Feasibility and Alternatives for Receipt, Storage, and Processing of HTGR Pebble Fuel at SRS

Appendix I: Waste/Material Disposition Strategy

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Robert H. Jones Jr.
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Feasibility and Alternatives for Receipt, Storage, and Processing of HTGR Pebble Fuel at SRS

Appendix I: Waste/Material Disposition Strategy

Robert H. Jones Jr.

October 2014

Prepared for the U.S. Department of Energy under contract number DE-AC09-08SR22470.

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Revision	Date	Description of Major Revision
Revision 0	October 16, 2014	Issued final

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EXECUTIVE SUMMARY

The U. S. Department of Energy Contractor, Savannah River Nuclear Solutions (SRNS), LLC and Forschungszentrum Jülich GmbH (Jülich) are partnering to develop a digestion technology to process graphite-based high temperature gas-cooled reactor (HTGR) nuclear fuel. The fuel consists of small kernels of uranium /thorium (U/Th) embedded in a graphite sphere ("pebbles").

The development of a digestion technology to process the fuel will be performed under the Work for Others Agreement Number WFO 13-021, *Research and Development on Graphite Destruction for the Pebble Bed Fuel Elements*. The single Step 1 deliverable associated with WFO 13-021 is a report on *Feasibility and Alternatives for Receipt, Storage and Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00184]. The report will include a summary of the process descriptions associated with the various options being considered for processing HTGR used fuel. The process descriptions and material balances identifying and quantifying the process waste streams generated by the options being considered are more thoroughly described in the report *Process Description for Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00209]. The options being considered are:

Option 1 Disposition of All Constituents via High Level Waste
Option 2 Dissolve and Separate Uranium for Disposition as Low Level Waste
Option 2T Dissolve and Separate Uranium and Thorium for Disposition as Low Level Waste
Option 6 Recover Kernels for Disposal via Melt and Dilute

Waste streams resulting from the processing of HTGR used fuel can be broadly categorized as process wastes and secondary wastes. Process wastes are those waste streams that result directly from process operations and often contain significant concentrations of the constituents of the used fuel being processed. Examples of process waste include:

- The solid waste resulting from the vitrification of the dissolved HTGR fuel (Option 1) or the vitrification of actinides and fission products separated from the dissolved HTGR used fuel (Options 2 and 2T).
- The solid waste resulting from the solidification of the liquid waste separated from the sludge containing the dissolved fuel constituents, e.g. saltstone (Options 1, 2 and 2T).
- The solid waste resulting from the solidification of the uranium stream (Option 2) or the uranium/thorium stream (Option 2T) separated from the dissolved HTGR used fuel.
- The solid waste (metal alloy) containing the uranium, actinides and fission products resulting from processing the used fuel kernels using the melt and dilute process (Option 6).
- The solid waste resulting from the solidification of the salt solution generated by head end operations to digest the carbon from HTGR used fuel prior to stabilizing the kernels using the melt and dilute process, e.g. saltstone (Option 6).
- The CASTOR® THTR/AVR casks (all options).
- The opened and empty TLK canisters and separated lids (all options).

Secondary wastes are those waste streams that result indirectly from process operations and maintenance activities. Secondary waste streams do not generally contain a significant portion of the HTGR used fuel constituents; although, the minor amount of radioactive contamination present in the secondary waste streams is representative of the radionuclides contained in the HTGR used fuel or a subset thereof. Examples of secondary waste include:

- Job control waste such as gloves, shoe covers, plastic suits, step-off pads, etc. resulting from normal operational activities or from maintenance activities.
- Used equipment and debris routinely generated from normal operations such as filters, cutting wheels or tools, sample vials, etc.
- Failed equipment such as vessels, agitators, pumps, valves, motors, instruments, etc.

Liquid HLW streams from processing HTGR used fuel will be processed through the existing liquid HLW system at the Savannah River Site. Planning for liquid HLW processing is documented in the report *Liquid Waste System Plan* [SRR-LWP-2009-00001]. The plan documents the activities required to disposition the existing and future liquid HLW streams and to ultimately remove radioactive liquid waste tanks from service. The *Liquid Waste System Plan* will require modification to incorporate the waste streams resulting from the processing of HTGR used fuel.

