ENGINEERING CHANGE NOTICE

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13a. Description of Change 1) Refined the definition of KE Basin "fuel wash" sludge. 2) Revised the volume estimates (nominal and bounding) for the KE Basin fuel wash sludge (calculated volume estimates for the fuel wash sludge components individually).	13b. Design Baseline Document? ☐ Yes ☒ No
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14a. Justification (mark one)			
Criteria Change ☒	Design Improvement ☐	Environmental ☐	Facility Deactivation ☐
As-Found ☐	Facilitate Const. ☐	Const. Error/Omission ☐	Design Error/Omission ☐

14b. Justification Details Previous volume estimates are being revised due to availability of additional data from evaluations of materials from the KE Basin fuel subsurface examinations.
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20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.		
Document Number/Revision	Document Number/Revision	Document Number/Revision
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K EAST BASIN SLUDGE VOLUME ESTIMATES FOR INTEGRATED WATER TREATMENT SYSTEM

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Abstract: This document provides estimates of the volume of sludge 1) expected from Integrated Process Strategy (IPS) processing of the fuel elements and 2) in the fuel storage canisters in K East Basin. The original estimates were based on visual observations of fuel element condition in the basin and laboratory measurements of canister sludge density. Revision 1 revised the volume estimates of sludge from processing of the fuel elements based on additional data from evaluations of material from the KE Basin fuel subsurface examinations. A nominal "Working Estimate" and an upper level "Working Bound" is developed for the canister sludge and the fuel wash sludge components in the KE Basin.

*Numatec Hanford Company, Richland, Washington.

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1.0 PURPOSE AND SCOPE

The purpose of this document is to provide an estimate of the volume of sludge expected from Integrated Process Strategy (IPS) processing of the KE Basin fuel storage canisters to support the Integrated Water Treatment System (IWTS), the Sludge Retrieval System (SRS) and the Sludge Treatment System. The previous volume estimates were based on visual observations of fuel condition and laboratory measurements of KE canister sludge density. The previous estimates are being revised based on the availability of additional data from evaluations of material from the K Basin fuel subsurface examinations (Pitner 1997 and Silvers 1998). Additionally, it was previously assumed that fuel wash sludge was generated by fuel metal pieces being granulated in the fuel wash machine and turned into sludge. This definition has been refined as the wash machine does not have the capability to significantly "granulate" the fuel pieces. However, it is expected that the washing process will cause further breakage of the elements and dislodge corroded uranium pieces, zirconium cladding, and loosely adhered material (such as coatings and internal sludge). This dislodged material is referred to as the fuel wash sludge and is assumed comprised of three components; coating, fuel pieces and internal sludge (i.e., sludge originating from within the fuel elements). During IWTS processing, the fuel wash sludge components will be separated into two feed streams based on particle size. Because the fuel subsurface examinations indicate the materials (coatings, internal sludge and fuel pieces) have a range of particle sizes, a volume is calculated for each fuel wash sludge component rather than a total volume for the wash sludge as a whole as was done in the previous volume estimate for fuel wash sludge.

A nominal "Working Estimate" as well as an upper level "Working Bound" were developed for the canister sludge and each of the fuel wash sludge components in the KE Basin.

2.0 RESULTS

The Working Estimates of the sludge volumes for IWTS, SRS and Sludge Treatment design basis are 3,000 liters for canister sludge, 149 liters for fuel pieces, 518 liters for internal sludge and 61 liters for coating sludge. The Working Bound is 7,400 liters for canister sludge, 373 liters for fuel pieces, 1294 liters for internal sludge and 92 liters for coating sludge.

3.0 ASSUMPTIONS AND ANALYSIS

3.1 KE CANISTER SLUDGE

Based on ultrasonic measurements of sludge depths in selected KE Basin canisters (Pitner 1996a), the "Working Estimate" of canister sludge volume is 3,000 liters. For the "Working Bound," the two sigma uncertainties of the measurements were used to calculate a value of 7,400 liters.

