stored in the K Basins. These activities support the strategy for removal of fuel from the basins and storage of fuel in a dry condition at an area remote from the Columbia River. This strategy currently consists of placing fuel in a Multi-Canister Overpack (MCO), drying the fuel while it resides in the MCO and conditioning some portion of the fuel to reduce its chemical reactivity. Characterization includes the examination of fuel elements, canisters, and associated sludge. It consists firstly of in-basin activities such as visual examination, sludge depth measurements, and sampling of gas and liquid in canisters. Secondly characterization encompasses the examination of samples of fuel and sludge which have been removed from the basins and shipped to laboratories.

Characterization has proceeded beyond the initial survey examinations described in the references. Additional materials (fuel, sludge, liquid, and gas samples) covering additional storage condition and fuel history variables, have been examined in the Basins and sent to shielded laboratories for analysis.

K EAST BASIN FUEL

Previous visual surveys (Reference 1) classified the fuel elements stored in the open canisters in K East Basin by the degree of damage visible from overhead. A recent survey of 39 fuel canister barrels was completed during which 450 individual elements (inner and outer elements) were lifted for inspection. Damage to bottom ends and cracking along element sides were ascertained. An example of one of these is shown in Figure 1. Elements were also subjected to various candidate processes for removal of fuel corrosion product and a whitish adherent sludge (which was successfully dislodged with a metal brush). Nine elements were shipped to hot cells for closer examination as part of this ongoing campaign. These examinations will include ascertaining whether the adhering sludge contributed significantly to the water evolved during fuel drying. Prior to the recent efforts only fuel from the K West Basin had been retrieved for hot cell examination.

K EAST BASIN SLUDGE

Previous efforts for sludge analysis concentrated on particulate accumulations on the floor of the K East Basin (Reference 2). A more recent survey by ultrasonic probe has determined the depth of sludge IN the actual K East open fuel canisters with results indicating over 12 inches sludge depth in some cases. Samples of the canister sludge (which is more radioactive and chemically reactive than floor sludge) have now been removed with specially designed equipment and shipped via cask to analytical laboratories several miles from the basin. Chemical/physical property comparisons are now being made versus floor sludge. Canister sludge has been found to be approximately 65 weight percent uranium whereas floor sludge was reported to be largely iron hydroxide. An example of the more reactive nature of canister sludge (hydrogen generation) is shown in Figure 2 where bubbles are seen to form as the canister sludge resides in the laboratory. The reactive species appear likely to be discrete widely separated particles since most of the uranium has been shown (by X-ray diffraction) to be oxidized.

K WEST BASIN GAS AND LIQUID SAMPLES

During a previous campaign (Reference 3) samples of liquid and gas were taken from the sealed canisters in K West Basin. They indicated a maximum cesium-137 concentration of 0.5 Ci in liquid per canister barrel with a cover gas consisting mostly of hydrogen. The hydrogen has replaced the original nitrogen cover gas introduced in the early 1980's when canisters were sealed and purged. A second campaign has now been conducted for 50 additional canisters (100 barrels) covering a wider range of canister types, fuel grades, and known fuel damage. Greater cesium concentrations than previously reported have been found. A few barrels were found to contain over 3 Ci of cesium-137 (Figure 3) during this campaign. Hydrogen was again found to be the primary gas recovered but the occasional presence of oxygen suggests that, although most hydrogen comes from corrosion reactions, some may be the result of radiolysis. These results are of significance to the design of water treatment scenarios which will be in place when all of the sealed canisters are opened for fuel relocation to interim storage.

K WEST BASIN FUEL

A campaign which resulted in the examination of three fuel elements from the sealed K West canisters is described in Reference 4 and the hot cell examination results are given in Reference 5. Based on the new gas/liquid samples described above, an additional 24 canister barrels have now been opened and the fuel elements inspected. The condition of the fuel elements was found to be very similar (from a corrosion damage point of view) to that of K East Basin elements (see Figure 4). Various cladding surface coatings were quite different from K East Basin, however, including several different colors and degrees of translucency.