LLW streams from processing HTGR used fuel will be processed through or disposed at the existing solid radioactive waste management facilities at the Savannah River Site where feasible. Planning for disposal of TRU waste and LLW is documented in the report *System Plan for Solid Waste Management* [SRNS-RP-2011-01321]. The plan provides a comparative analysis of options to determine a preferred treatment and disposal for all identified waste groups handled by Solid Waste Management and provides the scoping information necessary to support future solid waste budgetary requirements. The *System Plan for Solid Waste Management* may require modification to incorporate the impact of disposal of waste streams generated by the processing of HTGR used fuel. No TRU waste streams are anticipated to be generated from processing HTGR used fuel; however, if any are generated and they are considered defense related waste then they also would be processed through the SRS solid radioactive waste management facilities for final disposal at WIPP.

No mixed waste streams are anticipated to be generated; however, if they are, they would be collected, handled and treated in accordance with the SRS 1S Manual, *SRS Radioactive Waste Requirements* and the *System Plan for Solid Waste Management* [SRNS-RP-2011-01321].

The potential process waste streams and volumes associated with the four options evaluated in this report for processing HTGR used fuel are identified in the report, *Process Description for Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00209]. Tables 2.5-1 and 2.5-2 summarize the process HLW and LLW streams generated by the four options respectively.

The tables also include some of the major anticipated secondary waste streams. These lists of secondary waste should not be regarded as comprehensive. For HLW, the secondary waste streams with the potential for requiring a WIR determination are identified. Although listed as having the potential for requiring a WIR determination, these waste streams are assumed to be handled as LLW Accordingly, these waste streams are also replicated in Table 2.5-2. For LLW, the primary disposal path is identified and where applicable or available, alternate disposal path(s) are identified. All waste streams anticipated to be generated by processing HTGR used fuel are expected to have an identified path to disposal.

Table ES-1 Summary of HLW Streams

HLW Stream	Waste Volume [1] (units as noted)				WIR? [2]	Remarks
	Option 1	Option 2	Option 2T	Option 6		
Process Waste						
Vitrified HLW	101 DWPF canisters	32 DWPF canisters	15 DWPF canisters	NA	HLW	DWPF canisters are nominally 2' dia. X 10' high
Metal alloy waste form	NA	NA	NA	82 MCO containers	HLW	Assumes use of Hanford Multi-Canister Overpack (MCO) containers, nominally 2' dia. x 13' 4" high
Secondary Waste						
Failed equipment from solvent extraction	Waste Volumes Undetermined				E	The document Q-CIT-G-00001, *Waste Incidental to Reprocessing Citation Determination*, Attachment 1, Table 1 identifies similar failed equipment from HLW tanks as not HLW. Failed equipment associated with solvent extraction may still require a determination by Evaluation.
Job control waste associated with solvent extraction					C	Q-CIT-G-00001, Attachment 1, Table 1 identifies job waste of any type including job control waste (paper, plastic, clothing, respiratory equipment, glove bags, wipes, smears, etc.) as not HLW.
Maintenance waste associated with solvent extraction					C	Q-CIT-G-00001, Attachment 1, Table 1 identifies job waste of any type including maintenance waste (hand tools, electrical tools, hoses, cords, HEPA filters, etc.) as not HLW.
Laboratory equipment associated with analysis of samples from solvent extraction					C	Q-CIT-G-00001, Attachment 1, Table 1 identifies sample media (lab ware, thermometers, vials, tongs, etc.) as not HLW.

Notes:
1. NA = Not Applicable
2. Is a WIR determination potentially required? If so, does the Citation (C) or Evaluation (E) process apply? HLW indicates that a WIR determination is not needed because the waste stream is inherently HLW.

Table ES-2 Summary of LLW Streams

LLW Stream	Waste Volume [1] (units as noted)				Primary Disposal Path	Alternate Disposal Path
	Option 1	Option 2	Option 2T	Option 6		
Process Waste						
Solidified salt solution (e.g. saltstone)	1.45×10^6 gallons	1.65×10^6 gallons	1.65×10^6 gallons	9.68×10^5 gallons	SRS Z-Area Saltstone Facilities	None identified
Grouted uranium	NA	6.69×10^4 ft^3	NA	NA	SRS E-Area Components-In-Grout (CIG) Trench with grouted waste placed in CASTOR® casks	Nevada National Security Site (NNSS) or Waste Control Specialists (WCS) [4]
Grouted uranium/thorium	NA	NA	6.69×10^4 ft^3	NA		
CASTOR® THTR/AVR casks [2]	6.69×10^4 ft^3	Included in grouted uranium above	Included in grouted uranium/ thorium above	6.69×10^4 ft^3	SRS E-Area Engineered Trench (ET) or CIG Trench	Although disposal at the NNSS or WCS facilities is feasible, alternate disposal paths (i.e. offsite disposal) should not be needed for these waste streams. These waste streams should be readily accommodated in the SRS E-Area disposal facilities.
TLK canisters and lids [3]	Included in CASTOR® THTR/AVR casks above	7.89×10^3 ft^3	7.89×10^3 ft^3	Included in CASTOR® THTR/AVR casks above	SRS E-Area ET or CIG Trench	
Secondary Waste						
Failed equipment	Waste Volumes Undetermined				SRS E-Area ET or CIG Trench depending on physical size and radioactive inventory	Although disposal at the NNSS or WCS facilities is feasible, alternate disposal paths (i.e. offsite disposal) should not be needed for these waste streams. These waste streams should be readily accommodated in the SRS E-Area disposal facilities.
Job control waste					SRS E-Area ET	
Maintenance equipment					SRS E-Area ET unless overly large, then CIG Trench	
Laboratory equipment					SRS E-Area ET	
Used equipment and debris					SRS E-Area Slit Trench (ST) for debris and SRS E-Area ET for used equipment unless overly large, then CIG Trench	

