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1	1	Cog.Eng. K. G. Carothers		5/29/97	R1-51	1	1	C. J. Alderman		5/29/97	X3-85
1	1	Cog. Mgr. N. W. Kirch		5/29/97	R2-11	1	1			5/29/97	
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K BASIN SLUDGE PRETREATMENT REQUIREMENTS SUMMARY

K. G. Carothers
K. D. Fowler
J. P. Sloughter
Lockheed Martin Hanford Corporation, Richland, WA 99352
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Abstract: As part of the accelerated removal action to repackage and relocate the spent nuclear fuel from the 105-K East and 105-K West Fuel Storage Basins, DOE is considering the disposition of the radioactive basin sludge by transfer to one of Hanford's double-shell tanks. This document provides technical requirements for processing the K Basin sludge for acceptance into the Tank Waste Remediation System double-shell tank system.

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CONTENTS

1.0 INTRODUCTION 1

2.0 K-BASIN SLUDGE 2

3.0 WASTE TYPE 2

4.0 SAFETY AND TECHNICAL CRITERIA 2
- 4.1 CORROSION 3
  - 4.1.1 Parameters 3
  - 4.1.2 Basis 3
  - 4.1.3 Discussion 4
- 4.2 CRITICALITY 4
  - 4.2.1 Parameters 4
  - 4.2.2 Basis 4
  - 4.2.3 Discussion 4
- 4.3 ENERGETICS 5
  - 4.3.1 Parameters 5
  - 4.3.2 Basis 5
  - 4.3.3 Discussion 5
- 4.4 FLAMMABLE GAS 6
  - 4.4.1 Parameters 6
  - 4.4.2 Basis 6
  - 4.4.3 Discussion 6
- 4.5 HEAT GENERATION 6
  - 4.5.1 Parameters 6
  - 4.5.2 Basis 6
  - 4.5.3 Discussion 7
- 4.6 RETRIEVAL AND IMMOBILIZATION OPERATIONS 7
  - 4.6.1 Parameters 7
  - 4.6.2 Basis 7
  - 4.6.3 Discussion 7
- 4.7 PYROPHORIC MATERIALS 8
  - 4.7.1 Parameters 8
  - 4.7.2 Basis 8
  - 4.7.3 Discussion 8
- 4.8 TSCA REGULATED MATERIALS 8
  - 4.8.1 Parameters 8
  - 4.8.2 Basis 8
  - 4.8.3 Discussion 9

5.0 REFERENCES 10

ACRONYMS

DOE	U.S. Department of Energy
DST	Double-Shell Tank
Ecology	Washington State Department of Ecology
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
KE	105-K East (Basin)
KW	105-K West (Basin)
PCB	Polychlorinated Biphenyl
SpG	Specific Gravity
TSCA	Toxic Substance Control Act
TWRS	Tank Waste Remediation System

1.0 INTRODUCTION

As part of the accelerated removal action to repackage and relocate the spent nuclear fuel from the 105-K East (KE) and 105-K West (KW) fuel storage basins at the Hanford Site, the U.S. Department of Energy (DOE) is considering the disposition of the fuel basin radioactive sludge by transfer to one of Hanford's double-shell tanks (DSTs). Compatibility assessment of the sludge for transfer into a DST has identified several compatibility issues. These issues have been evaluated and it has been concluded that with appropriate pretreatment, the sludge can be safely stored and processed in the DST system.

The purpose of this document is to provide technical baseline requirements for processing K Basin sludge for acceptance into the Tank Waste Remediation Systems (TWRS) DST system. Material entering the DST system must comply with criteria for waste storage, waste retrieval, and waste immobilization. Established criteria exist for waste storage. However, criteria do not exist for retrieval and immobilization of material with characteristics different from existing tank wastes. These criteria are still emerging.

