Additional Information on K-Basins Knock-Out Pot Sludge

Source of Knock-Out Pot Sludge

The preparation activities for removal of N-Reactor fuel from the K-Basins included "cleaning" of the fuel elements. During these cleaning activities, the fuel and fuel storage canisters were placed into a primary cleaning machine that removed the sludge from the surface of the fuel elements. Removing the sludge from the fuel elements depended upon the sliding action of the fuel elements against one another and the release of the solid particles by the rinsing action of a water jet. The cleaning actions dislodged corrosion products, corroded uranium metal pieces, zirconium cladding, and loosely adhered materials from the surface of the fuel elements stored in the K-Basins. The removed materials were carried along in a piping system by the water used for washing the fuel. Larger pieces of material were then passed through a series of strainers and collection containers called Knock-Out Pots (KOP) and Settler Tanks.

After cleaning, the intact fuel elements were re-packed into multi canister overpacks. Damaged fuel and fuel pieces that had separated from the elements but were larger than ¼ inch were collected in special baskets, packed into multi canister overpacks and managed as spent nuclear fuel scrap/debris.

The Knock-Out Pot strainers limited the material passing through into the Knock-Out Pots to ¼ inch or less. This material that passed through the strainer then settled out in the Knock-Out Pots. Velocity of the water limited the material collected in the Knock-Out Pots to the ¼ inch maximum down to about 500 micron size. The Knock-Out Pots included an internal 500 micron filter at its outlet port assuring >500 micron particles were captured. The remaining material, less than about 500 microns, was carried along with the water to the Settler Tanks where the velocity of the water was much slower, allowing the particles to settle out. The material collected in the strainers upstream of the Knock-Out Pots was placed into temporary containers to be part of the spent fuel packaging activity. This larger than ¼ inch material will be managed as either spent nuclear fuel scrap or debris.

Knock-Out pot sludge is different from sludge formed in other parts of the K-Basin. Because this part of the N-Reactor spent fuel packing system was essentially a closed system, the sludge contained in the Knock-Out Pots and the Settler Tanks did not mingle with the sludge in other locations of the K-Basins. Thus, there is little sand, dirt, silt, and other foreign material in the sludge collected in these two locations.

Material Characteristics

The following is a review of five characteristics measured in N-Reactor spent fuel as compared to these same characteristics attributed to the KOP sludge.

Physical Characteristics

Knock-Out Pot Sludge- The KOP sludge is generated in a stream containing small particles, less than ¼ inch, without specific shape or form. The physical make-up of the sludge is not uniform, as a sample may contain mostly uranium or mostly corrosion products, or mostly cladding hydrides, etc. The cleaning action used in the fuel packaging preparation produced random size, configuration, and quantities of particles. The density of this sludge is about 10.5 grams per cubic centimeter.

N-Reactor spent fuel- The fuel elements are a precise mixture of metallic uranium and Zircaloy-2 cladding in a specific configuration, readily identifiable and retrievable for handling and packaging operations. The spent fuel elements are right cylinders, 26 inches long and 2.4 inches in diameter. The density of the spent fuel elements is 16.5 grams per cubic centimeter. At N-Reactor Basin, suspect fuel pieces discovered during deactivation were classified as spent fuel when greater than or equal to 0.25 inches, based on fissionable material content and retrievability. The fissionable material criterion was defined as 0.5 grams of ^{239}Pu, which was based on an approved safeguards plan for the N-Reactor fuel. In general, 0.5 gram of ^{239}Pu fissionable material would be an approximately 0.5 inch long piece of the outer fuel element, (2.4 inch outer diameter). As a point of comparison with other Hanford spent fuel recovery efforts, material discovered at Hanford's F-Reactor Basin was classified as spent fuel when the material was found to be pieces greater than or equal to a 1-inch long by 1 ½ inch diameter and containing less than 0.5 grams of ^{239}Pu fissionable material. This definition of SNF was based on nuclear material control requirements established in DOE O 474.1-1A, Manual for Control and Accountability of Nuclear Materials and recognizes both the attractiveness and feasibility of retrieving the material.

Chemical Characteristics[1]

Chemical Characteristics	Knock-Out Pot Sludge	KOP Sludge as %	N-Reactor Spent Fuel
Uranium, grams per cm^3	9.4	60	15.6
Metallic Uranium, grams per cm^3	9.4	60	15.6
Chemical Reactivity	High[2]	--	Low
Volume Expansion Potential, Final volume to initial volume	7.5	56	13.3

[1]The Knock-Out Pot sludge has not been sampled. All values reported are from the Spent Nuclear Fuel Project Data book, Volume 2, Sludge, HNF-SD-SNF-TI-015, Revision 12, 2004 that contains data taken from all of the sampling activities. Nominal Knock-Out Pot sludge values used in the data book, and reported here, are those used for safety analyses.