Notes:
1. NA = Not Applicable
2. Some or possibly all of the CASTOR® THTR/AVR casks may be used (repurposed) to contain the grouted uranium or grouted uranium/thorium waste streams. If so the quantities listed would be reduced accordingly.
3. The quantity of TLK canisters listed assumes that all 303 CASTOR® THTR casks contain one tall TLK canister each and that all 152 CASTOR® AVR casks contain two short TLK canisters each.
4. Disposal at the Nevada National Security Site (NNSS) is limited due to U-233 acceptance issues under existing administrative policies. Disposal at the Waste Control Specialists facility is limited by special nuclear material facility inventories outside of a disposal unit. Both facilities believe these issues can be successfully managed. Once these issues are addressed, both facilities could accept this material for disposal provided the waste package offered for disposal complies with the Certificate of Compliance (CoC) for the packaging, i.e. if Department of Transportation (DOT) compliant for shipment then these criteria would support compliant disposal configurations for waste form and nuclear criticality controls.

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TABLE OF CONTENTS

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ACRONYMS

AEA	Atomic Energy Act
AVR	*Arbeitsgemeinschaft Versuchreaktor*
C	Citation
CIG	Components-In-Grout
CFR	Code of Federal Regulations
CoC	Certificate of Compliance
DOE	Department of Energy
DOT	Department of Transportation
DWPF	Defense Waste Processing Facility
E	Evaluation
EPA	Environmental Protection Agency
ET	Engineered Trench
FR	Federal Register
HEU	Highly Enriched Uranium
HLW	High Level Waste
HTGR	High Temperature Gas-Cooled Reactor
LLW	Low Level Waste
MCO	Multi-Canister Overpack
NNSS	Nevada National Security Site
NWPA	Nuclear Waste Policy Act
RCRA	Resource Conservation and Recovery Act
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
ST	Slit Trench
THTR	*Thorium Hochtemperaturreacktor*
TRU	Transuranic
U/Th	Uranium/Thorium
WAPS	Waste Acceptance Product Specifications
WCS	Waste Control Specialists
WFO	Work for Others
WIPP	Waste Isolation Pilot Plant
WIR	Waste Incidental to Reprocessing

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1. Introduction

The U. S. Department of Energy (DOE) Contractor, Savannah River Nuclear Solutions (SRNS), LLC and Forschungszentrum Jülich GmbH (Jülich) are partnering to develop a digestion technology to process graphite-based high temperature gas-cooled reactor (HTGR) nuclear fuel. The fuel consists of small kernels of uranium /thorium (U/Th) embedded in a graphite sphere ("pebbles").

The fuel was fabricated using DOE-owned highly enriched uranium (HEU), and irradiated in one of two reactors, AVR (*Arbeitsgemeinschaft Versuchreaktor*) and THTR (*Thorium Hochtemperaturreacktor*) in Germany. The used fuel, consisting of approximately 920,000 pebbles, is stored at two locations in casks that are suitable for both storage and transportation. Fuel from the THTR reactor is stored in 303 casks at a cask Storage Facility in the city of Ahaus, and fuel from the AVR reactor is stored in 152 casks at the Jülich Research Center. The total uranium content of the used fuel is approximately one metric ton

The development of a digestion technology to process the fuel will be performed under the Work for Others Agreement Number WFO 13-021, *Research and Development on Graphite Destruction for the Pebble Bed Fuel Elements*. The single Step 1 deliverable associated with WFO 13-021 is a report on *Feasibility and Alternatives for Receipt, Storage and Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00184]. The report will include a summary of the process descriptions associated with the various options being considered for processing HTGR used fuel. The process descriptions and material balances identifying and quantifying the process waste streams generated by the options being considered are more thoroughly described in the report *Process Description for Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00209]. The options being considered are:

Option 1	Disposition of All Constituents via High Level Waste
Option 2	Dissolve and Separate Uranium for Disposition as Low Level Waste
Option 2T	Dissolve and Separate Uranium and Thorium for Disposition as Low Level Waste
Option 6	Recover Kernels for Disposal via Melt and Dilute

This report discusses the regulatory requirements associated with the management and disposal of the waste streams generated by the various process options and identifies the potential disposal paths for the waste streams. The information in this report will be summarized in the appropriate section of and included in the appendix of the report on *Feasibility and Alternatives for Receipt, Storage and Processing of HTGR Pebble Fuel at SRS* described above.

2. Applicable Regulations

The DOE Manual 435.1-1, *Radioactive Waste Management Manual*, describes the requirements and establishes specific responsibilities for implementing DOE Order 435.1, *Radioactive Waste Management*, for the management of DOE high-level waste, transuranic waste, low-level waste, and the radioactive component of mixed waste. DOE Order 435.1 requires that radioactive waste management activities be systematically planned, documented, executed and evaluated. The objective of DOE Order 435.1 is to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment. Additional applicable regulations cited by DOE Manual 435.1 include the following:

- DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees* - establishes the framework for an effective worker protection program to reduce or prevent injuries, illnesses and accidental losses by providing DOE Federal and contractor workers with a safe and healthful workplace. (Note: DOE Order 440.1A has been superseded by DOE Order 440.1B, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees.*)
- DOE Order 458.1, *Radiation Protection of the Public and the Environment* - establish requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of the DOE pursuant to the Atomic Energy Act (AEA) of 1954, as amended.
- DOE Order 5400.1, *General Environmental Protection Program* – Establishes environmental protection program requirements, authorities and responsibilities for DOE operations for assuring compliance with applicable Federal, State and local environmental protection laws and regulations, Executive orders and internal Department policies. (Note: DOE Order 5400.1 has been superseded by DOE Order 436.1, *Departmental Sustainability*.)
- Title 10 Code of Federal Regulations (CFR) Part 835, *Occupational Radiation Protection* – Establishes radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from the conduct of DOE activities.
- Applicable Executive Orders and other DOE directives.
- Applicable Federal, State and local laws and regulations.

The Savannah River Site (SRS) 1S Manual, *SRS Radioactive Waste Requirements*, provides the specific administrative, operational and technical compliance requirements for waste to be disposed at the SRS E-Area disposal facilities.

3. Waste Sources

Waste streams resulting from the processing of HTGR used fuel can be broadly categorized as process wastes and secondary wastes. Process wastes are those waste streams that result directly from process operations and often contain significant concentrations of the constituents of the used fuel being processed. Examples of process waste include:

- The solid waste resulting from the vitrification of the dissolved HTGR fuel (Option 1) or the vitrification of actinides and fission products separated from the dissolved HTGR used fuel (Options 2 and 2T).
- The solid waste resulting from the solidification of the liquid waste separated from the sludge containing the dissolved fuel constituents, e.g. saltstone (Options 1, 2 and 2T).
- The solid waste resulting from the solidification of the uranium stream (Option 2) or the uranium/thorium stream (Option 2T) separated from the dissolved HTGR used fuel.
- The solid waste (metal alloy) containing the uranium, actinides and fission products resulting from processing the used fuel kernels using the melt and dilute process (Option 6).
- The solid waste resulting from the solidification of the salt solution generated by head end operations to digest the carbon from HTGR used fuel prior to stabilizing the kernels using the melt and dilute process, e.g. saltstone (Option 6).
- The CASTOR® THTR/AVR casks (all options).
- The opened and empty TLK canisters and separated lids (all options).

The process waste streams are more thoroughly described in the report, *Process Description for Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00209].

Secondary wastes are those waste streams that result indirectly from process operations and maintenance activities. Secondary waste streams do not generally contain a significant portion of the HTGR used fuel constituents; although, the minor amount of radioactive contamination present in the secondary waste streams is representative of the radionuclides contained in the HTGR used fuel or a subset thereof. Examples of secondary waste include:

- Job control waste such as gloves, shoe covers, plastic suits, step-off pads, etc. resulting from normal operational activities or from maintenance activities.
- Used equipment and debris routinely generated from normal operations such as filters, cutting wheels or tools, sample vials, etc.
- Failed equipment such as vessels, agitators, pumps, valves, motors, instruments, etc.