Certain DST acceptance criteria are based on the combined waste in a tank after the proposed addition. Therefore, specific acceptance criteria for a planned addition are evaluated and established on a case-by-case basis. Waste acceptance and potential storage location are based on compatibility of the input stream with other stored waste. Compatibility comprises safety, regulatory, operational parameters and programmatic issues. The criteria consist of considerations for criticality prevention, flammable gas retention, heat generation, energetics, corrosion prevention, chemical compatibility, compatibility with existing TWRS regulatory permits, waste classification, waste pumpability and potential programmatic impacts.

Waste acceptance criteria are set at a screening level. Provisions are in place for analysis of input streams that do not meet screening criteria. Evaluation through safety analysis, process analysis and trade studies may be incorporated to establish revised Authorization Basis criteria specific to the analyzed transfer and/or to define input stream changes necessary to comply with criteria.

The K Basin sludge material posses new issues for acceptance of material into the DST system in that it exhibits physical and chemical characteristics different from the material currently stored in the tanks. In addition, K Basin sludge must be compatible with emerging criteria for retrieval and immobilization. Analysis of safety, waste compatibility, retrievability, transport, and immobilization aspects have identified a number of issues that will require adjustment of sludge characteristics prior to acceptance of the K Basin sludge into the DST system. This document summarizes those adjustment requirements.

2.0 K-BASIN SLUDGE

The total K Basin sludge will comprise KE Basin sludge, KE canister sludge, KW Basin sludge, KW canister sludge, and sludge from fuel washing activities. The primary differences between KE and KW sludges are the volume of "floor" sludge and the degree of uranium enrichment associated with the fuel stored in each basin. The fuel in the KW Basin consists of higher uranium enrichment than KE Basin.

Within the KE Basin a substantial difference exists between the floor sludge and the relatively undiluted spent fuel corrosion products and fuel fragments in the canisters and fuel wash sludge. The KE Basin contains a much larger quantity of floor sludge which consists of sand, rust, fuel corrosion products, and other debris.

Characterization data exists for the KE Basin floor and canister sludge. Characteristics of the other sludge types have been estimated based on this data, and process history (enrichment levels, etc.) The baseline definition of K Basin sludge characteristics is contained in Welsh, et al., 1996, and in Lodwick, 1997.

3.0 WASTE TYPE

Assessments of KE Basin floor sludge (Blaak, 1996) and KE canister sludge (Honeyman, 1997) have determined that the sludge would be a mixed, transuranic non-complexed, non-aging waste. Tank 241-AW-105 has been identified as the candidate receiver tank for the sludge from K Basin.

4.0 SAFETY AND TECHNICAL CRITERIA

Criteria for acceptance of material into the DSTs are contained in the following references: Boston, 1997; DOE 1988; Fowler, 1995a; HNF, 1996a; HNF, 1996b; Mulkey, 1996; and WHC, 1995.

The Waste Compatibility Program establishes the process of evaluating proposed transfers within and into the DST system, and provides screening criteria (Fowler, 1995b). Provisions and methodology are provided for more detailed analysis of conditions that do not meet these criteria. These analyses are made through safety assessments and engineering studies.

Waste compatibility assessments performed on the KE Basin floor sludge (Blaak, 1996) and canister sludge (Honeyman, 1997) identified areas that required further analysis. These analyses define the requirements for processing the K Basin sludge for safe storage and immobilization in TWRS.

Summarized and discussed below are the key criteria that must be met to resolve issues identified by compatibility assessments of K Basin sludge for acceptance by TWRS. Each summary contains a reference to the controlling document(s) that contains the criteria, a technical basis summary with reference to technical basis documentation, and a discussion specific to acceptance of K Basin Sludge into tank 241-AW-105. The following table summarizes requirements for K Basin sludge pretreatment for TWRS acceptance.