3.2 KE FUEL WASH SLUDGE

Experimental tests on the cleaning process have not been done; therefore, no samples of actual KE Basin fuel wash sludge components exist. However, examinations were made of the surface and/or subsurface of a KE Basin fuel element. The examinations included collection of coating pieces from the fuel cladding and particles recovered from the cracks in the fuel and from beneath the cladding material. Often the particulate material was accompanied by large (0.64 to 1.27 cm [0.25- to 0.5-in.]) pieces of fuel. In general, no great quantities of sludge or particulate fuel were found beneath the cladding breaches. However, substantial residue sample was obtained by straining the water from the spent fuel element container (SFEC [used to transport the fuel element to the 300 Area hot cells]), suggesting that loose fuel material escaped from breached areas during shipping and handling activities (Pitner 1997). The subsurface particles from the fuel elements and the residue from the SFEC make up the internal sludge. Data from the examinations of the coating, internal sludge and fuel pieces form the basis of the volume estimates (Pitner 1997, and Silvers 1998).

3.2.1 Assumptions

The following list of assumptions apply in the derivation of a volume estimate for the fuel wash sludge:

- In KE Basin, there are approximately 1,100 MTU of fuel contained in 50,577 fuel assemblies (Pajunen 1996).
- Most of the "Bad" fuel that will be lost during cleaning comes from the outer elements in the form of fuel pieces and internal sludge. This is based on visual observations (Pitner 1996b) and results from the K Basin fuel subsurface examinations (Pitner 1997). The outer elements have a volume of about 1 liter each. The quantities of fuel pieces and internal sludge due to the inner element are negligible compared to the amount due to the outer element.
- The fraction of fuel in the "Bad" category is 4% (Pitner 1996b). Based on visual observations of fuel and sludge loss during the recent "lift and look" examinations in the KE Basin, it is projected that, on the average, 10% of the outer element fuel volume would be lost during cleaning as a "Working Estimate." For the "Working Bound," the corresponding value is estimated to be 25%.
- The fraction of fuel assemblies that are in the "Defected" category is 38% (Pitner 1996b). For the "Working Estimate," an average of 2 cm³ (0.002 liter) of internal sludge would likely be displaced from assemblies in this category during cleaning. For the "Working Bound," the corresponding value is 5 cm³ (0.005 liter).
- The quantity of "gray" coating material recovered from surfaces of two KE fuel elements (KE Basin canisters 2350E and 2540E) has been estimated as 0.55 mg/cm² (Marschman 1997). This value was based on the weight of coating recovered and an estimate of the scraped surface. All of the fuel elements have coating material on the surfaces.

- Nominal dimensions of the fuel elements are:
 Nominal outer element = 6.14 cm OD x 4.32 cm ID x 66.04 cm long
 Nominal inner element = 3.25 cm OD x 1.22 cm ID x 66.04 cm long
- The efficiency of the washing machine in removing the coating from the cladding surface is assumed to be; 100% removed from the outside of the outer element, 50% removed from the inside of the outer element and outside of the inner element, and 0% removed from the inner element for the "Working" estimate. For the "Bounding" estimate, it is assumed 100% of the coating is removed from the inside and outside of both inner and outer elements.
- The dry particle density of the internal sludge from "Bad" and "Defected" fuel elements is assumed to be a mean of dry density measurements (it is assumed the dry density used in the calculations refers to solids density or particle density, not "bulk" dry density) from samples of the residual in the SFEC obtained during the fuel subsurface examinations (Silvers 1998).
- Dry density measurements were performed on only one coating sample from a KW fuel element. The KE element coating dry density is assumed to be the same as that reported for the KW coating. Coating dry density is assumed to be a mean of the two dry density measurements obtained from coating sample CS4 (Silvers 1998). The mean dry density for coating is therefore, 2.06 g/cc $((2.04 + 2.07) / 2)$. The density for fuel pieces is assumed to be 19 g/cc.
- Final as-settled sludge volumes for the three components are based on assuming an as-settled density of 11 g/cc for fuel pieces, 3 g/cc for internal sludge and 1.48 g/cc for coating. These assumptions are engineering judgements based on review of all the sludge and related density data.
- The quantities of material retrieved during the fuel subsurface examinations are summarized in Table 1 (Pitner 1997).

Table 1. Fuel Element Material Recovery Data Related to Wash Sludge Components.

Fuel Element Reference	Subsurface Sludge (g dry)	SFEC Residue (g dry)	Fuel Pieces ⁽¹⁾ (g)	Sample Reference
5427E KE "Bad" Category			100.02	FS1
		42.57		R1
	15.53			SSL1
	15.53		45.78 ⁽²⁾	SSL2
	4.78		4 ⁽³⁾	SSL3
	Total SS = 35.84	Total SFEC = 42.57	Total FP = 149.80	
6743U KW "Bad" Category		2.31		R2
	4.42			SSL4
	1.68			SSL5
7913U KW "Bad" Category		2.21		R3
	3.75		4 ⁽³⁾	SSL7
	8.19			SSL8
Mean Sum of KW "Bad"	Mean Total SS = (6.1 + 11.94)/2 = 9.02	Mean Total SFEC = (2.31 + 2.21)/2 = 2.26	Total FP = 4 ⁽⁴⁾	

⁽¹⁾Fuel Pieces are assumed to be "fuel particles" less than 1/4" in diameter. This results from the SNF Project operational definition of sludge (all material less than 1/4" in diameter).