4. Waste Characterization

The process and secondary waste streams resulting from processing the HTGR used fuel will be characterized as either high level waste (HLW), low level waste (LLW) or transuranic (TRU) waste. DOE Manual 435.1-1 defines the requirements for managing these wastes.

4.1 High Level Waste

DOE Manual 435.1-1 defines HLW as:

> "the highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation".

DOE Guide 435.1-1, *Implementation Guide for use with DOE M 435.1-1*, provides further guidance on the definition of HLW. DOE Guide 435.1-1 states that HLW waste streams are:

> "wastes that are generated as a product of reprocessing of spent nuclear fuel downstream of, and including, the first step in a separations process, and the consistent waste streams from subsequent extraction cycles or steps. Separation processes include aqueous separation processes, e.g., the Redox and the Purex processes, and nonaqueous processes, e.g., pyrometallurgical and pyrochemical processes. Wastes that are produced upstream of these separations processes, from such processes as chemical or mechanical decladding, fuel dissolution, cladding separations, conditioning, or accountability measuring, are not high-level waste".

Some of the process waste streams have the ability to be characterized as HLW. The solid waste resulting from the vitrification of the dissolved HTGR fuel (Option 1) or the vitrification of actinides and fission products separated from the dissolved HTGR used fuel (Options 2 and 2T) and the solid metal alloy waste form containing the uranium, actinides and fission products resulting from processing the used fuel kernels using the melt and dilute process (Option 6) would all be characterized as HLW. HLW requires disposal at a repository meeting the requirements of the Nuclear Waste Policy Act (NWPA) of 1982, as amended. No such repository is currently in operation; therefore, any HLW generated by processing HTGR used fuel would be temporarily stored at the Savannah River Site until a repository is open.

4.2 Transuranic Waste

DOE Manual 435.1-1 defines TRU waste as:

> "radioactive waste containing more than 100 nanocuries (3,700 Becquerel's) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for:
> (1) High-level radioactive waste;
> (2) Waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR Part 191 disposal regulations; or
> (3) Waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61".

Although none of the waste streams generated from the processing of the HTGR used fuel are expected to be characterized as TRU waste, the following waste streams have the potential to be characterized as TRU waste if the radioactive contaminants are high in TRU radionuclides:

- Some of the process streams such as the solid waste resulting from the solidification of the uranium stream (Option 2) or the uranium/thorium stream (Option 2T) separated from the dissolved HTGR used fuel. Note: These waste streams are assumed to be sufficiently cleaned/separated from the transuranic radionuclides present in the HTGR used fuel to allow disposal of the resulting final waste form as LLW considering both the process dilution required to meet uranium enrichment concentrations for disposal and the solid waste form chemistry.
- The CASTOR® THTR/AVR casks (all options) and the opened and empty TLK canisters and separated lids (all options).
- All secondary waste streams.

The Waste Isolation Pilot Plant (WIPP) is the only repository currently operating for TRU waste disposal; however, WIPP can only receive and dispose of TRU waste generated from defense related activities (b)(5)

4.3 Low Level Waste

DOE Manual 435.1-1 defines LLW as:

> "radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in section 11e.(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material".

As can be discerned from the definition, radioactive waste is characterized as LLW not because of what it is but because of what it is not. The following waste streams are expected to be characterized as LLW unless the radioactive contaminants are high in TRU radionuclides making the waste TRU waste:

- Some of the process streams such as the solid waste resulting from the solidification of the uranium stream (Option 2) or the uranium/thorium stream (Option 2T) separated from the dissolved HTGR used fuel.
- The CASTOR® THTR/AVR casks (all options) and the opened and empty TLK canisters and separated lids (all options).
- All secondary waste streams.

4.4 Waste Incidental to Reprocessing

Waste incidental to reprocessing (WIR) refers to a process for identifying waste streams that would otherwise be considered HLW due to their sources of generation (e.g. generated downstream of or from the first step in a separations process) or concentration, but can be managed in accordance with the DOE requirements for TRU waste or LLW, if the requirements for WIR are met. Either the Citation or Evaluation process described below is used when determining whether wastes from processing the HTGR used fuel shall be managed as HLW or as another waste type:

(1) Citation - Waste incidental to reprocessing by Citation includes used fuel processing wastes that meet the description included in the Notice of Proposed Rulemaking (34 FR 8712) for proposed Appendix D, 10 CFR Part 50, Paragraphs 6 and 7. These radioactive wastes are the result of processing operations.