K BASIN SLUDGE PRETREATMENT REQUIREMENTS SUMMARY	
REQUIREMENT	RESOLUTION
Corrosion	Add hydroxide and nitrite ions per HNF, 1996a.
Criticality	Treat sludge to achieve the following: • pH >8 • Particle Size < 50 micron • U^{235} content < 0.84 wt% OR • Iron/total U mass ratio: >0.18 for 0.947 wt% U^{235} >0.54 for 1.25 wt% U^{235}
Energetics	No issue identified in compatibility assessment.
Flammable Gas	Treat sludge to eliminate non-radiolytic gas generation. Sludge additions are within flammable gas retention control limits.
Heat Generation	Combined heat generation levels of basin sludge and 241-AW-105 contents are within limits.
Retrieval/ Immobilization	Particle size must be <177 microns. Limits established for criticality safety will satisfy this requirement.
Pyrophoric Material	Pretreat sludge to eliminate reactive materials.
TSCA Regulated Material	Pretreat waste such that it does not contain regulated levels of TSCA substances OR establish formal determination that TSCA regulations do not apply.

4.1 CORROSION

4.1.1 Parameters. The parameters for controlling corrosion in DSTs are hydroxide, nitrate, and nitrite ion concentrations in the tank wastes. The parameter limits are documented in HNF, 1996a.

4.1.2 Basis. The nitrite, nitrate, and hydroxide concentrations are limited in order to inhibit uniform corrosion rates and stress corrosion cracking. These parameters are controlled to prevent corrosion and deterioration of the DSTs (HNF, 1996a).

4.1.3 Discussion. Chemical adjustment of hydroxide, and nitrite ion concentrations will be required prior to addition to a DST. This is a straight forward routine chemical addition of sodium hydroxide and sodium nitrite.

4.2 CRITICALITY

4.2.1 Parameters. Parameters and control limits for criticality safety in DSTs are documented in WHC, 1995. K Basin sludge has a higher fissile material concentration than DSTs, therefore, a criticality feasibility analysis has been completed to define requirements necessary to assure criticality safety (Vail and Daling, 1997). This study concluded that the key control parameters are pH, particle size, uranium 235 enrichment levels, and neutron absorbers.

4.2.2 Basis. Subcriticality, in non-critically safe geometries, is ensured by maintaining fissile material concentrations below the minimum for which criticality is possible or by a subcritical mass ratio of neutron absorbers to fissile material. Controlling parameters are established to prevent fissile material concentration and segregation from the neutron absorbers. These parameters are homogeneity of the sludge, particle size, and chemical bonding of fissile material with neutron absorbers. Particle size criteria are designed to assure homogeneity and prevent segregation. Technical details are presented in Vail and Daling, 1997.

4.2.3 Discussion. The Criticality Feasibility Report concludes that criticality issues for K Basin sludge are resolved by pretreatment of the sludge to ensure particle sizes less than 50 microns, addition of chemicals to ensure the waste is alkaline, and addition of either depleted uranium for isotopic dilution of the U^{235} or addition of absorbers such as iron.

Adding the K Basin sludge to tank 241-AW-105 results in a fissile content and concentration considerably higher than current and proposed criticality limits for DSTs. A new criticality authorization basis for K Basin sludge, based on Vail and Daling, 1997, will be established for the DST receiver tank(s) prior to transfer of sludge to the DST system.

No uranium enriched above 0.947 wt% U^{235} has been stored in KE Basin. Material in KW Basin, however, contains fuel enriched above 0.947 wt% U^{235} but no higher than 1.25 wt% U^{235}. Isotopic dilution of the U^{235} to an equivalent green fuel content of 0.84 wt% U^{235} assures subcriticality for homogeneous systems. Chemical dissolution and precipitation is one method to assure sludge homogeneity identified in the Criticality Feasibility Report. The addition of depleted uranium as part of the sludge pretreatment process has been identified as a means of achieving the necessary isotopic dilution.