K WEST BASIN SLUDGE

No measurements have yet been made on floor sludge in K West Basin but the total amount is not voluminous except in remote pit areas. Recent ultrasonic measurements of sludge depth in the sealed K West canister barrels ranged up to a maximum of 18 cm (7 inches) with depths being quite nonuniform across the bottom of any given barrel. These measurements can be confused however, by other non-sludge debris. Several samples of this sludge have been shipped to laboratories and chemical analysis is still pending. These measurements, in concert with the analyses of canister liquid discussed above, lead to an estimate of the total canister sludge inventory for K West Basin of over 1,000 liters.

CONCLUSION

Examinations of fuel and sludge in the Hanford K Basins have evolved to encompass a greater number of data points and a greater suite of variables than those previously reported (Table 1). Fuel elements with bottom-end damage, more reactive sludges, and canister liquid with greater radionuclide concentrations have been identified. These will need to be considered as the processes and equipment development for interim storage of fuel and sludge move forward.

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ACKNOWLEDGEMENT

This work was sponsored by the United States Department of Energy under contract DE-AC06-96RL13200.

Table 1. Comparison of Recent K Basin Examinations with Previously Reported Efforts.

Data Type	Previous Scope	Recent Scope	Previous Results	Recent Results
K East Basin Fuel (open canisters)	Visual survey of exposed top ends of fuel residing in 3,500 canisters	Grapple, lift, and examine exterior of 450 elements. Nine elements shipped to hot cells	20 to 40% of elements failed with some failed fuel in most canisters	Fuel failure percentage similar to expected extrapolation of previous results
K West Basin Fuel (sealed canisters)	Three canisters opened. Three elements shipped to hot cells	Twenty-four canisters opened and examined. Fifteen elements shipped to hot cells	Limited sample constrains failure statistics	Fuel failure rate similar to K East Basin fuel
K East Basin Sludge	Sample and examine floor sludge only	Sludge retrieved from nine canisters and sent to laboratory	Nonreactive sludge with ≤21 wt% uranium	Reactive sludge with 65 wt% uranium
K West Basin Sludge	Data only on one remote pit* location	Sludge retrieved from nine canisters. Ultrasonic depth measurements	Depth measurement and chemistry in one remote pit	Analysis pending. Total sludge inventory in canisters estimated
K West Canister Gas and Liquid	Ten canisters (20 barrels) sampled. One irradiation/fabrication history represented	Fifty canisters (100 barrels) sampled. Multiple fuel lots and histories	≤0.5 Ci ^{137}Cs per barrel. Hydrogen generation dominates canister cover gas	≤4.1 Ci ^{137}Cs per barrel

*Remote pits are small appendages to a basin where tasks such as cask handling and water filtration are accomplished.

Fig. 1. K East Basin Fuel Elements (Five Inner and Five Outer) as Seen During a Comprehensive Visual Survey. (Note that up to seven fuel assemblies in a canister barrel each contain concentric inner and outer elements.)

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Fig. 2. Sludge from a K East Basin Canister Erupts as a Hydrogen Bubble is Released into Water Covering the Sample During Laboratory Examinations.

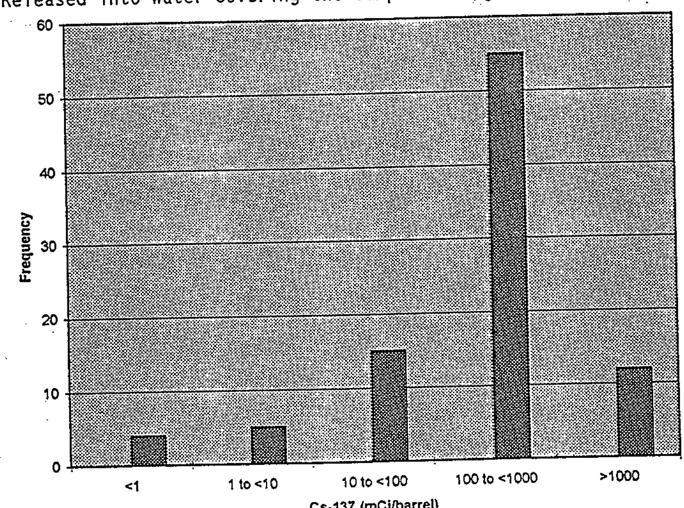

Fig. 3. Cesium Content Versus a Number of K West Basin Sealed Canister Barrels as Ascertained from a Survey of 50 Canisters (100 barrels).

Fig. 4. K West Basin Fuel Elements as Seen During a Comprehensive Visual Survey. Canister shown with and without lid.