(2) Evaluation - Determinations that any waste is incidental to reprocessing by the Evaluation process shall be developed under good record-keeping practices, with an adequate quality assurance process, and shall be documented to support the determinations. Such wastes may include but are not limited to processing wastes that:

(a) Will be managed as LLW and meet the following criteria:

1. Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical; and
2. Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C, Performance Objectives; and
3. Are to be managed, pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, and in accordance with the provisions of Chapter IV of this Manual, provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 CFR 61.55, Waste Classification; or will meet alternative requirements for waste classification and characterization as DOE may authorize.

(b) Will be managed as TRU waste and meet the following criteria:
1. Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical; and
2. Will be incorporated in a solid physical form and meet alternative requirements for waste classification and characteristics, as DOE may authorize; and
3. Are managed pursuant to DOE's authority under the Atomic Energy Act of 1954, as amended, in accordance with the provisions of Chapter III of this Manual, as appropriate.

Examples of waste streams that meet the requirements for the Citation process include job control waste such as gloves, shoe covers, plastic suits, step-off pads, etc. and used equipment such as filters, cutting wheels or tools, sample vials, etc. Examples of waste streams that may require a determination by the Evaluation process include failed equipment such as process vessels, jumpers, process pumps, etc. The document Q-CIT-G-00001, *Waste Incidental to Reprocessing Citation Determination*, provides specific guidance for waste generated at the Savannah River Site.

4.5 Mixed Waste

According to DOE Manual 435.1-1, mixed waste is "waste that contains both source, special nuclear, or by-product material subject to the Atomic Energy Act of 1954, as amended, and a hazardous component subject to the Resource Conservation and Recovery Act". Per DOE Manual 435.1-1, all HLW shall be considered mixed waste, unless demonstrated otherwise, and subject to the requirements of both the Atomic Energy Act (AEA) and the Resource Conservation and Recovery Act (RCRA). DOE/EM-0093, *Waste Acceptance Product Specifications for Vitrified High-Level Waste Forms*, requires determination and documentation that RCRA Subtitle C regulated wastes are not present and requires development of data to assure state and/or U.S. Environmental Protection Agency (EPA) requirements are addressed. Appropriate tests shall be performed, typically using prototypical specimens, to determine if the waste has hazardous characteristics or concentrations that would subject the waste to regulation under RCRA. Any RCRA listed component in the waste requires petitioning the EPA for an exemption to delist the waste. The vitrified product from the Defense Waste Processing Facility (DWPF) has undergone rigorous analysis to determine its RCRA characteristics (b)(5)

Process and secondary TRU waste and LLW streams are not anticipated to contain hazardous components; therefore, no mixed TRU waste or mixed LLW is anticipated from processing the HTGR used fuel.

5. Waste Treatment

Treatment of HLW shall be implemented in a manner that complies with DOE/EM–0093, *Waste Acceptance Product Specifications for Vitrified High-level Waste Forms,* or DOE/RW-0351P, *Waste Acceptance System Requirements Document*, for non-vitrified, immobilized high-level waste.

TRU waste shall be treated and packaged as necessary to meet the waste acceptance requirements for disposal at WIPP i.e. DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant*. Requirements specific to the Savannah River Site for preparing TRU waste for disposal at WIPP are contained in the SRS 1S Manual, *SRS Radioactive Waste Requirements*.

LLW disposed at the SRS E-Area disposal facilities shall meet the waste acceptance requirements of the SRS 1S Manual, *SRS Radioactive Waste Requirements*. LLW not meeting the requirements of the SRS 1S Manual shall be treated as necessary to meet the performance objectives of the E-Area disposal facility. Specific analysis on a case-by-case basis and/or revisions to the E-Area performance assessment may be required.

6. Disposal Strategy

Liquid HLW streams from processing HTGR used fuel will be processed through the existing liquid HLW system at the Savannah River Site. Planning for liquid HLW processing is documented in the report *Liquid Waste System Plan* [SRR-LWP-2009-00001]. The plan documents the activities required to disposition the existing and future liquid HLW streams and to ultimately remove radioactive liquid waste tanks from service. The *Liquid Waste System Plan* will require modification to incorporate the waste streams resulting from the processing of HTGR used fuel.