An alternate pretreatment method would be addition of an absorber during the dissolution/precipitation pretreatment process. Iron has been demonstrated to be an excellent moderator for DSTs because of its similar solubility to fissile material in alkaline solutions. Iron is already present in substantial quantities in the KE Basin floor sludge. Iron to total uranium mass ratios of 0.18 and 0.54 for 0.947 wt% and 1.25 wt% U^{235} enrichment respectively, would be necessary to assure criticality safety.

Existing DST sludge was generated by precipitation of metal hydroxide solids from solution. The various chemical processes at Hanford generated liquid waste that consisted of metals dissolved in nitric acid. Sodium hydroxide was added to these solutions to neutralize them prior to placement in the carbon steel underground tank system. This operation produced very fine, co-precipitated metal hydroxides including the fissile materials. These precipitates have small particle sizes and particle size distributions that form much of the current criticality safety basis in the tanks. Similar pretreatment of the K Basin sludge will produce a material with comparable chemical and physical characteristics.

4.3 ENERGETICS

4.3.1 Parameters. The parameters controlled are separable organic phases in the wastes and the ratio of exothermic to endothermic reactions. These parameters are defined in the Waste Compatibility Program, and Waste Compatibility Data Quality Objective (Fowler, 1995a; and Fowler, 1995b).

4.3.2 Basis. Wastes that exhibit exotherms have the potential for self heating and could potentially enter into a propagating chemical reaction. Net energy for heating waste from an exothermic reaction is reduced by endothermic reactions resulting from water losses, phase changes, and other competing reactions. Where endotherms are greater, a propagating reaction is inhibited.

Separable organics are generally excluded from the waste tanks to prevent organic vapors or distillates from accumulating in the tanks, overhead systems, or condensate collection systems. This will prevent organic liquid fires or vapor explosions.

4.3.3 Discussion. No separable organic phase has been identified by laboratory analyses. Large endotherms corresponding to the release of water from the sludge were found to exceed the exothermic reactions identified in the analyses. Pretreatment of the sludge to assure oxidation of any metal fragments will eliminate the presence of metals that could cause a potential metal-water or metal-air exothermic reaction.

4.4 FLAMMABLE GAS

4.4.1 Parameters. Flammable gas parameters include considerations for flammable gas generation and retention. Wastes that exhibit flammable gas generation rates above those for radiolytic, thermal mechanisms pose a new flammable gas generation source to the tanks and must be evaluated through the safety analysis process. Flammable gas retention parameters consist of the specific gravity (SpG) of the settled solids and a relationship between the solution SpG and depth of solids in a tank (Fowler, 1995a; Estey and Guthrie, 1996).

4.4.2 Basis. Specific gravity of waste is currently used as a determination of the potential for flammable gas retention. Safety becomes a concern when flammable gases accumulate to a concentration above their lower flammability limit (Fowler, 1995a).

Further analysis has indicated a correlation between the relative propensity of DST waste to retain gas and the depth of the waste classified as non-convective. Results showed that no episodic gas releases have been observed in DSTs where the product of the waste liquid SpG and the total solids depth (in inches) is less than 150 (Estey and Guthrie, 1996).

4.4.3 Discussion. Appropriate pretreatment of the sludge will eliminate non-radiolytic hydrogen gas generation from metal-water reactions and will result in material with a flammable gas generation rate commensurate with other tank wastes. A sufficient margin currently exists for the commingled waste specific gravity limit in tank 241-AW-105 to receive K Basin sludges and remain within the flammable gas limit. The K Basin sludge specific gravity is not expected to increase as a result of pretreatment.

Tank 241-AW-105 can currently receive up to 100,000 gallons of solids before exceeding the product of solids depth and liquid specific gravity limit. Bounding values of K Basin sludge volume are estimated to be 18,000 gallons. Pretreatment will increase the volume of solids, but is not expected to exceed the solids limits for tank 241-AW-105.

4.5 HEAT GENERATION

4.5.1 Parameters. Heat load in DSTs is controlled by limiting the radiolytic heat in the waste. Radiolytic heat is based on the amount of strontium 90 and cesium 137 measured in the waste. The controlling limits for these parameters are contained in HNF, 1996a.