⁽²⁾The amount of particulate in SSL2 is equivalent (visually) to SSL1, so 15.53 has been subtracted from the initial value reported (Pitner 1997).

⁽³⁾There is about 4 g (estimated) of fuel particles in SSL3 and SSL7

⁽⁴⁾ Note: the total fuel mass was not averaged based on engineering judgement that the washing machine would generate at least the 4 g per element in the "Bad" category.

3.2.2 Coating Material Mass

The nominal quantity of coating from one fuel assembly is calculated as follows (top and bottom end-cap surface area is assumed to be insignificant):

$$\text{Outer element} = 0.55 * (6.14 * 1 + 4.32 * 0.5) * 3.14 * 66.04 = 947 \text{ mg}$$

$$\text{Inner element} = 0.55 * (3.25 * 0.5 + 1.22 * 0) * 3.14 * 66.04 = 185 \text{ mg}$$

$$\text{Coating/fuel assembly} = 0.947 + 0.185 = 1.13 \text{ g}$$

The bounding quantity of coating from one fuel assembly is calculated as follows:

$$\text{Outer element} = 0.55 * (6.14*1 + 4.32*1) * 3.14 * 66.04 = 1193 \text{ mg}$$

$$\text{Inner element} = 0.55 * (3.25*1 + 1.22*1) * 3.14 * 66.04 = 510 \text{ mg}$$

$$\text{Coating/fuel assembly} = 1.19 + 0.510 = 1.70 \text{ g}$$

3.2.3 Percent Mix of "Bad" Fuel

The percentages of fuel pieces and internal sludge (based on an average of KE and KW data) in the "Bad" fuel category are determined as follows:

$$\text{Mass of Fuel Pieces} = (149.80 + 4)\text{g}/2 = 76.90 \text{ g}$$

$$\text{Mass of internal sludge} = (35.84+42.57+9.02+2.26)\text{g}/2 = 44.85 \text{ g}$$

Dry Density of Internal Sludge (IS):

$$\text{R1-6 mean density} = (7.98 + 8.04)/2 = 8.01 \text{ g/mL}$$

$$\text{R1-8 mean density} = (7.99 + 8.02)/2 = 8.01 \text{ g/mL}$$

$$\text{R1-14 mean density} = (8.01 + 7.99)/2 = 8.00 \text{ g/mL}$$

$$\text{R1-24 mean density} = (8.00 + 7.97)/2 = 7.99 \text{ g/mL}$$

$$\text{R1-60 mean density} = (7.85 + 7.84)/2 = 7.85 \text{ g/mL}$$

$$\text{R1-REC + R1-REC mean density} = (7.16 + 7.46)/2 = 7.31 \text{ g/mL}$$

$$\text{IS density} = (.35*8.01 + .04*8.00 + .03*7.99 + .06*7.85 + .51*7.31) = 7.56 \text{ g/mL}$$

$$\text{Volume Fuel Pieces} = 76.90\text{g} / 19 \text{ g/mL} = 4.05 \text{ mL}$$

$$\text{Volume IS} = 44.85 \text{ g} / 7.56 \text{ g/mL} = 5.93 \text{ mL}$$

$$\text{vol\% fuel pieces} = 41\%$$

$$\text{vol\% internal sludge} = 59\%$$

3.2.4 KE Fuel Wash Sludge Volume

Using the assumptions stated above, as-settled sludge volumes for KE fuel wash sludge components were calculated. The nominal "Working Estimate" and the upper level "Working Bound" volume calculations for the KE fuel wash sludge components are shown on Tables 2 and 3, respectively.

Table 2. KE Fuel Wash Sludge Component Nominal Volume Estimates.