LLW streams from processing HTGR used fuel will be processed through or disposed at the existing solid radioactive waste management facilities at the Savannah River Site where feasible. Low level process waste streams from H Canyon (Options 2 and 2T) are assumed to be sufficiently cleaned/separated from the transuranic radionuclides present in the HTGR used fuel to allow disposal of the resulting final waste form as LLW considering both the process dilution required to meet uranium enrichment concentrations for disposal and the solid waste form chemistry. Planning for disposal of TRU waste and LLW is documented in the report *System Plan for Solid Waste Management* [SRNS-RP-2011-01321]. The plan provides a comparative analysis of options to determine a preferred treatment and disposal for all identified waste groups handled by Solid Waste Management and provides the scoping information necessary to support future solid waste budgetary requirements. The *System Plan for Solid Waste Management* may require modification to incorporate the impact of disposal of waste streams generated by the processing of HTGR used fuel. No TRU waste streams are anticipated to be generated from processing HTGR used fuel (b)(5)

No mixed waste streams are anticipated to be generated; however, if they are, they would be collected, handled and treated in accordance with the SRS 1S Manual, *SRS Radioactive Waste Requirements* and the *System Plan for Solid Waste Management* [SRNS-RP-2011-01321].

The potential process waste streams and volumes associated with the four options evaluated in this report for processing HTGR used fuel are identified in the report, *Process Description for Processing of HTGR Pebble Fuel at SRS* [SRNL-TR-2014-00209]. Tables 2.5-1 and 2.5-2 summarize the process HLW and LLW streams generated by the four options respectively.

The tables also include some of the major anticipated secondary waste streams. These lists of secondary waste should not be regarded as comprehensive. For HLW, the secondary waste streams with the potential for requiring a WIR determination are identified. Although listed as having the potential for requiring a WIR determination, these waste streams are assumed to be handled as LLW Accordingly, these waste streams are also replicated in Table 2.5-2. For LLW, the primary disposal path is identified and where applicable or available, alternate disposal path(s) are identified. All waste streams anticipated to be generated by processing HTGR used fuel are expected to have an identified path to disposal.

Table 2.5-1 Summary of HLW Streams

HLW Stream	Waste Volume [1] (units as noted)				WIR? [2]	Remarks
	Option 1	Option 2	Option 2T	Option 6		
Process Waste						
Vitrified HLW	101 DWPF canisters	32 DWPF canisters	15 DWPF canisters	NA	HLW	DWPF canisters are nominally 2' dia. X 10' high
Metal alloy waste form	NA	NA	NA	82 MCO containers	HLW	Assumes use of Hanford Multi-Canister Overpack (MCO) containers, nominally 2' dia. x 13' 4" high
Secondary Waste						
Failed equipment from solvent extraction	Waste Volumes Undetermined				E	The document Q-CIT-G-00001, *Waste Incidental to Reprocessing Citation Determination*, Attachment 1, Table 1 identifies similar failed equipment from HLW tanks as not HLW. Failed equipment associated with solvent extraction may still require a determination by Evaluation.
Job control waste associated with solvent extraction					C	Q-CIT-G-00001, Attachment 1, Table 1 identifies job waste of any type including job control waste (paper, plastic, clothing, respiratory equipment, glove bags, wipes, smears, etc.) as not HLW.
Maintenance waste associated with solvent extraction					C	Q-CIT-G-00001, Attachment 1, Table 1 identifies job waste of any type including maintenance waste (hand tools, electrical tools, hoses, cords, HEPA filters, etc.) as not HLW.
Laboratory equipment associated with analysis of samples from solvent extraction					C	Q-CIT-G-00001, Attachment 1, Table 1 identifies sample media (lab ware, thermometers, vials, tongs, etc.) as not HLW.

Notes:
1. NA = Not Applicable
2. Is a WIR determination potentially required? If so, does the Citation (C) or Evaluation (E) process apply? HLW indicates that a WIR determination is not needed because the waste stream is inherently HLW.