4.5.2 Basis. The heat generation rate in a tank is limited to prevent localized boiling. The heat load was translated to Cs^{137} and Sr^{90} concentrations assuming that the tank holds one million gallons, and Cs^{137} and Sr^{90} are at 50 percent of the heat load limit. The heat load was then converted to μCi/liter using the Radionuclides Specific Activity and Heat Generation Chart. Technical basis are further documented in Barton, 1996; Foster, 1989; and Wilkins, 1984.

4.5.3 Discussion. Analysis of the K Basin floor sludge as defined in Lodwick, 1997 has shown that this fraction of the sludge can be safely stored in tank 241-AW-105. The heat load in 241-AW-105 currently is 1203 BTU/hr. The bounding estimates of K Basin sludge heat bearing inventory would add less than 10,000 BTU/hr to the receiving tank(s). The average strontium and cesium concentrations calculated for the bounding K Basin sludge mixed with current 241-AW-105 tank waste are well below the specification limit.

4.6 RETRIEVAL AND IMMOBILIZATION OPERATIONS

4.6.1 Parameters. The parameters that affect retrieval and immobilization are particle size and chemical composition. Chemical composition usually can be accommodated by blending of the tank wastes prior to immobilization. Waste additions are screened to evaluate unusually large quantities of glass limiting elements. Particle size is a key controlling parameter that affects retrieval and immobilization operations. Particle size limits for these activities are given in Boston, 1997.

4.6.2 Basis. The presence of large particles present a risk to the service life of retrieval and vitrification equipment and a risk to the product glass quality. The degree of risk is based on both the size and the count or number of large particles (Boston, 1997).

4.6.3 Discussion. Appropriate pretreatment of the K Basin sludge will provide a waste that is compatible with TWRS pretreatment and immobilization operations. Particle size limitations are the only technical limits that have been identified for retrieval and immobilization operations. Particle sizes of the K Basin sludge will need to be reduced for these activities. Chemical compositions are such that some blending of K Basin wastes will be required to minimize glass production. However, blending of tank wastes will be required independent of receipt of K Basin sludge.

Particle size can affect waste retrieval operations if the particles are too large and cannot be retrieved with the tank's other waste using the planned sludge mobilization technology and equipment. Particle sizes in the 50 to 250 micron range can also affect the bearings in the retrieval equipment.

Particle sizes in the immobilization process can affect glass melter performance. Particles that are too large or metallic can create inclusions in the glass product or form metal precipitates in the melter causing melter malfunction. An evaluation of melter technology and practices in place for vitrifying high level waste concluded that particle sizes should be limited to 177 microns (Boston, 1997).

4.7 PYROPHORIC MATERIALS

4.7.1 Parameters. Addition of pyrophoric materials in the DSTs is an unanalyzed condition that requires safety analysis.

4.7.2 Basis. Uranium and zirconium metals and uranium hydride are known pyrophoric materials because under specific physical states and environmental conditions they undergo spontaneous combustion (DOE, 1994). In a finely divided form, these materials can oxidize rapidly in the presence of air or moisture, generating sufficient heat to reach their ignition temperatures. Ignition at temperatures as low as room temperature (e.g., 20 °C) has been observed (Hartmann et al., 1951). Because of their pyrophoric characteristic, the presence of these materials in a DST would represent an ignition source not previously considered in safety analyses.

4.7.3 Discussion. Pretreatment of the K Basin sludge to deal with criticality issues will also eliminate the concerns for pyrophoric materials. The processing actions will eliminate reactive materials. Uranium metal and its hydride are expected to be in the sludge from the KE and KW canisters and the fuel washing processes. Sludge samples have been observed to bubble and produce hydrogen gas which has been attributed to metallic fuel corrosion (Omberg 1996).