KE FUEL WASH SLUDGE COMPONENT "WORKING ESTIMATES"				
50,577 fuel assemblies in KE Basin				
4% of Fuel Elements Bad		38% of Fuel Elements Defected		
Nominal lost: 10% of 1L		Nominal lost: 0.002 L		
Pick&Peel Recovery Data		Component Dry Densities		
Coating : 1.13 grams		Coat Density = 2.06 kg/L		
Internal Sludge 59% of volume		IntSludge Den. = 7.56 kg/L		
Fuel Particles 41% of volume		Fuel Den. = 19.0 kg/L		
Nominal Dry Volumes		L		
Voldryfp = (50577 assemblies)(0.04bad)(.10 L)(.41) =		83		
Voldryis = (50577 assemblies)(0.04bad)(.10L)(.59) =		119		
Voldef = (50577 assemb)(.38defected)(0.002 L) =		38		
Vcoat = (50577 assemb)(.00113 kg/2.06 kg/L) =		28		
Nominal Dry Masses		kg		
Mfp = Voldryfp * 19 kg/L =		1,576		
Mis = Voldryis * 7.56 kg/L =		902		
Mdef = Voldef * 7.56 kg/L =		291		
Mc = Vc * 2.06 kg/L =		57		
Component Wet Densities				
Coat WDen (WDc) = 1.48 kg/L				
IS WDen (WDis) = 3.0 kg/L				
Fuel WDen (WDfp) = 11 kg/L				
Component Settled Volumes using density of water = 1 kg/L				
Fuel Pieces Settled Volume:				
VH2O = (Mfp - Voldryfp*WDfp)/(WDfp-1) =		66 L		
VolWetFP = Voldryfp + VH2O =		149 L		
Coating Settled Volume:				
VH2O = (Mc - Vcoat*WDc)/(WDc-1) =		34 L		
VolWetC = Vcoat + VH2O =		61 L		
Internal Sludge Settled Volume:				
Vtdryis = Voldryis + Voldef =		158 L		
Mtis = Mis + Mdef =		1,193 kg		
VH2O = (Mtis - Vtdryis*WDis)/(WDis-1) =		360 L		
VolWetIS = Vtdryis + VH2O =		518 L		
fp = fuel pieces				
is = internal sludge				
def = sludge from defected fuel elements				
coat = c = coating				

Table 3. KE Fuel Wash Sludge Components Bounding Volume Estimates.

KE FUEL WASH SLUDGE "WORKING BOUND"			
50,577 fuel assemblies in KE			
4% of Fuel Elements Bad		38% of Fuel Elements Defected	
Bound lost: 25% of 1 L		Bound lost: 0.005 L	
Pick&Peel Recovery Data		Component Dry Densities	
Coating : 1.70 grams		Coat Density = 2.06 kg/L	
Internal Sludge 59% of volume		IntSludge Den. = 7.56 kg/L	
Fuel Particles 41% of volume		Fuel Den. = 19.0 kg/L	
Bounding Dry Volumes		L	
Voldryfp = (50577 assemblies)(0.04bad)(.25)(.41) =		207	
Voldryis = (50577 assemblies)(0.04bad)(.25)(.59) =		298	
Voldef = (50577 assemb)(.38defected)(0.005 L) =		96	
Vcoat = (50577 assemb)(.0017 kg/2.06 kg/L) =		42	
Bounding Dry Mass		kg	
Mfp = Voldryfp * 19 kg/L =		3,940	
Mis = Voldryis * 7.56 kg/L =		2,256	
Mdef = Voldef * 7.56 kg/L =		726	
Mc = Vc * 2.06 kg/L =		86	
Component Wet Densities			
Coat WDen (WDc) = 1.48 kg/L			
IS WDen (WDis) = 3.0 kg/L			
Fuel WDen (WDFp) = 11 kg/L			
Component Settled Volumes using density of water = 1 kg/L			
Fuel Pieces Settled Bounding Volume:			
VH2O = (Mfp - Voldryfp * WDFp) / (WDFp - 1) =		166 L	
VolWetFP = Voldryfp + VH2O =		373 L	
Coating Settled Bounding Volume:			
VH2O = (Mc - Vcoat * WDc) / (WDc - 1) =		50 L	
VolWetC = Vcoat + VH2O =		92 L	
Internal Sludge Settled Bounding Volume:			
Vtdryis = Voldryis + Voldef =		395 L	
Mtis = Mis + Mdef =		2,982 kg	
VH2O = (Mtis - Vtdryis * WDis) / (WDis - 1) =		899 L	
VolWetIS = Vtdryis + VH2O =		1,294 L	
fp = fuel pieces			
is = internal sludge			
def = sludge from defected fuel elements			
coat = c = coating			

4.0 REFERENCES

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