Table 2.5-2 Summary of LLW Streams

LLW Stream	Waste Volume [1] (units as noted)				Primary Disposal Path	Alternate Disposal Path
	Option 1	Option 2	Option 2T	Option 6		
Process Waste						
Solidified salt solution (e.g. saltstone)	1.45×10^6 gallons	1.65×10^6 gallons	1.65×10^6 gallons	9.68×10^5 gallons	SRS Z-Area Saltstone Facilities	None identified
Grouted uranium	NA	6.69×10^4 ft^3	NA	NA	SRS E-Area Components-In-Grout (CIG) Trench with grouted waste placed in CASTOR® casks	Nevada National Security Site (NNSS) or Waste Control Specialists (WCS) [4]
Grouted uranium/thorium	NA	NA	6.69×10^4 ft^3	NA		
CASTOR® THTR/AVR casks [2]	6.69×10^4 ft^3	Included in grouted uranium above	Included in grouted uranium/ thorium above	6.69×10^4 ft^3	SRS E-Area Engineered Trench (ET) or CIG Trench	Although disposal at the NNSS or WCS facilities is feasible, alternate disposal paths (i.e. offsite disposal) should not be needed for these waste streams. These waste streams should be readily accommodated in the SRS E-Area disposal facilities.
TLK canisters and lids [3]	Included in CASTOR® THTR/AVR casks above	7.89×10^3 ft^3	7.89×10^3 ft^3	Included in CASTOR® THTR/AVR casks above	SRS E-Area ET or CIG Trench	
Secondary Waste						
Failed equipment	Waste Volumes Undetermined				SRS E-Area ET or CIG Trench depending on physical size and radioactive inventory	Although disposal at the NNSS or WCS facilities is feasible, alternate disposal paths (i.e. offsite disposal) should not be needed for these waste streams. These waste streams should be readily accommodated in the SRS E-Area disposal facilities.
Job control waste					SRS E-Area ET	
Maintenance equipment					SRS E-Area ET unless overly large, then CIG Trench	
Laboratory equipment					SRS E-Area ET	
Used equipment and debris					SRS E-Area Slit Trench (ST) for debris and SRS E-Area ET for used equipment unless overly large, then CIG Trench	

Notes:
1. NA = Not Applicable
2. Some or possibly all of the CASTOR® THTR/AVR casks may be used (repurposed) to contain the grouted uranium or grouted uranium/thorium waste streams. If so the quantities listed would be reduced accordingly.
3. The quantity of TLK canisters listed assumes that all 303 CASTOR® THTR casks contain one tall TLK canister each and that all 152 CASTOR® AVR casks contain two short TLK canisters each.
4. Disposal at the Nevada National Security Site (NNSS) is limited due to U-233 acceptance issues under existing administrative policies. Disposal at the Waste Control Specialists facility is limited by special nuclear material facility inventories outside of a disposal unit. Both facilities believe these issues can be successfully managed. Once these issues are addressed, both facilities could accept this material for disposal provided the waste package offered for disposal complies with the Certificate of Compliance (CoC) for the packaging, i.e. if Department of Transportation (DOT) compliant for shipment then these criteria would support compliant disposal configurations for waste form and nuclear criticality controls.

7. References

1. DOE Order 435.1, *Radioactive Waste Management*, Change 1, August 28, 2001
2. DOE Manual 435.1-1, *Radioactive Waste Management Manual*, Change 2, June 8, 2011
3. DOE Guide 435.1-1, *Implementation Guide for use with DOE M 435.1-1*, July 9, 1999
4. DOE Order 436.1, *Departmental Sustainability*, May 2, 2011
5. DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*, Change 2, March 14, 2013
6. DOE Order 440.1B, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*, Approved May 17, 2007, Certified June 17, 2011
7. DOE Order 458.1, *Radiation Protection of the Public and the Environment*, Change 3, January 15, 2013
8. DOE Order 5400.1, *General Environmental Protection Program*, Change 1, June 29, 1990
9. DOE/EM-0093, U.S. Department of Energy Office of Environmental Management, *Waste Acceptance Product Specifications for Vitrified High-Level Waste Forms*, Revision 3, November 2012
10. DOE/RW-0351P, *Waste Acceptance System Requirements Document*
11. DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, Revision 7.4, April 22, 2013
12. Q-CIT-G-00001, *Waste Incidental to Reprocessing Citation Determination*, Revision 0, April 2010
13. *SRNL-TR-2014-00184, Feasibility and Alternatives for Receipt, Storage and Processing of HTGR Pebble Fuel at SRS* , September 2014, Draft
14. Savannah River Site (SRS) 1S Manual, *SRS Radioactive Waste Requirements*, January 1, 2012
15. SRNL-TR-2014-00209, E. N. Moore, et al, *Process Description for Processing of HTGR Pebble Fuel at SRS*, September 2014, Draft
16. SRNS-RP-2011-01321, *System Plan for Solid Waste Management*, Revision 0, August 2011
17. SRR-LWP-2009-00001, *Liquid Waste System Plan*, Revision 19, May 15, 2014
18. Title 10 Code of Federal Regulations Part 835, *Occupational Radiation Protection*
19. Work for Others Agreement Number WFO-13-021, *Research and Development on Graphite Destruction for the Pebble Bed Fuel Elements,* April 23, 2014