Analysis of the pyrophoric hazards associated with transferring and storing K Basin sludge containing uranium metal and its hydride in a DST indicates that the rate of oxidation of metal or hydride is sufficiently low in aqueous media to prevent ignition. However, the analysis concluded that spontaneous combustion of exposed sludge that is allowed to dry out cannot be discounted based on the available literature (Daling et al., 1997). Consequently, new tank controls would have to be established to ensure the sludge always remained submerged in an aqueous supernate. Although technically feasible, maintaining a liquid layer over K Basin sludge that has been transferred to a DST would introduce a new long-term safety hazard that is not acceptable to TWRS Facility operations through final immobilization.

4.8 TSCA REGULATED MATERIALS

4.8.1 Parameters. The parameters for Toxic Substance Control Act (TSCA) regulated material in TWRS DSTs is that TSCA regulated substances not be present or formal determination be made that they are not regulated under TSCA.

4.8.2 Basis. TWRS tank farm facilities are not permitted under the TSCA for storage and treatment of polychlorinated biphenyls (PCBs) or other TSCA regulated substances. These substances also present significant programmatic risk to multi-billion dollar private initiatives for retrieval and treatment of tank waste for final immobilization.

Waste planned for transfer to the TWRS DST system will not be accepted if the waste contains PCBs or any other substance regulated under TSCA based on process knowledge and/or sample analysis, unless a formal determination is made and agreement reached with regulators that applicable threshold quantities are not exceeded. In the latter case, TSCA regulation would have to be interpreted such that it would not add any regulatory requirements to DST wastes.

4.8.3 Discussion. Characterization of the K East Basin floor and pit sludge has detected PCBs in concentrations above the TSCA regulated threshold concentration of 50 parts per million (Schmidt, 1997). The PCB found in the sludge was reported as a spill to the U.S. Environmental Protection Agency (EPA) and consequently all of the floor and pit sludge is assumed to be a TSCA regulated waste. The same PCB found in the floor sludge has been detected in the KE Basin canister sludge (Silvers, 1997).

Negotiations with the Washington State Department of Ecology (Ecology) and the EPA are ongoing as required by Hanford Federal Facility Agreement and Consent Order, Milestone M-34, to determine a regulatory path for K Basin sludge retrieval. An alternative presented to these regulatory agencies includes options to destroy or remove PCBs. PCB destruction/removal levels will be baselined when the negotiations have concluded.

Alternatives for addressing the removal of hazardous substances located in the K East and K West Basins are being evaluated in an Engineering Evaluation/Cost Analysis (EE/CA). The sludge from the floors, pits, and canisters of the basins are included in the substances considered by the EE/CA. The DOE, Richland Operations Office, in cooperation with the EPA and Ecology, will use the EE/CA process to determine the appropriate removal action for the sludge and other basin hazardous substances. An appropriate regulatory strategy will have to be determined once a preferred removal action is selected.

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DE&S Hanford, Inc.					
C. J. Alderman (5)	X3-85	X			
W. M. Funderburke	R2-38	X			
E. J. Lipke	R1-49	X			
R. J. Lodwick	X3-78	X			
K. L. Pearce (2)	R3-11	X			
Lockheed Martin Hanford Corp.					
D. G. Baide	S5-05	X			
T. M. Blaak	S5-13	X			
L. E. Borneman	R1-90	X			
V. C. Boyles	R2-11	X			
K. G. Carothers (3)	R2-11	X			
K. D. Fowler (2)	R2-11	X			
K. M. Hodgson	R2-11	X			
J. O. Honeyman	G3-21	X			
N. W. Kirch	R2-11	X			
J. G. Kristofzski	R2-12	X			
C. H. Mulkey	R1-51	X			
W. E. Ross	S5-07	X			
T.C.R.C	R2-12	X			
Lockheed Martin Services, Inc.					
Central Files	A3-88	X			
Numated Hanford Corporation					
I. G. Papp	H5-49	X			
J. P. Sloughter (3)	H5-49	X			