[2] Treatment is required due to the significantly larger surface area to particle mass of the KOP sludge which results in a higher level of chemical reactivity compared to N-Reactor Spent Fuel.

Fissile Characteristics

Knock-Out Pot Sludge-The fissile gram equivalent for this sludge has been conservatively assumed to be the same as that of the N-Reactor spent fuel, 9468 fissile gram equivalents per metric ton of uranium, but has not been characterized.

Radiological Characteristics [3]

Radiological Characteristics	Knock-Out Pot Sludge[4]	N-Reactor Spent Fuel[4]	KOP Sludge as % of N-Reactor SNF
Pu-238	5.04E+02	8.36E+02	72
Pu-239	9.97E+02	1.65E+03	60
Pu-240	6.48E+02	9.06E+02	71
Am-241	1.67E+03	2.77E+03	60
Cs-137	6.56E+04	1.09E+05	60

[3]All values reported are from the Spent Nuclear Fuel Project Data book, Volume 2, Sludge, HNF-SD-SNF-TI-015, Revision 12, 2004 that contains data taken from all of the sampling activities and has not been corrected for decay. Nominal Knock-Out Pot sludge values used in the data book, and reported here, are those used for safety analyses.
[4] Units are micro curies per ml

Heat Generation Characteristics

Two measures are available to evaluate the heat generation capability of irradiated material: Decay power in watts per cubic meter of material; and watts per metric ton of uranium. For the KOP Sludge, the decay power in watts per cubic meter of sludge is 690, or about 60% of the 1140 for the N-Reactor spent fuel[5].

The measurement of watts per metric ton of uranium is the same for the KOP sludge and the N-Reactor spent fuel (73)[6]. This result is not unexpected as this measurement parameter looks at an individual constituent, uranium, within the materials. The parameter does not account for the material as a whole as does the measurement of watts per cubic meter.

Although there are definite similarities evident between the KOP sludge and the N-Reactor spent fuel, an examination of the five characteristics demonstrates that the sludge exhibits characteristics that are substantially different than spent nuclear fuel.

Material Processing Overview

The KOP sludge will be removed from the KOP while still in the K-Basin. All operations will be done underwater. A criticality safe collection vessel will be placed near the KOP. The KOP lid and strainer will be removed and the accumulated material isolated from

[5,6] All values reported are from the Spent Nuclear Fuel Project Data book, Volume 2, Sludge, HNF-SD-SNF-TI-015, Revision 12, 2004 that contains data taken from all of the sampling activities. Nominal Knock-Out Pot sludge values used in the data book, and reported here, are those used for safety analyses.

the KOP sludge and managed as SNF debris. The KOP baffles (internal to the KOP) will be removed and placed into the collection vessel for cleaning by washing with a water wand. The sludge material removed in this manner will be allowed to settle in the collection vessel. The sludge within the KOP body will then be vacuumed out and discharged into the collection vessel.

The KOP sludge within the collection vessel will be transferred to the packaging facility, located in the Cold Vacuum Drying Facility (CVDF), by means of pumping a slurry, very similar to the system used for transferring the KE-Basin sludge to the KW-Basin. After transfer to the CVDF the KOP sludge will be partially dewatered and then fed forward to a corrosion vessel where the uranium metal will be oxidized to uranium oxide.

In order to reduce the potential for hydrogen gas generation caused by the reaction between uranium metal and water, the uranium metal in the KOP sludge will be oxidized through a corrosion process. Corrosion will be conducted in a moderately pressurized criticality safe corrosion vessel at 160^{o} C. It is anticipated that the corrosion time for KOP will be approximately 9-12 days per batch of sludge.

After the corrosion process, the KOP will be fed to buffer storage tanks where it is batched to a smaller assay tank where assay measurements will be taken using a BNFL Instruments IPAN^{tm} system. The assay tank feeds to an agitated batch dosing tank to ensure homogeneity and is used to meter the correct amount of sludge into each drum.

The final process step involves the use of the BNFL Mobile Solidification System (MOSS) to grout the sludge. This system is highly automated and has steps in the process where the sludge contents are mixed with cement powders to ensure homogeneity. The grouted waste drum is then placed into interim storage awaiting final disposition.